Institute of Molecular Physics, Polish Academy of Sciences
Faculty of Physics, Adam Mickiewicz University, Poznań

The European Conference

PHYSICS OF MAGNETISM 2021

June 28 - July 2, 2021, Poznań, Poland

ABSTRACTS

Poznań 2021

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Faculty of Physics, Adam Mickiewicz University, Poznań

The European Conference

PHYSICS OF MAGNETISM 2021 (PM'21)

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Abstracts

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The European Conference

PHYSICS OF MAGNETISM 2021

June 28 - July 2, 2021
Poznań, Poland

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SCHEDULE

Monday, June 28, 2021

10^{15} - 10^{45} **Opening**
Bogdan Idzikowski, Roman Micnas, Tomasz Toliński, Maciej Krawczyk

Opening Lecture
Chairmen: Bogdan Idzikowski, Roman Micnas

10^{45} - 11^{30} **Laurens W. Molenkamp**
Experimental Physics III, University of Würzburg,
Würzburg, Germany
Quantum anomalous Hall effect in V-doped (Bi,Sb)$_2$Te$_3$

Plenary session I
Chairmen: Bogdan Idzikowski, Roman Micnas

11^{30} - 12^{00} **Seigo Tarucha**
RIKEN Center for Emergent Matter Science, Wakō, Japan
Si platform for implementing spin-based quantum computing

12^{00} - 12^{30} **Changqing Jin**
Institute of Physics, Chinese Academy of Sciences (IOPCAS),
Beijing, China
New emergent materials driven via synergetic extreme conditions

12^{30} - 13^{00} **Anders Bergman**
Department of Physics and Astronomy, Uppsala University,
Uppsala, Sweden
Self-induced spin glass phase in dhcp Nd

13^{00} - 14^{00} long break

14^{00} - 16^{00} **ORAL SESSION I**

(Session A) Chairman: Piotr Bogusławski
Jarosław Juraszek (O-1-01), Maciej Fidrysiak (O-1-02),
Krzysztof Wohlfeld (O-1-04), Bartłomiej Wiendlocha (O-1-05),
Damian Krychowski (O-1-06), Jakub Kaczkowski (O-1-07),
Krzysztof Wójcik (O-1-11), Ganesh Ji Omar (O-1-18)

(Session B) Chairman: Tomasz Cichorek
Jacek Dziarmaga (O-2-01), Dorota Gotfryd (O-2-02),
Alexander Mook (O-2-03), Jiri Chaloupka (O-2-04),
Imre Hagymási (O-2-07), Aritra Sinha (O-2-08),
Piotr Kozłowski (O-2-09), Radovan Vranik (O-2-10)

(Session C) Chairman: Adam Pikul
Tianping Ma (O-3-01), Qi Wang (O-3-03),
Paweł Gruszecki (O-3-04), Gabriel D. Chaves-O'Flynn (O-3-07),
Ryszard Gieniusz (O-3-11), Jan Kisielewski (O-3-15),
Simon Streib (O-3-16), Justyna Rychły (O-3-18)

16^{00} - 16^{15} short break

Monday, June 28, 2021

Plenary Session II

Chairman: Andrzej Ślebarski

16^{15} - 16^{45} **M. Zahid Hasan**
Department of Physics, Princeton University, Princeton, NJ, USA
Magnetic topological quantum matter

16^{45} - 17^{15} **Tomasz Dietl**
Institute of Physics of the Polish Academy of Sciences, Warszawa, Poland
Interfacing topological materials: search for the origin of zero-energy modes and low-temperature dephasing

17^{15} - 17^{45} **Dariusz Kaczorowski**
Institute of Low Temperature and Structure Research, PAS, Wrocław & Institute of Molecular Physics, PAS, Poznań, Poland
On the hunt for topological superconductors

17^{45} - 18^{15} **Silke Bühler-Paschen**
Institute of Solid State Physics, Vienna University of Technology, Wien, Austria
Correlation-driven topological semimetals

18^{15} - 18^{30} short break

18^{30} - 20^{15} **ORAL SESSION II**

(Session A) Chairman: Tomasz Błachowicz
Marvin Lenk (O-1-12), Andrzej Wiśniewski (O-1-13), Piotr Stefański (O-1-15), Piotr Majek (O-1-20), Andrii Sotnikov (O-1-21), Artur Błachowski (O-1-22), Anna Zarzecka (O-1-25)

(Session B) Chairman: Krzysztof Rogacki
Jozef Strečka (O-2-11), Karol Szałowski (O-2-12), Katarína Karl'ová (O-2-13), Robert Pełka (O-2-14), Jannis Willwater (O-2-15), Leonie Heinze (O-2-16), Zbigniew Wojtkowiak (O-2-17)

(Session C) Chairman: Andrzej Szewczyk
Marian Mihalik (O-3-20), Matus Mihalik (O-3-33), Piotr Tomczak (O-3-22), Anuj Dhiman (O-3-28), Andrzej Janutka (O-3-29), Sebastian Paischer (O-3-30), Zichao Li (O-3-32)

Tuesday, June 29, 2021

Plenary Session III
Chairman: Bogdan Dąbrowski

Session sponsored by QUANTUM DESIGN GmbH

11^{00} - 11^{30} **Piotr Kuświk**
Institute of Molecular Physics of the Polish Academy of Sciences, Poznań, Poland
Magnetic domains without domain walls and their influence on magnetization reversal process in ferrimagnetic Tb/Co multilayers

11^{30} - 12^{00} **Dimitrios Niarchos**
Institute of Nanoscience and Nanotechnology, N.C.S.R. Demokritos, Athens, Greece
"Artificial multi-elements" based on high entropy alloys as "building blocks" for novel magnetic alloys suitable for permanent magnets: special cases $ThMn_{12}$ and $SmFe_3CoNi$

12^{00} - 12^{30} **Ivan Škorvánek**
Institute of Experimental Physics SAS, Košice, Slovak Republic
Soft magnetic amorphous and nanocrystalline bilayer ribbons for sensor applications

12^{30} - 13^{00} **Dawid Pinkowicz**
Faculty of Chemistry, Jagiellonian University, Kraków, Poland
Are room-temperature molecular photomagnets possible and how to reach them?

13^{00} - 14^{00} long break

14^{00} - 16^{00} **ORAL SESSION III**

(Session A) Chairman: Krzysztof Wohlfeld
Adolfo Avella (O-1-03), Amir Eskandari-asl (O-1-19), Alexander Moskvin (O-1-26), Vladislav Borisov (O-3-13), Luciano Jacopo D'Onofrio (O-3-27), Robin Neumann (O-3-05), Maxime Barbier (O-3-06), Hai Zhong (O-3-08)

(Session B) Chairman: Artur Błachowski
Nicholas Sedlmayr (O-4-04), Piotr Bogusławski (O-4-11), Michał Grzybowski (O-4-12), Sławomir Ziętek (O-4-13), Stanisław Łazarski (O-4-14), Anna Krzyżewska (O-4-15), Alexandra Domozhirova (O-4-16), Abdul Khaliq (O-4-17)

(Session C) Chairman: Tadeusz Domański
Bogdan R. Bułka (O-5-27), Stefan Krompiewski (O-5-28), Justyn Snarski-Adamski (O-5-23), Mirali Jafari (O-5-24), Maria Zentková (O-5-25), Zbigniew Kurant (O-5-26), Krzysztof Sobucki (O-5-21), Wojciech Marciniak (O-6-03)

16^{00} - 16^{15} short break

Tuesday, June 29, 2021

Young & Brilliant Session I
Chairman: Piotr Kuświk

Session under the patronage of the POLISH YOUNG ACADEMY, PAS

16^{15} - 16^{35} **Börge Göbel**
Martin Luther University & Max-Planck-Institut
für Mikrostrukturphysik, Halle (Saale), Germany
Beyond skyrmions: Alternative magnetic nano-objects for spintronics

16^{35} - 16^{55} **Hariom Jani**
Department of Physics, National University of Singapore
Discovery and control of room-temperature antiferromagnetic topological textures

16^{55} - 17^{15} **Michael Heigl**
Institute of Physics, University of Augsburg, Germany
Dipolar-stabilized first and second-order antiskyrmions in ferrimagnetic multilayers

17^{15} - 17^{35} **Andrew Ross**
Institute of Physics, Johannes Gutenberg-University
& Graduate School of Excellence Materials Science, Mainz, Germany
Control and understanding of magnon transport in insulating antiferromagnets

17^{35} - 17^{55} **Krzysztof Szulc**
Institute of Spintronics and Quantum Information,
Adam Mickiewicz University, Poznań, Poland
Multilayered spin-wave devices based on transmission and resonance phenomena

17^{55} - 18^{15} short break

Poster Session I

18^{15} - 18^{35}: P-1-01, P-2-08, P-4-09, P-3-07, P-3-28, P-5-09, P-5-28, P-6-14, P-7-01

18^{35} - 18^{55}: P-1-02, P-2-09, P-4-10, P-3-11, P-3-29, P-5-10, P-5-29, P-6-15, P-7-02

18^{55} - 19^{15}: P-1-03, P-2-10, P-4-11, P-3-12, P-3-30, P-5-12, P-5-30, P-6-16, P-7-03

19^{15} - 19^{35}: P-1-04, P-2-11, P-4-12, P-3-13, P-3-31, P-5-13, P-5-31, P-5-33, P-7-04

19^{35} - 19^{55}: P-1-05, P-2-13, P-4-13, P-3-14, P-3-32, P-5-14, P-5-32, P-6-19, P-7-05

19^{55} - 20^{15}: P-1-06, P-2-14, P-4-14, P-3-15, P-3-33, P-5-16, P-6-01, P-6-32, P-7-07

Wednesday, June 30, 2021

Plenary Session IV
Chairman: Marek Przybylski

Session sponsored by QNAMI AG

11^{00} - 11^{30} **Del Atkinson**
Department of Physics, Durham University, Durham, United Kingdom
Interactions across ferromagnetic/heavy metal thin-film interfaces: Proximity-induced magnetisation, spin transport and the Dzyaloshinskii-Moriya interaction

11^{30} - 12^{00} **Stéphane Mangin**
Institut Jean Lamour, Université de Lorraine, Nancy, France
Spin-transport mediated single-shot all-optical magnetization switching of metallic films

12^{00} - 12^{30} **Rafael Sánchez**
Dep. de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Madrid, Spain
Andreev-Coulomb drag in coupled quantum dots

12^{30} - 13^{00} **Sang-Im Yoo**
Department of Materials Science and Engineering, Seoul National University, Seoul, Republic of Korea
Excellent microwave absorption properties of partially substituted SrW-type hexaferrites in the Ka band (26.5–40 GHz)

13^{00} - 14^{00} long break

14^{00} - 16^{00} **ORAL SESSION IV**

(Session A) Chairman: Andrzej Maziewski
Ewa Młyńczak (O-3-09), Vinayak Shantaram Bhat (O-3-10), Marcin Białek (O-3-12), Ramon Cardias (O-3-14), Andrea Ehrmann (O-3-21), Kirill Krasikov (O-3-23), Ivan P. Miranda (O-3-25), Menka Jain (O-1-28)

(Session B) Chairman: Bartłomiej Wiendlocha
Bivas Rana (O-5-01), Michał Ślęzak (O-5-02), Anastasios Markou (O-5-03), Tadeusz Domański (O-5-04), Wojciech Brzezicki (O-5-05), Sukanta Kumar Jena (O-5-06), Gabriela Wójtowicz (O-5-07), Pushpendra Gupta (O-4-18)

(Session C) Chairman: Witold Skowroński
Simone Köcher (O-6-01), Christian Holzmann (O-6-02), Lingjia Shen (O-6-05), Andrzej Musiał (O-6-06), Matthias Küß (O-3-02), Vladislav Gubanov (O-3-24), Valentin Sakharov (O-3-19)

16^{00} - 16^{15} short break

Wednesday, June 30, 2021

Young & Brilliant Session II
Chairman: Jarosław W. Kłos

Session under the patronage of the POLISH YOUNG ACADEMY, PAS

16^{15} - 16^{35} **Krzysztof Ptaszyński**
Institute of Molecular Physics, Polish Academy of Sciences, Poznań, Poland
Quantum thermodynamics with nanospintronic devices

16^{35} - 16^{55} **Anna Francuz**
Institute of Physics, Jagiellonian University, Kraków, Poland
Determining topological order with tensor networks

16^{55} - 17^{15} **Marta Roman**
Faculty of Applied Physics and Mathematics, Gdańsk University of Technology, Gdańsk, Poland
Interplay between multiple charge density waves and magnetic states in $\mathbf{R}NiC_2$ ***compounds***

17^{15} - 17^{35} **Giuseppe Cuono**
International Research Centre Magtop, Institute of Physics, Polish Academy of Sciences, Warsaw, Poland
Magnetic phases in the quasi-one dimensional $A_2Cr_3As_3$ ***(A=Na, K, Rb, Cs) superconductors***

17^{35} - 17^{55} **Rafael Martinho Vieira**
Uppsala University, Sweden & Åbo Akademi, Finland
First-principles approach to calculate entropy in magnetocaloric materials

17^{55} - 18^{15} short break

Poster Session II

18^{15} - 18^{35}: P-1-08, P-2-15, P-4-15, P-3-16, P-3-34, P-5-15, P-6-02, P-6-20, P-7-08

18^{35} - 18^{55}: P-1-09, P-2-16, P-4-16, P-3-17, P-3-35, P-5-17, P-6-03, P-6-21, P-7-09

18^{55} - 19^{15}: P-1-10, P-2-17, P-4-17, P-3-22, P-3-36, P-5-18, P-6-04, P-8-05, P-7-10

19^{15} - 19^{35}: P-1-11, P-2-18, P-5-35, P-3-23, P-5-01, P-5-19, P-6-05, P-4-18, P-7-11

19^{35} - 19^{55}: P-1-12, P-4-01, P-3-02, P-3-24, P-5-04, P-5-20, P-6-06, P-6-24, P-7-12

19^{55} - 20^{15}: P-2-01, P-4-05, P-3-03, P-3-25, P-5-05, P-5-34, P-6-07, P-6-25, P-8-01

Thursday, July 1, 2021

Plenary session V
Chairman: Jacek Kossut

11^{00} - 11^{30} **Rembert A. Duine**
Institute for Theoretical Physics, Utrecht University,
Utrecht, Netherlands
Magnonic black holes

11^{30} - 12^{00} **Burkard Hillebrands**
Fachbereich Physik Technische Universität Kaiserslautern,
Kaiserslautern, Germany
From magnon Bose-Einstein condensation to a magnonic qubit

12^{00} - 12^{30} **Jeroen van den Brink**
Institute for Theoretical Solid State Physics IFW Dresden
& Department of Physics TU Dresden, Dresden, Germany
Spin liquids in honeycomb iridates and $RuCl_3$

12^{30} - 13^{00} **Alberta Bonanni**
Institute for Semiconductor and Solid State Physics,
Johannes Kepler University, Linz, Austria
About the ferromagnetic topological crystalline insulator $Sn_{1-x}Mn_xTe$ and the correlated antiferromagnetic semiconductor MnTe

13^{00} - 14^{00} long break

14^{00} - 16^{00} **ORAL SESSION V**

(Session A) Chairman: Karol Szałowski

Mario Fix (O-4-02), Maciej Chrobak (O-4-03),
Evangelos Almpanis (O-4-10), Piotr Trocha (O-4-05),
Damian Tomaszewski (O-4-06), Sarah Heidtfeld (O-4-07),
Piotr Busz (O-4-08), Krzysztof Grochot (O-4-09)

(Session B) Chairman: Michał Ślęzak

Carmine Autieri (O-5-08), Alexander Shick (O-5-09),
Archana Mishra (O-5-10), Maciej Wiesner (O-5-11),
Kamil Nowak (O-5-13), Hubert Głowiński (O-5-14),
Fatih Zighem (O-5-16), Javier Herrero-Martin (O-5-17)

(Session C) Chairman: Marian Mihalik

Mehran Mirzaei (O-7-02), Rafał Bielas (O-7-03),
Bernadeta Dobosz (O-8-01), Michał Jurczyszyn (O-8-02),
Tomasz Polak (O-8-03), Piotr Rzeszut (O-7-01),
Francisco Meirinhos (O-1-09), Agnieszka Cichy (O-1-17)

16^{00} - 16^{30} short break

Thursday, July 1, 2021

16^{30} - 18^{00} **ORAL SESSION VI**

(Session A) Chairman: Andrzej Wiśniewski

Christian Martens (O-1-10), Xiaodong Zhang (O-1-14), Konrad Jerzy Kapcia (O-1-16), Sylwia Gutowska (O-1-23), Przemysław R. Grzybowski (O-1-24), Ryszard Radwański (O-1-27)

(Session B) Chairman: Anna Bajorek

Sebastian A. Díaz (O-2-06), Karol Załęski (O-5-18), Cesar Tejera-Centeno (O-5-19), Roger Kalvig (O-5-20), Piotr Mazalski (O-5-22), Alberto Calloni (O-5-15)

18^{00} - 18^{15} Short break

Poster Session III

18^{15} - 18^{35}: P-2-02, P-4-02, P-3-04, P-3-18, P-5-02, P-5-22, P-6-08, P-6-26, P-8-02

18^{35} - 18^{55}: P-2-03, P-4-03, P-3-05, P-3-19, P-5-03, P-5-23, P-6-09, P-6-27

18^{55} - 19^{15}: P-2-04, P-4-04, P-3-06, P-3-20, P-5-11, P-5-24, P-6-10, P-6-28, P-6-17

19^{15} - 19^{35}: P-2-05, P-4-06, P-3-10, P-3-21, P-5-06, P-5-25, P-6-11, P-6-29, P-5-21

19^{35} - 19^{55}: P-2-06, P-4-07, P-3-08, P-3-26, P-5-07, P-5-26, P-6-12, P-3-01

19^{55} - 20^{15}: P-2-07, P-4-08, P-3-09, P-3-27, P-5-08, P-5-27, P-6-13, P-6-31, P-4-19

Friday, July 2, 2021

Plenary session VI (4 x 30 min.)
Chairman: Józef Spałek

11^{00} - 11^{30} **Andreas Baumgartner**
Department of Physics, University of Basel, Basel, Switzerland
Quantum dot spin valves and Cooper pair splitter spin correlation experiments using ferromagnetic split-gates

11^{30} - 12^{00} **Ireneusz Weymann**
Faculty of Physics, Adam Mickiewicz University in Poznan, Poznań, Poland
Interplay of magnetism and superconductivity in correlated nanoscale systems

12^{00} - 12^{30} **Tomasz Klimczuk**
Faculty of Applied Physics and Mathematics, Gdańsk University of Technology, Gdańsk, Poland
Tuning magnetism in the rare earth (RE) $REIr_3$ ***and*** $RENiC_2$ ***intermetallic compounds***

12^{30} - 13^{00} **Antonio Bianconi**
Rome International Center for Materials Science Superstripes RICMASS, Rome, Italy
Spin-orbit coupling tuning Fano-Feshbach resonant multigap superconductivity

13^{00} - 14^{00} long break

Plenary Session VII
Chairman: Nicholas Sedlmayr

14^{00} - 14^{30} **Roman Puźniak**
Institute of Physics of the Polish Academy of Sciences, Warszawa, Poland
Pressure induced enhancement of superconducting state properties and its correlation with crystallinity degradation of Fe-Te-Se single crystals

14^{30} - 15^{00} **Eugene A. Demler**
Lyman Laboratory, Department of Physics, Harvard University, Cambridge, USA
Single-spin qubit magnetic spectroscopy of the correlated electronic states

15^{00} - 15^{30} **Andrzej M. Oleś**
Institute of Theoretical Physics, Jagiellonian University, Kraków, Poland
Entanglement in doped spin-orbital Mott insulators: Orbital or charge dilution versus spin-orbital polarons

Friday, July 2, 2021

Plenary Session VII ***cont.***
Chairman: Nicholas Sedlmayr

15^{30} - 16^{00} **George Jackeli**
Max Planck Institute for Solid State Research
& Institute of Functional Matter and Quantum Technologies,
Univeristy of Stuttgart, Stuttgart, Germany
Ordered and quantum disordered states in spin-orbit coupled correlated systems

16^{00} - 16^{30} short break

Plenary Session VIII
Chairman: Bogdan Bułka

16^{30} - 17^{00} **Anna Dyrdał**
Faculty of Physics, Adam Mickiewicz University in Poznan,
Poznań, Poland
Current-induced spin polarization in topological insulators and its role in magnetotransport

17^{00} - 17^{30} **Giovanni Vignale**
Department of Physics and Astronomy, University of Missouri,
Columbia, MO, USA
Orbital Hall effect as an alternative to valley Hall effect in gapped graphene

17^{30} - 18^{00} **Evgeny Y. Tsymbal**
Department of Physics and Astronomy, and Nebraska Center for Materials and Nanoscience, University of Nebraska, Lincoln, NE, USA
New approaches for Néel vector detection in antiferromagnetic spintronics

18^{00} - 18^{15} short break

Closing Lecture
Chairman: Józef Barnaś

18^{15} - 19^{00} **Albert Fert**
Unité Mixte de Physique CNRS/Thales, Palaiseau, France
2D magnets: from fundamental to spintronic devices

Awards, Summary and Closing

19^{00} - ... Bogdan Idzikowski, Roman Micnas, Tomasz Toliński, Maciej Krawczyk

INVITED LECTURES

Quantum anomalous Hall effect in V-doped $(Bi,Sb)_2Te_3$

Kajetan M. Fijalkowski,[1,2] Charles Gould,[1,2] and Laurens W. Molenkamp[1,2]

[1] *Faculty for Physics and Astronomy (Experimentelle Physik III), Universität Würzburg, Am Hubland, D-97074, Würzburg, Germany*
[2] *Institute for Topological Insulators (ITI), Am Hubland, D-97074, Würzburg, Germany*

The anomalous Hall effect [1], despite being more than a century old, remains of great interest for fundamental research purposes, especially in the context of novel magnetic materials such as magnetic topological insulators. Careful analysis of the anomalous Hall transport in a magnetic topological insulator, V-doped $(Bi,Sb)_2Te_3$, indicates the presence of two contributions of opposite sign. Their response to a variety of experimental parameters suggests that one contribution originates on the surface, and the other in the bulk of the magnetic topological insulator layer [2].

When the structural parameters of V (or Cr)-doped $(Bi,Sb)_2Te_3$ material are carefully optimized, at sufficiently low temperatures this ferromagnetic material is known to exhibit the quantum anomalous Hall effect [3], characterized by conduction through a single dissipationless chiral edge channel, even at zero external magnetic field. This perfect electronic transport quantization was quickly recognized as a promising platform for quantum metrology, as a zero field quantum resistance standard. Metrologically comprehensive experiments reveal a great precision of the anomalous Hall resistance quantization in our films [4].

Finally, careful analysis of the underlying fundamental physics reveals the existence of two distinct types of quantum anomalous Hall states, related to the systems' dimensionality. Both regimes are experimentally accessible by changing the layer thickness. Thinner films exhibit a conductivity tensor flow diagram equivalent to that of a two-dimensional electron gas, implying a fundamentally two-dimensional origin of the effect. When the film thickness is increased, a transition to the three-dimensional regime is observed. In the three-dimensional limit, the conductivity scaling changes to the one expected for electronic transport on two parallel topological interfaces, encapsulating a volume of distinct topology. This three-dimensional bulk supports axion electrodynamics, revealing the existence of an additional term in the Maxwell's equations, and a quantum state of matter called an "axion insulator" [5,6].

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Si Platform for Implementing Spin-based Quantum Computing

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Application of elelctron (or hole) spins confined into Si quantum dots for implementing quantum computing is receiving increased attention because of various advantages such as long decoherence time ($\lesssim$ msec), small physical area per qubit ($\leqslant 0.1$ μm^2), high temperature operation ($\gtrsim$ K), and compatiblity with industrial technology. Indeed various techniques have been developed for manipulating spins, including operation of single and two-qubit gates with high fidelity and above 1.5 K and fabrication of CMOS based qubit devices. In this talk I will first review recent advances in embodying the advantages of Si devices with Si/SiGe and Si-MOS as platforms, and then discuss technical development to implement fault tolerant computation, including high-fidelity gate operations of one to three qubits. I will finally review recent efforts to scale up the qubit system based on the industrial technology.

New Emergent Materials Driven via Synergetic Extreme Conditions

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Synergetic extreme conditions such as pressure in combination with magnetic field or temperatures can dramatically change the magnetic states of materials leading to emergent phenomena such as novel superconductivity. It originates from the modification of multiple quantum interactions with respect to extreme conditions. Here we introduce our recent progress on the topic of pressure generated superconductivity in the compressed configurations of materials.

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Self-induced spin glass phase in dhcp Nd

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One of the most intriguing phases of magnetic order is manifested by the spin glass state. These systems exhibit glassy dynamics, including ageing and memory effects. Their peculiar dynamics can be explained from an energy landscape with several local minima combined with larger energy barriers resulting in non-ergodic behavior. Such energy landscapes have historically been associated with disorder and thus spin glass dynamics have been expected to only occur in chemically disordered materials, such as transition metal alloys.

Here we will present recent theoretical and experimental findings [1] of glassy dynamics in a material with limited chemical disorder: thick films of elemental crystalline Nd. In bulk, Nd crystallizes in the dhcp structure and earlier studies have indicated the existence of several non-collinear states across its phase diagram. We will discuss our interpretation that the low temperature state of dhcp Nd can in fact be described as a self-induced spin glass and how the exchange interactions in the material can cause the energy landscape that drives the glassy dynamics.

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Magnetic Topological Quantum Matter

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Electrons organize in ways to give rise to distinct phases of matter such as insulators, metals, magnets, superfluid or superconductors. In the last ten years or so, it has become increasingly clear that in addition to the symmetry-based classification of matter, topological consideration of wavefunctions plays a key role in determining distinct or new quantum phases of matt er [see, for an introduction, Hasan & Kane, Reviews of Modern Physics 82, 3045 (2010)].

In this talk, I briefly introduce these new topological concepts in the context of their experimental realizations in three dimensional magnetic matter. As examples, I present how tuning a topological insulator whose surface hosts an unpaired Dirac fermion can give rise to emergent Weyl fermion and "fractional" Fermi surfaces; and strongly correlated magnetic, Chern or many-body states of matter. These "magnetic topological matter" harbor novel and unprecedented properties that may lead to the development of next generation quantum technologies.

Interfacing topological materials: search for the origin of zero-energy modes and low-temperature dephasing

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I will review surprising phenomena observed when interfacing topological materials with normal metals, magnetic layers, superconductors, and amorphous semiconductors. In particular, point-contact spectroscopy with silver microcontacts reveals a transition to a low-temperature phase characterized by zero-energy modes superimposed on an energy gap showing a Bardeen-Cooper-Schrieffer-type of criticality. However, no global superconductivity is detected in these systems. An experimental[1] and theoretical[2] search for the origin of this striking behavior in diamagnetic, paramagnetic, and ferromagnetic topological crystalline insulators (Pb,Sn,Mn)Te will be presented. I will also touch upon the question of the effects of magnetic layers upon the topological surface Dirac cones as well as the interfacial physics of Weyl semimetals covered by various superconductor films.[3] Finally, I will discuss surprising Berry phase quantization on both sides of topological phase transition, revealed by experimental and theoretical studies of weak-antilocalization magneto-resistance in $Pb_{1-x}Sn_xSe$ epilayers.[4] The results also point to temperature-independent dephasing by amorphous Se overlayers, which is interpreted in terms of a hitherto overlooked contribution of mirror-symmetry breaking to dephasing.

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On the hunt for topological superconductors

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Topological superconductor (TSC) hosting Majorana bound states (MBS) has been established as a milestone that might shift our scientific trajectory from fundamental research to practical applications in topological quantum computing. Various roadmaps have been proposed in order to realize TSC. One of the intensively studied pathways is the emergence of MBS via proximity effect in systems built from s-wave superconductors and strongly spin-orbit coupled semiconductor nanowires [1], ferromagnetic atomic chains [2], or 3D topological insulators [3]. A promising route towards TSC is through appropriate doping of archetypal topological insulators, such as Bi_2Se_3 [4], or crystalline topological insulators, like SnTe [5]. Another possibility is to induce TSC by external pressure, as achieved, e.g., for Weyl semimetal $MoTe_2$ [6]. Parallel to all these efforts, an intensive search is being conducted for stoichiometric materials, in which TSC will be an intrinsic property emerging at ambient pressure. Most recently, some evidence for such a behavior has been found, e.g., in nematic superconductors $PbTaSe_2$ [7] and $CaSn_3$ [8]. Another strong hope for MBS realization is related to unconventional superconductors with high total angular momentum pairing, predicted teoretically to occur in half-Heusler topological semimetal YPtBi [9].

In my talk, I will present some examples of our own research aimed at identifying novel TSC candidate materials. In particular, I will briefly review our comprehensive experimental studies on superconducting Pd-Bi binaries [10] and rare-earth-based half-Heusler bismuthides [11].

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Correlation-driven topological semimetals

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The insight that nontrivial topology can be implemented in electronic materials via special configurations of their electronic bands has revolutionized condensed matter science. The broad bands of weakly interacting materials and their good description with density functional theory have been instrumental to visualize topological bandstructures (e.g. by ARPES). To pin down unique topological properties or even control them—the ultimate goal for topological quantum devices—however, remain a formidable challenges. This is where strongly correlated electron systems come into play. As evidenced for the noncentrosymmetric and nonsymmophic heavy fermion material $Ce_3Bi_4Pd_3$ [1], strong electron correlations can drive "extreme topological responses" [2-4]. Furthermore, the excellent tunability of strongly correlated electron systems in terms of their correlation physics [5] appears to also allow to control the topological characteristics of these systems [6]. In this talk I will discuss the background, with focus on strong correlation phenomena, present results on $Ce_3Bi_4Pd_3$, and discuss implications, noting also the possible involvement of quantum criticality in stabilizing correlation-driven topological phases [7].

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Magnetic domains without domain walls and their influence on magnetization reversal process in ferrimagnetic Tb/Co multilayers

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In the past, great interest in ferrimagnetic (FI) rare-earth (RE) - transition metal (TM) films with perpendicular magnetic anisotropy (PMA) was motivated by their potential applications in magneto-optical memories. Nowadays, the FI films are intensively investigated because of recently discovered phenomena (all-optical switching, fast domain wall propagation, creation and propagation of skyrmions), which are important for a wide range of potential applications. Here, a recently found property of magnetically patterned FI-Tb/Co multilayers will be described. Using 10keV He ion bombardment we reduce the magnetic contribution of the Tb sublattice to effective properties of Tb/Co as the ion dose increases. As a result, an ion bombardment allows to locally change the domination from Tb+(RE+) to Co+(TM+) in multilayers that are Tb dominated prior to the bombardment. This local magnetic patterning was used to fabricate a 2D-lattice of artificial magnetic domains. This domain pattern exhibits an interesting spin texture, in which adjacent magnetic domains with oppositely oriented effective magnetization exist without domain walls in between [1]. This unique magnetic configuration is very stable due to a deep minimum in the energy of the system caused by flux closure and a corresponding reduction of the magnetostatic energy without a corresponding increase in energy by exchange and anisotropy terms relevant to the walls. This stability strongly affects the magnetization reversal process of this system [2].

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"Artificial Multi-Elements" based on High Entropy Alloys as "building blocks" for novel magnetic alloys suitable for Permanent Magnets: Special cases $ThMn_{12}$ and $SmFe_3CoNi$

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Demand for rare earths or cobalt is set to soar the next decade boosted especially by demand for valuable NdPr or SmCo magnets used in electric motors (electric vehicles, wind turbines, consumer electronics, military & aerospace applications). The global permanent magnet market size is expected to reach €30 billion by 2030 from the current €20 billion. It is predicted that by 2030 a) Market for rare-earth oxides will increase 5-fold, b) annual NdFeB shortages of 48,000 tonnes expected by 2030, c) annual Dy oxide Shortages of 1850 tonnes is expected by 2030. Extending the forecasting of Dr. M.Sagawa , who has predicted that by 2050 every one on earth will be served by at least 2 robots each one having at least 10 magnets, the new market has to be served by novel groundbreaking approaches.

For centuries the design concepts of alloys has been based on only one or two principle elements, while minor fraction of other elements are added for property enhancement. This classical approach was broken in 2004 by Yeh et.al, who suggested of a new alloy design concept, which he called high entropy alloys. The original definition was "multiprincipal elements alloys composed of five or more elements in equal or near-atomic percentages". Most of the current dominant (PMs) are **intermetallic compounds** containing rare earth elements e.g. NdPr or Sm and Co, both expensive and originating mainly from either China or Congo. These natural elements from the periodic table have a fixed atomic radii, fixed valence electron configuration and specific electronegativity, parameters that are crucial for the formation of intermetallic compounds. By **creating artificial multi-elements** of the type of HEAs based on multicomponent rare-earth elements (RE-HEAs) and HEAs based on multicomponent transition metal elements (TM-HEAs), we have created a library of elements **with tunable atomic radii, valence electron configuration and electronegativity. This approach enhances the opportunities for discovering novel permanent magnets.**

The concept of using artificial elements based on either rare-earths or transition metals is depicted in Figure 2. for the case of $SmCo_{5-}$type alloys, an approach that we followed for the stabilization of the $SmFe_3CoNi$ magnetic phase. We have extended this substitutional approach to the class of $RFe_{12-x}T_x$ a and $R_2Fe_{14}B$ alloys and the results so far are given in Table 1.

Sample	Ms(emu/g)	H_A(T)	Tc (K)	Hc $_{(expected)}$ (T)	$(BH)^{theor}{}_{max}$ (MGOe)
(RE-HEAs)-Co_5	75-90	>10	> 800	>1	8-18
Sm-$(TM\text{-}HEAs)_5$	65-80	> 8T	> 800	>1	8-15
(RE-HEAs)-$Fe_{11}TiN_x$	120-135	>6T	570-600	>0.8	9-18
(RE-HEAs)2-Fe14B	125-145	3-6	550-600	>1	10-25

We will present a general approach by unlocking the new possibilities of using artificial elements to create new magnetic alloys that can be processed towards (PMs) to address the opportunities that are shown in Figure 1.

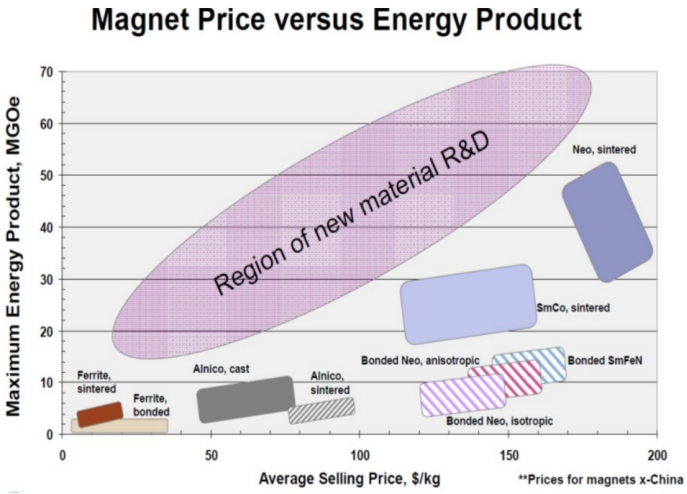

Figure 1. Opportunities for novel magnet alloys, suitable for permanent magnets, as a function of $(BH)_{max}$ vs cost (Arnold Engineering).

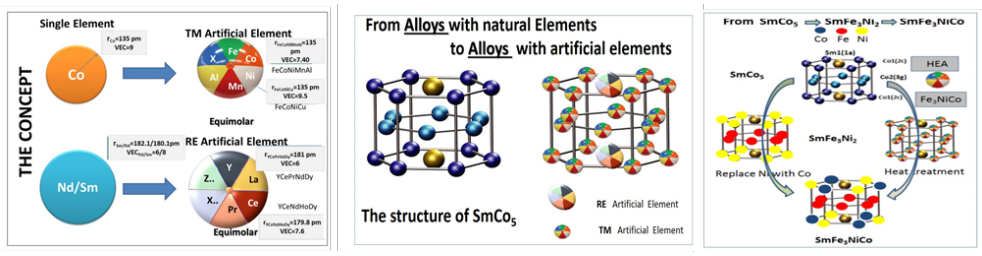

Figure 2. Three steps towards HEA-Magnetic Alloys. Step1 is the fabrication of the artificial elements RE-HEAs and TM-HEAs with variable atomic radii and valence electron concentration, Step2 use these artificial elements to synthesize model structures as counter-alloys of existing structures e.g. $SmCo_5$ and in Step3 with proper heat treatment stabilize through entropy optimization a phase e.g. $SmFe_3CoNi$, that otherwise is not possible because the formation energy is just slightly positive.

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Soft magnetic amorphous and nanocrystalline bilayer ribbons for sensor applications

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Rapidly solidified amorphous and/or nanocrystalline bilayer ribbons are interesting for their intrinsically graded properties, which can be used in design of magnetic sensors or actuators. A double-nozzle planar flow casting technique offers the possibility of simultaneous formation of two mechanically solid connected layers with different composition and uniform thickness of tenths of microns along the ribbon length. It makes possible combining unlike alloys with selected properties and unique overall behavior. A special attention of our work was devoted to bilayers with different magnetic and magnetoelastic properties. The composition of the individual layers was chosen from the Fe-Cu-Nb-Si-B, Fe-Nb-Si-B, Fe-Ni-Nb-B, Fe-Co-Nb-B and Co-Si-B alloy systems, respectively. By using of proper heat treatment, it was possible to transform the separate layers or entire bilayers to nanocrystalline state. In order to optimize the application performance of prepared bilayers, a thermal processing under presence of external magnetic field was employed. We show that besides the effects of field-annealing, the magnetic behavior in such bilayers is strongly influenced by interlayer stresses, which are induced in material due to different thermal expansion of two mechanically coupled individual layers. This can lead to very large induced magnetic anisotropies. The magnetostatic bias effects between layers with different magnetic softness can also play an important role in magnetization reversal process. Examples of our recent work on development of new rapidly quenched bilayer ribbons with improved soft magnetic and/or magnetoimpedance characteristics will be presented and the added value of such materials for use in magnetic sensors will be briefly highlighted.

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Are room-temperature molecular photomagnets possible and how to reach them?

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Visible light photoexcitation of some molecules/molecular solids can lead to a dramatic change of their magnetization. This is the so called photomagnetic effect and the relevant compounds are called photomagnets. In other words, photomagnets belong to a class of photoresponsive compounds that become paramagnetic, ferromagnetic or simply change their magnetic properties upon illumination – a property that is hardly accessible in conventional magnetic solids such as metal alloys and oxides.

The first examples of photomagnetism in molecular compounds are related to the discovery of the light-induced excited spin state trapping (LIESST) effect in some octahedral Fe^{II} spin crossover (SCO) compounds[1] followed by the report of the light-induced shift of the magnetic ordering temperature in $K_{0.2}Co_{1.4}[Fe(CN)_6]\cdot 6.9H_2O$ Prussian Blue analog (PBA) due to the charge transfer induced spin transition (CTIST).[2] Similar photomagnetic behavior was also observed for some octacyanomolybdate(IV)-based systems[3] including the recent report of the LIESST-like behavior of $[Mo^{IV}(CN)_8]^{4-}$ itself in a $[Mo^{IV}(CN)_8Zn_2\{tren\}_2]$ compound.[4] Various photomagnetic building blocks were successfully used in the design and construction of multifunctional photomagnetic compounds.[5,6] However, only a handful, mostly based on Fe^{II} and Mo^{IV} centers, were shown to be intrinsically photomagnetic.

During the talk I will focus on multiple photomagnetic experiments for various cyanometallate-based compounds ranging from simple salts to bimetallic coordination polymers, that show photomagnetic switching associated with the photodissociation reaction occurring in the solid state (see also Figure 1):

$$[M^m(CN)_n]^{(m-n)} \rightarrow [M^m(CN)_{n-1}]^{(m-(n-1))} \cdot CN^- \quad (1)$$

In order to confirm this photodissociation mechanism, the aforementioned photomagnetic studies are accompanied by single crystal X-ray diffraction structural analysis and/or UV-vis-IR spectroscopy studies before and after irradiation. Thanks to the slow relaxation of the photoinduced CN-dissociated state and very strong magnetic coupling interactions between the photoexcited paramagnetic cyanometallates and the early transition metal ions, these unique coordination complexes hold great promise as building blocks for the construction of room-temperature photomagnets. This is partly confirmed by several examples of coordination polymers based on Mn^{II}, showing the highest photo-induced magnetic ordering temperatures exceeding the boiling point of liquid nitrogen for $[Mn^{II}(imH)]_2[W^{IV}(CN)_8]_n$ [7] and approaching 130 K for $[Mn^{II}_2(pydz)][W^{IV}(CN)_8]_n$.[8] Changing Mn^{II} to V^{II} should shift the current 130 K limit to room temperature.[9]

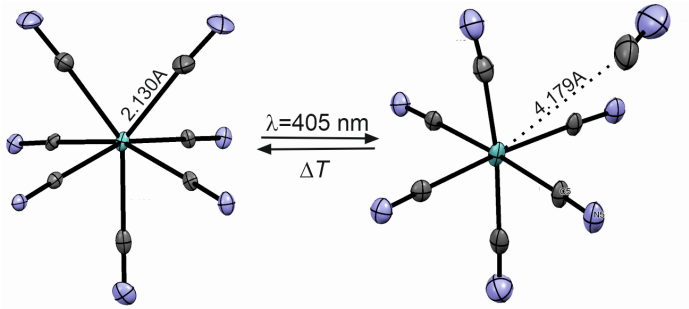

Figure 1. An example of the reversible photo-induced ligand dissociation in the solid state upon violet light irradiation of the polycrystalline sample of potassium heptacyanomolybdate(III) dihydrate.

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Interactions across ferromagnetic/heavy metal thin-film interfaces: Proximity-induced magnetisation, spin transport and the Dzyaloshinskii-Moriya interaction

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Several physical mechanisms in magnetism are linked to electronic interactions that take place across the interface between magnetic (FM) and non-magnetic (NM) thin-film layers. These interfacial interactions mediate phenomena that are significant for spintronics applications, such as interfacial anisotropy, and are the subject of ongoing research including interfacial Dzyaloshinskii-Moriya interactions (iDMI) and the proximity-induced-magnetization (PIM) of heavy metals in contact with a FM layer. The materials and physical structure at the interface are critical to these effects and also to spin transport through the interfaces. This is key in FM/NM systems for magnetic damping, via the pumping of spin current into NM layers, and spin-orbit torque (SOT) switching, resulting from the propagation of spin-current into a FM layer. The linkage between these interfacial phenomena has been the subject of debate, such as the relationship between DMI and proximity induced magnetisation and the role of PIM in spin transport across FM/NM interfaces. Further debate has surrounded the determination of the spin-diffusion length from spin-pumping analysis and spin-pumping through insulating layers. The focus here is on the relationships between these interfacial phenomena and spin-transport across the interface.

The relationship between interfacial proximity-induce magnetisation and iDMI is presented for the Co/Pt system [1], as a function of Au and Ir spacer layers. The nature of PIM in heavy metals layered with ferrimagnetic systems is then discussed for Pt in contact with rare earth:transition metal alloy films to understand the relationship between the Pt moment and the two ferrimagnetic sublattices [2].

Spin transport across FM/NM interfaces is introduced [3] and the effects of interface structure, NM thickness [4] and tunnelling through an insulating oxide layer [5] are discussed and descibed with an updated physical description for the analysis of spin-transport from spin-pumping in FM/NM systems [6] that shows a consistent understanding is obtained when a thickness dependent spin-diffusion length in the NM layer is used. Finally new results and analysis demonstrate a clear relationship between interfacial PIM, damping and the ease of spin current propagation across the interface.

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Spin-transport Mediated Single-shot All-optical Magnetization Switching of Metallic Films

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During the last decade all-optical ultrafast magnetization switching in magnetic material thin film without the assistance of an applied external magnetic field has been explored [1,2]. It has been shown that femto-second light pulses can induce magnetization reversal in a large variety of magnetic materials [3,4]. However, so far, only certain particular ferrimagnetic thin films exhibit magnetization switching via a *single* femto-second optical pulse. All optical helicity dependent switching of a ferromagnetic layer could be demonstrated for a low number of pulses [5]. We will present the single-pulse switching of various magnetic material (ferrimagnetic, ferromagnetic) within a magnetic spin-valve structure and further show that the four possible magnetic configurations of the spin valve can be accessed using a sequence of *single* femto-second light pulses. Our experimental study reveals that the magnetization states are determined by spin-polarized currents generated by the light pulse interactions with the GdFeCo layer [6]. A detail study showing how spin-polarized currents are generated and how they interact with magnetic layers (Ferromagnetic or Ferrimagnetic) to lead to magnetization switching will be presented [7,8].

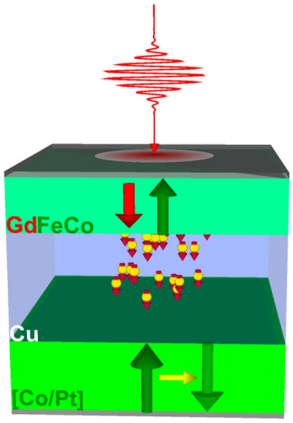

Figure 1: Sketch of a spin-valve structure used to demonstrate femto-second single pulse switching of each magnetic layer independently. The generation of femto-second spin current is shown to play a major role.

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Andreev-Coulomb drag in coupled quantum dots

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Electrical power can be generated in a quantum dot system that rectifies the energy absorbed from non-equilibrium fluctuations of its environment. Typically, this depends on tiny energy-dependent asymmetries of the device [1]. We show that larger currents are expected in hybrid systems, where a superconductor hybridizes even-parity states (with 0 and 2 electrons) in the quantum dot. We consider the environment to consist on a quantum dot Coulomb-coupled to the conductor one. The non-equilibrium charge fluctuations in the second dot correlate with the Andreev processes that inject Cooper pairs in the superconductor. This provides the necessary symmetry breaking energy transfer. We analyze this mechanism in two configurations depending on the non-equilibrium source: i.e., when the quantum dot is coupled to (i) two terminals at different chemical potential, and (ii) a single but hot terminal. We show that pair and quasiparticle contributions can be distinguished by a change of sign of the generated current [2].

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Excellent microwave absorption properties of partially substituted SrW-type hexaferrites in the Ka band (26.5–40 GHz)

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It has been a challenging task to achieve an excellent microwave absorber in Ka band (26.5 – 40 GHz) which can exhibit the reflection loss (RL) less than -20. Such excellent microwave absorbers in Ka band are obtainable from partially substituted Strontium W-type (SrW) hexaferrites. Decomposition of partially substituted SrW hexaferrites during furnace-cooling could be effectively suppressed by the heat treatment in a reduced oxygen pressure [1,2]. For this study, the complex permittivity and complex permeability of samples were measured, and the reflection losses were calculated based on the obtained permittivity and permeability spectra. Details will be presented for discussion.

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Magnonic Black Holes

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In this talk I will discuss analogue-gravity set-ups that are based on the manipulation of spin waves in magnetic materials with spin transfer torques, i.e., torques due to spin-polarized currents. I will discuss both the implications for the field of analogue gravity and for the field of magnonics that aims to build applications based on manipulation of spin waves.

From magnon Bose-Einstein condensation to a magnonic qubit

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There is an enormous need for faster and more efficient information processing. Quantum computing is widely discussed as future computing technology, especially with regard to computing power and scaling properties.

Macroscopic quantum states of matter such as Bose-Einstein condensate (BEC) are excellent candidates for quantum information processing, particularly due to their inherent coherency. The wave function of the BEC describes a highly populated boson state and thus justifies a semiclassical approach.

In this talk, I will start with the principles of the magnon BEC. I will show that using the raping cooling mechanism as a new and universal approach enables BEC of magnons in nanostructured systems [1]. We can also prepare the magnon BEC in confined systems employing parallel parametric pumping [2]. Novel methods to manipulate the dynamics of magnon BEC based on the spin Hall effect and the lateral confinement will be discussed [2-3].

Further, I will present the way to enable room-temperature quantum computing functionalities using a two-wavevector component magnon BEC in magnetic films [4]. It is based on the fact that the dispersion characteristics of the magnons in an in-plane magnetized magnetic film have two energy minima at finite opposite wavevectors, where the magnon condensation occurs. Similar to a qubit in quantum computing, the superposition of a two-component magnon BEC can be described as a state on the surface of a Bloch sphere. We developed novel methods to initialize and manipulate such magnon BECs as a qubit representative. For instance, I will show that the magnon qubit can be initialized by wavevector selective parallel pumping enabling the single magnon BEC formation in one of the lowest energy states. Furthermore, by translating the concept of Rabi oscillations into the wavevector domain, I will demonstrate that the two components of the magnon BEC exchange their densities with time. All proposed methods are supported by numerical simulations [4].

Our investigations greatly extend the freedom to study the dynamics of magnon BEC in confined systems and to design integrated circuits for magnon BEC-based applications at room temperature. Moreover, they bridge the fields of quantum computing and macroscopic quantum states of magnons.

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Spin liquids in honeycomb iridates and $RuCl_3$

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The observed richness of topological states on the single-electron level prompts the question what kind of topological phases can develop in more strongly correlated, many-body electron systems. Correlation effects, in particular intra- and inter-orbital electron-electron interactions, are very substantial in $3d$ transition-metal compounds such as the copper oxides, but the spin-orbit coupling (SOC) is weak. In $5d$ transition-metal compounds such as iridates, the interesting situation arises that the SOC and Coulomb interactions meet on the same energy scale. The electronic structure of iridates thus depends on a strong competition between the electronic hopping amplitudes, local energy-level splittings, electron-electron interaction strengths, and the SOC of the Ir $5d$ electrons. The interplay of these ingredients offers the potential to stabilise relatively well-understood states such as a 2D Heisenberg-like antiferromagnet in Sr_2IrO_4, but in principle also far more exotic ones, such a topological Kitaev quantum spin liquid, in (hyper)honeycomb iridates. I will discuss the microscopic electronic structures of these iridates, their proximity to idealized Heisenberg and Kitaev models and our contributions to establishing the physical factors that appear to have preempted the realization of quantum spin liquid phases so far and include a discussion on the $4d$ transition metal chloride $RuCl_3$.

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About the ferromagnetic topological crystalline insulator $Sn_{1-x}Mn_xTe$ and the correlated antiferromagnetic semiconductor MnTe

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An interplay of conservation and breaking of local and global symmetries in topological phases of matter leads to the emergence of topological phenomena including quantum anomalous (QAH) Hall effect, topological superconductivity, and non-Abelian quantum statistics. Magnetically doped topological crystalline insulators (TCI) were foreseen to host topologically protected QAH states generating multiple dissipationless edge and surface conduction channels with Chern number $C \geq 1$. The symmetry protected topological phase of the SnTe class of TCI, is characterized by a mirror symmetry resulting in topological surface states. Theoretical and experimental studies demonstrated that four Dirac points are located at the time-reversed-invariant-momentum (TRIM) points for the (111) surface of the SnTe compounds. We provide an overview on how we have proven the opening of the gaps at the TRIMs in ferromagnetic $Sn_{1-x}Mn_xTe$ (111) thin epitaxial layers grown on BaF_2(111). The emergence of hysteretic magnetoconductance and anomalous Hall effect point at the onset of a hole mediated ferromagnetic ordering and the anomalous Hall angle is found to be one of the highest recorded for magnetic topological quantum materials [1].
Moreover, we summarize our recent findings on coherent ultra-fast spin dynamics and coupling between magnetism and optical properties in antiferromagnetic epitaxial MnTe [2,3].

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Quantum dot spin valves and Cooper pair splitter spin correlation experiments using ferromagnetic split-gates

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Using the electron spin in 'spintronic' devices promises a large range of applications, for example in new types of transistors, or to gain fundamental insights into quantum physics. To these ends, we introduced individually magnetized ferromagnetic split-gates (FSGs) [1] to locally polarize the electron spin states, for example in semiconductor quantum dots (QDs). We first report on a double QD spin valve [2] consisting of two weakly coupled semiconducting QDs in an InAs nanowire, each with independently magnetized FSGs oriented either in parallel or anti-parallel. In tunneling magnetoresistance (TMR) experiments, we demonstrate a strongly reduced spin valve conductance for the *anti-parallel* orientations at zero external magnetic field, with QD polarizations of $\sim 27\%$. This value can be improved considerably by tuning the gate voltages and by a small external magnetic field ($\sim 40\,\mathrm{mT}$), yielding a continuously electrically tunable TMR signal. Using a simple model, we reproduce all our experimental findings, with a gate tunable QD polarization of up to $\pm 80\%$ [2].

The real strengths of such spin-polarized QDs as spintronic elements lies in their straight forward implementation into more complex nanoelectronic devices, for example in combination with superconducting elements. Here we present spin current correlation measurements in a Cooper pair splitter [3, 4]: in a standard superconductor, electrons of opposite spins form spin singlet Cooper pairs. These electrons can be spatially separated using two QDs coupled in parallel to a superconductor. These QDs we again spin-polarize by individual FSGs and measure the resulting electrical currents. In this case, we find a suppression of the split Cooper pair currents by $\sim 50\%$ for the two *parallel* magnetization configurations, compared to the anti-parallel configuration. This is consistent with a negative spin correlation between the two split Cooper pair currents: intuitively, a Cooper pair cannot split into two electrons of the same spin projection. From these experiments we find a spin correlation of $\left\langle \hat{C}_{\mathrm{exp}} \right\rangle \leq -1/3$ [5], clearly demonstrating a negative spin correlation due to Cooper pairing. This number deviates from the ideal case of -1, mainly due to the non-ideal spin polarization of the individual QDs [6].

Such QD spin filters are suitable for various other applications, for example to perform a solid-state Bell test [6], to investigate spin patterns in Rashba nanowires [7], or in equal spin Andreev reflection [8] at Majorana-type bound states.

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Interplay of magnetism and superconductivity in correlated nanoscale systems

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Magnetic impurities immersed in a superconductor give rise to the formation of the Yu-Shiba-Rusinov states – the sub-gap states that can be probed by Andreev spectroscopy in quantum dot superconducting heterostructures. When the coupling between a magnetic impurity and a superconducting host grows, a phase transition between the Kondo-screened and unscreened phases emerges, followed by the formation of the many-body singlet state, whose spatial extension is referred to as the Kondo screening cloud. We analyze the properties of this cloud in the case of spin-1/2 impurity attached to an s-wave superconductor. We show that, although the Kondo state does not form in the unscreened phase, the Kondo cloud does exist in both quantum phases, however, while screening is complete in the screened phase, it is only partial in the unscreened phase. We also demonstrate that the compensation, a quantity introduced to characterize the integrity of the cloud, is universal, and can be related to the magnetic impurities' g-factor. Moreover, focusing on the sub-gap transport regime, we inspect the transport properties of strongly correlated coupled quantum dot systems, pointing at nonlocal pairing as a source of spin exchange and Kondo screening. Finally, we discuss the transport behavior of magnetic impurities in the presence of one-dimensional topological superconductors exhibiting Majorana zero-energy modes.

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Tuning magnetism in the rare earth (RE) $REIr_3$ and $RENiC_2$ intermetallic compounds

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The attractiveness of lanthanide based compounds comes from a unique opportunity to tune the magnetic properties. For example, it has been shown by Berndt Matthias that 1% of Gd diluted in La already suppresses superconductivity, and, with as little as 3% of Gd, a ferromagnetic state is observed with a Curie temperature $T_C = 1.3$ K. Meanwhile, the borocarbide RET_2B_2C (RE = rare-earth, T = Ni, Pd, Pt) family is probably the most intensively studied among RE-based compounds. The most remarkable features of the physical properties in RET_2B_2C is the coexistence of superconductivity with long range magnetic ordering.

In this lecture I would like to discuss recent results obtained in two other fascinating rare earth families: $REIr_3$ and $RENiC_2$. In the first, superconductivity is observed for $LaIr_3$ and $CeIr_3$, whereas $PrIr_3$ and $NdIr_3$ are ferromagnets. A heavier rare-earth metal can also be used (Gd-Ho) but the crystal structure changes from $PuNi_3$-type to $AuCu_3$-type and a long range magnetic behavior is preserved.

The second family to be presented, will be the ternary carbide $RENiC_2$ system, in which various unusual physical properties are observed. $LaNiC_2$ is a noncentrosymmetric superconductor with $T_{sc} = 2.9$ K, while $YNiC_2$ and $LuNiC_2$ were reported to be paramagnetic down to 1.9 K. $SmNiC_2$ is a ferromagnet with Curie temperature $T_C = 17.5$ K whereas the other lanthanide based $RENiC_2$ (with the exception of $PrNiC_2$) reveal antiferromagnetic behavior with Néel temperatures varying from 25 K for $TbNiC_2$ to 3.4 K for $HoNiC_2$. Moreover, $RENiC_2$ compounds (with the exception of La and Ce) show charge density wave formation. The Peierls temperature shows remarkably linear behavior from Sm to Lu and T_{CDW} exceeds 300 K for the heaviest lanthanides (Ho – Lu).

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Spin-Orbit Coupling tuning Fano-Feshbach Resonant Multigap Superconductivity

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We present a scenario where the interactions leading to room temperature superconductivity is driven by the lattice effects at nanoscale while for 35 years the major theoretical proposals have been based on exotic interaction is a homogneous macroscopic lattice. We show that the room temperature superconductivity can be reached in a three-dimensional (3D) superlattice of metallic nannoscale modules (stripes or layers). The presence of a confinement potential along the direction orthogonal to the modules is reflected in an electronic multiband structure which leads to multigap superconductivity and amplification of the critical temperature.

In mulilayers, interfacing different materials in the direction of confinement breaks the spatial inversion symmetry allowing a Rashba spin-orbit coupling (RSOC) The electrons in-plane are, thus, subjected to an effective magnetic field which orients the spin in a direction orthogonal to the momentum. This is reflected in a spin-splitting of the subbands that characterize the superlattice.

We study the combined effect of multigaps superconductivity and RSOC and to see how, by appropriately varying the intensity of the Rashba coupling, the structural characteristics of the system it is possible to obtain an amplification of the critical temperature. The interplay of the RSOC and superlattice structure leads to an extended van Hove singularity in the density of states (DOS) at the Brillouin zone edge with an unconventional Lifshitz transition for one of the two helicity states of the spin-orbit split electron spectrum giving an amplification of the gaps and critical temperature. The evaluation of the superconducting gap and the critical temperature is done by including in the Bogoliubov equation the quantum configuration interaction between the gaps. In the small fermi surface the electron-phonon interaction dependent both on the band indices and on the wavevectors along the confinement direction. Therefore, unlike the Bardeen–Cooper–Schrieffer (BCS) theory, the superconducting coupling is not constant but has a matrix structure giving the amplification of the superconducting critical temperature due to the resoance between different condensates in different coupling regimes.

Our results allow to reconstruct the superconducting dome typical of materials at high critical temperatures and to obtain critical temperatures close to room temperature. Moreover our rsults provide a roadmap to effectively vary the effect of the RSOC via the tuning of the superlattice structure, Finally we provide precise indications on the values of the parameters involved in view of possible practical realizations in a way potentially relevant for spintronics functionalities in several existing experimental platforms and materials.

Key words: superconductivity, Fano-Faschbach resonance, topological matter, Lifshitz transition, Rashba spin-orbit coupling.

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Pressure induced enhancement of superconducting state properties and its correlation with crystallinity degradation of Fe-Te-Se single crystals

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We have already shown that the inhomogeneous spatial distribution of ions with nanoscale phase separation enhances the superconductivity in superconducting Fe-Te-Se chalcogenides [1]. The almost ideal single crystal of $FeTe_{0.65}Se_{0.35}$ exhibits a greater width of superconducting transition and a considerably smaller value of the critical current density in comparison with non-uniform sample of the same compound. Resistivity results confirm that the inhomogeneous spatial distribution of ions and presence of small hexagonal-like phase in chalcogenides with nanoscale phase separation seems to enhance the superconductivity in this system [2]. Here, detailed investigations of Ni substituted $Fe_{0.994}Ni_{0.007}Te_{0.66}Se_{0.34}$ and unsubstituted $Fe_{0.99}Te_{0.66}Se_{0.34}$ crystals performed at ambient and under hydrostatic pressure are presented. Under ambient pressure the weakening of superconducting state properties was observed in $Fe_{0.994}Ni_{0.007}Te_{0.66}Se_{0.34}$ crystal, with disorder introduced by Ni substitution, as compared with those in $Fe_{0.99}Te_{0.66}Se_{0.34}$. For $Fe_{0.994}Ni_{0.007}Te_{0.66}Se_{0.34}$, the x-ray diffraction studies have revealed a degradation of crystal quality under applied elevated pressure. Superconducting state properties of single phase $Fe_{0.99}Te_{0.66}Se_{0.34}$ crystal, such as the upper and lower critical fields, were found to be poorer, at both ambient and hydrostatic pressure, than those observed for $FeTe_{0.5}Se_{0.5}$ crystals exhibiting pronounced nanoscale phase separation. Comprehensive studies of impact of pressure on crystal structure and on superconducting state properties confirm that enhancement of superconductivity under pressure correlates with appearance of mosaicity.

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Single-spin qubit magnetic spectroscopy of the correlated electronic states

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A single-spin qubit placed near the surface of a material acquires an additional contribution to its relaxation rate due to magnetic noise created by low energy excitations of the electron system. I will discuss how this noise can be used to investigate correlated electronic states, including superconductors, magnetic insulators, and one dimensional systems.

Entanglement in Doped Spin-Orbital Mott Insulators: Orbital or Charge Dilution versus Spin-Orbital Polarons

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Spin-orbital entanglement [1] occurs when spin and orbital correlations cannot be factorized and one has to go beyond mean field factorization of the ground or excited states. We show that spin-orbital entanglement is induced on superexchange bonds by Ising spin-orbit coupling when either spin or orbital quantum fluctuations are finite [2]. The interplay of spin and orbital degrees of freedom is very well visible in the spectral properties of a charge (hole) injected into the spin-orbital system and provides a potentially simple experimental method of investigating the character of orbital order in the system [3]. Spin–orbital fluctuations weaken orbital order particularly in transition metal oxides with t_{2g} orbital degrees of freedom $\{c,a,b\} \equiv \{xy,yz,zx\}$ and provide novel mechanism of ferromagnetic spin coupling by $\{a,b\}$ orbital fluctuations. Here we compare two kinds of doping by charged defects in t_{2g} orbital systems and present various mechanisms of destabilizing orbital order. Substitutional doping of Ru(d^4)–systems by $3d^3$ ions results in orbital dilution and the exchange on hybrid d^4-d^3 bonds modifies locally (or globally) spin–orbital order [4]. Subtle effects may be also induced by the lattice. For instance, the structure of the d^3-d^4 spin–orbital coupling in the presence of octahedral rotations favors a distinct type of orbital polarization pointing towards the impurity and outside the impurity–host plane [5]. In contrast, doping by d^2 transition metal ions yields charge dilution and topological phases in the orbital model [6]. Finally, each charged (Sr,Ca) defect replacing R ion in R_{1-x}(Ca,Sr)$_x$VO$_3$ (R=La,Y) generates a spin–orbital polaron in the defect cube. We show that $\{a,b,c\}$ orbital rotations are then induced—they disturb orbital order near the charged defect and a doped hole [7]. As a result, the collapse of G-type orbital order occurs but C-AF spin order stays robust under increasing doping.

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Ordered and Quantum Disordered States in Spin-Orbit Coupled Correlated Systems

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We will theoretically explore how the spin-orbit coupling could give rise to the unusual ordered, amorphous or liquid states of the spin-orbital and the spin-lattice degrees of freedom depending on the local d-electron counting and the lattice geometry. From this perspective, we will discuss d^1 and d^2 correlated transition metal compounds, such as molybdenum oxides with double perovskite or pyrochlore structures [1-3] and layered honeycomb materials [4], and provide a brief overview of the available experimental rezults.

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Orbital Hall effect as an alternative to valley Hall effect in gapped graphene

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Gapped graphene has been proposed to be a good platform to observe the valley Hall effect, a transport phenomenon involving the flow of electrons that are characterized by different valley indices. In the present work, we show that this phenomenon is better described as an instance of the orbital Hall effect (OHE), where the ambiguous "valley" indices are replaced by a physical quantity, the orbital magnetic moment, which can be defined uniformly over the entire Brillouin zone. This description removes the arbitrariness in the choice of arbitrary cutoff for the valley-restricted integrals in the valley Hall conductivity, as the conductivity in the OHE is now defined as the Brillouin zone integral of a new quantity, called the orbital Berry curvature. This reformulation in terms of OHE provides a direct explanation to the accumulated opposite orbital moments at the edges of the sample, observed in previous Kerr rotation measurements.

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New approaches for Néel vector detection in antiferromagnetic spintronics

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Antiferromagnetic (AFM) spintronics is an emerging field of research, which exploits the Néel vector to control spin- and orbital-dependent transport properties. This talk will address three novel approaches to detect the Néel vector in collinear compensated AFM metals via their transverse and longitudinal conductivity. The first approach utilizes room-temperature AFM metal MnPd2 that allows the electrical control of the Dirac nodal line by the Néel spin-orbit torque [1]. The reorientation of the Néel vector leads to switching between the symmetry-protected degenerate state and the gapped state which modulates the spin Hall conductivity. The second approach involves the nonlinear anomalous Hall effect that can be used to detect the Néel vector in most compensated antiferromagnets supporting the antidamping spin-orbit torque [2]. The magnetic crystal group symmetry of these antiferromagnets, such as CuMnSb, combined with spin-orbit coupling produce a sizable Berry curvature dipole and hence the nonlinear anomalous Hall effect. The third approach highlights antiferromagnets exhibiting a non-spin-degenerate Fermi surface and thus momentum-dependent spin polarization which can be functionalized in AFM tunnel junctions [3]. Using RuO_2 as a representative example of such antiferromagnets, a giant tunneling magnetoresistance effect is predicted for RuO_2-based AFM tunnel junctions. These results broaden the scope of materials and approaches, which can be exploited in AFM spintronics.

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Current-induced spin polarization in topological insulators and its role in magnetotransport

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The current-induced spin polarization (CISP) has become a hallmark of spin-orbitronics and one of the most efficient spin-to-charge interconversion mechanisms. CISP is especially strong in topological insulators (TIs) due to the spin-momentum locking. Interestingly, the nonequilibrium spin polarization is at the origin of various phenomena such as spin-orbital and bilinear magnetoresistance as well as spin-orbit torques. Moreover, the fact that CISP in TIs strongly depends on the position of chemical potential makes the spin-orbit torque and magnetoresistance phenomena strongly tunable by gating or doping.

I will review the most important consequences of nonequilibrium spin polarization in TIs. First, I will describe the nature of magnetoresistance effects induced by CISP. In particular, I will explain, among others, how CISP results in a strong BMR signal in TIs with isotropic Fermi contours. Then, I will discuss spin-orbit torque in TIs and will focus on the case of thin films of TIs attached to ferromagnetic layers. In such systems, the simultaneous presence of the hybridization between the surface states and the in-plane magnetization leads to a giant anisotropic magnetoresistance and highly tunable spin-orbit torque.

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2D magnets: from fundamental to spintronic devices

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The advent of graphene fifteen years ago kicked off an active research of other 2D materials and the list of interesting 2D materials, nonmagnetic or magnetic, metals, semiconductors or insulators, increased considerably during the recent years. The focus of my talk is on 2D magnets. I will review their physical properties (influence of proximity effects and electric fields, spin-orbit effects, chiral interactions, multiferroic properties) and present their potential for applications in spintronics (provided that their ordering temperature can be enhanced).

YOUNG & BRILLIANT LECTURES

Quantum thermodynamics with nanospintronic devices

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In recent years there has been an increasing interest in the thermodynamics of nanoscopic systems operating far from equilibrium [1]; this is due to both their fundamental importance (e.g., in biochemical processes occurring in cells) and their possible applications (e.g., as thermoelectric devices converting heat into work). In particular, the studies of such systems facilitated the discovery of new physical laws describing the universal properties of thermodynamic fluctuations (e.g., fluctuation theorems) as well as revealed a deep connection between thermodynamics and information theory. Nanoelectronic systems have been found to be attractive candidates for the study of thermodynamic phenomena occurring at the nanoscale level due to ease of control of their parameters and relative simplicity of their theoretical description [2]. However, the role of electronic spin in nanoscopic thermodynamic processes has been so far largely unexplored.

Here I show that the spin degree of freedom can be utilized to investigate novel thermodynamic phenomena. This is demonstrated on the example of nanospintronic devices based on quantum dots attached to spin-polarized leads. The first part of my presentation shows that the coherent spin dynamics, induced by an external magnetic field, can be used to reduce the power fluctuations in thermoelectric generators, thus improving the stability of their operation [3]. Most notably, the fluctuations can be reduced below the lowest value allowed for incoherent systems by a so called thermodynamic uncertainty relation [4]. The second part shows that the system of two exchange-coupled quantum dots can be used to realize a Maxwell's demon-like behavior: one dot can cool down its environment with a uniform temperature, converting heat into work, without the energy transfer to the second dot [5]. This paradox, apparently violating the second law of thermodynamics, can be solved by relating the entropy transfer between the dots to the information carried by a spin current; a quantitative description of such a phenomenon can be provided by means of a quantum information theory [6].

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Beyond skyrmions: Alternative magnetic nano-objects for spintronics

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Magnetic skyrmions have attracted enormous research interest since their discovery a decade ago. Especially the non-trivial real-space topology of these nano-whirls leads to fundamentally interesting and technologically relevant effects – the skyrmion Hall effect of the texture and the topological Hall effect of the electrons. Furthermore, it grants skyrmions in a ferromagnetic surrounding great stability even at small sizes, making skyrmions aspirants to become the carriers of information in the future.
Still, the utilization of skyrmions in spintronic devices has not been achieved yet, among other reasons, due to shortcomings in their current-driven motion. In this talk, we present our recent advances in the field of topological spin textures that go beyond skyrmions. The majority of the discussed objects can be considered the combination of multiple skyrmions or the skyrmion analogues in different magnetic surroundings, as well as three-dimensional generalizations. We classify the alternative magnetic quasiparticles – some of them observed experimentally, others theoretical predictions – and present the most relevant and auspicious advantages of this emerging field [1].
A special focus is on magnetic antiskyrmions [2,3,4], bimerons [5], antiferromagnetic skyrmions [6] and hopfions [7]. These objects exhibit advantageous emergent electrodynamic effects compared to conventional skyrmions, either due to their lower symmetry or due to a compensated topological charge. As we will show, all four of these objects can be driven parallel to the current, without a skyrmion Hall effect which makes them the ideal bits in data storage devices. Furthermore, we predict several interesting emergent electrodynamic effects like a pure topological Hall effect for the bimeron [5] or a topological spin Hall effect for the antiferromagnetic skyrmion [6]. Also, we show that some of these objects can even coexist, allowing for an advanced version of the racetrack memory data storage, where a bit sequence could, for example, be encoded by a sequence of skyrmions ('1' bit) and antiskyrmions ('0' bit). This concept would be more reliable than conventional racetracks.

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Discovery and control of room-temperature antiferromagnetic topological textures

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Ferromagnetic skyrmions and their anti-particles have shown great promise as topologically-protected information carriers for racetrack or neuromorphic applications[1]. However, presence of dipolar fields, restricting the formation of ultra-small textures, and the deleterious skyrmion Hall effect, have so far inhibited their practical implementation[2]. Alternatively, antiferromagnetic (AFM) analogues, made from topological whirling of compensated sublattices, are predicted to exhibit relativistic dynamics, deflection-free motion and size scaling[2,3]. While the latest observations of skyrmions in synthetic AFM stacks have exhibited some desirable properties[4], equivalent demonstrations in natural AFM systems are yet to emerge. Moreover, sublattice compensation also makes it very difficult to directly detect and control AFM textures via standard techniques.

Here, I will firstly discuss a recently-developed approach to perform vector-mapping of the Néel order-parameter in AFM textures using angle-dependent dichroic photoemission microscopy[5,6]. Then, I will present a general field-free approach, employing the Kibble–Zurek transition[6], that we used to realize a wide family of topological AFM textures, including exotic Bloch and Néel merons or antimerons (half-skyrmions) and bimerons (topologically equivalent to skyrmions). In the earth-abundant oxide – hematite (α-Fe_2O_3) – capped with a Pt over-layer, these textures can be nucleated and stabilized at room temperature. They have characteristic sizes of the order 100 nm and are experimentally tunable via control of the exchange, anisotropy and interfacial interactions[6]. I will then briefly present our new ionic approach to control AFM anisotropy in a non-volatile and reversible manner[7], which may eventually be driven via electric-fields to engineer the above topological textures. I will conclude by discussing how our results may be translatable to a wider family of AFM materials[7]. Given that currents in the Pt over-layer are known to provide spin-orbit torques to the AFM under-layers[8], it may soon become possible to electrically drive some members of the topological family, thereby paving a new pathway towards the construction of low-energy antiferromagnetic applications[1,2,3].

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Dipolar-stabilized first and second-order antiskyrmions in ferrimagnetic multilayers

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Skyrmions and antiskyrmions are topologically protected spin structures with opposite vorticities. Particularly in coexisting phases, these two types of magnetic quasiparticles may show fascinating physics and potential for spintronic devices. While skyrmions are observed in a wide range of materials until now antiskyrmions were exclusive to materials with D_{2d} symmetry [1].

In our recent work, we have shown first and second-order antiskyrmions stabilized by magnetic dipole-dipole interaction in Fe/Gd-based multilayers [2]. Using Lorentz transmission electron microscopy imaging, we observed coexisting first and second-order antiskyrmions, Bloch skyrmions, and type-2 bubbles and determine the range of material properties and magnetic fields where the different spin objects form and dissipate. Phase diagrams of the spin objects were created in dependence on magnetic out-of-plane field, temperature, saturation magnetization, and uniaxial magnetic anisotropy. We performed micromagnetic simulations to obtain more insight into the studied system and conclude that low values of saturation magnetization and uniaxial magnetic anisotropy lead to the existence of this zoo of different spin objects and that they are primarily stabilized by dipole-dipole interaction. Further, we investigated the nucleation process of antiskyrmions experimentally and theoretically revealing the necessity of a crossing point of three magnetic stripe domains to form an isolated antiskyrmion with an out-of-plane magnetic field.

The previous unobserved second-order antiskyrmions and the disclosed coexistence of antiskyrmions and skyrmions potentially reachable for a whole range of different materials provide great potential for further studies on quasi-particle interactions, spin dynamics as well as for possible future applications in spintronics.

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Control and understanding of magnon transport in insulating antiferromagnets

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With THz spin dynamics, unrivalled stability against magnetic field perturbations, and a lack of stray fields enabling large packing densities, antiferromagnetic (AFM) materials are positioned to become key in future low power spintronic devices. In this talk I will focus on functionalising the magnon transport properties of the insulating AFM α-Fe_2O_3 for magnonic applications. Not only does this material benefit from an ultra-low damping magnetic damping [1], but it has a controllable magnetic ordering [2,3] and shows topologically non-trivial skyrmionic domain structures.

First, I will highlight that long distance magnon transport can be achieved in non-local spin-transport devices, making use of circularly-polarised magnon modes excited by an electrical, interfacial spin-bias with spin diffusion lengths of up to 9 μm in single crystals [4]. Then, as single crystals are undesirable for devices, we explore high-quality thin film α-Fe_2O_3 of different crystalline orientations. We find that long distance transport of circularly-polarised magnons is possible in these films with intrinsic spin diffusion lengths of hundreds of nanometres [5], orders of magnitude larger than previously reported for thin film AFMs. This key result demonstrates that even in thin films, this material benefits from low magnetic damping. I will introduce how the efficiency of the transport mechanisms can be tuned by field cycling of the domain structure and the relative orientations of the magnetic field and magnetic anisotropies. The manner by which the AFM domain structure leads to frequency dependent decay lengths will also be discussed.

Finally, the observation of the transport of circularly polarised magnons relies on stabilising the AFM easy-axis phase of α-Fe_2O_3 at temperatures below the Morin transition (260 K). At room temperature the magnon modes adopt a linearly polarisation and become unable to transport angular momentum. Despite this, I demonstrate that room temperature magnon transport is indeed possible through a superposition of differently polarised magnon modes that dephase [1,6]. In parallel, I will show that a high magnetic symmetry is not necessary for efficient magnon transport. The dilute substitution of ferric ions with Zn drastically alters the magnetic anisotropy, lowering the magnetic symmetry of the system [6]. Even in this low-symmetry system, magnon transport is still seen over micrometres, where the non-local resistance displays a periodic beating with magnetic field due to the magnon Hanle effect.

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Determining topological order with tensor networks

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Exotic phases of matter beyond the Landau paradigm gained much attention in the recent years due to their experimental realizations as well as the development of powerful numerical methods like tensor networks. Among those exotic phases there are topologically ordered phases, the analysis of which is especially hard due to degeneracy of the ground state and no local order parameter. Topological order gained recognition after it was realized, thanks to Alexei Kitaev, that quantum computational models can be written in the language of condensed matter systems [1]. However apart from few exactly solvable models [1,2,3] the analysis of lattice Hamiltonians for the occurance of topological order was considered a very hard problem.

In my presentation I will describe the numerical methods to determine both Abelian and non-Abelian topological order starting from a lattice Hamiltonian [4,5]. The key idea is to find the topological S and T matrices, which (in most known cases) can be considered as a nonlocal order parameter of topologically ordered phases, in the sense that they give us unambiguous information about the model along with its excitations and their statistics. With the 2D tensor network – *Projected Entangled Pair States*, the method allows to analyze states which were not achievable by the state-of-the-art 2D DMRG algorithms due to long correlation length and it is immune to any small perturbations of the tensors, which had been a long feared problem due to numerical inaccuracies which may arise during the ground state optimization. Furthermore our construction enables an elegant description [6] of the model in terms of the mathematical structure underlying the topologically ordered phases of matter – *modular tensor category*.

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Interplay between multiple charge density waves and magnetic states in $R\mathrm{NiC_2}$ compounds

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The ternary rare-earth nickel dicarbides $R\mathrm{NiC_2}$ (R - rare earth metal) which crystallize in a non-centrosymmetric, orthorhombic crystal structure is a unique system offering an opportunity to tune the ground state with varying R atom. The charge density wave (CDW) formation related to quasi-one-dimensional electronic features and Fermi surface nesting has been found for most of the members of the $R\mathrm{NiC_2}$ family (R = Dy – Lu, Y) [1]. $\mathrm{LaNiC_2}$ compound is an unconventional superconductor [2], $\mathrm{SmNiC_2}$ undergoes a ferromagnetic transition [3] and the rest of the compounds (apart from nonmagnetic $\mathrm{YNiC_2}$, $\mathrm{LuNiC_2}$ and $\mathrm{PrNiC_2}$ where only a weak magnetic anomaly is observed) order antiferromagnetically below 25 K.

The comprehensive studies on both poly- and single-crystalline $R\mathrm{NiC_2}$ compounds in terms of relations between various types of ordering will be presented here. The main emphasis will be put on the analysis of the CDW mutually interacting with magnetism as well as of the nature of multiple CDW transitions regarding the extended phase diagram of $R\mathrm{NiC_2}$ family [1]. In contrast to completely destructive influence of ferromagnetism on the CDW previously found for $\mathrm{SmNiC_2}$ [3], positive impact of the magnetic anomaly on CDW in $\mathrm{PrNiC_2}$ [4] and partial suppression of the CDW state by antiferromagnetic transition observed in $\mathrm{NdNiC_2}$ [4], $\mathrm{GdNiC_2}$ [5] and their solid solutions [6], [7] will be discussed here. For late-lanthanide-based $R\mathrm{NiC_2}$ (R = Y, Lu [8] and Tm [9]), the large positive magnetoresistance (reaching 470%), induced by the high-mobility carriers from small pockets of imperfectly-nested Fermi surface induce, will be also reported here.

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Multilayered spin-wave devices based on transmission and resonance phenomena

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Low energy consumption and high frequencies of spin waves are an essence of the computing based on magnonic logic devices. Steering of the signal is one of key elements in the problem of multifunctional computing units and miniaturized high-efficiency devices are highly desirable. Here, we propose devices based on multilayered ferromagnetic thin-film structures benefiting from the transmission and resonance phenomena. We used the Dzyaloshinskii-Moriya interaction to show the effect of unidirectional coupling where the spin wave can be transferred between the layers in only one direction of propagation. This effect was used to make the spin-wave diode and circulator[1]. The diode bases on the unidirectional coupling with the high-damping element where the spin wave is highly attenuated. The circulator take use of opposite unidirectional coupling due to opposite Dzyaloshinskii-Moriya constant sign in co-planar waveguides. The devices work with high efficiency in wide frequency range. Also, we used the multimode rectangular resonator to propose multifunctional device which can be used to steer the signal depending on the working frequency[2]. This device combine the functionality of directional coupler, circulator, splitter, and wave reflector. The device take use of the existence of the circulating resonant modes of different chirality. Our work opens the possibility to take the step into 3D magnonics and their further miniaturization making them competitive with the electronic logic components.

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Magnetic phases in the quasi-one dimensional $A_2Cr_3As_3$ (A=Na, K, Rb, Cs) superconductors

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Very recently, the $A_2Cr_3As_3$ (A=Na, K, Rb, Cs) [1] family of superconductors has been discovered. They are quasi-one-dimensional with double-walled nanotubes propagating along the c-axis and the Cr-atoms form triangles in the a-b plane, but the hybridization between different nanotubes is relevant [2,3]. Referring to the magnetism, theoretical investigations [4] suggest that the triangular geometry tends to frustrate antiferromagnetism. However, significant phonon instabilities have been found [5]. The Cr-triangles in the double walled subnanotubes $[(Cr_3As_3)^{2-}]_\infty$ are no longer equilateral, this could lead to an absence of frustration. Here we study the magnetism for the $A_2Cr_3As_3$ compounds and the parent compound KCr_3As_3 [6], by using density functional theory approach, in the cases of presence of the distortions in the Cr-triangles recently predicted [5]. We show that the strong interplay between the lattice and the spin degrees of freedom promotes a new collinear ferrimagnetic ground state within the chains [7]. We predict that in the region of parameters corresponding to a regime of moderate correlations the $A_2Cr_3As_3$ compounds are non-magnetic but on the verge of the magnetism, sustaining interchain ferromagnetic spin fluctuations while the intrachain spin fluctuations are antiferromagnetic. We also show that uniaxial strain is a viable tool to tune the non-magnetic phase towards an interchain ferromagnetic instability [8]. We are confident that this investigation can provide relevant insights about the interplay between superconductivity and magnetism in this class of materials.

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First-principles approach to calculate entropy in magnetocaloric materials.

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The increasing interest in the application of magnetocaloric materials for magnetic cooling devices has led to an intensive search for new materials with a more attractive performance to cost ratio. Yet, many magnetocaloric materials display complex behaviours, which are not fully comprehended. High-throughput studies based on first-principles calculations can play a crucial role to detect new magnetocaloric material while increasing the insight on these materials. However, to identify systems of interest in a large body of data, screening parameters are required and must be carefully chosen considering a balance between accuracy and cost of the calculations. A key quantity to characterize the performance of these systems is the entropy variation between two magnetic phases. In this work, electronic, structural and magnetic properties of bulk FeRh and Gd have been studied from first principles aiming to find a reliable non-tailored approach to determine the entropy variation of the magnetocaloric effect being obtained good agreement with experimental results for the total entropy.

In case of FeRh the electronic (S_{ele}), lattice (S_{lat}), and magnetic (S_{mag}) entropy contributions have approximately the same order of magnitude and the same sign. For Gd, we find that besides S_{mag}, it is important to include the contribution of S_{ele} for an accurate estimation of the total entropy variation.

Furthermore, the calculated entropy contributions for FeRh suggest that the magnetic subsystem drives the metamagnetic transition. Taking into consideration the used model, the adiabatic magnon model, there is a strong indication that small magnetic fluctuations play an important role in the magnetic transition. Also, it is found for FeRh that the Debye model cannot accurately predict S_{lat} due to the existence of soft vibrational modes on the phonon spectra.

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ORAL CONTRIBUTIONS

ABSTRACT CATEGORIES

1. Strongly Correlated Electrons and High Temperature Superconductivity

Heavy fermions and Kondo systems; Charge, orbital, and multipole orderings and excitations; Quantum phase transitions; Metal-insulator transitions; Highly correlated metals and insulators; Itinerant electron magnetism; Organic conductors; Low dimensional conductors, Correlation effects in mesoscopic systems; Multiferroics

2. Quantum and Classical Spin Systems

Low dimensional quantum magnets; Frustrated magnets and spin liquids; Quantum phase transitions; Lattice effects and spin Peierls systems; Solitons and nonlinear effects; Statistical mechanics of quantum and classical systems; Molecular magnetism; Quantum tunnelling and coherence; Quantum information; Organic and organo-metallic materials

3. Magnetic Structure and Dynamics

Crystal field and anisotropy; Magnetic structure and spin waves; Dynamic phenomena; Electronic structure; Magnetic interactions; Rare-earth and actinide magnetism; Transition metal alloys and compounds; Spin glasses; Random magnets; Magnonic crystals

4. Spin Electronics and Magneto-Transport

Magnetoresistance effects; Current induced magnetization reversal; Spin injection and accumulation; Spin Hall effect, Magnetic Semiconductors; Optical properties; Quantum computation

5. Nano-structure, Surfaces, and Interfaces

Surfaces and interfaces; Films, multilayers and superlattices; Exchange interaction and anisotropy; Spin dynamics, Patterned films; Nanoparticles; Nanowires and dots

6. Soft and Hard Magnetic Materials

Amorphous and nanocrystalline materials; Granular materials; Ferrites, garnets and microwave materials; Permanent magnets; Magnetization processes; Magneto-elastic and magnetostrictive materials; Modeling and simulations

7. Applications

Magnetic sensors; Ferromagnetic shape-memory materials; Actuators and magnetic drives; Magnetic refrigeration; Magnetic fluids; Magnetic separation and levitation

8. Other Topics

Biomagnetics; Magnetism in medicine; Measuring techniques and instruments; Magnetic recording and memories

Non-saturating lower critical field of the multiband superconductor $PrOs_4Sb_{12}$ with broken time-reversal symmetry

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Topological superconductivity is a highly interesting unconventional state of matter that provides a natural platform for realizing Majorana edge modes being central to various proposals for quantum computation. Among various scenarios, chiral superconductivity is a long-sought topological state that spontaneously breaks time-reversal symmetry through the development of Cooper pairing with finite angular momentum. However, despite intensive theoretical studies and huge experimental efforts, no material has been proven definitively to be a chiral superconductor.

The heavy-fermion and multiband superconductor $PrOs_4Sb_{12}$, for which a μSR study and polar Kerr effect measurements showed evidence of broken time-reversal symmetry below the critical temperature $T_c \simeq 1.85$ K, is a leading candidate to display chiral superconductivity. Based on measurements of the temperature dependence of the lower critical field $H_{c1}(T)$, we have recently proposed a multiband and multisymmetric scenario, in which a superconducting condensate is composed of a sign-changing smaller gap and a large isotropic s-wave gap [1].

To develop a detailed understanding of multicomponent superconductivity in $PrOs_4Sb_{12}$, we have extended measurements of $H_{c1}(T)$ down to temperatures as low as 7 mK utilizing a 2DEG Hall magnetometry. We observe a sudden increase in $H_{c1}(T)$ deep in a superconducting state, indicative of a rare case of two nearly decoupled bands. Furthermore, a non-saturating and concave behavior of $H_{c1}(T)$ below about 0.45 K, clearly points at a sing-changing symmetry of the smaller gap. Equally remarkable is a high sensitivity of this characteristic to electron irradiation. Even small concentration of artificial atomic defects is a tuning parameter changing unusual superconducting properties of $PrOs_4Sb_{12}$. We observe the saturated dependence of $H_{c1}(T)$ and a strong suppression of its enhancement. This is in contrast to the two-band isotropic s-wave homologue $LaRu_4As_{12}$ which shows that atomic defects in this case change both gaps similarly. The above-mentioned observations indicate that impurities apparently destroy a sign-changing order parameter in $PrOs_4Sb_{12}$, which superconductivity will be discussed in the context of a putative chiral spin-triplet pairing state.

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A unified microscopic description of paramagnon and plasmon excitations in hole-doped high-T_c cuprates

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More than 30 years after the discovery of high-T_c superconductivity in copper oxides, the origin of Cooper pairing is still a matter of intense debate, with both purely-electronic- and collective-excitation-driven mechanisms being considered. Recent resonant inelastic x-ray scattering (RIXS) experiments have revealed unanticipated robust collective magnetic excitations (paramagnons), as well as low-energy charge modes (acoustic plasmons) in metallic paramagnetic phase of the cuprates (see, e.g., [1,2]), providing a new insight into the nature of those correlated systems. Very recently, we have formulated a new theoretical framework to discuss both equilibrium- and collective-dynamical properties of those materials [3,4]. It is based on a variational wave-function approach, combined with field-theoretical $1/\mathcal{N}_f$ expansion, accounting for leading-order quantum-fluctuation corrections. Our results are compared quantitatively with recent experiments [3, 5], showing a good overall agreement for both paramagnon- and plasmon-excitation branches. To test our method, we also benchmark our results against those of determinant quantum Monte Carlo and functional renormalization group [4].

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Defects, Disorder, and Spin-Orbital Polarons in Orbital Degenerate, Doped Mott Insulators

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We elucidate the role played by charged defects and doped holes in doped Mott insulators with active orbital degrees of freedom and, in particular, in doped vanadate perovskites [1-5]. We use a degenerate Hubbard model extended by terms that describe crystal-field splittings and orbital-lattice coupling, as well as by the long-range Coulomb potential terms of charged defects and doped holes [1]. We show that the multiplet structure of the excited states generated in such systems by strong electron interactions is well described within the unrestricted Hartree-Fock approximation [1]. A soft gap of kinetic origin develops in the defect band and survives defect disorder. This behavior naturally emerges in the statistical distribution of gaps among different defect realizations, which turns out to be of Weibull type [2]. Our results provide clear indications that doped holes are bound to charged defects and form small spin-orbital polarons whose internal kinetic energy is responsible for the opening of the soft gap [3]. Such a generic behavior leads to complex non-hydrogen-like defect states that tend to preserve the underlying C-type spin and G-type orbital order [2]. Another fundamental characteristic of these systems is the persistence of spin and orbital order up to high doping, in contrast to the loss of magnetic order in high-Tc cuprates at low defect concentration. We show that the rotation of the t_{2g} orbitals, induced by the electric field of defects, is a very efficient perturbation that largely controls the suppression of orbital order in these compounds [4]. From the change of kinetic and superexchange energy, we can conclude that the motion of doped holes, which is the dominant effect for the reduction of magnetic order in high-T_c compounds, is of secondary importance here as well as the quadrupolar components of the Coulomb fields of doped holes. These rotations modify the spin-orbital polaron clouds and compete with orbital rotations induced by defects [5], but we find that the gradual decline of orbital order with doping has its origin in the off-diagonal couplings of orbital rotations induced by the charges of the doped ions.

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Revisiting the problem of the single hole in an antiferromagnet

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The problem of the propagation of the single hole introduced into the antiferromagnetic ground state is one of the most studied in the "cuprate physics", for it can be solved in a relatively controlled manner [1]. Nevertheless, the possibility of simulating hole-doped antiferromagnets in the cold atom experiments [2] have recently triggered a renewed interest into this problem.

In this contribution, I plan to give an overview of some of our most recent studies which try to understand the propagation of the single hole in the antiferromagnet using the magnon language, with a special attention paid to the interaction between the magnons [3-4]. Thus, first I will present a novel intuitive picture which explains why the electron's spin and charge degree of freedom can separate in a one-dimensional lattice, though a similar situation cannot occur in two dimensions [3]. Next, I will show that the string potential, which is believed to be felt by the hole moving in a two-dimensional Ising antiferromagnet, is more easily destroyed than one could naively expect [4]. Finally, I will discuss what might be the impact of such findings on the future studies of the superconducting cuprates or the optical lattice simulations of the Hubbard model.

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Superconductivity in noncentrosymmetric $ThCoC_2$ and the effect of Ni doping

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$ThCoC_2$ is a noncentrosymmetric superconductor with $T_c = 2.5$ K, which can be significantly increased by Ni doping to 12 K in $ThCo_{0.6}Ni_{0.4}C_2$. Based on the non-BCS temperature dependence of magnetic penetration depth, superconductivity in $ThCoC_2$ was recently proposed to be a nodal *d*-wave and mediated by the spin fluctuations [1]. Also, non-BCS behaviors of the electronic specific heat and the magnetic upper critical field were reported before. In this work electronic structure, phonons and electron-phonon coupling are studied in $ThCoC_2$ on the basis of ab initio computations. Effect of the spin-orbit coupling on the electronic structure and electron-phonon interaction is analyzed. The thermodynamic properties of the superconducting state are determined numerically by solving Eliashberg equations. The evaluated electron-phonon coupling constant $\lambda = 0.59$ remain in a decent agreement with the experimental estimates, showing that the electron-phonon interaction is strong enough to explain the observed Tc, however it requires an enhanced value of the Coulomb pseudopotential $\mu*$, which may suggest presence of enhanced electronic interactions. Calculated temperature dependence of the electronic specific heat and magnetic penetration depth strongly deviate from the BCS model. Moreover, neither the BCS model nor the presented Eliashberg solutions can explain their experimentally observed temperature dependence, supporting the hypothesis of a non-s-wave gap symmetry in $ThCoC_2$. Finally, effect of Ni doping on electron-phonon coupling is studied using the KKR-CPA method and the strong increase of λ is found, in agreement with experimental results. This further supports the electron-phonon interaction to be the pairing mechanism of superconductivity in this material.

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Transport through strongly correlated triple quantum dot

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Strong electron correlations are discussed for the system of three capacitively coupled quantum dots, each of which is connected to a separate pair of electrodes. The finite-U mean field slave boson approach is used. The analysis is carried out in a wide range of parameter space including both repulsive and attractive intra- and inter-dot interactions. Gate voltage dependencies of occupation, local magnetic moment, isospin and conductance, as well as fluctuations of these quantities are studied. Depending on the ratio and the sign of interaction parameters and occupation, either charge ordered states or different many-body resonances arise. In the emerging charge Kondo effects pseudospin fluctuations correspond to a coherent movement of six electrons into and out of the system.

Cation ordering in Bi-based double perovskites: a density functional analysis

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Perovskites with two different types of cations at one of the sublattices, namely the A-site ($AA'B_2O_6$) and the B-site ($A_2BB'O_6$) are called double perovskites. For these compounds, the cation ordering can exist. There are some general rules for such systems [1, 2]. For example, the order at the B-site than at the A-site occurs more frequently. A typical ordering pattern for such compounds is rock-salt. The cation ordering also appears when the difference between the ionic radii and/or oxidation states is significant. Recently, the isovalent cation ordering in the Bi_2FeAlO_6 [3] was observed. In this work, we analyzed the role of ionic radius and magnetic ordering in the formation of the B-site cation ordering in Bi-based perovskite oxides with the general formula Bi_2MFeO_6 and $Bi_2MM'O_6$ where M and M' are Al, Ga, In, and Sc [4]. We found that despite the presence of the lone pairs at the Bi atoms the aforementioned general rules of cations ordering are fulfilled for non-magnetic cations. However, if one of the B-site cations is magnetic the layered ordering has lower energy than the rock-salt one. Finally, for the (pseudo)tetragonal structures the columnar ordering is favored for Bi_2MFeO_6.

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Time evolution of terahertz-pumped heavy-fermion systems

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The search and characterisation of new quantum phases of matter has recently been intensified by the application of terahertz (THz) spectroscopy in the time domain to heavy-fermion systems [1-3]. It was experimentally shown that a single-cycle terahertz laser pulse disrupts the strongly correlated (Kondo) ground state in heavy-fermion compounds such as $CeCu_{6-x}Au_x$, which recover after a characteristic delay time τ_K^*, accompanied by the emission of a temporally confined terahertz echo pulse. In this way, time-domain terahertz spectroscopy provides direct access to both, the quasiparticle spectral weight and the characteristic time or energy scales, across a heavy-fermion quantum phase transition [1-2]. The transient nature of such non-equilibrium dynamics leads to new and interesting many-body physics, raising questions about the established properties of quasiparticles.

In the present work we develop the theoretical description of this heavy-fermion non-equilibrium dynamics. The electronic part of the system is captured by an Anderson model described by a time-dependent version of the non-equilibrium Non-Crossing Approximaton (NCA). The THz photons are treated as a quantum field with its own dynamics and are coupled to the heavy fermion-system by a dipole interaction. In this way, incident THz pulses with arbitrary pulse shape can be implemented as an initial condition. At the same time, the photon quantum dynamics allow for re-emission of radiation and, thereby, the necessary release of energy during the relaxation dynamics to the heavy-fermion ground state. These coupled dynamics are solved by a novel adaptive 2-time-stepping algorithm. We also discuss the thermalisation to ambient temperature in terms of a Lindblad-like coupling to the electromagnetic environment as a bath.

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Non-equilibrium dynamics of stripes in cuprate superconductors

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In recent years pump-probe experiments have turned out as a powerful tool to investigate the dynamics of correlated materials [1], e.g. transition metals or heavy fermion systems. In these experiments the system is prepared in a non equilibrium state by a strong laser pulse and than the relaxation is examined by standard optical techniques.

This method has also been applied to stripe ordered nickelates and cuprate superconductors where it allows to study the coupled order-parameter dynamics of charge- and spin-density waves and superconductivity [2,3,4].

Here we use the time-dependent Gutzwiller approximation (TDGA) [5] for the single-band Hubbard model to analyze the non-equilibrium dynamics for stripe ground states of different symmetry. In particular we are interested in the interplay between spin and charge dynamics which is analyzed by quenching the system either in the charge or spin sector. This allows us to investigate the coupled relaxation dynamics as a function of the inserted energy. Further insight is provided by mapping the Gutzwiller dynamics onto a time-dependent Landau approach which lacks the double occupancy contribution to the time-evolution but allows to tune the coupling between spin- and charge degrees of freedom.

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Multiple quantum phase transtitons in low-bandwidth two-impurity Kondo systems

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Since the seminal papers of Jones and Varma [1,2], the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction Y between two Kondo impurities is conventionally modeled by a Heisenberg coupling term J_H. It gives rise to a quantum phase transition between the Kondo and the RKKY phases in the two-impurity Kondo model for arbitrarily large Kondo couplings, even in the presence of charge fluctuations. However, the significance of this result is still controversial. Firstly, the transition is extremely fragile to particle-hole asymmetry, smearing the critical point into a crossover in its presence [3,4]. This has lead to the common belief that it cannot be realized in a realistic 2-impurity system and has made its relevance for lattice models debatable. Moreover, in the model Y and the Kondo exchange J_K are considered independent, although Y is genuinely generated from J_K, and the Kondo temperature depends on Y, as has been shown experimentally [5] and theoretically [6].

Recently, it has been shown that the quantum phase transition can be restored for weaker particle-hole symmetry by parameter fine-tuning [7]. We revisit the problem to show, by numerical renormalization group calculations, that in the geometry of two impurities, coupled each to a different host as in [5], Y induced solely by J_K and the inter-host exchange coupling J_Y causes the transition for a properly symmetric case, if J_K is not too strong. Moreover, another phase transition occurs then at very strong J_Y, which is not present in Jones-Varma model [1,2], and counter-intuitively drives the system to the Kondo-like state again, although with non-universal impurity spectral density. The two critical values of J_Y head towards each other for increasing J_K, and above a critical value of J_K both transitions are replaced by a single crossover. We explain the phase diagram by analyzing the relevant quasi-particle picture and propose an experiment in magic-angle bi-layer graphene where our predictions could hopefully be tested.

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Dynamical properties of topological Kondo insulators

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Topological Kondo insulators (TKIs) are a new class of topological insulators, emerging through the interplay of strong correlations and spin-orbit coupling [1]. In TKIs, the bulk is a narrow band insulator due to the appearance of a localized Kondo resonance near the Fermi level and its hybridization with the conduction band. Additionally, the strong spin-orbit coupling of the localized moments generates a non-local hybridization between the local moments and the conduction band, which results in a topologically nontrivial band structure and gapless surface states. In the past, TKIs have been described predominantly by slave-boson mean-field (SBMF) [2] calculations. Such static methods are unable to capture finite life-time effects of the heavy Kondo quasiparticles. It is therefore not possible to investigate physics at the boundaries, like the dynamical emergence of topological edge states, where SBMF calculations become uncontrolled (e.g. [3]). We design a spin-orbit coupled dynamical mean-field theory (cf. [4]) with an auxiliary-particle conserving approximation (cf. [5]) as an impurity solver. With this, we aim at calculating characteristic, observable quantities, like the surface conductivity, including life-time effects.

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Impact of pressure on the Griffiths phase and exchange-bias in the disordered cobaltite $Gd_{0.5}Sr_{0.5}CoO_{3-\delta}$

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The exchange bias (EB) effect and an appearance of the Griffiths-phase (GP) were found in half-doped cobaltite $Gd_{0.5}Sr_{0.5}CoO_{3-\delta}$ exhibiting a significant quenched disorder due to the ion size mismatch between Sr and Gd. The disorder weakens the ferromagnetic (FM) interactions between Co ions, leading to low transition temperature $T_C = 90$ K. A clear GP behavior was detected in the temperature range between T_C and the Griffiths temperature $T_G = 225$ K. It was found that, the EB exists in $Gd_{0.5}Sr_{0.5}CoO_{3-\delta}$ for entire temperature range below $T_G = 225$ K, in contrast to the limited, low-temperature EB observed so far in perovskite cobaltites. Pressure leads to a decrease of T_C with a coefficient of $dT_C/dP = 1$ K/kbar and dramatically suppresses GP, resulting in a rapid decrease in T_G at a rate of dT_G/dP = -3.6 K/kbar. Similarly, the EB field does not change significantly in the FM phase but it promptly collapses with pressure in GP. Pressure effectively eliminates local structure deformations that are responsible for magnetically ordered clusters existing above T_C. Pressure-induced transition from the high-spin Co^{3+} state to the low-spin state is mainly responsible for the observed decay of the Griffiths phase and simultaneous EB collapse, as well as, for a decrease in T_C under pressure.

Tuning the tilting of the spiral plane by Mn doping in $YBaCuFeO_5$ multiferroic

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The low-magnetic ordering temperatures (typically<100 K) critically restrict the potential uses of magnetoelectric multiferroics for spintronics and low-power magnetoelectric devices. The frustrated perovskite $YBaCuFeO_5$ (YBCFO) displays magnetism-driven ferroelectricity at unexpectedly high temperatures [1,2]. It is considered one of the best candidates to high-temperature chiral multiferroics with strong magnetoelectric coupling. In $RBaCuFeO_5$ perovskites (R: rare-earth or Y) A-site cations are fully ordered whereas their multiferroic properties strongly depend on the preparation method and the partial Fe/Cu disorder at the B-site. Cationic disorder is normally promoted changing the cooling rate after the last annealing, generating magnetic frustration and incommensurate spiral order that can persist above room temperature [1].

However, in this chiral magnetic oxide the orientation of its magnetic spiral can be critical for the multiferroic and magnetoelectric response. In this work, we have synthesized and studied $YBaCuFe_{1-x}Mn_xO_5$ samples doped with Mn, with the aim of increasing spin-orbit coupling effects, and found that the overall Fe/Cu cation disorder at the B-sites can be increased by doping without changing the sample preparation process. In $YBaCuFe_{1-x}Mn_xO_5$ samples prepared under the same conditions, the T-x magnetic phase diagram have been constructed in the range 10K-500K combining magnetometry, x-ray and neutron diffraction measurements [3]. The tilting angles of the spins in the collinear, θ_{col}, and spiral phases, θ_{spiral}, barely vary with temperature. In the collinear phase θ_{col} is also independent of the Mn content. In contrast, the presence of Mn produces a progressive reorientation of the plane of the magnetic helix in the incommensurate phase, capable to transform the helicoidal spin ordering into a cycloidal one, which may critically determine the ferroelectric and magnetoelectric behavior in these compounds. When increasing the Mn content the rotation plane of the spins moves away from the ab plane where the Dzyaloshinskii–Moriya based models predict null spontaneous polarization.

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Majorana states in $1D$-topological superconductor with on-site Coulomb interactions

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We consider theoretically a $1D$ semiconducting wire with strong Rashba interaction in proximity of s-wave superconductor. The wire is exposed to external magnetic field perpendicular to the effective Rashba field. Such a device configuration provides suitable conditions for the appearance of topological p-wave superconductivity.
The system is modeled by a tight binding Hamiltonian with Rashba hopping term and induced s-wave superconductivity. Additionally, we take into account short-range on-site Coulomb interactions inside the wire. The calculations are performed utilizing recursive Green's function method, and Coulomb interactions are treated selfconsistently within Hubbard I approximation.
We demonstrate that the presence of Coulomb interactions has a global and a local effect on superconducting topological state and Majorana state formation. Globally, the topological state is promoted by Coulomb interactions by opening the p-wave superconducting gap at lower magnetic fields as compared to the noninteracting case. Moreover, Coulomb interactions produce the Shiba-like Hubbard bands in the density of states of the wire when the II-nd Hubbard levels of each site enter the superconducting gap. Locally, at the particular site of the wire, Coulomb interactions induce the appearance of particle-hole pairs of sharp resonances associated with the II-nd Hubbard quasiparticle in-gap levels of this particular site. Due to quantum interference between Hubbard quasiparticle bands and sharp local resonances at the end-sites, a pair of Fano resonances appears in the particle and hole sector of the density of states. We show that quantum interference is governed by the competition between two-particle and single-particle tunneling processes, which has a decisive effect on the Majorana peak formation. Depending on the position of the sharp in-gap Hubbard levels, controlled by external magnetic field, one of the two types of tunneling prevails. Strikingly, for the dominance of two-particle processes the Majorana peak is strongly suppressed, whereas for the dominant single-particle tunneling it is not altered. Finally, for such a magnetic field value that the Hubbard levels cross at Fermi energy, the Majorana peak is destroyed completely.
As a side effect, we emphasize the difference in tunneling current between two superconductors with strong spin-orbit interaction, when an accidental quasiparticle level is residing at Fermi energy, and when the true Majorana resonance is present. This could be a hint for experimental verification of true topological end-states of the wire.

Extended Falicov-Kimball Model: Rigorous Analytic Solution in Large Dimensions

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The Falicov-Kimball model is a simplified version of the Hubbard model, where only electrons with, e.g., spin down, are itinerant and the other are localized [1-3]. Here, we discuss results for the extended Falicov-Kimball model (including also intersite interactions) on the Bethe lattice in the large-dimension limit derived within the dynamical mean field theory formalism, which is an exact approach in this limit [3-6]. Within this method, we found rigorously analytic expressions for the temperature-dependent density of states at half-filling [4,5]. We detected stability regions of eight different kinds of ordered phases, where both charge order and antiferromagnetism coexist (five of them are insulating and three are conducting) as well as three different nonordered phases. Moreover, we analyzed their thermodynamic properties [5-7]. The results are compared to those obtained within the standard Hartree-Fock approximation [6,7]. For small interactions the anomalous temperature dependence of the order parameter, characterized by the sharp reduction near $T \approx T_C/2$, occurs [6].

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Orbital ordering of ultracold alkaline-earth atoms in optical lattices

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The impressive development of experimental techniques in ultracold quantum degenerate gases of alkaline-earth-like (e.g., ^{173}Yb) atoms in recent years has allowed investigation of strongly correlated multiorbital systems. Long-lived metastable electronic states in combination with decoupled nuclear spin give the opportunity to study the Hamiltonians beyond the possibilities of current alkali-based experiments. Motivated by recent experimental progress, by means of dynamical mean-field theory allowing for complete account of SU(2) rotational symmetry of interactions between spin-1/2 particles, we study ultracold quantum gases of alkaline-earth-like atoms loaded into three and quasi-two dimensional optical lattices. In particular, we focus on the fermionic mixture of ytterbium-173 atoms due to their unique properties which allow to realize and investigate in detail strongly-correlated many-body physics and emerging low-temperature phases in these mixtures. We focus on the recent realization of the two-band Hubbard model and study potential long-range ordered states. The theoretical analysis is performed in the region of applicability of the tight-binding approximation at different lattice depths and different band filling. We obtain dependencies for relevant physical observables, in particular magnetization, particle density in each band, double occupancy, compressibility and entropy. We construct phase diagrams at finite temperature and various lattice depths.

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Orbital Engineering of Spin-Orbit effect at Correlated Oxide Interface

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Using interlayer interaction to control functional heterostructures with atomic-scale designs has become one of the most effective interface-engineering strategies nowadays. Here, we demonstrate the effect of a crystalline $LaFeO_3$ buffer layer on amorphous and crystalline $LaAlO_3/SrTiO_3$ heterostructures. The $LaFeO_3$ buffer layer acts as an energetically favored electron acceptor in both $LaAlO_3/SrTiO_3$ systems, resulting in modulation of interfacial carrier density and hence metal-to-insulator transition. For amorphous and crystalline $LaAlO_3/SrTiO_3$ heterostructures, the metal-to-insulator transition is found when the $LaFeO_3$ layer thickness crosses 3 and 6 unit cells, respectively. Such different critical $LaFeO_3$ thicknesses are explained in terms of distinct characteristic lengths of the redox-reaction-mediated and polar-catastrophe-dominated charge transfer, controlled by the interfacial atomic contact and Thomas-Fermi screening effect, respectively. Our results not only shed light on the complex interlayer charge transfer across oxide heterostructures but also provides a new route to precisely tailor the charge-transfer process at a functional interface.

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Three-pole Composite Operator Method for the t-J model

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We analyze the characteristic features and the anomalous behavior of the local and the momentum-dependent properties of the t-J model using a novel three-pole approximation within the Composite Operator Method[1-5]. Accordingly, we choose an operatorial basis made of three composite fields describing the main excitations of the system: (i) the lower Hubbard operator and its dressing by (ii) spin and (iii) charge nearest-neighbor excitations. Within a generalized mean-field and exploiting algebraic constraints, we obtain a set of self-consistent equations for the physical parameters of the system, namely, the nearest and the next-nearest neighbor charge-charge and spin-spin correlations and the kinetic energy. The results are compared to those of well-known numerical methods on finite systems in order to assess the quality of the approximation.

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Majorana fermions in a world of strong correlations

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Majorana fermions awakened the interest of many physicists of various specializations in the last few years. Originally considered in the field of elementary particles, now play a significant role in condensed matter physics and quantum information, all because of topological superconductors, where such quasiparticles can be observed. As a result, Majorana fermions will be topologically protected bound states, which may prove particularly applicative as a qubit - quantum bit necessary to perform operations on quantum computers. There is an exciting race going on right now, where the goal is to demonstrate the existence of such zero-energy states, in one-dimensional topological superconductors, among others. Majorana fermions may be found at the ends of such nanowires.

The goal of this presentation is to confront the Majorana zero-energy modes with well-known strongly correlated systems, where phenomena, such as the Kondo effect are present, which stimulates physicists all over the world. One of the most prominent examples of such systems in a mesoscopic scale, where the Kondo effect plays a vital role, is a quantum dot. Right now, with the aid of technology and experience, quantum dots are being deeply explored, not only in regards to electronic transport but also thermoelectric effects such as thermopower or thermal conductance, which are the effects of an applied temperature gradient. Currently, answering the question of how such exotic quasi-particles can affect these well-known systems plays a meaningful role in condensed matter physics research.

Our contribution to this dynamically developing area is the theoretical study of the double quantum dot system in the presence of Majorana fermion, associated with effective coupling V_M. Our research is based on the well-established numerical renormalization group method, which allows describing the quantum transport effects in strongly correlated mesoscopic systems with great accuracy. We are showing that the presence of such half-fermionic particles destroys the second stage of Kondo screening, giving rise to a fractional value of conductance in one spin channel, which is directly coupled with the nanowire. On the other hand, we signalize the effects such as characteristic thermopower sign change induced by the Majorana coupling, as well as unconventional behavior of the spin polarization in the presence of a topological superconductor.

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Low-temperature phases of SU(4)-symmetric fermionic mixtures in optical lattices

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The quantum gases of alkaline-earth-like atoms are playing a significant role in understanding of physically rich phenomena of multiflavored fermionic mixtures, due to their properties at low temperatures. Since experimentally accessible values for the entropy per particle are currently too high for direct exploration of magnetic phases in the ultracold fermionic gases, the theoretical studies allow to handle such case [1,2]. We apply dynamical mean-field approach to the Hubbard model for the case of four-component SU(4)-symmetric fermionic gas to study both paramagnetic hysteresis between metallic and Mott-insulating phases, as well as transitions between the paramagnetic metal/insulator and antiferromagnetic (AFM) insulator phases. In contrast to previous studies of the half-filled SU(4)-symmetric Hubbard model [3], at quarter filling (one particle per site) we identify both the two-sublattice AFM and plaquette-ordered/four-sublattice AFM phases with the corresponding entropy-driven hierarchy for critical temperatures. Experimentally relevant observables, such as the double occupancy, compressibility, and entropy per particle are studied in detail.

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^{57}Fe and ^{151}Eu Mössbauer studies of 3*d*-4*f* spin interplay in $EuFe_{2-x}Ni_xAs_2$

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Mössbauer spectroscopy is a useful local probe for investigation of the iron-based superconductors [1] and their parent compounds. The $EuFe_{2-x}Ni_xAs_2$ compounds exhibiting 3*d* and/or 4*f* magnetic order were investigated by means of ^{57}Fe and ^{151}Eu Mössbauer spectroscopy [2]. Additionally, results for the end members of this system, i.e. $EuFe_2As_2$ and $EuNi_2As_2$, are reported for comparison. It was found that spin-density-wave order of the Fe itinerant moments is monotonically suppressed by Ni-substitution. However, the 3*d* magnetic order survives at the lowest temperature up to at least x = 0.12 and it is certainly completely suppressed for x = 0.20. The Eu localized moments order regardless of the Ni concentration, but undergo a spin reorientation with increasing x from the alignment parallel to the *a*-axis in the parent compound, toward *c*-axis alignment for x > 0.07. The change of the 4*f* spins ordering from antiferromagnetic to ferromagnetic takes place simultaneously with a disappearance of the 3*d* spins order what is the evidence of a strong coupling between magnetism of Eu^{2+} ions and the conduction electrons of $[Fe_{2-x}Ni_xAs_2]^{2-}$ layers. The Fe nuclei experience the transferred hyperfine magnetic field due to the Eu^{2+} ordering for Ni-substituted samples with x > 0.04, while the transferred field is undetectable in $EuFe_2As_2$ and for compound with a low Ni-substitution level. It seems that the 4*f* ferromagnetic component arising from a tilt of the Eu^{2+} moments to the crystallographic *c*-axis leads to the transferred magnetic field at the Fe atoms.

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The interplay of $4f$ state and superconductivity in $CeIr_3$: DMFT study.

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$CeIr_3$ has caught the attention over the past few years. It grows in trigonal structure and is a superconductor below $T_c = 3.1\,\mathrm{K}$. On the one hand the muon spin rotation and relaxation measurement shows its superconductivity to be of nearly BCS character [1], while on the other hand multiband character of this effect has been deduced from temperature dependence of critical magnetic field [2].
In our first work [3] we have shown, that its electronic band structure, including multiband Fermi surface, is dominated by Ir $5d$ states, thus their are suggested to be crucial for superconductivity of $CeIr_3$.
However, the role of $4f$ states of cerium is still unclear. If nearly BCS character of superconductivity is a case in $CeIr_3$, the McMillan formula for electron-phonon coupling (EPC) constant should be proper and resulted value 0.67 should agree with the EPC constant calculated as a renormalization of electronic part of heat capacity, $\lambda = \frac{\gamma_{expt}}{\gamma_{calc}} - 1$, where γ_{expt}, γ_{calc} are Sommerfeld constants determined on the basis of measured heat capacity and calculated electronic structure respectively. However, the result of letter formula is strongly dependent of a treatment of f states in calculations, being equal to 1.47 in the case of GGA approximation of electronic correlation and 3.40 in the case of GGA+U approximation. Both values are in strong disagreement with McMillan value, suggesting, that both approximations of electronic band structure of $CeIr_3$ fail and a role of $4f$ states is more subtle.
Here we are presenting the new approach to the band structure of $CeIr_3$ with help of embedded dynamical mean field theory (eDMFT) [4], which allows to treat f states properly. We show, that $4f$ states of Ce are present around the Fermi level more than previous study show, leading to smaller renormalization of heat capacity and a better agreement with McMillan value of EPC constant. This study show, that even if Ir $5d$ states are crucial for superconductivity of $CeIr_3$, Ce $4f$ states are also important, as they are present around Fermi level and are weakening the electron-phonon interactions.

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New fractional exclusion statistics in exactly solvable models.

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Fractional Exclusion Statistics (FES) has been introduced by Haldane in an attempt to model anyon gas thermodynamic properties. However his basic definition of generalised Pauli exclusion principle and following g-factor does not specify problem fully. In further developement Wu introduced additional assumption for particles obeying FES and derived so-called Haldane-Wu distributions which are generalisations of Bose-Einstein and Fermi-Dirac distributions. In this contribution I show that several classes of exactly solvable one dimensional models, in a limit of extremal correlations, exhibit generalised Pauli exclusion principle in accordance with Haldane definiton. However by calculating exact partition function of those models I show that they follow a new form of FES different from Haldane-Wu distribution. Furthermore, I show that such FES describes effects going beyond thermodynamics of standard Luttinger Liquid, and argue that this form of FES is generic for extremally correlated systems.

Interplay of Kondo effect and RKKY interaction in $CePdIn_{1-x}Sn_x$

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In this contribution we report occurrence of disorder-driven local quantum criticality (LQC) in $CePdIn_{1-x}S_x$ compounds. Quantum-criticality in frustrated magnetic systems is an emerging topic in current solid state physics. Recent studies revealed the frustration changes the picture of typical quantum criticality, introducing quantum critical phase being expanded over some range of tuning parameter [1]. Our approach involves the substitution of tin as the p-electron substitution in the $CePdIn_{1-x}S_x$ and the hydrogen sorption.

Intriguing properties of $CePdIn_{1-x}S_x$ compounds like valence fluctuations, quantum phase transitions and heavy fermion behaviour results from the competition between the RKKY indirect magnetic exchange and the Kondo screening [2,3]. They are responsible for establishing long-range magnetic order and Fermi liquid state (FL), respectively.

It seems that in case of $CePdIn_{1-x}S_x$, no typical quantum critical point (QCP) or phase (CQPh) is approached with total suppression of magnetic ordering. There is a strong premise to conclude that local disorder may be an origin of observed twofold nature of Ce 4f states showing nFL behavior and magnetic ordering simultaneously. The above conclusions were drawn from a set of complementary studies including neutron diffraction, specific heat and transport measurements carried out at sub-Kelvin range.

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Model of charge triplets for high-T_c cuprates

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Starting with a minimal model for the CuO_2 planes with the on-site Hilbert space reduced to only three effective valence centers $[CuO_4]^{7-,6-,5-}$ (nominally $Cu^{1+,2+,3+}$) with different conventional spin and different orbital symmetry we propose a unified non-BCS model that allows one to describe the main features of the phase diagrams of doped cuprates within the framework of a simple effective field theory. Unconventional bosonic superconducting phase (BS) related with a composite (two-hole) on-site boson quantum transport is shown to compete with antiferromagnetic insulating phase (AFMI), charge order (CO), and metallic Fermi liquid (FL) via phase separation regime. All the phases AFMI, CO, BS are separated from the 100% coherent metallic FL phase by the "third order" phase transition line $T^{\star}(p)$, which is believed to be responsible for the onset of the pseudogap phenomena as a main candidate for the upper "pseudogap" temperature. Puzzlingly, but it is the electron-lattice interaction, which in the BCS model determines s-wave pairing, in the model of local composite bosons gives $d_{x^2-y^2}$-symmetry of the superconducting order parameter, thus showing once again a substantial involvement of the lattice in the cuprate's HTSC.

Physics of strong electron correlations: $YbRh_2Si_2$, $CeRh_2Si_2$, NiO and Ba_2IrO_4

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Strong electron correlations occur very often in the modern solid-state physics and chemistry, quantum and classical. They are charged to be a reason, in fact, for everything. Strong correlations are, for instance, charged to be a reason of unability of the first-principles studies based on the local density approximation (LDA) to describe the insulating ground state of $3d/4f$ oxides. Also strong correlations are regarded to be a reason for heavy-fermion (h-f) phenomena in Ce, Yb or U intermetallics. Despite of their occurrence in most of scientific papers we feel that their physical meaning is quite physically undescribed. The aim of the present contribution is to clarify the predominant origin of strong electron correlations in transition-metal compounds, i.e. compounds containing 3d/4f/5f/4d/5d atoms, in particular with respect to the on-site or the intersite correlations. We claim a substantial physical importance of the on-site electron correlations. In all titled compounds there is growing experimental evidence for realization of Yb^{3+}, Ce^{3+}, Ni^{2+} and Ir^{4+} ions with integer number of electrons in the open-electron shell forming $4f^{13}$, $4f^1$, $3d^8$ and $5d^5$ strongly-correlated quantum systems, respectively. We are fully aware that our scientific point of view is in sharp contrast to widely spread view that h-f phenomena are associated with strong mixed valence and/or strong hybridization of localized f electrons with conduction electrons. In our view this large specific heat at low temperatures originates from difficulties in the removal of the ionic Kramers-doublet ground state. In last years crystal-field Kramers-doublet states have been revealed in profound h-f $YbRh_2Si_2$ and $CeRh_2Si_2$ intermetallics. According to us the h-f excitations are spin-like charge-neutral low-energy excitations, (< 0.2 meV), in contrary to charge excitations expected by the hybridization Fermi-liquid mechanism.

For NiO the value of the magnetic moment and its direction have been reproduced taking into account the crystal-field and spin-orbit interactions. The fine-electronic structure in Ba_2IrO_4 is governed by the intra-ionic spin-orbit coupling. Finally we would like to point out that the formation of ions, with realization of localized discrete energy states, close to the Fermi level, is manifestation of on-site strong-electron correlations. The presented view is in line with Georges et al. [Ann.Rev.Cond.Mat.Phys. 4 (2013) 137; arXiv:1207.3033v2] who pointed out that the Hund's rule coupling (intra-atomic exchange) is responsible for strong electron correlations. We would like to note that one of us (RJR) already 25 years ago pointed out the importance of crystal-field and spin-orbit interactions, obviously acting on Hund's rules physics, for theoretical description of magnetic and electronic properties of 3d/4f/5f/4d/5d compounds, both intermetallics and oxides.

Antiferromagnetism and magnetocaloric effects in $GdCrO_3$ based compounds

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Here we present a comparative study of the structural, magnetic, and magnetocaloric properties of polycrystalline rare-earth chromite ($RCrO_3$) compounds, focusing on the effect of Gd-site or Cr-site substitutions on the caloric properties of $GdCrO_3$. For this work, the bulk powder/pellets were synthesized by the citrate solution route. $RCrO_3$ materials were found to stabilize in orthorhombically distorted perovskite structure. The ionic radii, orthorhombic strain, in-plane & out-of-plane $Cr-O_1-Cr$ bond angles, bond lengths, all influences the *Néel* temperature (T_N^{Cr}) and magnetocaloric properties of the compounds. For example, the Néel temperature changes from 155 K for $Er_{0.33}Gd_{0.67}CrO_3$, to 167 K for $GdCrO_3$ and 275 K for $GdFe_{0.5}Cr_{0.5}O_3$. The maximum value of magnetic entropy change ($-\Delta S$) at 7 T for $Er_{0.33}Gd_{0.67}CrO_3$, $GdCrO_3$ and $GdFe_{0.5}Cr_{0.5}O_3$ were 10.7 $J\,kg^{-1}K^{-1}$ (at 15 K), 31.5 $J\,kg^{-1}K^{-1}$ (at 5 K), and 30.7 $J\,kg^{-1}K^{-1}$, respectively. Corresponding relative cooling power were 416.4 $J\,kg^{-1}$, 531.1 $J\,kg^{-1}$, and 566.5 $J\,kg^{-1}$, respectively. Details and discussion of these results along with those of Cr-doped samples will be presented.

Tensor network study of the $m = 1/2$ magnetization plateau in the Shastry-Sutherland model at finite temperature

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The two-dimensional iPEPS tensor network is evolved in imaginary time with the full update (FU) algorithm to simulate the Shastry-Sutherland model in a magnetic field at finite temperature directly in the thermodynamic limit. We focus on the phase transition into the $m = 1/2$ magnetization plateau, which was observed in experiments on $SrCu_2(BO_3)_2$. For the largest simulated bond dimension, the early evolution in the high-temperature regime is simulated with the simple update (SU) scheme and then, as the correlation length increases, continued with the FU scheme towards the critical regime. We apply a small-symmetry breaking bias field and then extrapolate towards zero bias using a simple scaling theory in the bias field. The combined SU+FU scheme provides an accurate estimate of the critical temperature, even though the results could not be fully converged in the bond dimension in the vicinity of the transition. The critical temperature estimate is improved with a generalized scaling theory that combines two divergent length scales: one due to the bias and the other due to the finite bond dimension. The obtained results are consistent with the transition being in the universality class of the two-dimensional classical Ising model. The estimated critical temperature is 3.5(2)K, which is well above the temperature 2.1K used in the experiments.

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Spin-orbital entanglement in magnetic quantum materials

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Strong relativistic spin–orbit coupling (SOC) in 4*d* and 5*d* materials leads to novel phenomena such as the complex phase behaviour observed in the extended Kitaev–Heisenberg model [1]. In this context we investigate spin–orbital entanglement (SOE) which plays a crucial role in the understanding of strongly correlated electrons in transition metal oxides. We study a transparent example of the intimate relation between quantum entanglement and SOC. To this end we numerically diagonalize one-dimensional spin–orbital model with the SU(2)⊗SU(2) 'Kugel – Khomskii' exchange supplemented by SOC of the Ising type for chains up to $L = 20$ sites [2,3]. We observe a substantial difference in the entanglement for small versus large SOC. While most of the features of the ground state with small SOC resemble the vanishing SOC limit, the phase diagram for large SOC regime is divided between the classical fluctuation—free region and surprisingly vast region where quantum fluctuations persist, including highly quantum 'stripe'—like area with maximal SOE. From a broader perspective, these results provide a basis to infer the generic properties of entanglement in transition metal oxides with finite SOC at higher dimension.

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Interaction-stabilized topological magnon insulator in honeycomb ferromagnets

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Condensed matter systems admit topological collective excitations above a trivial ground state, an example being Chern insulators formed by Dirac bosons with a gap at finite energies. However, in contrast to electrons, there is no particle-number conservation law for collective excitations. This gives rise to particle number-nonconserving many-body interactions whose influence on single-particle topology is an open issue of fundamental interest in the field of topological quantum materials.

Taking magnons in honeycomb-lattice ferromagnets as an example (e.g., $CrBr_3$, CrI_3), we uncover topological magnon insulators that are stabilized by interactions through opening Chern-insulating gaps in the magnon spectrum [1]. This can be traced back to the fact that the particle-number nonconserving interactions break the effective time-reversal symmetry of the harmonic theory. Hence, magnon-magnon interactions are a source of topology that can introduce chiral edge states. Importantly, interactions do not necessarily cause detrimental damping but can give rise to topological magnons with exceptionally long lifetimes. We identify two mechanisms of interaction-induced topological phase transitions and show that they cause unconventional sign reversals of transverse transport signals, in particular of the thermal Hall conductivity.

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Towards Kitaev Spin Liquid in 3*d* Transition Metal Compounds

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The idea of realizing the Kitaev honeycomb model in iridates and ruthenates with d^5 electronic configuration [1] attracted a lot of interest in the last decade. In these materials the large spin-orbit coupling (SOC) combines the spin and orbital moments into pseudospins-1/2 forming the basis for the magnetic model. Due to the orbital component, the superexchange interactions among pseudospins acquire strong bond-selective anisotropy. Evidence is mounting that the dominant pseudospin interaction is indeed of the predicted Kitaev type but the main attraction – the quantum spin-liquid phase – is hampered by the presence of subdominant interactions stabilizing long-range zigzag magnetic order.

An interesting alternative was proposed recently – 3*d* honeycomb systems with d^7 ions such as Co^{2+} were suggested to host Kitaev physics as well [2,3]. A natural question is raised: Is the SOC in 3*d* compounds strong enough to overcome the orbital moment quenching by crystal fields? To address this, we study in detail the exchange interactions derived for honeycomb cobaltates including trigonal crystal field Δ and construct the corresponding phase diagram using the numerical method introduced in [4]. We find that the pseudospin-1/2 Hamiltonian is dominated by Kitaev interaction for a broad range of Δ values and the non-Kitaev terms nearly vanish at small Δ, resulting in spin liquid ground state. Considering $Na_3Co_2SbO_6$ as an example, we find that this compound is proximate to a Kitaev spin liquid phase, and can be driven into it by slightly reducing Δ by about 20 meV. Here the smaller SOC of 3*d* compounds actually comes as an advantage – it enables to easily tune the interactions, e.g., via strain or pressure control. We thus argue that cobaltates may offer the most promising search area for Kitaev model physics.

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Chiral Hinge Magnons in Second-Order Topological Magnon Insulators

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When interacting spins in condensed matter order ferromagnetically, their ground-state wave function is topologically trivial. Nonetheless, in two dimensions, ferromagnets can support spin excitations with nontrivial topology, an exotic state known as topological magnon insulator (TMI). Here, we theoretically unveil and numerically confirm a novel ferromagnetic state in three dimensions dubbed second-order TMI, whose hallmarks are excitations at its hinges, where facets intersect. Since ferromagnetism naturally comes with broken time-reversal symmetry, the hinge magnons are chiral, rendering backscattering impossible. Hence, they trace out three-dimensional paths about the sample unimpeded by defects and are topologically protected by the spectral gap. They are remarkably robust against disorder and highly tunable by atomic-level engineering of the sample termination. We predict that a van der Waals heterostructure built from chromium trihalide and transition metal dichalcogenide monolayers exhibits second-order magnon topology. Our findings empower magnonics, the harnessing of spin waves as information carriers, with the tools of higher-order topology, a promising route to combine low-energy information transfer free of Joule heating with three-dimensional vertical integration.

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Possible Inversion Symmetry Breaking in the $S = 1/2$ Pyrochlore Heisenberg Magnet

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We address the ground-state properties of the long-standing and much-studied three-dimensional quantum spin liquid candidate, the $S = \frac{1}{2}$ pyrochlore Heisenberg antiferromagnet. By using $SU(2)$ density-matrix renormalization group (DMRG), we are able to access cluster sizes of up to 128 spins. Our most striking finding is a robust spontaneous inversion symmetry breaking, reflected in an energy density difference between the two sublattices of tetrahedra, familiar as a starting point of earlier perturbative treatments. We also determine the ground-state energy, $E_0/N_{\text{sites}} = -0.490(6)J$, by combining extrapolations of DMRG with those of a numerical linked cluster expansion. These findings suggest a scenario in which a finite-temperature spin liquid regime gives way to a symmetry-broken state at low temperatures. [1]

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Quantized Bubble Nucleation

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Non-equilibrium dynamics of slow quenches across continuous phase transitions have been understood very successfully under the unifying theory of Kibble-Zurek mechanism. However, relatively less attention has been paid to understanding dynamics across first order quantum phase transitions(FOQPT). In an attempt to mitigate this, here I will show the consequences of a slow dynamical ramp across the FOQPT transition line present in the Ising model with both transverse and longitudinal fields [1]. The existence of potential barrier, quintessential to the FOQPTs, gives rise to metastability in the dynamical state. Such metastability can wear off either by dynamical instability due to disappearance of the potential barrier, or by nucleating bubbles of the true ground state driven by quantum fluctuations. While the former scenario have been studied across certain first order phase transitions under the framework of Kibble-Zurek theory, here I will present our analysis of the generic situation of the breakdown of metastability by nucleation of bubbles. Specifically, we identify special resonant regions in the longitudinal field, where the metastable state can easily tunnel to nucleate bubbles of specific sizes (quantized). Further I will describe our attempt to explain the entire non-adiabatic process under the umbrella of Landau-Zener theories. In recent times, quantum simulations of non-equilibrium dynamics of many-body spin systems have met with remarkable success owing to improvement in atom trapping technology and long life-time of Rydberg atoms[2,3,4], with the potential to observe different ordered phases with broken symmetry. Such tremendous experimental achievements make possible to investigate quantized nature of bubble nucleations in one and higher dimensions. Our work therefore is of relevance for both current theoretical as well as experimental endeavours.

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Modeling of electronic and magnetic properties of mixed-valence polyoxovanadate molecular magnets.

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Due to a large structural variety and many oxidation states of vanadium ions polyoxovanadates (POVs) exhibit rich magnetic properties and therefore find many technological applications. In sufficiently symmetric POVs some of the valence electrons are not localized at particular vanadium ions and have itinerant character. In this contribution we use the density functional theory (DFT) and effective Hamiltonian approaches to elucidate electronic and magnetic properties of a family of mixed-valence polyoxovanadate molecular magnets $X@V_{22}O_{54}$, composed of a spherical host shell $V_{22}O_{54}$ with itinerant valence electrons, and containing various diamagnetic guest anions $X{=}VO_2F_2^-$, ClO_4^-, SCN^-. Exploiting the synergy of the two methods and using highly efficient computational approach based on large parallel computers and an evolutionary algorithm we have managed to avoid or limit the shortcomings of the both methods (such as overparametrisation in the fitting procedure, or uncertainty of parameter estimation by DFT) and have obtained results fully concordant with each other and with the experiment. It is shown that the guest anions strongly influence the magnetism of the molecules. The number of valence electrons and their distribution varies with the type of a guest anion. Moreover, different guest anions induce different exchange interactions between shell V^{4+} ions.

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Stable Organic Radicals On Metal Substrates Studied by Scanning Tunneling Microscopy

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Adsorption of stable organic radicals on metal surfaces changes their electronic properties on a wide scale. Thorough preparation of samples with submonolayer coverages makes it possible to study single adsorbed molecules with an unpaired electronic spin [5], as well as smaller molecular clusters with interesting topographic properties and possible mechanical degrees of freedom [4]. At this conference I will present scanning tunneling microscopy (STM) studies of α, γ-bisdiphenylene-β-phenylallyl (BDPA) [1,2] and 2,2-diphenyl-1-picrylhydrazyl (DPPH) [3], two well-known stable organic radicals, adsorbed on Au(111) and Ag(111) surfaces.

Our STM studies of BDPA on Au(111) [1,2] provide strong indications of spin preservation upon adsorption due to the presence of a Kondo resonance close to the Fermi level. It was also shown that BDPA forms self-aligned directed one-dimensional chains of various length. Nearly identical chains were observed in our recent experiments with BDPA on Ag(111). The presence of a Kondo resonance in the point scanning tunneling spectra (STS) taken from BDPA on the Ag(111) surface has not yet been directly observed and so the question of spin preservation of BDPA on this metal surface remains open. Electronic structure simulations show that BDPA interacts stronger with silver than with gold, giving a possible explanation of the differences in the BDPA's electronic properties in these two cases.

DPPH is another showcase of a magnetic single-spin system made up of a molecule adsorbed on a metal surface. We reported on the Kondo resonance in the characteristic STS spectra of this system in our recent study [3].

Magnetic molecular systems such as BDPA and DPPH radicals adsorbed on Au(111) surface play a pivotal role in investigation of single-molecule spin transitions by means of our novel experimental technique: radio frequency scanning tunneling spectroscopy (RF-STS).

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Influence of a spatial anisotropy on presence of the intermediate one-half magnetization plateau of spin-1/2 Ising-Heisenberg branched chain

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The spin-1/2 Ising-Heisenberg branched chain constituted by regularly alternating Ising spins and Heisenberg dimers involving an additional side branching is rigorously solved in a magnetic field by the transfer-matrix method. The spin-1/2 Ising-Heisenberg branched chain involves two different types of the Ising couplings and one type of the Heisenberg coupling. The ground-state phase diagram and magnetization curves of the spin-1/2 Ising-Heisenberg branched chain are examined depending on a relative strength of the coupling constants. Three different ground states were found depending on a mutual interplay between the magnetic field and three different coupling constants: the modulated quantum antiferromagnetic phase, the quantum ferrimagnetic phase, and the classical ferromagnetic phase. It is shown that the spatial anisotropy connected to two different Ising coupling constants substantially influences a breakdown of the intermediate one-half magnetization plateau of the spin-1/2 Ising-Heisenberg branched chain reported in our previous work for the special case involving just one type of the Ising coupling constant [1]. The magnetic structure of the investigated spin-1/2 Ising-Heisenberg branched chain is inspired by the heterobimetallic coordination polymer $[(Tp)_2Fe_2(CN)_6(OCH_3)(bap)Cu_2(CH_3OH) \cdot 2CH_3OH \cdot H_2O]$ (Tp = tris(pyrazolyl)hydroborate, bapH = 1,3-bis(amino)-2-propanol) [2].

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Two-spin and multi-spin quantum entanglement in V12 polyoxovanadate molecular nanomagnet

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Molecular nanomagnets constitute a highly interesting class of modern magnetic materials and offer a plethora of intriguing properties of quantum origin [1]. One of the possible applications of such systems can be connected with quantum computations [2-4]. For implementing the quantum algorithms, the presence and sufficient persistence of quantum entanglement is at least a desirable feature.

In the paper we present the computational study of quantum entanglement in V12 polyoxovanadate molecular cluster nanomagnet [5]. Its low-temperature magnetic properties are ruled by the behaviour of the non-interacting tetramers composed of quantum spins $S = 1/2$ [5,6]. The theoretical characterization of the system of interest is based on anisotropic quantum Heisenberg model. Both spin-space anisotropy and anisotropy related to the presence of two unequal couplings in the tetramer are included. The thermodynamic description is constructed using canonical ensemble in the presence of the external magnetic field. The exact analytic and numerical diagonalization is applied to the Hamiltonian; the interaction parameters are taken from the experiment [5].

The most typical two-particle entanglement is quantified using the Wootters concurrence [7], measuring the entanglement of formation. The values of Wootters concurrence are investigated for V12 as a function of the temperature and the external magnetic field, using analytic and numerical approach. The importance of the anisotropies in the studied tetramer for the quantitative description of the quantum entanglement is emphasized. To supplement the results concerning the two-particle entanglement and to capture a broader category of multiparticle entanglement, the fidelity [8] is used and its behaviour is discussed. The effect of quantum level crossings present in the energy spectrum of V12 on the studied properties is highlighted.

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Effect of uniaxial single-ion anisotropy on a stability of intermediate magnetization plateaus of a spin-1 Heisenberg diamond cluster

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Ground-state phase diagrams and magnetization curves of a spin-1 Heisenberg diamond cluster with two different coupling constants and uniaxial single-ion anisotropy are investigated in a presence of the external magnetic field with the help of exact diagonalization methods. It is shown that the spin-1 Heisenberg diamond cluster exhibits several remarkable quantum ground states, which are manifested in zero- and low-temperature magnetization curves as intermediate plateaus at 1/4, 1/2 and 3/4 of the saturation magnetization. It is demonstrated that the width of the fractional magnetization plateaus depends basically on a relative strength of the coupling constants as well as uniaxial single-ion anisotropy, which may substantially shrink or even cause full breakdown of some intermediate magnetization plateaus. The investigated quantum spin-1 Heisenberg diamond cluster is motivated by the magnetic structure the homotetranuclear nickel compound $[Ni_4(\mu\text{-}CO_3)_2(aetpy)_8](ClO_4)_4$ (aetpy = 2-aminoethyl-pyridine) [1], which displays in low-temperature magnetization curve two intermediate magnetization plateaus detected at 1/2 and 3/4 of the saturation magnetization.

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Towards rationalizing photoswitchable behavior of $Cu_2^{II}Mo^{IV}$ cyanido-bridged molecule

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$[Cu^{II}(enpnen)]_2[Mo^{IV}(CN)_8]\cdot 7H_2O$ (enpnen = N,N′–bis(2–aminoethyl)–1,3–propanediamine) molecular cluster compound was subject to a series of irradiations with the light of 405 nm. On irradiation isothermal magnetization at 1.8 and 5 K in the field range 0 - 70 kOe as well as magnetic susceptibility in the temperature range of 2 - 300 K were subsequently detected. Both types of magnetic signals were next analyzed assuming that the irradiation triggers two independent processes: the metal to metal charge transfer (MMCT) leading to a state with the Arrhenius-type relaxation and the spin crossover (SC) transition ending in a state whose relaxation displays a threshold behavior. The first mechanism leads to an electron from the spinless Mo(IV) configuration being transferred to one of the Cu(II) ions transforming the trimer into the state Cu(II)-N-C-Mo(V)-C-N-Cu(I), with spin 1/2 on the Mo(V) ion and the spinless Cu(I) ion. The other mechanism gives rise to an excited paramagnetic Mo(IV)* linked to two paramagnetic Cu(II) centers with a possible superexchange interaction. The spin of the excited Mo(IV)* species is equal to 1 and associated to a disruption of the 5s-electronic pair. A reasonable result of simultaneous fitting the full series of susceptibility data to the model taking into account both mechanisms corroborates their presence. Moreover, the parameters thus obtained are also consistent with the magnetization data. The presented approach to understanding the behavior of photoswitchable material upon irradiation has never been used before.

Exotic magnetization plateau in the S=1/2 kagome candidate $Y_3Cu_9(OH)_{19}Cl_8$

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In the field of quantum magnetism, obtaining insight into the nature of the quantum spin liquid state is one of the central issues. Largely, this is triggered by the discovery of the Heisenberg kagome antiferromagnet candidate Herbertsmithite [1]. Correspondingly, significant efforts have been made to find new materials with antiferromagnetically coupled kagome layers and to investigate the exotic quantum liquid state, $Y_3Cu_9(OH)_{19}Cl_8$ has been synthesized recently [2]. No magnetic order was found in muon spin relaxation measurements and elastic neutron scattering on the powder [3]. However, recent measurements indicate that there are important differences in the structure and the magnetic behavior at low temperatures between the powder and the hydrothermally grown single crystals (powder samples showing signs of hydrogen deficiency), triggered by different procedures for sample preparation. Indeed, in contrast to the powder samples, the single crystals undergo a long-range magnetic ordering transition, as seen in bulk thermodynamics, muon spin relaxation [4] and inelastic neutron diffraction experiments below a temperature of 2.1 K.

To extensively characterize the magnetic behaviour of single crystalline $Y_3Cu_9(OH)_{19}Cl_8$, we carried out magnetization measurements parallel and perpendicular to the Kagome planes in pulsed magnetic fields. Surprisingly, at low temperatures a magnetization plateau is visible in a field range from 19 T to 25 T for both field configurations. The plateau sets in at a comparatively small magnetization value of $\sim$0.2 μB/Cu and is thus slightly less than the 1/3 plateaus previously observed in other kagome systems. We discuss possible mechanism for this exotic magnetization plateau.

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Magnetism of single-crystalline clinoatacamite, $Cu_2Cl(OH)_3$, a distorted antiferromagnetic kagome compound

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Model compounds of frustrated (quantum) spin systems can often be found realized in natural minerals. Among them the mineral clinoatacamite, $Cu_2Cl(OH)_3$, has been discussed as a frustrated quantum spin system in the past [1–5]. It is the end-member compound of the $Cu_{4-x}Zn_x(OH)_6Cl_2$ family with $x = 0$ and thus is structurally related to the mineral herbertsmithite with $x = 1$. Clinoatacamite crystallizes in a monoclinic structure with the space group $P2_1/n$ [6]. In the past, studies on polycrystals have shown that this material undergoes magnetic transitions at 18.1 K and 6.4 K [1]. A neutron diffraction study on deuterated clinoatacamite powder has revealed magnetic reflections with a propagation vector $\mathbf{q} = (0, 0, 0)$ below the lower transition temperature [3]. Recently, we have carried out band-structure calculations for clinoatacamite which indicate that its crystal structure can be read as antiferromagnetic kagome layers which are coupled ferromagnetically.

Here, we present the results of our magnetic characterization of mineral clinoatacamite single crystals by means of thermodynamic as well as neutron diffraction measurements in zero and applied magnetic fields. We have found that at low temperatures ~ 6.4 K there is a double magnetic transition and that the region of the phase diagram between 6.4 and 18.1 K contains several field-induced phases of unknown nature with a complex field-evolution ($\mathbf{H} \parallel b$ axis). We further characterize the magnetic behavior of clinoatacamite by means of single-crystal neutron diffraction.

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Verification of the new Baxter phase in the 3D Ashkin-Teller model

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Although the lattice Ashkin-Teller (AT) model is one of the most important in statistical physics and is being studied for decades [1,2], it still attracts a great interest, raises many applications and intriguing questions that have not found satisfactory answers, as it is a non-trivial generalization of the widely used Ising model. The effective Hamiltonian H of the AT model is of the form: $-H/(k_{\mathrm{B}}T) = \sum_{[i,j]}\{K_2(s_is_j + \sigma_i\sigma_j) + K_4 s_i\sigma_i s_j\sigma_j\}$, where the summation occurs over the pairs of nearest neighbors, Ising spins s_i and σ_i reside on the same cubic lattice site, k_B is the Boltzmann constant, and T is the temperature of the system. As a result, the order parameter contains three components $\langle s\rangle$, $\langle\sigma\rangle$, and $\langle s\sigma\rangle$, each of which can order independently. Here, the symbol $\langle ...\rangle$ denotes the thermal average. The 3D AT model demonstrates an interesting and complex phase diagram [2] which contains weakly to strong first-order phase transitions, continuous ones, many tricritical and bifurcation points, as well as the wide crossover region. Here we concentrate on the interesting mixed phase region, where $\langle s\sigma\rangle = 0$ and either $\langle s\rangle \neq 0$ and $\langle\sigma\rangle = 0$ or $\langle s\rangle = 0$ and $\langle\sigma\rangle \neq 0$ with ferromagnetic order, which is the most complex and least recognized one [1,2]. In particular, the subject of our research is the border region with the Baxter phase, in which all three components are ordered ferromagnetically and $\langle s\rangle = \langle\sigma\rangle$. Ditzian *et al.* observed a narrow region here where $\langle s\rangle$, $\langle\sigma\rangle$, and $\langle s\sigma\rangle$ are nonzero, but $\langle s\rangle \neq \langle\sigma\rangle$, despite the symmetry of both components resulting from the Hamiltonian. Recently, Santos *et al.* [1] presented the MFT results from the Bogoliubov inequality for the 3D AT model on a cubic lattice for clusters with 1-, 2-, 4-, and 8-sites and they identified this region as the new Baxter$^{(2)}$ phase for the first time. In this paper, we use our extensive Monte Carlo computer experiments [2] to explore this intriguing Baxter$^{(2)}$ phase region in a 3D AT model. Due to the existence of metastable and unstable phases in this region, we based our computer experiments not only on the Metropolis algorithm, but also on our recently discovered cluster one [2]. At the transition of the system from the mixed phase region to the Baxter one, a step energy change is observed for all three components of the order parameters, however, two of them order by reducing their internal energy, at the expense of the step change in the internal energy of the already ordered component. The sum of the latent heat of the entire system is different from zero, and we demonstrate that it is equal to the sum of the latent heat of individual components of the order parameter computed separately. Our results show that as the system size increases, this region indicated as Baxter$^{(2)}$ phase is becoming narrower and disappears in the thermodynamic limit.

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Magnetic antiskyrmions in tetragonal Heusler materials with D_{2d} symmetry

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Skyrmions are magnetic nano-objects with distinct chiral, noncollinear spin textures found in various magnetic systems with crystal symmetries that give rise to specific Dzyaloshinskii–Moriya (DMI) exchange vectors. In previous studies, depending on the crystal symmetry, two distinct types of skyrmions were observed experimentally, namely, Bloch and Néel skyrmions. An important goal is to find new material systems that can host new magnetic topological structures.

A very interesting skyrmionic structure, the magnetic antiskyrmion, was only recently experimentally observed in acentric tetragonal Heusler compounds with D_{2d} crystal symmetry [1]. Antiskyrmions are characterized by boundaries that have alternating Bloch and Néel type wall components as one traces around the boundary. Direct imaging by Lorentz transmission electron microscopy (LTEM) shows field stabilized antiskyrmion over a wide temperature range. These results enlarge the family of magnetic skyrmions and pave the way to the engineering of complex bespoke designed skyrmionic structures.

We have shown that antiskyrmions have unique properties derived from the unique DMI exchange interaction. We have shown that antiskyrmions are much more robust compared to the Bloch skyrmions in the cubic B20 compounds. For example, the field-temperature phase stability window for antiskyrmions, that we have determined from LTEM, is largely insensitive to the sample thickness in contrast to B20 materials [2]. We have carried out detailed micromagnetic simulations that confirm our experimental observations.

Another important property of antiskyrmions that we have discovered [3] is that their size increases by more than an order of magnitude from around 100 nm to more than 1.1 micrometer as the thickness increased. This extreme size tunability is shown to arise from long-range magnetic dipolar interactions, which typically play a much less important role for B20 skyrmions. This tunability in size makes antiskyrmions very attractive for technological applications.

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Nonreciprocal magnetoacoustic surface waves in a dipolar coupled ferromagnetic bilayer

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Surface acoustic waves (SAWs) have made their way into many everyday devices, thanks to the greatly reduced wavelength of SAWs compared to free-space microwaves of the same frequency. These "nano earthquakes" can be efficiently launched and detected on piezoelectric substrates with periodic metallic gratings in the MHz- to GHz-range. However, SAWs are in general propagating reciprocally, which means that SAW propagation does not change under inversion of the propagation direction and limits the usage of SAWs as reciprocal devices.

Since spin waves (SWs) are known to show a pronounced nonreciprocal behavior, magnetoelastic coupling of SAWs with SWs is a straightforward approach to obtain nonreciprocal magnetoacoustic surface waves (MASWs). Besides the nonreciprocity of the SAW-SW coupling mechanism itself [1,2], the SW dispersion relation can be nonreciprocal. For example, the Dzyaloshinskii–Moriya interaction (DMI) in an ultrathin ferromagnetic/heavy metal bilayer causes SW nonreciprocity and thus induces nonreciprocal SAW propagation [3].

In our recent study, we experimentally demonstrate the large coupling between SAWs and SWs to obtain highly nonreciprocal MASWs in a dipolar coupled ferromagnetic bilayer [4]. We show that nonreciprocal symmetric and antisymmetric SW modes form in a NiFe/Au/CoFeB magnetic bilayer. Furthermore, we model our results in a phenomenological approach and discuss the high tuneability of the nonreciprocity in such a bilayer.

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Nanoscale magnonic devices

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Spin waves, and their quanta magnons, are of great interest as potential data carriers in future low-energy computing devices. The phase of a spin wave provides an additional degree of freedom, while the scalability of structures and wavelengths down to the nanometer regime [1] are further advantages. Recently, a set of magnonic data processing units was demonstrated. However, the development of each of them requires specialized investigations and, usually, one device design is suitable for one function only. Moreover, an integrated all-magnonic circuit, which is suitable for the cascading of multiple magnonic units, has not yet been demonstrated.

Here, we present the experimental realization of a nanoscale magnonic directional coupler, which consists of two single-mode spin-wave waveguides with 350 nm width, separated by a gap of 320 nm [2,3]. A U-shaped antenna is used to excite spin waves and space-resolved Brillouin Light Scattering (BLS) spectroscopy is exploited for detection. It is shown that the data is coded into the spin-wave amplitude is guided towards one of its two outputs depending on the signal frequency, magnitude, and on the magnetic field. Using micromagnetic simulations, we also propose an integrated magnonic half-adder that consists of two directional couplers and we investigate its functionality for information processing within the magnon domain.

Furthermore, we propose a new field of inverse-design magnonics which combines magnonics with the very active field of machine learning. The functionality can be specified first, and a feedback-based computational algorithm is used to obtain the device design. To demonstrate the universality of this approach, linear, nonlinear and non-reciprocal functionalities of magnonic devices are explored using the examples of magnonic (de-)multiplexer, nonlinear switch and circulator [4].

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Magnon Scattering by a Driven Space-Time Magnonic Crystal

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The breaking of continuous spatial translational symmetry is the most important indicator of' crystal formation, whereas the breaking of the translational symmetry in time is fundamental for temporal crystals. The idea of systems with broken translational symmetry in space and time, so-called Space-Time Crystals, was proposed by F. Wilczek in 2012 [1].

Using scanning transmission X-ray microscopy we experimentally demonstrate at room-temperature and explain with micromagnetic simulations, the formation of a dynamical magnetic pattern characterized by a periodicity in both time and space in a thin permalloy stripe pumped by a spatially uniform microwave field [2]. Such a system can be considered as a driven space-time magnonic crystal (STMC). Moreover, we demonstrate an interaction of magnons with this STMC, resulting in the appearance of 100 nm long spin waves that are much shorter than the waves expected from the dispersion relation of the uniformly magnetized permalloy stripe at the pumping frequency. We show that this short wave originates from the second Brillouin zone of the magnonic band structure of the driven STMC. This founding clearly confirms the dynamical formation of the periodicity in space in a homogeneous ferromagnetic element.

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Orbital Magnetic Moment of Magnons

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It is commonly accepted that magnons—collective excitations in a magnetically ordered system—carry a spin of $1\hbar$ or, phrased differently, a magnetic moment of $g\mu_\mathrm{B}$. In this talk, I demonstrate that magnons carry magnetic moment beyond their spin magnetic moment. Our rigorous quantum theory uncovers a magnonic orbital magnetic moment brought about by spin-orbit coupling. We apply our theory to two paradigmatic systems where the notion of orbital moments manifests itself in novel fundamental physics rather than just quantitative differences. In a coplanar antiferromagnet on the two-dimensional kagome lattice the orbital magnetic moment gives rise to an orbital magnetization. While the spin magnetization is oriented in the kagome plane, the orbital magnetization also has a finite out-of-plane component leading to "orbital weak ferromagnetism." The insulating collinear pyrochlore ferromagnet $Lu_2V_2O_7$ exhibits a "magnonic orbital Nernst effects," i. e. transversal currents of orbital magnetic moment induced by a temperature gradient. The orbital magnetization and the orbital Nernst effect in magnetic insulators are two signatures of the orbital magnetic moment of magnons.

$Mo_4Ce_4Al_7C_3$: A nanolamellar ferromagnetic Kondo lattice

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The study of Rare-Earth (RE) based compounds has been at the forefront of condensed matter physics for decades, due to the variety of magnetic and electronic ground states that they display. Recently, rare-earth-based nanolaminates have attracted attention because of their rich magnetism and their potential as precursors for strongly correlated two-dimensional materials, opening the door to exciting fundamental science as well as technological applications. We report on the $Mo_4Ce_4Al_7C_3$ phase, which belongs to a recently discovered family of nanolaminates with a $Mo_4RE_4Al_7C_3$ stoichiometry in which the RE order within planes, and featuring 2 nonequivalent lattice sites for the RE to sit on [1]. Single crystals of this compound were grown using high temperature solution growth. Bulk magnetisation revealed a transition to a ferromagnetic (FM) order below T_C=10.5K, with the easy magnetisation axis in the out-of-plane direction. X-ray absorption near edge structure (XANES) performed at the Ce L_3-edge revealed that Ce is in a mixed-valence state [1]. X-ray Circular Magnetic Dichroism (XMCD) carried out at the edges of the Mo, Al and C elements of the compound allowed us to conclude that one of the 2 nonequivalent Ce sites is in a $4f^1$ configuration and is responsible for the FM, while the other one is in a mixed-valence state and does not participate to the FM [1,2]. We were also able to establish which of the 2 Ce lattice sites is FM, and which one is in a mixed-valence state. High-pressure XANES showed an evolution of the initially mixed-valent Ce site, up to a fully $4f^0$ configuration at around 20GPa. This measurement, together with high pressure magnetoresistance measurements across the ferromagnetic transition unveiled a clear Kondo behaviour. Angle-Resolved photemission spectroscopy coupled with density functional theory highlight a delocalisation of conduction electrons in the out-of-plane direction. [2]

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String Method Exploration of the Energy Landscape in Perpendicularly Magnetized Nanodisks with Dzyaloshinskii-Moriya Interaction

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There is a great interest on the use of magnetic skyrmions for information storage and processing. A majority of research investigates skyrmion dynamics over extended films where they have potential to serve as information carriers [1]. Another potential use is in confined structures, where they can be energy minima and so can be used to encode a bit of information [2-4]. Most of these studies stop after identifying the existence of energy minima and comparing their energy values as a measure of stability. However, this provides no information about how robust a given configuration is with respect to thermal fluctuations, since this requires identification of the minimum energy barrier between different energy minima.

The String Method for the Study of Rare Events is a numerical technique to find minimum energy paths between energy minima, and has been previously applied to micromagnetic problems. The method finds magnetization configurations corresponding to saddle points of the energy lanscape and consequently a value for the energy barrier that needs to be overcome by thermal fluctuations for the system to switch between different states.

Here, we apply the String Method to study the energy landscape of nanodisks capable of hosting magnetic skyrmions. The value of D determines which of these configuration corresponds to a global minimum, as well as the minimum energy path between them. In all cases, the edge of the device plays a key role in the annihilation of magnetic skyrmions. For small D, the skyrmion maintains its shape as it drifts to the edge where its gets expelled from the disk. For intermediate D, a secondary energy minimum as the skyrmion deforms and a single meron is expelled from the nanodisk. As D grows larger, the energy landscape becomes richer due to the appearance of many more skyrmionic energy minima.

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Quantitative imaging of antiferromagnetic spin cycloidal textures on strain engineered $BiFeO_3$ thin films with a scanning nitrogen-vacancy magnetometer

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Multiferroics, such as $BiFeO_3$, in which antiferromagnetism and ferroelectricity coexist at room temperature, appears as a unique platform for spintronic [1] and magnonic devices [2]. The nanoscale structure of its ferroelectric domains has been widely investigated with piezoresponse force microscopy (PFM), revealing unique domain structures and domain wall functionalities [3, 4], but nanoscale magnetic textures present in $BiFeO_3$ and their potential for spin-based technology remain concealed. Depending on the strain, growth conditions and crystal orientation, the magnetic state of $BiFeO_3$ thin films can either show different types of non-collinear cycloids, canted G-type antiferromagnetic orders, or even a mixture of these [5]. In this report, we present two different antiferromagnetic spin textures in multiferroic $BiFeO_3$ thin films with different epitaxial strains, using a scanning Nitrogen-Vacancy magnetometer (SNVM) based on a single NV defect in diamond with a dc field sensitivity of $\sim 1\ \mu T/\sqrt{Hz}$. The two $BiFeO_3$ samples were grown $DyScO_3$ (110) and $SmScO_3$ (110) substrates using pulsed laser deposition. The striped ferroelectric domains in both samples are first observed by the in-plane PFM. The corresponding SNVM images confirm the existence of the spin cycloid texture. For the $BiFeO_3$ grown on $DyScO_3$ (110) substrate, the 90-degree in-plane rotation of the ferroelectric polarization imprints the 90-degree in-plane rotation of the cycloidal propagation direction along k_1= [-1 1 0], corresponding to the type-I cycloid. On the contrary, in the $BiFeO_3$ film grown on $SmScO_3$ (110) substrate, the propagation vectors are found to be along $k_1^{'}$= [-2 1 1] and $k_2^{'}$= [1 -2 1] directions in the neighboring domains separated by the 71° domain wall. Our results here shed the light on future potential for reconfigurable nanoscale spin textures on multiferroic systems by strain engineering.

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Electronic structure of Fe(001) with symmetry breaking due to the magnetization direction

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Interplay of the exchange interaction and the spin-orbit interaction introduces subtle modifications to the electronic band structure of a ferromagnet that lower the symmetry of the system with respect to the nonrelativistic case. This effect brings prominent consequences, such as the emergence of the magnetocrystalline anisotropy, intrinsic anomalous Hall effect, or anisotropic magnetoresistance. In this contribution, we will discuss the experimental results obtained for thin Fe(001) films epitaxially grown on Au(001) using high resolution angle-resolved photoelectron spectroscopy as well as spin- and k-space resolved photoemission microscopy. We have observed clear modifications of the electronic band structure of Fe(001) near the Fermi level, depending on the magnetization direction. We will show opening/closing of the spin-orbit gaps within the bulk electronic structure [1], as well as substantial shifts in energy and momentum of the quantum well states [2]. The quantized states that we observed can be responsible for the oscillations of the magnetic anisotropy in Fe(001) thin films with periods of about 5 and 9 monolayers. The experimental results will be confronted with the photoemission simulations performed starting from the initial band structure described by the GW method and taking into account intrinsic broadening of the final state along the wavevector perpendicular to the sample surface.

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Direct Observation of Magnon Modes in Kagome Artificial Spin Ice with Topological Defects

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Kagome artificial spin ice (KASI) is a network of Ising type nanobars on a kagome lattice [1-3]. The magnetodynamic study of such disordered state has been confined to global magnetodynamics [4]. From fundamental physics side such dynamically controlled microstates may offer a way to create Dirac strings via microwave assisted switching in a controlled manner interior to the KASI lattice and study the disordered regime systematically. From magnonic application perspective mesoscopic experimental study of such micro-states of KASI is key towards their usage in as a new type of microwave filter [5] and reprogrammable magnonic crystals [6]. We investigate spin dynamics of KASI where topological defects confine magnon modes in Ni81Fe19 nanomagnets arranged on an interconnected kagome lattice using broadband spin wave spectroscopy, magnetic force microscopy, and micro-focus Brillouin light scattering (BLS) microscopy. Micro-focus BLS performed on magnetically disordered states exhibit a series of magnon resonances which depend on topological defect configurations detected by magnetic force microscopy. Nanomagnets on a Dirac string and between a monopole-antimonopole pair show pronounced modifications in magnon frequencies both in experiments and simulations. Our work is key for the creation and annihilation of Dirac strings via microwave assisted switching and reprogrammable magnonics based on ASIs.

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Hysteresis of the frequency spin wave excitations in Ir/Co/Pt mutlilayers with Dzyaloshinskii-Moriya interaction

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Multilayered systems consisting of ferromagnetic layers alternating with non-magnetic heavy metal layers exhibiting perpendicular magnetic anisotropy (**PMA**) and Dzyaloshinskii-Moriya Interaction (**DMI**) are now intensively studied because of interesting physics and potential applications e.g. skyrmion-hosting systems [1]. The evolution of topological skyrmions as a function of Co thickness d has been recently studied across the Spin Reorientation Transition (**SRT**) in $(\mathrm{Pt/Co}(d)/\mathrm{Ta})_N$ (N – number of repetitions) multilayers using Lorentz Transmission Electron Microscopy [2]. Close to the **SRT**, it is possible to perform Brillouin Light Scattering (**BLS**) studies of spin wave excitations even without applying external magnetic fields H. In the present work, we investigated $(\mathrm{Ir/Co}(d)/\mathrm{Pt})_N$ multilayers with negative effective uniaxial anisotropy and large **DMI**. The samples were deposited by magnetron sputtering with N=1 or N= 6. Using Longitudinal Magneto Optical Kerr Effect (**LMOKE**) and magnetic force microscopies we determined the following magnetization configuration: large macrodomains (several dozen micrometers size) with in-plane "core" magnetization which are modulated by small nanodomains (about 100 nm size) differentiated by out-of-plane magnetization. Using **BLS** spectrometer, the hysteresis behaviors of the **DMI** sensitive: Stokes f_S and anti-Stokes f_{AS} frequencies as well as their frequencies difference Δf as the functions of the in-plane magnetic field were observed. The **BLS** signal is related to the in-plane "core" magnetization component of domains. The hysteresis of $\Delta f(H)$ is correlated with the switching of the large macrodomains observed with **LMOKE**. These experimental results are supported by micromagnetic simulations.

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Strong coupling of antiferromagnetic resonance to sub-tehahertz cavity fields

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We study coupling of electromagnetic waves to antiferromagnetic resonance at herahertz (THz) frequencies [1]. Magnon-polaritons are investigated in ferromagnetic materials [2]. Antiferromagnetic materials that are interesting due to their high-frequency dynamics, however, there are very few reports of strong magnon-photon coupling in that case [3]. We reported experimental observation of magnon-polaritons in high-temperature antiferromagnet hematite α-Fe_2O_3. A cube of hematite was placed inside a 3-dimensional cavity that has the lowest resonance at about 0.24 THz. We measured transmission spectra in 200-350 GHz frequency band as a function of temperature at above room temperature. Frequency of the magnetic resonance rises with temperature and shows very clear avoided crossing with the first cavity mode. We estimate the cooperativity factor of the polariton states at about 40 [4].

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Magnetic interactions and excitations in high-T_c three-dimensional Slater insulator $NaOsO_3$

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In contrast to Mott insulating phase found in many correlated systems, the Slater insulator in three dimensions is very rare and has been observed in a handful of compounds. One prominent example is $NaOsO_3$ which undergoes an antiferromagnetic transition at 410 K where a small electronic gap $\sim$0.1 eV is induced [1,2]. Interestingly, the continuous metal-insulator transition in $NaOsO_3$ is challenging even for the state-of-the-art theory. In this work, our goal is to study the magnetic interactions in this $5d$ oxide and to analyze the effect of different theory approximations on the predicted magnetic properties. Our calculations are based on density functional theory where electronic correlations are included on the static mean-field level and the relativistic generalization of the magnetic force theorem, both available in the RSPt electronic structure software [3]. The quality of the theoretical description is assessed by comparing the calculated and measured magnon spectra [4]. We have clarified the role of different types of magnetic interactions, i.e. Heisenberg, Dzyaloshinskii-Moriya and symmetric anisotropic exchange as well as the on-site anisotropy, by disentangling their contributions to the magnetic excitation spectra.

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New insights on the Dzyaloshinskii-Moriya interaction

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We have derived an expression of the Dzyaloshinskii-Moriya interaction (DMI), where all the three components of the DMI vector can be calculated independently, for a general, non-collinear magnetic configuration. The formalism is implemented in a real space – linear muffin-tin orbital – atomic sphere approximation (RS-LMTO-ASA) method. We have tested our implementation for systems such as Mn_3Sn, trimers Cr on Au(111) and Mn on Ag(111) and Au(111); as well as Mn dimer on W(001). Our results have shown that non-collinear magnetism changes drastically the values and directions of the DMI and differently from the conventional DMI, that discrepancy does not come directly as a spin-orbit coupling effect. We give a macroscopic explanation to this by dividing the DMI into spin- and charge-currents contribution and studying the relation between the non-collinearity and the emergence of these currents. For the dimer case, we explicitly show the part of the DMI that comes from the spin-orbit coupling and the part of the DMI that comes from the non-collinearity. It highly suggests that, in small clusters, high-order of DMI-like terms in the spin-Hamiltonian become strongly relevant, e.g. four-spin, six-spin interactions. We believe that these results are important in the study of excited states of small clusters and its spin-dynamics.

Magnetic ordering in single films and multilayers with Dzyaloshinskii-Moriya interaction, influenced by static and dynamic magnetic field.

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Dzyaloshinskii-Moriya interaction (DMI) induces chirality in magnetic alignment. A characteristic magnetic texture, observed in a single ultrathin magnetic film with DMI, is a spin spiral[1], topologically similar to skyrmions. In multilayered systems possible magnetic configurations are even more complicated, as the chirality can appear also across the stack of films. In this work we use micromagnetic simulations to study both single films and multilayer systems of varying magnitude of DMI and magnetic anisotropy. We analyse an occurence of possible competing textures, taking into account their energies. Moreover, we influence the systems with magnetic field, either static or dynamic, to study the material parameters of practical importance, being accessible experimentally: magnetic susceptibility, hysteresis curve, period of magnetic domain structure (for static field), ferromagnetic resonances, and dispersion relations (for rf-oscillating dynamic field).

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Local spin Hamiltonians in ab initio spin dynamics

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The derivation of effective spin Hamiltonians from ab initio electronic structure calculations is an important tool for modeling the spin dynamics of magnetic materials since a full electronic description of the dynamics is numerically very challenging. We contrast two different approaches that we label as "local" and "global". The global approach aims at describing arbitrary spin configurations, whereas the local approach is only valid for small magnetic fluctuations locally around a given spin configuration. We argue that global symmetry requirements, such as time-reversal symmetry, do not necessarily restrict local spin Hamiltonians if the dependence of the effective exchange parameters on the magnetic state is taken into account. We present a general formalism to map tight-binding electronic structure theory to a local spin Hamiltonian and we check our formalism by means of numerical calculations for iron dimers and chains [1].

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Shaping spin wave spectra of 1D magnonic crystals via geometrical parameters

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The spin wave spectra in one-dimensional magnonic crystals (1D MCs) is complex and depend on many factors. We performed a combined experimental and theoretical study of the influence of geometrical parameters of constituent stripes and separation width between them on the spin wave spectrum of 1D MC. These geometrical factors affect directly (by geometrical constrains – spin waves are confined inside the stripes) or indirectly (by spin wave pinning – spin waves can be freed to different extend on the edges of stripes) on the spin wave frequency [1]. We have performed the TR-MOKE measurements of the frequencies of long-wave modes, corresponding to the ferromagnetic resonance (FMR) modes, for 1D MCs in the form of the arrays of stripes of different widths (500 nm, 860 nm, and 1000 nm) and separations ranging from 100 nm up to 1000 nm [2]. We have compared these results with frequency-domain finite element method calculations. For each given stripe's width, we can distinguish two limits of the FMR frequencies – the upper limit for a single stripe (which is a good approximation for arrays of stripes separated by very wide spacers – in order of thousand nanometers) and the bottom limit for the stripes attached to each other (for spacers' widths tending to zero), building thin magnetic layer. The dipolar SW pinning is enhanced when the separations between constituent stripes are increasing. These changes lead to the lifting of the FMR frequency and are more significant when the separations are still small. The increase of FMR frequency is accompanied by the reduction of spin wave group velocity. We showed that changes in geometrical parameters of 1D MCs significantly influence, via dipolar interactions, spin wave pinning which, in turn, is a key factor for the FMR frequency changes of 1D MCs observed in the TR-MOKE experiment.

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Corrugated YIG films as basic elements for 3D magnonics

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In this work, we consider corrugated magnetic films (with the corrugation depth exceeding film thickness) which can be used as one of the possible basic elements for 3D arrangement of magnonic divices [1-3]. Both experimentally and theoretically, we explore propagation of spin waves (SW) in corrugated yttrium-iron garnet (YIG) films deposited by ion-beam sputtering on gadolinium gallium garnet substrates with periodical arrays of etched grooves. Effects of SW spectrum quantization, Bragg diffraction and discrete diffraction were found out to develop in the studied samples. It was shown that consideration of the corrugated YIG films according to the model of effective medium can give the dispersion of surface SW in the long-wavelength region and the position of long-wavelength boundary frequency having good agreement with the experiment.

Size reduction of magnonic elements for the aim of miniaturization leads to the decrease of SW wavelength, thus, resulting in necessity to use exchange-dominated SW (EDSW). We demonstrate experimentally and by modelling that EDSW can be generated at a thickness step under microwave uniform pumping or pumping through the surface SW propagating across the step [4].

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Magnetic properties of $TbMn_{1-x}Fe_xO_3$ single crystals

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$TbMnO_3$ is a multiferroic compound, exhibiting magnetic ordering of Mn ions, with a sinusoidally modulated collinear magnetic structure along the *a*-axis (*Pnma* space group) below $T_N = 41$ K. This magnetic structure changes to a cycloidal phase below $T_s = 28$ K, which is accompanied by the emergence of a spontaneous electric polarization along the *b*-axis, accordingly to Dzyaloshinskii-Moriya model. On further cooling, Tb^{3+} spins order independently from the Mn^{3+} sublattice at $T_1 = 7$ K [1, 2]. In order to tune the balance between the competitive ferro- and antiferromagnetic interactions leading to frustrated magnetic structures, we have studied the effect of Fe^{3+} substitution for Mn^{3+} on selected physical properties of $TbMn_{1-x}Fe_xO_3$, with $x = 0$ to 0.05 and we presented a detailed characterization of the structural, thermal, magnetic, polar and magnetoelectric properties of the $TbMn_{1-x}Fe_xO_3$ system as well as a lattice dynamical study at low temperatures by Raman spectroscopy [3, 4]. We have found that already at $x = 0.05$ ferroelectricity is lost and below this concentration there is a strong dependence of the magnetoelectric response on Fe concentration.
Our present paper is focused on the study of magneto crystalline anisotropy which we performed on oriented $TbMn_{1-x}Fe_xO_3$ single crystals ($x = 0.0$, 0.02 and 0.04) by magnetization and AC susceptibility measurements. Our measurements revealed huge magneto crystalline anisotropy with respect to main crystallographic axes. The magnetic phase transitions at T_N, T_s and T_1 are connected with anomalies in magnetization and AC susceptibility measurements performed along *b*-axis. On the other hand field induced magnetic transitions we observed below T_1 only on measurements along *a*-axis and *c*-axis.

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Domain wall logics in coupled bent ferromagnetic nanofibers

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Magnetic nanofibers can be used for data transport and storage, especially related to the emerging field of neuromorphic computing [1,2]. Domain walls in bent nanofibers can nucleate, e.g., due to rotating local magnetic fields. Their propagation through bent nanofibers, however, depends on the bending direction in correlation to the rotational orientation of the magnetic field, making such nanofibers suitable for semi-deterministic logic operations. Here we report on domain wall nucleation, propagation and annihilation in bent nanowire networks with multiple data inputs and outputs. Our results show that for a minimum of three coupled nanowires, logic operations become possible, while four nanowires show a broad spectrum of logic operators in the corresponding truth tables. Based on these dynamic micromagnetic simulations, we suggest possible architectures of nanowire-based logics.

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New insight into magnetic anisotropy within Ferromagnetic Resonance experiments

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The phenomenon of ferromagnetic resonance (FMR) is still being widely used for determining the magnetocrystalline anisotropy constants of magnetic materials. We show that one can interpret the resonance condition (the Smit-Beljers equation) as the relationship between resonance frequency and curvature of the spatial distribution of free energy at resonance. Subsequently, taking this relationship into account and using cross-validation of numerical solutions of the Smit-Beljers equation [1,2] we show how to determine accurately all the relevant constants (saturation magnetization, g-factor, magnetocrystalline anisotropy constants) entering this equation and related to the tested sample in FMR experiments. Specifically, three examples are given of calculating such constants from FMR data: we use historical Bickford's measurements from 1950 for bulk magnetite [3], Liu's measurements from 2007 for a 500 nm thin film of a weak ferromagnet (Ga, Mn)As [4], and Wang's measurements from 2014 for an ultrathin film of YIG [5]. In all three cases, the constants we have determined are consistent with the results of other measurements. In the fourth numerical example, we show, using Heinrich *et al.* FMR measurements from 1991 for ultrathin Co film [6], that the presented method can also be a test for the correctness of the assumed form of the ferromagnet free energy at resonance. Eventually, in the fifth numerical example, basing on Roemer *et al.* broad-band measurements from 2012 for Fe thin films [7], the unambiguity of the determined parameters in the present approach is briefly discussed.

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3D $(H-\theta-\varphi)$ magnetic phase diagram of ErB_{12} antiferromagnetic metal with dynamic charge stripes

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The presence of several simultaneously active degrees of freedom in strongly correlated electronic systems (SCES) often leads to the formation of complex, multicomponent phase diagrams [1] (see, for example, Mn oxides called manganites and HTSC cuprates). Such solids can be extremely useful in practice, exhibiting a giant response to weak external perturbations, but often have a complex chemical composition and low crystal structure symmetry. It was established recently, that magnetic RB_{12} dodecaborides (R=Ho, Er, Tm) can be treated as model SCES, having electronic phase separation (dynamic charge stripes along the <110> axis) [2,3] with incommensurate antiferromagnetic ground state. Previous studies of HoB_{12} antiferromagnet have shown the presence of the strongest magnetoresistance anisotropy in the form of a Maltese cross with numerous magnetic phases [4].

The aim of this work is to investigate the nature of the charge transport anisotropy and the appearance of a large number of magnetic phases in the highly symmetric ErB_{12} single crystal. Since the orientation of the magnetic moments in ErB_{12} strongly depends on both the magnitude and the direction of the external magnetic field, we measured the magnetization and magnetoresistance in the range of magnetic fields up to 8 T at liquid helium temperatures with the rotation of the sample during the experiment around different principal axes in the crystal.

A detailed study of the location of phase boundaries showed that the main sectors of the phase diagram are formed along directions perpendicular (H || [001]) and parallel (H || [110]) to dynamic charge stripes. From the analysis of the reconstructed 3D magnetic phase diagram, it was concluded that dynamic fluctuations of the electron density (charge stripes) are responsible for the suppression of the indirect Ruderman-Kittel-Kasuya-Yoshida (RKKY) exchange between the neighboring Er^{3+} ions located in the <110> directions.

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Spin-wave tunable transport in the reconfigurable magnonic waveguides

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The study of physical principles that determine the possibility of using spin waves (SW) to create information signal processing devices based on magnonics principles is of great interest [1]. Microstructures based on the iron-yttrium garnet (YIG) can be used in the processing of spin-wave signals due to the low attenuation. To control the properties of propagating spin waves (SW), the method of structuring YIG films and creating irregular micro- and nanoscale waveguides, including structures with broken translational symmetry, can be used [2].

In this work, the numerical simulations results of the spin wave propagation in a magnonic irregular microwaveguide, as well as the propagation of spin waves when creating a temperature gradient by laser radiation [3] in the waveguide curvature region are presented. The structure is an irregular YIG microwaveguide with a width of $w = 500\ \mu m$, thick $d_1 = 10\ \mu m$ placed at 500 μm-thick (d_2) gadolinium gallium garnet (GGG) substrate. The structure was placed in an external magnetic field with the magnitude $H_0 = 1200\ Oe$ directed along the x-axis in order to excite a magnetostatic surface wave (MSSW).

By the means of Brillouin light scattering technique, we obtained 2-D intensity maps of the spin wave propagating in the structure in the case of laser heating is on and off.

It is shown that control of SW propagation characteristics is possible due to the inhomogeneous configuration of the internal magnetic field along the direction of SW propagation. Also, the main operating modes of the proposed structure were revealed with local modulation of the structure properties (magnetization and the internal magnetic field by laser heating).

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Gilbert damping on systems without inversion symmetry: the $Fe_{50}Co_{50}(100)$ case

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Gilbert damping has a critical importance in determining the lifetime, diffusion, transport and stability of domain walls, magnetic vortices, skyrmions, and other complex magnetic configurations. Given its high scientific interest, the possibility to obtain this quantity in a first-principles fashion [1] opens new perspectives of optimizing materials for devices. A way to do that is to use Kambersky's breathing Fermi surface (BFS) and torque-correlation (TC) [2,3] models, which have been explored in terms of pure/alloy bulk and surfaces via reciprocal-space methods. However, considering the nonlocality of the damping parameter that is predicted for itinerant magnets [4], there is still a gap in literature for systems with lack of inversion symmetry. Therefore, we will discuss a recent implementation of an ab-initio calculation of the damping in the real-space RS-LMTO-ASA method [5], based on the BFS and TC models. This allowed us to capture via first-principles the origins of the large damping anisotropy experimentally observed in $Fe_{50}Co_{50}(100)$ [6,7].

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Atto-second out-of-equilibrium dynamics in germanium

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Implementing XUV-ray spectroscopy is one of the challenging topics in solid-state physics [1-5]: indeed, it can be a crucial step to unveil the early time dynamics of fundamental processes in systems such as semiconductors, metals, superconductors and topological materials. Therefore, it is essential to build theoretical tools in order to understand the experimental results and what actually happens in solid-state systems on a new and finer time-scale: the atto-second scale. Studying and simulating electron dynamics on the atto-second scale is a new element useful for revealing the fundamental forces driving electron dynamics and leading to the physics related to topological phase transitions. With this in mind, we have developed a theoretical-numerical tool in order to control the time evolution of the electronic band populations in germanium on the atto-second scale when perturbed by a near-IR pump probe. First of all, we have had to deduce the unperturbed germanium band structure by Elk. After that, we have resorted to Wannier90 to compute Maximally-Localized Wannier Functions (MLWFs) from a specific number of Bloch wave functions and obtain the hopping terms. Subsequently, we studied the perturbed case by the Peierls substitution method. We have inferred a system of coupled first-order differential equations describing the out-of-equilibrium time evolution of band populations. The results obtained describe electronic transitions from the valence to the conduction band on the atto-second scale. The overall tool can be extended to other systems like superconductors and topological materials.

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Magnetization reversal and domain structure in Ta/CoFeB/MgO films and its dependence on CoFeB Thickness

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Magnetization processes and magnetic domain structures were studied for Ta/CoFeB (thickness d from 1.24 to 1.60nm)/MgO stacks deposited by dc/rf magnetron sputtering on thermally-oxidized Si substrates. Polar magneto-optical Kerr effect (PMOKE) based magnetometry and microscopy were used. Thickness dependence of magnetic anisotropy was evaluated and described by both second and fourth orders of anisotropy constants. While increasing d, owing to the dependence, magnetization reorientation from out-of-plane to in-plane direction through an easy cone magnetization region (1.37 nm $<$ d $<$ 1.39 nm) was deduced. Magnetic field pulses driven magnetization reversal processes were analyzed using a developed software capable of digital processing of images from PMOKE microscope. Magnetization reversal processes for out-of-plane easy axis stacks indicated significant increase of the density of nucleation centers and change in domain morphology while increasing d up to the magnetization reorientation thickness. Magnetic after effect was found. The thinnest films with d = 1.24 and 1.28 nm show an appearance of straightened narrow stripe domains resulting from a magnetic dipolar repulsion [1]. The application of such structures as spin-wave nano-channels could be promising.

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High-frequency response of superferromagnetic metal-dielectric nanocomposites

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Dynamical magnetic response of superferromagnetic dispersions of metallic nanoparticles in dielectric matrices is studied for the microwave range of the driving magnetic field, using micromagnetic simulations. The attention is focused on layers of several nanocomposites of potential application as core materials in microinductors and transformers, (on chip power converters have to operate in a high-frequency range due to the high spatial confinement) [1], [2]. The nanocomposites offer reduction of the eddy-current losses due to a high resistivity at a relatively-high permeability and lack of intra-particle domain structure. Strong magnetic response is achievable via excitation of FMR or the oscillatory motion of domain walls depending on the orientation of the driving in-the-plane field relative to the easy axis, (the transverse or longitudinal field, respectively). We simulate idealized nanocomposites by assuming the nanoparticles to be identical and homogeneously dispersed. The material parameters are extracted from data, based on the random magnetic anisotropy (RMA) model. For example composites of the nanoparticles of Co or $Fe_{65}Co_{35}$ dispersed in Al_2O_3, SiO_2 or MgF_2 are tested with regard to the limit efficiency of the response in terms of the high permeability and low hysteretic losses of power. In paticular, we discuss the dependence of the response (magnetization) amplitude on the nanoparticle concentration and frequency limitations on the stability of the domain structure. Beyond FMR and the domain-wall assisted dynamics, we simulate the response to the rotating in-the-plane field, which drives a precession (almost in-the-plane rotation) of the magnetization below a threshold frequency and above a threshold-field value. Such an excitation mode is related to the highest possible amplitude of the magnetization oscillations at lowered hysteretic loss compared to the linear-field-excited modes. Moreover, the rotational mode is not accompanied by the domain-wall motion, thus, by the excess losses.

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Magnonic properties of disordered Fe_xCo_{1-x} alloys

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The coherent potential approximation (CPA) is widely used for the study of electronic properties of disordered materials. It was shown in the literature that the magnetic properties of disordered materials can be calculated in a similar way [1]. Using this method in combination with a modified version of the random phase approximation originally introduced by *Callen* [2], we present a thorough study of disordered iron cobalt alloys Fe_xCo_{1-x}. Among other properties we analyze the magnonic spectrum, the lifetimes of magnons, and the shape of the magnonic modes in real space. The generality of our method allows us to investigate this material at finite temperatures and perform a first study on the influence of short range order. We show that disordered Fe_xCo_{1-x} alloys exhibit many of the properties desired for magnonic crystals like a high Curie temperature, magnon energies well within the terrahertz regime, and most importantly a bandgap in the magnonic spectrum which is stable up to high temperatures and shows a nontrivial dependence on the Co concentration.

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Phase selection in Mn-Si alloys by fast solid-state reaction with enhanced skyrmion stability

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B20-type transition-metal silicides or germanides are noncentrosymmetric materials hosting magnetic skyrmions, which are promising information carriers in spintronic devices. The prerequisite is the preparation of thin films on technology-relevant substrates with magnetic skyrmions stabilized at a broad temperature and magnetic-field working window. The canonical example is the B20-MnSi film grown on Si substrates. However, the as-yet unavoidable contamination with MnSi1.7 occurs due to the lower nucleation temperature of this phase. In this work, we report a simple and efficient method to overcome this problem and prepare single-phase MnSi films on Si substrates. It is based on the millisecond reaction between metallic Mn and Si using flash lamp annealing (FLA). By controlling the FLA energy density, we can grow single-phase MnSi or MnSi1.7 or their mixture at will. Compared with bulk MnSi the prepared MnSi films show an increased Curie temperature of up to 41 K. In particular, the magnetic skyrmions are stable over a much wider temperature and magnetic-field range than reported previously. Our results constitute a novel phase selection approach for alloys and can help enhance specific functional properties such as enhancing the stability of magnetic skyrmions.

Magnetization reversal in $NdMn_{0.8}Fe_{0.2}O_3$ compound

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We report on magnetization and AC susceptibility measurements performed on $NdMn_{0.8}Fe_{0.2}O_3$ single crystal in temperature range 2 K – 390 K and in magnetic fields up to 7 T. We confirm Néel temperature $T_N \sim 57$ K in agreement with [1] and we report strong magnetocrystalline anisotropy in this compound. At $T = 2$ K, this anisotropy results to ferromagnetic-like hysteresis loop with coercive field of 1.32 T along b-axis and butterfly-type hysteresis loops for *a*- and *c*-axes with coercivity of 0.4 T and ~ 0.1 T, respectively.

We also report the magnetization reversal process below T_N and in the field-cooled (FC) regime. Negative FC magnetization was observed for $\mu_0 H = 10^{-2}$ T and for all three main crystallographic axes, namely below 21.7(1) K; 25.9(1) K and 22.7(1) K for *a*-; *b*- and *c*-axis, respectively. One of the explanations is that both, Nd and Mn sublattices order already at T_N. Then, different temperature dependence of magnetic moment in these sublattices produces magnetization reversal process. This explanation directly supports the model presented in [2]. The second explanation of the effect can be found within the theory of cluster formation as presented in [3]. This scenario can be supported by the double peak in AC susceptibility at T_N and subsequent frequency-dependent bump in the imaginary part of AC susceptibility at 25 K $< T < T_N$. The detailed discussion and comparison of these two possible models will be provided in the contribution.

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Magnetically switchable ultrafast spintronic THz emitters

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The recent discovery of ultrafast spintronic THz emitters has attracted a lot of attention due to their high power, broadband emission as well as easy fabrication [1,2]. They are based on nanometer-thin bilayers of a ferro-/ferrimagnetic (FM) and a nonmagnetic (NM) metal layer and rely on the inverse spin Hall effect. The THz emission properties can be tuned by using different FM and NM materials, tailoring the magnetic properties [3], or building functional layer stacks [4]. Here, we present a spin valve THz emitter, which allows for switching of the THz emission amplitude by a small magnetic field of a few mT [5].

The operation of the switchable THz emitter is based on a magnetically soft free Fe layer and a pinned Fe layer, which is exchange biased by an antiferromagnetic $Ir_{23}Mn_{77}$ film. The Fe layers are magnetically decoupled from each other by thin NM spacer layers of Pt or W, which exhibit a high spin Hall angle. Excitation of the structure with ultrashort optical laser pulses leads to the creation of spin currents from the two Fe layers into the sandwiched NM film. There, the spin currents are converted into ultrafast charge currents by the inverse spin Hall effect. Depending on the relative magnetization direction of the two Fe layers, and hence the polarization of the spin currents, these charge currents add up or cancel each other out, leading to a high or vanishing THz emission. The relative alignment of the two Fe layers can be controlled by switching the free Fe layer with applied magnetic fields on the order of 10 mT, while the magnetization direction of the pinned Fe layer remains constant due to the exchange bias. Therefore, the system allows the switching from the low to the high amplitude THz emission state by small applied magnetic fields, enabling easy implementation and high switching rates.

Our study demonstrates the large potential of ultrafast spintronic THz emitters and combines the high power and broadband emission with an easy to use switching mechanism.

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Nontrivial topology of Mg- and Fe-doped single-crystalline Bi_2Se_3 studied by Shubnikov-de Haas oscillations

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Electronic structure of topological insulators is characterized by simultaneous occurrence of gapped bulk states and massless Dirac fermions at the surface. The latter are protected by time-reversal symmetry, which leads to lack of backscattering of massless fermions on impurities. It results in high efficiency of spin pumping as well as anomalous magnetotransport, both being very promising from application point of view (e.g. in modern electronic devices).

Despite the increasing knowledge of 3D topological insulators, it is not fully explained whether and how small changes in Bi_2Se_3 stoichiometry affect non-trivial topology. There are several techniques to prove it: one of them is the determination of Berry phase which can be done by analysis of Shubnikov-de Haas quantum oscillations.

In this work we present systematic study of magnetoresistance in pristine and Mg- and Fe-doped Bi_2Se_3 single crystals. The measurements were carried out by four-probe technique with a lock-in amplifier using $^3He/^4He$ dry dilution refrigerator "Triton" combined with the "Nanonis Tramea" system for quantum transport measurements. The measurements were performed in temperature range from 100 mK to 30 K in magnetic field up to 14 T. The results reveal that low level doping has a significant influence on the frequency and amplitude of Shubnikov-de Hass oscillations. The Berry phase obtained from Landau level fan diagram indicates that a small amount of magnetic dopant (1 % Fe) does not affect the non-trivial topology, preserving non-zero Berry phase. Charge dopant (2 % Mg) modifies topology of electronic structure leading to changes of the Berry phase from π to nearly zero.

Spin Orbit Torque in Quantum Well Edges

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Spin orbit torques generated by topologically protected spin currents can be used to switch magnetic moments using lower current densities than conventional spin transfer torques, making them potentially useful for spintronics devices. Here we investigate the torque generated on the edge of time reversal invariant quantum spin Hall (QSH) systems also known as the two-dimensional or $\mathbb{Z}_2$ topological insulators which are known to posses spin polarized, robust, propagating edge states. The helical edge modes of QSH systems can be utilized as a source of spin-polarized current to induce magnetization dynamics in the ferromagnetic island adjacent to it. We have studied the proximity effect of a (anti-)ferromagnetic island on the properties of the edge-states of the QSH system and the possibility of achieving efficient spin transfer via the polarized edge currents. We will report on the robustness of the polarized edges and the spin torque exerted on the neighbouring magnetic material.

Nagaoka ferromagnetism in spin-polarized transport through quadruple quantum dot system

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Motivated by the experimental evidence of Nagaoka ferromagnetism in quantum dot systems [1], we search for possible confirmation of such kind of ferromagnetism by analyzing the electric and thermal transport properties. In particular, we consider four quantum dots arranged in a two-by-two square lattice, coupled to external ferromagnetic source and drain electrodes. Turning on and off the specific conditions for Nagaoka's ferromagnetism to occur by changing the value of intra-dot Coulomb interactions, we determine the transport coefficients, including electric and heat conductance, thermopower, tunnel magnetoresistance and current polarization. The calculations have been performed both for equilibrium and out-of-equilibrium regimes. We have found that some results can indirectly confirm the ferromagnetic alignment of electron spins.

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Kondo effect in the presence of the spin accumulation and non-equilibrium spin currents

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The Kondo effect is related to a screening of the quantum dot (or impurity) spin by nearby free electrons. In the view of spintronics the important issue is the Kondo screening in the presence of spin effects due to e.g. magnetic field, ferromagnetic leads and non-equilibrium spin accumulation. We present a theoretical description of the influence of the spin accumulation in metallic Fermi leads on the Kondo effect in quantum dots and Kondo alloys. We discuss the interplay of the spin accumulation, magnetic field, and ferromagnetic leads spin polarization on the Kondo spin-dependent densities of states, conductance and resistance. The presence of the above-mentioned factors by breaking the spin symmetry leads to the suppression of the Kondo effect. However, these effects can, for appropriately selected parameter values, compensate each other, which may lead to the restoration of the Kondo effect in the analyzed systems. We show the correctness of our model by comparing it with the experimental data [1].

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Generation of Terahertz Transients from $Co_2Fe_{0.4}Mn_{0.6}Si$ Heusler alloy/ Heavy-Metal Bilayers

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The detailed understanding of the spin-to-charge conversion process has been gaining importance due to intended applications for high speed spin-based electronic devices. It has been shown recently, that spin-to-charge conversion via the inverse spin-Hall effect (ISHE) can be employed for the generation of electro-magnetic transients showing frequency content extending up to the Terahertz (THz) frequencies [1]. In the present work we generated pulses of THz radiation by optical excitation of $Co_2Fe_{0.4}Mn_{0.6}Si$ (CFMS)/Heavy Metal (HM) bilayers. CFMS is a half-metal with a band gap in one spin channel and hence shows, in the ideal case, a 100% spin polarization at the Fermi level, which is expected to result in substantial enhancement of interfacial spin current polarization [2]. We compared the efficiency of THz transients for four CFMS/HM bilayers, where HM stands for either Pt, Ta, Cr or Al. Our results show the highest THz amplitude for the CFMS/Pt bilayer. Furthermore, we demonstrate the tunability of the THz amplitude by an external magnetic field and observe the opposite THz polarity for reversed field directions. We ascribe the generation process to the ISHE [3]. In order to investigate the role of the interface in THz generation efficiency, we measured spin-mixing conductances, characterizing the CFMS/HM barrier spin transparency using a ferromagnetic resonance (FMR) experiment and compared it with the THz peak amplitudes. Our measurements show that, although the efficiency of THz generation is mostly governed by spin-orbit coupling, the barrier transparency, as well as spin diffusion length and spin current density play an important role.

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The controlled electrical manipulation of the quantum dot spin detectable in the dc electron transport.

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The possibility of a controlled manipulation of the quantum dot spin, detectable in the electron transport is a very promising challenge, especially from point of view of application in information storage and processing technologies. To this aim we develop the theory of the electron transport through quantum dot weakly coupled to ferromagnetic leads with noncollinear magnetizations, that can be obtained experimentally [1]. One can observe much richer transport behavior of quantum-dot spin valves, as compared to single magnetic tunnel junctions, that relies on the possibility to generate a nonequilibrium spin accumulation on the quantum dot, depending on system parameters such as gate and bias voltages, charging energy, asymmetry of the tunnel couplings, and external magnetic field. Our theory indicates that the interplay of spin-dependent tunneling and Coulomb interaction in quantum-dot spin valves gives rise to an interaction driven spin precession, due to an internal effective exchange magnetic field [2-5] and external magnetic field in the limit of weak dot-lead coupling. It is important that this complex spin dynamics can be induced and observed even in the dc electron transport. We proved that from the dc current-voltage characteristic we can extract information about spin dynamics. In addition we propose the FMR like experiment in the quantum dot and we show that the exchange field present in this system can be widely used in nano-spinelectronics, as a local field controlled by the gate or bias voltages also at high temperatures. Moreover, these particular geometries can be used to induce and detect electron spin resonance (ESR) from a single spin as it was recently demonstrated for the first time in the spin polarized scanning tunneling microscope - electron spin resonance (STM-ESR) experiment [6-7].

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Current-Induced Magnetization Switching of Exchange-Biased NiO Heterostructures Characterized by Spin-Orbit Torque

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Spin-orbit torque (SOT)-induced magnetization switching provides a potentially efficient alternative to spin-transfer torque switching in spin valves or magnetic tunnel junctions. Current induced SOT-switching of perpendicular magnetization is observed in an external magnetic field collinear with the current (but non-collinear with the magnetization), which, however, is impractical in device applications. In this work, we study magnetization switching induced by spin-orbit torque in W (Pt)/Co/NiO heterostructures with variable thickness of W and Pt heavy-metal layers, a perpendicularly magnetized Co layer, and an antiferromagnetic NiO layer [1]. Using current-driven switching, magnetoresistance and anomalous-Hall-effect (AHE) measurements, we determine the perpendicular and in-plane exchange-bias field. Several Hall-bar devices possessing in-plane exchange bias from both systems are selected and analyzed in relation to our analytical switching model of the critical current density as a function of Pt and W thickness, resulting in an estimation of the effective spin Hall angle and perpendicular effective magnetic anisotropy. We demonstrate in both the W(Pt)/Co/NiO systems deterministic Co magnetization switching without an external magnetic field, which is replaced by an in-plane exchange-bias field. Moreover, we show that due to a higher effective spin Hall angle in the W-based system than in Pt, the relative difference between the resistance states in the magnetization current switching to the difference between the resistance states in magnetic field switching determined by AHE ($\Delta R/\Delta R_{AHE}$) is about twice as high in W-based devices than in Pt, while the critical switching-current density in W-based devices is one order lower than in Pt. The current-switching stability and the training process are discussed in detail.

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Micron-sized spherical optomagnonic resonators

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Controlling the interaction between visible/near-infrared light and spin waves could enable magnon-based microwave-to-optical transducers appropriate for quantum-computing applications [1], as well as fast and energy-efficient magnetic recording and signal processing technologies [2]. To this end, dual photonic-magnonic, so-called optomagnonic, cavities have recently been attracting increasing interest owing to their ability to simultaneously control photons and magnons and their mutual interaction. Here, on the basis of rigorous numerical calculations, we report on the coupling between spin waves and optical Mie resonances inside a dielectric magnetic spherical particle, which acts as an optomagnonic cavity [3-5]. Such dielectric magnetic particles with diameters of just a few microns support high-Q optical Mie resonances and localized spin waves, providing an ultra-small and compact platform for enhanced modulation of light by spin waves through multi-magnon absorption and emission mechanisms. We also report a thorough theoretical investigation of magnon-assisted photon transitions in such particles, where, matching the intra-band splitting of optical Mie modes (induced by particle magnetization) to the frequency of the Kittel magnon, gives rise to high-efficiency triply resonant optical transitions between these modes via emission or absorption of a magnon. Finally, we provide evidence for significantly increased optomagnonic interaction as compared to similar processes between whispering gallery modes of sub-millimeter spheres, enabled by the reduced magnon mode volume.

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Transition metal ions in ZnO: theory of the $s, p-d$ exchange coupling

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The $s, p-d$ exchange coupling between free carriers and $d-$electrons of the transition metal (TM) dopants constitutes the basic feature of diluted magnetic semiconductors. We study the TM dopants ranging from Ti to Cu in ZnO within the density functional theory [1]. The $+U$ terms are employed to improve both the ZnO band structure and the position the TM levels. Detailed features of each ion are analysed, and general trends are indicated.

The $s-d$ coupling constant $N_0\alpha$ is almost the same for all TM ions, 0.5 eV. In contrast, the $p-d$ constant $N_0\beta$ varies about 10 times when going from V to Cu. In the cases of Fe, Co and Ni, the sign of $N_0\beta$ depends on the charge state of dopant, since the constant is positive (i.e. ferromagnetic) for 2+ and negative (antiferromagnetic) for 3+ ions. Moreover, $N_0\beta$ for light holes and heavy holes can differ by a factor 2, or even have opposite signs. These unexpected features of $N_0\beta$ were not recognized in previous investigations.

Analysis of the wave functions of ZnO:TM reveals the leading mechanisms of both $s-d$ and $p-d$ couplings. Those mechanisms are different for electrons and holes because of the different symmetries of their wave functions. In agreement with the Anderson picture, the main features of the $N_0\beta$ constant are determined by the $p-d$ hybridization between the d(TM) and p(O) orbitals, and thus by the energies of TM levels relative to the valence band maximum. In turn, the $N_0\alpha$ originates mainly in the intra-atomic direct exchange between the s and d electrons of the dopant ion. However, the spin polarization of the oxygen neighbours of the TM ion induced by the $p-d$ hybridization leads to the spin polarization of the s(O) orbitals, which enhances the value of $N_0\alpha$. A reasonable agreement with experimental data is obtained.

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Antiferromagnetic Hysteresis above the Spin Flop Field

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Antiferromagnetic materials have attracted a lot of attention recently due to their unique properties that create potential applications in spintronics such as data storage or long-distance spin transport. The anisotropy plays a critical role in determining the magnetic configuration of AFs. In this work, we experimentally addressed the anisotropy of thin film antiferromagnetic CoO with adjacent Pt by spin Hall magnetoresistance. Spin flop transition and spin canting are reflected in electrical signal in agreement with the macrospin model. Unexpectedly, hysteretic behaviour in the angular dependence of magnetoresistance is detected above spin flop field and persist up to the highest tested magnetic fields (30 T). It indicates that the Néel vector cannot be aligned parallel to a hard axis with magnetic field few times larger than the spin flop field (7 T). The introduction of an effective spin flop field that is not a constant parameter but depends on the external magnetic field yields good agreement with the experimental results. It suggests that anisotropy in CoO can be modified by the magnetic field.

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PyMag - macrospin modeling tool for spintronics applications

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Fabrication and characterization of spintronics devices such as sensors, spin torque oscillators or spin diode detectors require many advanced cleanroom and experimental techniques [1]. However, the use of dedicated simulation tools may vastly reduce this effort. Here, we present a tool for computer design, simulation and optimization of spintronic devices and magnetic multilayer structures. Magnetization trajectories of a simulated element are computed using the macrospin model by numerical integration of the Landau–Lifshitz–Gilbert (LLG) equation, taking into account the ferromagnetic properties of component layers and couplings between them. In contrast to the existing microspin modelling frameworks [2,3] macrospin model combines high speed of operation with sufficient reproduction of physical phenomena behind. Python-based Graphical-User-Interface (GUI) allows for convenient management of the simulations and their comparison against the experimental data. Fast computational backend in C++ [4] is provided along with the GUI and may be used as a standalone application. PyMag provides an easy way for simulating magnetization dynamics in two different modes which correspond to the following experimental techniques: spin diode (SD) ferromagnetic resonance (FMR) and pulse induced magnetization magnetometry (PIMM-FMR). In SD-FMR mode, magnetization is excited by radio-frequency (RF) sinusoidal current, which generates oscillating resistance due to the magnetoresistance (anisotropic, spin Hall, giant magnetoresistance), giving rise to a DC voltage across the element. In the PIMM mode, PyMag computes the Fast Fourier Transform (FFT) from the magnetization oscillations excited by a short pulse of the magnetic field. The user may view the results as maps where the amplitudes of the oscillations are plotted as a function of frequency, and magnitude or angle of the magnetic field. Likewise, the magnetization-field (M-H) and resistance-field (R-H) loops are calculated as a function of magnetic field magnitude or angle, given a magnetisation vector converged to the steady-state.

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Spin-orbit torque induced magnetisation dynamics and switching in CoFeB/Ta/CoFeB system with mixed magnetic anisotropy

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Spintronic devices development is important for the design of new energy-efficient storage and processing technologies [1]. Recently, spin Hall magnetoresistance and spin orbit torque (SOT) effects in the bilayers of heavy metals (HM), exhibiting large spin-orbit coupling (such as W [2], Ta [1] or Pt [3]) and ferromagnet (FM) have been intensively studied. For example. in Ta/CoFeB bilayers SOT-induced switching without external magnetic field [4], domain wall movement dynamics [5] and analog-memristor behaviour [6] have been reported. Here, we present FM/HM/FM system where the HM is used as a source of the spin current and as a tunable coupler between the two FM layers. Bottom and top $Co_{20}Fe_{60}B_{20}$ layers exhibit in-plane (IPMA) and perpendicular magnetic anisotropy (PMA), respectively [3]. The coercive field measured using anomalous Hall effect increases with decreasing t_{Ta} down to around 1 nm, alongside with an increase in SOT-induced switching current density. Ferromagnetic resonance measurements were also performed in order to determine the coupling energy via Ta spacer. Modelling the dispersion relation using Landau-Lifshitz-Gilbert equation for IPMA and PMA magnetized FM layers enabled determination of the saturation magnetisation, anisotropy energy and the interlayer coupling between the two FM. The decrease in t_{Ta} leads to a change from negligible coupling for t_{Ta} = 8 nm, through antiferromagnetic for t_{Ta} = 1.4 nm, to ferromagnetic coupling for t_{Ta} = 0.72 nm, where the field-free SOT-switching can be partially achieved.

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Selected transport phenomena induced by cubic forms of spin-orbit interaction in 2D structures

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In two-dimensional systems, the lack of inversion symmetry leads, in principle, to the two well-known types of spin-orbit coupling: the Dresselhaus SOC and the Rashba one. In most cases, the k-linear forms of these two couplings are considered. In the case of Rashba systems, the k-cubed component may exist regardless of the k-linear one and has been found, e.g., in strained-Ge/SiGe heterostructure [1]. Moreover, it has been shown experimentally that 2DEG at interfaces of perovskite oxides, such as $LaAlO_3/SrTiO_3$, reveals strong SOC of the Rashba type, and the k-cubed form may play an important role [2]. The cubic Dresselhaus SOC is also often neglected, whereas this component may be important at higher carrier concentrations.

We will discuss and summarize our recent studies of selected transport phenomena, such as anomalous Hall and Nernst effect and current-induced spin polarization in effective models describing magnetic and nonmagnetic 2DEG with the k-cubed form of Rashba and Dresselhaus SOC. Using Matsubara Green's function formalism in the linear response regime, we obtained detailed analytical and numerical results. We focused, e.g., on the interplay between SOC and exchange interaction, the role of temperature and distinct properties of k-cubed SOC concerning k-linear one [4].

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Electronic transport and optical properties of WTe_2 single crystal

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Layered transition metal dichalcogenides (TMDs) attract a lot of attention due to their diverse properties and are considered to be promising materials for optoelectronics, nanoelectronics, and spintronics. TMD WTe_2 is known to be a type-II topological Weyl semimetal. Non-trivial topology of the electronic band structure of these materials causes intriguing electronic properties such as non-saturating extremely large magnetoresistance, ultrahigh current carrier mobility, etc. The purpose of this work is a comprehensive study of the electronic transport and optical properties of WTe_2. WTe_2 single crystals were grown by the chemical vapour transport method. Electrical resistivity, magnetoresistivity, and Hall Effect were measured in the temperature range from 2 K to 300 K in magnetic fields of up to 9 T. Since WTe_2 has a layered structure, the electronic transport properties are anisotropic. Therefore, the measurements were carried out when an electric current flowed in the $(00l)$ plane of the sample, and then perpendicular to it; a magnetic field was directed perpendicular to it. The optical properties were measured by the Beattie method in the spectral range of 0.2–5.0 eV at room temperature. The temperature dependence of the electrical resistivity has a "metallic" type. Whereas the applied magnetic field causes a "turn on" effect at low temperatures, that is a minimum in the temperature dependence of the resistivity, the temperature of which rises in higher fields. At this minimum, it is assumed that the mean free path l is equal to the Larmor radius r_H. This allows us to estimate the value of l. The magnetoresistivity is observed to increase with a magnetic field according to the quadratic law, which is caused by the compensation of charge carriers in WTe_2. Their concentration and mobility were determined from Hall Effect measurements. Optical studies did not reveal features characteristic of metals. The optical conductivity spectrum is found to be a broad band, formed by interband transitions. The presence of peaks in the infrared region indicates the formation of low-energy gaps in the band spectrum of WTe_2. The optical characteristics are in good agreement with the data on electronic transport at room temperature.

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Frustrated magnetic ordering in $Ge_{1-x-y}(Sn_xMn_y)Te$ multiferroics

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Diluted magnetic semiconductor (DMSs) multiferroics offer intriguing possibilities and potential for spintronic applications due to the incorporation of magnetic ions in semiconducting lattice [1]. Ferroelectric GeTe based multiferroics propose striking properties to explore entanglement of magnetic and spin-orbit coupling in one system [2]. Further studies of these materials establish the basis for Rashba spin splitting, magnetoresistance, spin-torque manipulation of magnetic domains and novel quantum phases like topological insulators. In this work, we present systematic studies of ferroelectric GeTe based $Ge_{1-x-y}(Sn_xMn_y)Te$ crystals grown in the range $0.18 \leq x \leq 0.79$ and $0.020 \leq y \leq 0.086$, focused over their magnetic, magnetotransport and ferroelectric properties. We examined the ferroelectric phase transition temperature changes with the chemical composition of the samples. Temperature dependent ac susceptibility measurements were performed to explore the behavior of magnetic ordering of the chosen compositions. In extensively studied group IV-VI narrow band gap semiconductors, the Ruderrnan-Kittel-Kasuya-Yosida indirect-exchange in-teraction is known to mediate ferromagnetism via free carriers, here we report $Ge_{1-x-y}(Sn_xMn_y)Te$ multiferroic and its magnetic exchange interactions. Furthermore, multiferroic structures such as $Ge_{1-x-y}(Sn_xMn_y)Te$ present the possibility to understand the dynamics at the ferroic domain walls which could lead to atomic scale electronics [3].

Keywords: Diluted magnetic semiconductors, multiferroics, magnetoresistance, frustrated magnetic ordering.

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Simultaneous observation of anti-damping and inverse spin Hall effect in $La_{0.67}Sr_{0.33}MnO_3$/Pt

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Manganites have shown potential in spintronics due to their low Gilbert damping (α) and insulating characteristics. Here, LSMO (20 nm)/Pt (t_{Pt} = 0, 3 and 10 nm) bi-layer samples have been prepared on $SrTiO_3$ (001) substrate using an oxygen plasma assisted molecular beam epitaxy system. ISHE measurements are performed using home modified coplanar wave-guide (CPW) based ferromagnetic resonance (FMR) spectroscopy [1]. We have studied the static and dynamic properties of the LSMO/Pt systems. A decrease in α has been observed with increase in Pt thickness. We performed angle dependent ISHE to disentangle other rectification voltage from spin pumping voltage. From angle dependent ISHE measurement spin Hall angle were calculated 0.033 and 0.014 for samples with 3 and 10 nm of Pt, respectively [2]. High spin pumping voltage and reduction in Gilbert damping makes this system ideal for the spintronic applications.

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Nonlinear control of damping constant by electric field in ultrathin ferromagnetic films

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The performances of many spintronics devices are governed by the damping constant and magnetic anisotropies of constituent materials. The spin-orbit coupling (SOC) has been found to be the origin of these material parameters. Therefore, electric field control of latter parameter is in high demand for developing energy efficient nanoscale spintronics devices. Although, electric field control of interfacial magnetic anisotropies is well studied and understood, the damping constant, on the other hand, has conventionally been controlled by current induced spin-orbit torque. Here, we have taken an alternative approach to control damping constant by electric field. We have performed ferromagnetic resonance measurement by spin pumping and inverse spin Hall effect technique to investigate variation of damping constant with electric field in CoFeB/MgO heterostructures. Interestingly, we have found nonlinear variation of damping coinstant with electric field, especially, for ultrathin CoFeB films. With the help of theoretical argument we explicitly show that the presence of Rashba SOC at ferromagnet/insulator interface and the electric field dependence of Rashba coefficient may account for the observed nonlinear behavior. Furthermore, we show that the engineering of underlying and oxide materials properties, i.e., bulk SOC, Rashba SOC, to tune the spin angular momentum relaxation pathways could possibly increase the device functionality significantly.

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Resolving the Spin Structure of Antiferromagnets in SOLARIS

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X-ray magnetic linear and circular dichroism (XMLD and XMCD) measurements performed at the XAS end-station in Polish synchrotron SOLARIS enabled us to follow the magnetic properties of epitaxial CoO(111)/Fe(110) and NiO(111)/Fe(110) bilayers. We find that in both studied cases FM sublayer plays a dominant role and determines the magnetic state of the neighboring AFM, however completely different interaction mechanisms are involved. In CoO/Fe bilayers the AFM spins are totally frozen although their orientation is imprinted by magnetization of Fe layer when the system passes the Neel temperature of CoO. Once the Fe layer gratfs the particular magnetic anisotropy (MA) into the CoO overlayer, it later remains frozen and insensitive to external factors like external magnetic field or Fe magnetization direction [1]. In contrast, for NiO/Fe bilayers we find that due to the weak intrinsic MA of NiO, the NiO spins are rotatable and always follow the reorientation of Fe magnetization that can be controlled by external magnetic field or via the temperature and thickness driven spin reorientation of Fe(110). In the case of the temperature induced spin reorientation transition in Fe(110), it allowed us to implement all-temperature, field-free switching of AFM moments in NiO/Fe bilayers [2].

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Topological Hall effect in tetragonal Heusler thin films

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Magnetic materials that host topological spin textures have come to the forefront of condensed matter physics and material science as potential candidates for future spintronic applications. Of these spin textures, skyrmions and antiskyrmions are mesoscale whirling objects with distinct chiral magnetic boundaries and opposite topological charges. Of particular interest is the antiskyrmion, which was theoretically predicted to exist in certain tetragonal materials with acentric crystal structures as, e.g., D_{2d}. Recently, the tetragonal Heusler compounds [1] show to host antiskyrmions, in addition to other topological spin textures of interest. Spin chirality in metallic materials with noncoplanar spin structure gives rise to a Berry phase induced topological Hall effect (THE), which can be used to distinguish magnetic textures for device applications.

Here, we present the structural, magnetic, and transport properties in epitaxial thin films of the tetragonal Mn_xPtSn and Mn_2RhSn Heusler compounds [2,3]. We tune the Mn content (x) by magnetron sputtering, which allows for microscopic control of the magnetic exchange parameters. Further, we observe topological Hall signatures of two distinct chiral spin textures. With our thin film method, we can access a novel and fundamental understanding of this compound not possible with other methods.

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Unconventional transition to topological superconductivity in a self-organized magnetic ladder

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In bulk materials magnetism and superconductivity are regarded to be conflicting phenomena. Their coexistence in nanoscopic heterostructures, however, can lead to emergence of novel states of matter – a topological superconducting phase being one prominent example. We show that magnetic atoms arranged into nanowires [1,2] or ladders [2] on top of conventional superconductor develop their helical ordering which selfsustains the topologically nontrivial phase of itinerant electrons, hosting the Majorana boundary modes. Furthermore, we predict an *unconventional transition to topological phase without any gap closing* due to discontinuous mismatch (π-shift) of the helical ordering between the legs of magnetic ladder proximitized to superconductor. The underlying mechanism is generic, and could be generalized to different dimensions, and to different forms of topological order, potentially opening up new perspectives for designing the topological matter.

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Weak antilocalization and one-dimensional topological states in the layered SnTe systems

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Inspired by the study of topological properties of multilayer SnTe systems with atomic steps [1], we have studied quantum effects in magnetotrasport for such type of systems [2]. The weak (anti)localization is an interference effect of closed scattering paths that results in (increase)decrease of the conductance with respect to the classical value and its (decrease)increase in external magnetic field with respect to zero field value. We have successfully related this value to the Berry phase of Fermi cross-sections to explain the measurement in the perpendicular magnetic field and we have adopted the calculation of the so-called Cooperon correlator in the parallel field. Finally, topologically non-trivial states were also found in the tight-binding model of the SnTe nanowire. These include both end- and hinge- states in the normal state as well as Majorana end-states in the superconducting phase.

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Magnetic domain structure and interfacial Dzyaloshinskii-Moriya interaction in the epitaxial W/Co/Pt multilayers

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The Dzyaloshinskii-Moriya interaction (DMI) is responsible for creation of chiral magnetic spin structures like: spin spirals or skyrmions, which are potential candidates for data storage in thin film technology. In this work we investigate the domain structure and the DMI strength in the epitaxial W(1 nm)/Co(0.6 nm)/Pt(1 nm) multilayers with perpendicular magnetization. These systems exhibit a better defined crystalline structure and the interfaces, crucial for DMI, in comparison to commonly studied sputtered stacks. In the as-deposited state the labyrinth configuration of magnetic domains is observed. It can be converted to the stripe domains by application of the in-plane oriented magnetic field. The DMI strength is determined from the domain structure size in the effective medium approach [1]. It reaches as high as $D_{eff} = 2.64$ mJ/m^2 (surface DMI parameter $D_S = 1.83$ pJ/m) value for repetition number of the basic trilayer equal to 10 [2]. The experimentally observed domain structure and the DMI strength are exactly reproduced in the micromagnetic modelling and DFT calculations, respectively. Moreover, the DFT calculations revealed the interfacial nature of DMI and the additive contribution from the two W/Co and Co/Pt interfaces. The determined DMI strength suggests that the structure of the domain walls might be of the pure Néel type.

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Towards efficient simulations of quantum transport with open–system tensor networks

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Understanding non–equilibrium quantum thermodynamics is one of the utmost tasks in designing modern nanoelectronics and quantum thermal machines. In pursuit of this, a number of recent advances pave the way toward rigorous, controlled numerical simulations of quantum transport through a low–dimensional working medium in contact with fermionic reservoirs at fixed temperatures and chemical potentials.
One notable and high–fidelity numerical approach combines tensor networks and an open system methodology, where relaxation maintains a chemical potential or a temperature drop between the finite representation of the contacts [1, 2]. External relaxation of the implicit leads results in several characteristic features. Green's function formalism [3-5] provides a clear interpretation of those features for non–interacting models. Their adequate understanding is necessary to identify the regime where the true, natural (Landauer or Meir–Wingreen) steady–state conductance is recovered in the simulation.

In the presentation, I will discuss the interpretation of the quantum transport properties in connection to the relaxation parameter within the extended reservoir approach [5]. I will comment on our findings on the efficiency of used to discretize the reservoirs [6]. Finally, I will present relevant ingredients necessary for efficient open–tensor–network simulations of quantum transport [1]. We employ the latter to demonstrate that the characteristic features observed for non–interacting models are persistent also in the case of many–body interactions in the working medium [5], building towards a universal methodology for many–body quantum transport simulations.

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Berry phase engineering at oxide interfaces

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Three-dimensional strontium ruthenate ($SrRuO_3$) is an itinerant ferromagnet that features Weyl points acting as sources of emergent magnetic fields, anomalous Hall conductivity, and unconventional spin dynamics. Integrating $SrRuO_3$ in oxide heterostructures is potentially a novel route to engineer emergent electrodynamics, but its electronic band topology in the two-dimensional limit remains unknown. Here we show that ultrathin $SrRuO_3$ exhibits spin-polarized topologically nontrivial bands at the Fermi energy. Their band anticrossings show an enhanced Berry curvature and act as competing sources of emergent magnetic fields. We control their balance by designing heterostructures with symmetric ($SrTiO_3/SrRuO_3/SrTiO_3$ and $SrIrO_3/SrRuO_3/SrIrO_3$) and asymmetric interfaces ($SrTiO_3/SrRuO_3/SrIrO_3$). Symmetric structures exhibit an interface-tunable singlechannel anomalous Hall effect, while ultrathin $SrRuO_3$ embedded in asymmetric structures shows humplike features consistent with multiple Hall contributions. The band topology of two-dimensional $SrRuO_3$ proposed here naturally accounts for these observations and harmonizes a large body of experimental results.

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Electronic structure and magnetic properties of Dy-doped Bi_2Te_3

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Doping the topological insulator Bi_2Te_3 with rare-earth ions is a way to introduce the high magnetic moments into the material [1]. Ferromagnetic order can break time-reversal symmetry, opening a gap in the topological surface states.The correlated band theory implemented as a combination of the relativistic density functional theory with the Anderson impurity model [2] is applied to theoretical investigation of the electronic and magnetic character, and the magnetic anisotropy for Dy-doped Bi_2Te_3 topological insulator. For both ferro- and anti-ferromagnetic Dy-planes in Bi_2Te_3 we found the in-gap flat f-bands located at the top of the valence band of Bi_2Te_3. The positive uniaxial MAE is predicted for $(Dy_xBi_{1-x})_2Te_3$ with $x = 0.33$. The experimental resonant photoemission spectra are well reproduced by the calculations [3]. These studies can be important to explore the potential use of rare-earth doped topological insulators in the low-power spintronic devises.

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Yu-Shiba-Rusinov Qubit

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Magnetic impurities coupled to *s*-wave superconductors lead to spin polarized in-gap states, the so called Yu-Shiba-Rusinov (YSR) states. The quantum states stemming from two nearby impurities (dimer) pertain to an effective two-level system which we propose to use as a qubit, the building block of a quantum computer. Using a time-dependent Green function approach, we derive an effective Hamiltonian describing the YSR qubit evolution as a function of distance between the impurities, their relative orientations, and their dynamics. We then employ both numerical and analytical methods to show that the YSR qubit states can be both controlled and read out efficiently utilising the dynamics of the magnetic impurities that engenders it. Finally, we address the effect of the spin noises originating from the classical impurities on the coherence properties of the YSR qubit, and show a robust qubit behaviour for a wide range of experimentally relevant parameters.

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Electron-phonon coupling in the copper intercalated Bi_2Se_3 hybrid devices.

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We investigated charge and heat transport in copper intercalated Bi_2Se_3 topological insulator in temperatures ranging from 15 mK up to 250 K. Both superconducting aluminium leads and normal, golden leads were employed for contacting the samples. Measurements of magnetoconductivity of the Al-contacted sample were performed at temperature T = 100 mK using magnetic fields ranging from 0 T up to 5 T. Fitting results of the experiment with the HLN model[1] were consistent with weak localization, and it yielded the materials parameters: the coherence length (33 nm), mean-free path (12 nm), spin-orbit scattering length (19 nm) and mobility (593 cm^2/Vs). Weak localisation and electron-electron intercatios[2] were major processes contributing to the conductivity in the Au-contacted sample.

Disorder-related small unit cell deformation of the topological insulator enhanced separation of the in-plane and cross-plane processes. Such separation resulted in charge and phonon confinement in quintuple layers of the topological insulator. Shot noise measurements revealed that heat transport in the layered material is more sensitive to such an anisotropy than charge transport. The anisotropy was reflected in the heat flux investigated in three temperature ranges. The heat flux showed T^2 temperature dependence at $T < 7$ K, which changed to T^3 at 7 K $< T <$ 12 K and to T^4 at $T >$ 12K. A model of electron scattering on transverse acoustic phonons taking into account dynamic and static disorder as well as the Kapitza[3] resistance originating from the mismatch between acoustic phonons impedances of an investigated material and a substrate is found to be in accordance with the data.

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Surface electronic structure of magnetically doped topological insulators studied by means of STM and STS

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Topological insulators represent a quantum state of matter characterised by simultaneous occurrence of bulk energy gap and peculiar topological surface states, which form Dirac cones with linear dispersion relation. Topological states occur among others in three-dimensional single crystalline Bi_2Se_3. Doping can be used to shift the Fermi level into the linear region and thus realize the quantum topological transport. However, dopants may also influence the topological states, and in the special case of magnetic dopant, the topological states can be destroyed [1]. On the other hand, the recent literature reports that magnetic topological insulators exist [2]. The goal of our work is to determine how small amounts of both magnetic and non-magnetic dopants influence the electronic structure and what are the consequences for the surface topological states.

We present scanning tunnelling microscopy (STM) and scanning tunnelling spectroscopy (STS) study of single crystals of pristine Bi_2Se_3, non-magnetically doped $Bi_{1.96}Mg_{0.04}Se_3$ and magnetically doped $Bi_{1.98}Fe_{0.02}Se_3$. STM images of all investigated crystals exhibit a variety of surface defects. Due to well confined probing region STS offers an unique possibility to find out how the single structural defect or dopant modify the local density of states (LDOS) at the surface. We observe clear differences in LDOS structure depending on whether the measurement was carried out at the defect or far from the defect. Small amounts of both magnetic and non-magnetic dopants introduce subtle changes in the LDOS of the surface. However, they do not destroy the topological surface states of studied material.

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The relation between the ratio of orbital to spin magnetic moment and anisotropy of Au/CoFeB/Au and Au/CoFe/Au thin films

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The magnetic anisotropy is known to arise from several contributions like e.g. the difference in the orbital moment between the easy and hard magnetization axes. When the thickness of a thin film approaches a single nanometer range, the interface effects start to play the dominant role. At the interface, where the breaking of translation symmetry occurs, extra phenomena can be observed like e.g. Dzyaloshinskii–Moriya interaction and surface anisotropy. In that paper, we study how the interface influences the effective magnetic anisotropy and orbital to spin magnetic moment ratio. The Au/CoFeB-wedge/Au and Au/CoFe-wedge/Au samples were deposited by magnetron sputtering. We have measured the ratio of orbital to spin magnetic moment using vector network analyzer ferromagnetic resonance (VNA-FMR). The results were compared with ab initio calculations. We show that the effective magnetic anisotropy (the sum of a shape and surface anisotropy) and the ratio of orbital to spin moment follow the same inverse proportionality with the thickness of the ferromagnetic layer. These results suggest that the orbital magnetic moments at the interface are larger than the value for bulk. This enhancement of orbital moment at the interface may be a source of the surface anisotropy in those systems.

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Elucidating the magnetic behaviour of metastable Fe/Ni layers grown on top of the oxygen-reconstructed Fe(001) surface

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The growth of epitaxial Fe/Ni heterostructures offers the unique possibility of stabilizing unusual crystallographic phases, possibly characterized by novel electronic and magnetic properties.[1] From the fundamental point of view, the investigation of such systems aims at (i) elucidating the physics which comes into play during the formation of heterointerfaces and ultra-thin films and (ii) linking the structural and electronic characteristics to the magnetic response of such complex systems in terms, *e.g.*, of their magnetic coercivity and anisotropy.[2] Conversely, from the point of view of applications, magnetic nanostructures and novel magnetic phases are expected to rival the performances of more expensive rare earths-containing materials.[3]

We present a structural and spectroscopic characterization of ultra-thin Ni films grown on *bcc* Fe. At variance with previous literature investigations, the substrate is treated in order to form an oxygen superstructure, namely the Fe-p(1x1)O surface. The presence of an oxygen overlayer, capable of floating at the Ni/Fe sample surface even at room temperature, contributes to a peculiar morphological evolution and intervenes in the structural relaxation of the metastable Ni overlayer, as anticipated by our previous studies.[4] In the present work, we extend our investigation away from the Ni/Fe interface and focus on the magnetic behaviour of this system by the combined use of spin-resolved photoemission spectroscopy (SR-PES) and inverse photoemission spectroscopy (SR-IPES). A strong decrease in the surface polarization is observed with increasing thickness of the *bcc* Ni layer, with a clear quenching of the magnetization signal associated with specific surface features. The spectral spin-polarization typical of *bcc* Fe is then recovered by growing an additional ultra-thin Fe layer on top of Ni, all with no signs of surface relaxation, as testified by low energy electron diffraction (LEED). On the one hand, this observation suggests the possibility of applying our method to the growth of Fe/Ni multilayers with little or no structural evolution. On the other hand, given the abrupt onset of the Fe magnetization, observed even at monolayer coverage, we suggest that such Fe overlayer could be considered prototypical for the study of the magnetic behaviour of highly decoupled or nearly free-standing low-dimensional systems.[5]

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Multicracking and magnetic behavior of magnetic nanowires/polymer substrate systems

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This work presents the effect of large strains (up to 20%) on the behavior of magnetic nanowires ($Ni_{80}Fe_{20}$ and $Ni_{60}Fe_{40}$) with a thickness of 20 nm deposited on a Kapton substrate.For that purpose, 0.5×0.5 cm^2 arrays of nanowires have been fabricated on 125 μm thick-rectangular (0.6×4.0 cm^2) Kapton substrates. Note that no adhesion layer (Cr, Ti, ...) has been deposited on the substrate in order to avoid their influence on the possible initiation of cracks in the nanowires. The multicracking phenomenon was followed by in situ tensile tests combined with atomic force microscopy measurements. These measurements show, on the one hand, a delay in crack initiation relative to the nonpatterned thin film and, on the other hand, a saturation of the length of the nanowire fragments. The magnetic behavior has been analyzed by using ferromagnetic resonance technique. The ferromagnetic resonance line profile (intensity, width) in the case of $Ni_{80}Fe_{20}$ is minimally affected by the numerous cracks, which is explained by the small variation in magnetic anistropy and the low magnetostriction coefficient of $Ni_{80}Fe_{20}$ [1,2] while it is strongly affected in the case of $Ni_{60}Fe_{40}$ nanwoires. Indeed, in the case of Ni60Fe40 nanowires, the initial shape anisotropy is completely compensated by the applied strains.

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Reversible control of electric polarization in SrTiO3-CoFe2O4 at room temperature by XAS

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Strain engineering of thin-film heterostructures is one of the most widespread and successful approaches to improve the performance of real devices such as transistors, electrochemical energy conversion devices, or multiferroic memories [1,2]. We have engineered local strain in quantum paraelectric SrTiO3 exploiting CoFe2O4 magnetostrictive properties and succeeded in reversibly controlling the electron distribution in the Ti valence band of SrTiO3-CoFe2O4 heterostructures at room temperature. Using soft x-ray absorption spectroscopy, we have observed changes in the energy level scheme of Ti $3d$ orbitals upon the application of an external magnetic field which suggest the development of a net electric polarization. Such an induced state disappears upon field removal. Our approach might be applied to other 2D heterostructures offering the possibility to induce and reversely control novel properties found at the interface, such as polar vortexes or two-dimensional electron gases, and thus it could lead to the realization of a new class of functional devices for information storage and sensing applications.

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Surface potential influence on the growth of Co_2FeSi Heusler alloys thin films on graphene

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All-spin logic devices are based on the lateral spin valve (LSV) structure, which consists of two (or more) laterally separated ferromagnetic electrodes bridged by a nonmagnetic channel. The basic operation is switching of the bistable nanomagnets between their stable states representing binary data if enough torque is exerted on them [1]. The main building blocks of LSV devices are: spin injectors/detectors (ferromagnetic electrodes) and a spin transport channel. The suitable spin transport channel should allow for long spin lifetime and long distance spin propagation. The experimental studies of spin transport measurements identified graphene as the most favourable material for spin transport channel in spin-logic devices [2]. The key feature of the spin injectors/detectors is their electrons spins polarization at the Fermi energy. Hence, the ideal candidates for spin injection/detection are half-metallic ferromagnets which exhibit 100% spin polarization of conduction electrons. Examples of these are some Heusler alloys: NiMnSb, Co_2FeSi, Co_2MnSi, among others [3]. However, the growth of the Heusler alloys on the graphene was not studied before. Graphene properties depend strongly on the underlying material, number of layers, etc. Furthermore, the surface state affects adsorption, surface migration and aggregation of deposited atoms. Herein, we present the influence of the surface potential of the graphene substrate on growth properties of Co_2FeSi Heusler alloys thin films deposited by molecular beam epitaxy.

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Ab-initio approach to interface effects at spinel ferrite heterostructures

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Spinel ferrite heterostructures that combine hard and soft magnetic materials have gained importance in areas as diverse as the search for efficient rare-earth free permanent magnets, or the development of new therapies to treat cancer. The combined system is expected to profit from the individual properties of each component, but the presence of interfaces may add features that are difficult to isolate from experiments. Even restricting to undefective interfaces between isostructural ferrites, such as $CoFe_2O_4/NiFe_2O_4$ or $CoFe_2O_4/MnFe_2O_4$, we need to consider lattice mismatches, bond rearrangement and novel superexchange paths that may affect the global magnetic response. This is particularly relevant for CFO, with a large magneto elastic coefficient highly sensitive to minor strains and modifications of the system symmetry. Here we show how density functional theory simulations are particularly adequate to explore these effects, identifying key aspects that need to be considered to tune the magnetic properties in the presence of multiple interfaces. We evaluate the coexistence of different orientations and crystal terminations to determine the influence of mismatch-induced strains and partial inversion on the net magnetisation, magnetic anisotropy and superexchange paths. We prove the determinant role of the cation distribution and structural inversion on the magnetisation and magnetic anisotropy. Our results provide a useful guide to understand magnetic measurements of hard/soft spinel ferrite heterostructures, and identify the determinant role of even ideal interfaces on the properties of the joint system.

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Long-range ordered superlattice of carbon within $Mn_5Ge_3C_{0.5}$ epitaxial films

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Mn_5Ge_3 is a metallic ferromagnet with the Curie temperature of 296 K, that can be increased up to 450 K by the addition of carbon [1]. It crystallizes in the hexagonal D_{88} structure with Mn atoms occupying two magnetically and structurally inequivalent positions: 4d (Mn_I) and 6g (Mn_{II}). Recent ^{55}Mn NMR studies performed on a pristine Mn_5Ge_3 evidenced the unquenched orbital moment of Mn in both sites, giving rise to a high out-of-plane anisotropy [2]. The anisotropy of the orbital moment was found to be strongly reduced by the presence of carbon, which enters interstitially occupying the 2(b) octahedral voids and strongly reduces the magnetic moment of the Mn_{II} atoms located in the corners of a host octahedron [3]. We now present the ^{55}Mn NMR study performed on a series of epitaxial 30 nm thick $Mn_5Ge_3C_x$ films in the entire concentration range (nominal carbon content varying between $0 < x < 0.85$). Up to x=0.5 the Mn_{II} atoms are found in two distinctly different magnetic states, labelled as Mn_{II} (no carbon nearest neighbor) and Mn_{II_C} (one carbon nn). The latter site gives rise to a satellite NMR line shifted down by 82 MHz - with increasing carbon concentration the signal intensity is systematically transferred from Mn_{II} to Mn_{II_C}. The NMR spectra recorded from films with a nominal carbon content above x=0.5 are identical: the original Mn_{II} NMR signal disappears, but no second satellite line is observed, even though there are two available 2(b) positions around the Mn_{II} atoms. These observations imply that the spatial distribution of carbon is not statistical, tending to a selective occupancy of every second available 2(b) site in the Mn_5Ge_3 lattice along the c-direction and setting the limit for the uptake of carbon in the Mn_5Ge_3 lattice to x=0.5. Considering that the 2(b) voids are located in the same atomic plane as the Mn_I atoms, in case of their random occupancy one would expect a distribution of different Mn_I environments. However, the observed evolution of the Mn_I NMR line as a function of carbon concentration reveals that the carbon-filled voids are ordered also in-plane, and form a highly ordered superlattice within the hexagonal D_{88} structure. This postulate is confirmed by the reported stabilization of the Mn_5Ge_3 crystal lattice in presence of carbon. A self-organizing tendency of carbon is well documented in different carbon- and graphen-containing nanostructures, but to our knowledge this is the first evidence of carbon long range order within an alien crystal lattice. This observation may encourage efforts to grow other highly ordered carbon-doped systems in view of engineering their magnetic properties.

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Control of the phase of spin wave reflected from a subwavelength Gires-Tournois interferometer

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The usage of metasurfaces consisted of nano-resonators was an innovatory concept in photonics and optics which led to designing of multiple devices of performance exceeding classical applications. It becomes possible with metasurfaces to change the properties of a wave at subwavelength distances. However, this concept has not been extensively studied in magnonics even though control of the phase of the spin waves (SWs) at ultra-short distances is of great importance for application.

We numerically study the influence of a sub-wavelength stripe placed over a ferromagnetic film made of permalloy on the phase of reflected SWs [1]. We consider resonators made of two types of materials, permalloy and a material with saturation magnetization lower than permalloy. Utilizing frequency-domain finite element method calculations we showed that by changing the geometry properties of the stripe and the layer we can obtain a full angle phase change of the reflected wave. Additionally, for certain geometries, the resonance behaviour can be seen in the bilayer part of the system consisted of the layer and the stripe. Those resonances are present when the Fabry-Pérot condition is met and then the phase of reflected SW changes abruptly with a small alteration of geometry of the system. We have shown that the occurrence of the resonances can be modified by changing thicknesses of the magnetic elements. To explain the behaviour of the SWs in the system, the two-mode model analysis was developed. This analysis shows that the symmetric fast mode of the bilayer gives an input to a steady increase of the phase. On the other hand, the antisymmetric slow mode is responsible for the resonances in the system, as its input is significant only when the Fabry-Pérot condition is fulfilled.

Summarizing, our system can be regarded as a realization of the magnonic Gires-Tournois interferometer of subwavelength width suitable for the control the phase of the SW. This system may be used as a building block in more complicated magnonic devices as phase shifters or detectors of magnetic particles.

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Creation of submicrometer sized domains by temperature-induced changes of magnetic anisotropy in ultrathin a Co/NiO bilayer

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Ultrathin films systems with Perpendicular Magnetic Anisotropy (PMA) consisting of alternating ferromagnetic and heavy metal layers have attracted a lot of attention, because of potential applications in spintronics and magnetic logic devices. For such applications, ultrathin FM layers in contact with oxides are very promising systems [1]. Here, we study the temperature-induced changes of magnetic anisotropy and magnetic domain structure and magnetization reversal processes of exchange-biased Au/Co/NiO/Au polycrystalline system [2], which shows strong perpendicular magnetic anisotropy of the Co layer [3] at room temperature (RT). The domain structure and its evolution were investigated under various temperature sample treatment (in the range of RT – 200 ^{0}C) without and under the external out-of-plane magnetic field (H_{oop}) by means of magnetic force and polar magneto-optical Kerr effect (PMOKE) microscopies. Using PMOKE based magnetometry we observed spin reorientation transition (SRT) from perpendicular to in-plane magnetization state around 150 ^{0}C. This temperature-driven SRT allows us to investigate the influence of magnetic state on domains structure at remanence after the zero-field cooling (ZFC) process. ZFC from temperature above 150 ^{0}C down to RT leads to the appearance of a domain structure with submicrometer size, while domains with sizes around 100 μm were found at RT after demagnetization under decreasing alternating H_{oop} fields. It is interesting that, after demagnetization by ZFC process, the small domains vanish by applying H_{oop} and large domain (100 μm) re-appear after field driven demagnetization [2]. This experimental results will be compared based on theoretical approach of domain structure evolution while approaching SRT [4].

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Magnetic properties of 3d, 4d, and 5d transition-metal atomic monolayers in Fe/TM/Fe sandwiches: Systematic first-principles study

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Previous studies have accurately determined the effect of transition metal point defects on the properties of bcc iron [1-2] and the magnetic properties of transition metal monolayers on the iron surface have been studied equally intensively. In this work, we investigated the magnetic properties of the $3d$, $4d$, and $5d$ transition-metal (TM) atomic monolayers in Fe/TM/Fe sandwiches using the FPLO (full-potential local-orbital) scheme of density functional theory [3]. We prepared models of Fe/TM/Fe structures using the supercell method [4]. We selected the thickness of the layer such that the atomic Fe layers furthest from the TM layer exhibit the properties of bulk iron-bcc. Perpendicular to the plane of the layer, we observe charge and spin density waves in iron-bcc. We determined the values and orientation of the magnetic moments in the TM atomic layers. Furthermore, we investigate the dependence of those layers on a magnetocrystalline anisotropy energy.

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Spin valve effect in two-dimensional VSe_2 system

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Vanadium based dichalcogenides, VSe_2, are two-dimensional materials in which magnetic V atoms are arranged in a hexagonal lattice and are coupled ferromagnetically within the plane. However, adjacent atomic planes are coupled antiferromagnetically [1]. This provides new and interesting opportunities for application in spintronics and data storage devices. A spin valve magnetoresistance may be achieved when magnetic moments of both atomic planes are forced to parallel alignment by an external magnetic field. The resistance change associated with the transition from antiparallel to parallel alignment is qualitatively similar to that observed in magnetic metallic layerd structures. Detailed electronic structure was obtained from DFT calculations. Then, the ballistic spin-valve magnetoresistance was determined within the Landauer formalism.

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Magnetocaloric effect in $La_{0.70}Ag_{0.25}MnO_3$ magnetic nanoparticles

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Experimental study of magnetocaloric effect (MCE) was performed by indirect and direct methods on $La_{0.70}Ag_{0.25}MnO_{3+\delta}$ nanoparticles. The rhombohedral crystal structure (R-3c space group) of nanoparticles was modified by annealing at 800°C in different atmosphere (air, O_2 and Ar). Direct measurements of the adiabatic temperature change ΔT were carried out by a method of modulation [1] in magnetic fields of 1.8 T. In this case an alternating magnetic field is applied to the sample, which, due to the magnetocaloric effect, induces a periodic change in the temperature of the sample. The indirect method based on determination of the magnetic entropy change ΔS from measurements of magnetic isotherms was undertaken in magnetic fields up to 7 T in the same temperature range as a direct measurement of MCE. Heat treatments affects mainly the content of oxygen and number of defects in the crystal structure which both have significant effect on magnetic properties. The Curie temperature T_C increases from 250 K to 319.5 K and to 322.9 K with the content of oxygen. On the other -ΔS at 7 T decreases from 5.82 $Jkg^{-1}K^{-1}$ to 4.35 $Jkg^{-1}K^{-1}$ and to 3.76 $Jkg^{-1}K^{-1}$ with oxygen content. The direct measurement of MCE revealed that the dependence $\Delta T(f)$ is well described by the expression published in [1], the frequency exponent n= 0.49 and $\Delta T_{f=0}$ =0.284 K. The sample demonstrates the stability of the MCE up to 1000 cycles of switching on and off the magnetic field without any signs of degradation. The paper extends results of our study performed on similar type of nanoparticles [2, 3].

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Magnetic ordering in epitaxial ultrathin Co layers surrounded by Pt and W covers

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The magnetic properties of epitaxial layered structures $Pt(d_{Pt1})/W(d_{W1})/Co(d_{Co})/Pt(d_{Pt2})/W(d_{W2})$ substantially depend on the thicknesses of the component W bottom layer and Co magnetic film. Using the polar magnetooptical Kerr effect PMOKE based magnetometry and microscopy, magnetic force microscopy and Brillouin Light Scattering (BLS) spectrometry the following features have been investigated: (i) the magnetic anisotropy and magnitude of Dzyaloshinskii-Moriya interaction (DMI) and (ii) magnetic domain structure evolution driven by magnetic field. Conditions (arrangement and thickness of the component layers) for perpendicular magnetic anisotropy (PMA) occurrence were determined. Studies of the samples with different thicknesses d_{W1}, d_{Co} (and selected d_{Pt1}= 10 nm, d_{Pt2}= 3 nm, d_{W2}= 0 nm) revealed: (i) existence of large DMI characterized by effective coefficient D_{eff} as high as 1.5 mJ/m^2; (ii) possibility of creation the bubble/skyrmion lattices while approaching the transition region (driven by increasing d_{W1} or decreasing d_{Co}) from PMA to superparamagnetic state. Small domain creation was observed also while approaching spin reorientation transition driven by d_{Co} increase or d_{W1} decrease. The micromagnetic simulations (using experimentally determined magnetic anisotropy field and D_{eff} constant) reproduced the magnetic domain structures and magnetization processes observed experimentally.

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Quantum coherence in noise power spectrum in quantum dots

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In quantum optic experiments coherent properties of light are described by the coherent function of the first and the second order (or higher orders). In analogy interference of electron waves were studied in transport through nanostructures, for example the Aharonov-Bohm effect and the Fano resonance. These effects were observed in measurements of the differential conductance, which corresponds to the first order coherence function. The current correlation function (referred as noise power) describes fluctuations of the currents and it is related with the second coherence function. The problems of interference in the noise power spectrum have had little interest [1,2].
Here, we want to present studies of the noise power spectrum, in particular, dynamics of coherent intra- and inter-level current correlations in two quantum dots (2QD) in a T-shape geometry. Such the system seems to be a good choice, because the conductance shows the Fano resonance with a characteristic dip due to destructive interference of a travelling wave with an localized state. Using the nonequlibrium Green functions (NEGF) and neglecting Coulomb interactions we derived exact formulae for the current and the frequency dependent current-current correlation functions. For the high voltage bias the shot noise dominates and shows the particle nature of the electron transport. Performing the spectral decomposition we are able to separate the currents flowing through the bonding and the antibonding state. Therefore, we can distinguish between the intra- and inter-level current correlation contributions to the noise power spectrum. In particular, we show that for a weak coupling with the electrodes the noise spectrum has dips at frequencies characteristic to inter-level excitations and the corresponding current correlations are negative. When the coupling with the electrodes is larger than the separation between the states, the electron transport changes its nature. The dynamics of the current correlations is different: there are two coherently coupled relaxators with different relaxation frequencies. These two regimes of current dynamics are separated by a quantum critical point. The wave nature of the electron transport and the quantum interference can be observed in the noise power spectrum for equilibrium and in the linear response limit, where the current fluctuations on the same tunnel junction become relevant. In this limit the noise spectrum is related with the admittance by to the fluctuation-dissipation theorem.
Our theoretical predictions can be verified by measurement of noise power spectrum in an active quantum detector coupled via an on-chip resonant circuit to the quantum dot system [3].

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Different types of magnetic edge configurations in selected graphene-like nanoribbons

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Theoretical studies of electronic and magnetic properties of selected graphene-like nanolayers are presented. The method is based on a tight-binding type Hamiltonian with Hubbard corrections. The main attention is focused on the zigzag nanoribbons and their magnetic configurations. It is shown that the latter determine energy band structures and may lead to a half-metallic behavior of some graphene-like systems. Interestingly, apart from the well-known parallel and antiparallel arrangements of the ferromagnetic edges, it is also possible that only one edge is ferromagnetic and the other is paramagnetic. Such a one-edge magnetic configuration may appear in graphene, stanene and phosphorene for properly chosen gating and edge-doping.

Computationally Driven Evaluation of Magnetocrystalline Anisotropy

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Custom-tailored magnetic materials are a crucial component in numerous modern technologies from data storage to energy conversion and communication technologies. The experimental search for new high-performance magnets can profit considerably from guidance by theoretical simulations. Computational screening approaches however depend on reliable first-principle methods for calculating the key physical properties which underlie the magnetism of the material. One of them is the magnetocrystalline anisotropy (MCA), which contributes to the magnetic hardness. From an atomistic point of view, the MCA defines the alignment of the atomic magnetic moments with respect to the lattice based on the spin-orbit coupling (SOC) between the potential energy landscape and the electron spin. The determination of MCA is a challenging task for both experimentalists and theoreticians, as it is highly sensitive to a number of factors and parameters.

For the well-studied $X(acac)_3$ (X = V, Cr, Mn, Fe) coordination complexes we specifically explore and compare different methods for calculating the MCA: the finite energy difference approach (force theorem) within periodic boundary conditions by means of VASP and all-electron, full-potential perturbative approaches in ORCA ranging from PT2 on PBE DFT to CASSCF-PT2 and NEVPT2. We explicitly study the influence of cluster geometry and various computational parameters at different levels of theory. Finally, we address the challenges involved in high-throughput MCA calculations for bulk materials by discussing the example of $L1_0$-FePt.

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Perpendicular magnetic anisotropy in TmIG and GdIG thin films

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Yttrium iron garnet (YIG) has been well studied as its low Gilbert damping parameter promises use in spintronic devices and sensors. Recently, research turns towards the similar rare earth iron garnets with a more complex magnetic structure, such as the ferrimagnetic insulators thulium iron garnet (TmIG) and gadolinium iron garnet (GdIG). In thin film form, magnetic shape anisotropy favors an in-plane magnetic easy axis. However, thin films grown on lattice-mismatched sGGG or GSGG substrates exhibit a magnetoelastic anisotropy favoring an out-of-plane easy axis [1,2]. Therefore, tuning of the magnetic easy axis and ultimatelly perpendicular magnetic anisotropy (PMA) was achieved, enabling further research in the field of spintronics.

In our study, TmIG and GdIG thin films were grown epitaxially on sGGG and GSGG substrates by pulsed laser deposition (PLD). To ensure single crystalline growth of stoichometric thin films and a smooth surface morphology the films are prepared at elevated temperatures of $600 - 620°\mathrm{C}$, with low deposition rates of $0.01 - 0.03\,\frac{\mathrm{nm}}{\mathrm{s}}$ and in an oxygen atmosphere of $p_{\mathrm{O}_2} = 0.04\,\mathrm{mbar}$ and $0.02\,\mathrm{mbar}$ for TmIG and GdIG, respectively.

The PLD grown TmIG/sGGG and GdIG/GSGG thin films show PMA around room temperature [1]. Furthermore, for TmIG a gradual strain relaxation with increasing film thickness and a subsequent loss of PMA for 200 nm thick films is observed [1].

The antiferromagnetically coupled Gd^{3+} and the net Fe^{3+} magnetic sublattices of GdIG posses different thermal characteristics, resulting in a magnetic compensation point. The GdIG thin films with thicknesses between 15 nm and 200 nm show a magnetic compensation temperature in the range between 200 K and 300 K, affected by the induced strain as well as the film stoichometry. Additionally, a change from PMA to an in-plane easy axis below roughly 150 K due to the strongly increased magnetic shape anisotropy is observed for the 30 nm thick film. The smooth surface morphology with a root mean square roughness of $0.2 \pm 0.1\,\mathrm{nm}$ is a key prerequisite for future research exploiting surface effects like the inverse spin Hall effect.

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Magnetic properties of carbon-doped $Fe_{1-x}Co_x$ supercells studied by conformation space mapping

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$Fe_{1-x}Co_x$ disordered alloy is known to have notable magnetic properties in uniaxially strained body-centred tetragonal structure [1,2]. Such deformation can be, to some extent, obtained by introducing interstitial impurities of small atoms like boron, carbon or nitrogen [3].

A wide range of artificially induced distortions and alloy compositions can be simulated using density functional theory (DFT). Chemical disorder in the alloy can be approximated by various methods, including virtual crystal approximation (VCA) or coherent potential approximation (CPA), as well as by conformational space reduction by specific sampling schemes such as special quasirandom structures (SQS). However, it has been shown that for supercells of a few dozen atoms, a more direct approach by the study of all possible symmetrically inequivalent arrangements of atoms in a stoichiometric concentration is feasible [4].

We present a DFT analysis of $Fe_{1-x}Co_x$ stoichiometric supercells doped with an interstitial carbon atom by sampling a large part of possible geometrically inequivalent atomic positions occupancies by Fe and Co atoms in a full range of Co concentrations. Magnetic, such as magnetocrystalline anisotropy and magnetic moments, as well as structural properties, were calculated using FPLO (full potential local-orbit) scheme and compared with methods of chemical disorder approximation – VCA, CPA and SQS.

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Microscopic Mechanism of the Exchange Bias in $Mn_{50}Ni_{40-x}Sn_{10+x}$: a Small-Angle Neutron Scattering Study

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Polycrystalline Ni–Mn–Sn Heusler alloys show a large exchange bias field below a blocking temperature T_B [1-3], making them promising candidates for future spin valve and magnetic recording devices. Here, we use small-angle neutron scattering (SANS) [4] to directly image the magnetization process in $Mn_{50}Ni_{40-x}Sn_{10+x}$ in the reciporcal space. At zero field and low temperatures, we are able to observe the coexistence of ferromagnetic domains (> 100 nm) and local clusters (~ 10 nm). In the field-induced magnetization process below T_B, the ferromagnetic domains and domain / cluster interfaces exhibit a large susceptibility at the exchange bias field, as revealed by the Porod fitting to the scattering data, while the local clusters remain relatively resilient. These results agree with the theory where exchange bias results from the ferromagnetic unidirentional anisotropy formed at the interfaces between different magnetic phases [5].

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Deeper insight into crystal structure and magnetic properties of $(Fe_{0.7}Co_{0.3})_2B$ alloys with 5*d* atom substitutions

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If the theoretical and experimental methods provide complementary information on the system studied, their appropriate combination provides the data allowing a comprehensive interpretation of the phenomena taking place in the investigated system. We applied this approach, combining ab-initio calculations and various experimental techniques in the search for new alloys that could be used for production of rare-earth free permanent magnets. Our first-principles calculations for the substituted $(Fe_{0.66}Co_{0.28}W_{0.06})_2B$ and $(Fe_{0.66}Co_{0.28}Re_{0.06})_2B$ alloys showed about 15% decrease in magnetic moment, relative to that of $(Fe_{0.7}Co_{0.3})_2B$, also showing a twofold increase in magnetocrystalline anisotropy energy for the alloy with Re. To confirm experimentally these results, fully amorphous ribbons of $(Fe_{0.7}Co_{0.3})_2B$ and $(Fe_{0.675}Co_{0.275}X_{0.05})_2B$ (X = W, Re) were obtained by the melt-spinning method. Differential scanning calorimetry results indicate the highest temperature of the first crystallization peak (T_p = 574°C), and consequently the highest thermal stability, for the $(Fe_{0.675}Co_{0.275}Re_{0.05})_2B$ alloy. All of the investigated alloys were isothermally annealed at two different temperatures. The XRD patterns provide evidence of crystallization of the $(Fe,Co)_2B$ phase after isothermal annealing with a slightly different lattice parameter depending on the alloy composition. The Re substituted alloy shows the highest saturation magnetization from among the investigated samples, equal to 1126 emu/cm^3. The Mössbauer spectra of the annealed alloys consist of two sextets for $(Fe_{0.7}Co_{0.3})_2B$ or three sextets for the alloys doped with Re and W. The third sextet is related to the localization of Fe atoms in additional defect positions.

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Neuromorphic computing architecture based on serially connected magnetic tunnel junctions

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Neuromorphic computing architectures have superior properties over conventional computers in solving a number of problems such as image or voice recognition, combinatioral optimization, or prediction[1]. As a concept, neural networks (NN) have been proved to be fast and flexible. However, their implementations in conventional digital architecture require large amount of resources, as subsequent multiplication and addition operations need to be performed for each input (synapse) of a single neuron.

Here, we present a complete architecture for neuromorphic computing including: multi-bit cell forming a programmable synaptic weight, electronic neuron and artificial NN together with simulation results of a representative problem solution.

The proposed multi-state cells (MSC) are realized as serially connected magnetic tunnel junctions (MTJ), where N MTJs cells create $N+1$ discrete resistance states [2], which store a synaptic weight of a neuron. A single electronic neuron is implemented as a circuit involving voltage inputs (as synapses), voltage output (which might be connected to a second layer of neurons, or act as an output), pairs of MSC, differential amplifier and a sigmoidal transient function generator. Each weight is stored as a pair of MSC at each synapse and manipulating resistance balance between these two MSC related to each input, positive, negative or zero weights may be achieved.

To verify the viability of the concept, MNIST[3] database of handwritten numbers was used as an example for NN image recognition. The network was taught using software representation on a subset of MNIST database, and the synaptic weight values were mapped to the possible memristor states. Finally, the simulations of the NN were carried out, while feeding input with different number images.

The presented design of the artificial NN might be successfully used for a wide range of applications. The proposed architecture is compliant with MRAM production technology, which has already reached 22 nm level[4], therefore, the circuits can be manufactured using the existing technology.

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An eddy current speed sensor for rectangular bars

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Eddy current speed sensors have attracted fewer attentions in comparison with other types of speed sensors such as optical and variable reluctance speed sensors despite their simplicity and non-destructive configuration. Recent developments in the electronic signal processing with higher precision and more compact structure cause that the eddy current speed sensors are attractive for numerous industrial applications. Utilizing motional eddy currents in the conductive metallic bodies with smooth surface is common in electromagnetic devices, for example, eddy current brakes. The same phenomena from motional eddy currents effects could be utilized in the eddy current speed sensors. Motional eddy current causes asymmetric magnetic flux distribution around permanent magnet or coil as excitation source, which can be detected by induction coils, Hall sensors, fluxgate sensors or AMR sensors [1]. We use excitation coils and pick up coils with AC signal in this paper. Excitation and pick up coils can have perpendicular or parallel configuration [2]-[4]. Axisymmetric coils with parallel configuration are considered in this paper, which wound around the moving conductive rectangular bars [3]. The aluminium and solid iron bars used for the moving part are measured and analyzed to evaluate magnetic materials effects on the performance of eddy current speed sensor. The 2D and 3D numerical models are developed for the analysis of the eddy current speed sensors with rectangular bars for moving part. The measurements and analysis are performed at different speeds and excitation frequencies.

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The influence of particle shell on magnetic heating in Pickering emulsions

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Magnetic colloidal systems heated under alternating magnetic fields have attracted scientific attention mainly because of potential applications of such generated local temperature elevation in magnetic hyperthermia therapy of cancers. The mechanism of heating due to magnetic relaxation and hysteresis losses is generally well-known, and the effort is being progressively directed to provide knowledge of how different factors affect heating efficiency including the type of the material of particles, their sizes, and the parameters of applied magnetic fields. However, we show that another factor can be the solidity of particle shells when so-called Pickering emulsion droplets are placed in the alternating magnetic field.

In our works, the temperature rise in oil-in-oil emulsions stabilized with magnetic particles of different sizes varied for the different appearance of emulsion. The emulsions with droplets not fully-covered by particles demonstrated better heating efficiency than the emulsions with stable droplets (1). It was explained by deteriorating magnetic interactions when particles were densely arranged on the droplet surface and the high temperature potentially remained in nanoscale inside the droplets enclosed by particles. What is more, the temperature observed during cooling down was also different what indicated again that the solidity of the particle shell can influence the heat transfer from the inside the droplet to the surrounding medium (2). The presented study can bring the new applications of magnetic Pickering emulsions in local heating such as the formation of colloidal capsules (3).

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ESR (Electron Spin Resonance) method to control the interaction of magnetic nanoparticles with cells

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The application of nanomaterials is studied in many fields. In medicine they are considered, among others, as drug carriers. Magnetic nanoparticles are of particular interest in this field. This is possible due to their magnetic properties. ESR (Electron Spin Resonance) is a method that allows to study their magnetic properties, control their quality, taking into account the fact that a drug is attached to their surface, and their influence on biological material (cells). Based on temperature measurements, their superparamagnetism can be confirmed. By increasing the resolution of the ESR spectra, it is possible to obtain precise information on the surface of nanoparticles (surface defects). Nanoparticles can be functionalized by attaching selected drugs to their surfaces. These can be spin labels that act as free radicals scavengers. In this case, based on the ESR spectra, two sources of information are obtained: one about the magnetic core and its properties, and the other, from the attached spin label, about what is happening on the surface of nanoparticles. The analysis of ESR signals allows obtaining information on how nanoparticles are affected by the environment in which they are located and what interactions take place between them and, for example, the cells to which they are added. All these issues are shown in the paper.

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Distribution of Mn dopants in Bi_2Se_3 single crystals

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Bi_2Se_3 single crystals belong to the class of materials called Topological Insulators (TI). These are insulators in the bulk with surface states protected by time reversal symmetry, that is resistant to non-magnetic impurities, defects and geometry deformations. Although magnetic dopants are expected to destroy these unique properties, thin films of TI doped with V and Cr reveal robust ferromagnetic ordering and quantum anomalous Hall effect, a prerequisite of non-trivial topology. This opens up a possibility to externally control magnetic properties of TI, which is important both for fundamental and technological interest, particularly in view of recent developments in magnetoelectrics and spintronics.

Among crystalline TI the long range magnetic order is established only in the Mn doped Bi_2Te_3 in the temperature range $T_C < 12$ K [1,2]. On the other hand, the ordering temperature of Mn doped Bi_2Se_3 is significantly lower [3]. Magnetic susceptibility of this system depends strongly on stoichiometry that is tentatively ascribed to the differences in relative distribution of Mn dopants between Bi sites and interstitial position within quintuple layers (QL) and van der Walls (vdW) gap.

We performed systematic studies of the distribution of Mn dopants in single crystalline Bi_2Se_3 by means of Extended X-ray Absorption Fine Structure (EXAFS) analysis, supported by Density Functional Theory (DFT) calculations. It revealed that substitution sites and O_h vdW interstitials are occupied by Mn dopants, as observed in thin films [4]. However, the other kind of interstitials, i.e. O_h QL and T_d vdW, although less abundant, are recognized as well. The latter were rationalised by the cohesive energy of different Mn interstitials in Bi_2Se_3 structure provided from *ab initio* calculations and related to the results of bulk magnetic measurements.

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Coexistence of two kinds of superfluidity in Bose-Hubbard model with density-induced tunneling

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With use of the U(1) quantum rotor method in the path integral effective action formulation, we have confirmed the mathematical similarity of the phase Hamiltonian and of the extended Bose-Hubbard model with density-induced tunneling. Moreover, we have shown that the latter model exhibits two coexisting (single-particle and pair) superfluid phases. Phase separation of the two has also been confirmed, determining that there exists a range of coefficients in which only pair condensation, and not single-particle superfluidity, is present.

POSTER CONTRIBUTIONS

ABSTRACT CATEGORIES

1. Strongly Correlated Electrons and High Temperature Superconductivity

Heavy fermions and Kondo systems; Charge, orbital, and multipole orderings and excitations; Quantum phase transitions; Metal-insulator transitions; Highly correlated metals and insulators; Itinerant electron magnetism; Organic conductors; Low dimensional conductors, Correlation effects in mesoscopic systems; Multiferroics

2. Quantum and Classical Spin Systems

Low dimensional quantum magnets; Frustrated magnets and spin liquids; Quantum phase transitions; Lattice effects and spin Peierls systems; Solitons and nonlinear effects; Statistical mechanics of quantum and classical systems; Molecular magnetism; Quantum tunnelling and coherence; Quantum information; Organic and organo-metallic materials

3. Magnetic Structure and Dynamics

Crystal field and anisotropy; Magnetic structure and spin waves; Dynamic phenomena; Electronic structure; Magnetic interactions; Rare-earth and actinide magnetism; Transition metal alloys and compounds; Spin glasses; Random magnets; Magnonic crystals

4. Spin Electronics and Magneto-Transport

Magnetoresistance effects; Current induced magnetization reversal; Spin injection and accumulation; Spin Hall effect, Magnetic Semiconductors; Optical properties; Quantum computation

5. Nano-structure, Surfaces, and Interfaces

Surfaces and interfaces; Films, multilayers and superlattices; Exchange interaction and anisotropy; Spin dynamics, Patterned films; Nanoparticles; Nanowires and dots

6. Soft and Hard Magnetic Materials

Amorphous and nanocrystalline materials; Granular materials; Ferrites, garnets and microwave materials; Permanent magnets; Magnetization processes; Magneto-elastic and magnetostrictive materials; Modeling and simulations

7. Applications

Magnetic sensors; Ferromagnetic shape-memory materials; Actuators and magnetic drives; Magnetic refrigeration; Magnetic fluids; Magnetic separation and levitation

8. Other Topics

Biomagnetics; Magnetism in medicine; Measuring techniques and instruments; Magnetic recording and memories

Study of quench dynamics in Kondo systems using time-dependent NRG method

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We have studied dynamical properties of one- and two-channel Kondo systems after different quenches in Hamiltonian variables. Electronic structure of initial Hamiltonian (before quench) and final Hamiltonian (after quench) was calculated using density matrix numerical renormalization group method implemented using matrix product states formalism [1]. We show spectral properties and static averages of operators of impurity local variables. Quench dynamics was studied as real-time evolution of operators of interest calculated as time-dependent expectation values. We study behavior of Loschmidt echo, measuring the possibility of system returning to its initial state after some quench.

We have considered multiple quench protocols in Kondo systems as for example: switching on/off the Kondo couplings between impurity and metallic band states, varying of J coupling to one channel while keeping constant the second one, or simultaneous quench of both coupling constants. Particularly interesting are quenches around non-Fermi liquid critical point in the two-channel Kondo model. We systematically study quenches when varying strength from very small (aka continuous quench limit [2]) to large one (discrete, pulse-like quenches), focusing on dependence of system response due to quench on the boundary conditions. Furthermore we study such dynamics in the presence of applied external magnetic field. We also discuss stability of system properties with the increase of temperature. Finally, we compute the conductance for most relevant examples above, showing the influence of dynamics and stability of the Kondo correlated state on current properties.

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Multiband $d-p$ model and the electronic structure of doped quasi-two dimensional NiO_2 layer

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Superconductivity found in doped $NdNiO_2$ is puzzling as two local symmetries of doped NiO_2 layers compete [1], with presumably far-reaching implications for the involved superconductivity mechanism [1]. In spite of the great similarity between CuO_2 and NiO_2 planes, there are substantial differences in the electronic structure [2]. Along the family of infinite-layer nickelates $RNiO_2$ with rare-earth R spanning across the lanthanide series, the out-of-plane lattice constant decreases dramatically with an accompanying increase of Ni x^2-y^2 bandwidth; however, surprisingly, the role of oxygen charge transfer diminishes [3].

We introduce and investigate the multiband $d-p$ model (all d orbitals on Ni and p on O included), similarly to that used for $LaMnO_3$ compound [4], describing a quasi-two dimensional NiO_2 layer such as realized in $Nd_{1-x}Sr_xNiO_2$ [4] where superconductivity was discovered. The model takes into account anisotropic nickel-oxygen $d-p$ and oxygen-oxygen $p-p$ hopping processes, complicated crystal-field splittings, the on-site Coulomb repulsions and Hund's exchange tensors both at nickel and at oxygen ions. We investigate periodic boundary Ni−O clusters (4×4 and 8×8 NiO_2 units) with these interactions treated in the Hartree-Fock approximation [4]. The valence electron number n (per NiO_2 unit) is assumed to be approximately $n=21-x$ (due to surrounding Nd^{3+} and Sr^{2+} ions). Electronic structure of the layer is investigated for $x=0$, 0.125, 0.25 and 0.5. For ideal undoped system $NdNiO_2$ (no Sr admixture) we get strong insulator with degenerate ground state—both nonmagnetic, and magnetic (ferromagnetic, C-type and G-type antiferromagnetic) have all the same energy. However, for nonzero self-dopings x the system becomes conducting (zero HOMO-LUMO gap), also with quasi-degenerate ground state due to numerous competing magnetic metastable states. (Possibilities of getting locally triplet states at Ni ions are also investigated, similarly as in [5]). These findings correlate well with experimental data and with other theoretical predictions available in the literature.

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Magnetic susceptibility anisotropy of epitaxial films $Nd_{2-x}Ce_xCuO_4/SrTiO_3$

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The magnetic susceptibility in the high-quality epitaxial films $Nd_{2-x}Ce_xCuO_4/SrTiO_3$ without annealing in underdoped region ($x = 0.135$, 0.145) and after annealing in overdoped region ($x = 0.18$) with different orientation of the c-axis was investigated. The electron doping is generated by replacing the Nd^{3+} ions in the parent compound Nd_2CuO_4 with Ce^{4+} to form a non-superconducting antiferromagnet $Nd_{2-x}Ce_xCuO_{4+\delta}$. Additional annealing in oxygen-free atmosphere leads to suppress the static antiferromagnetic order and to appearance of the superconductivity. The strong anisotropic behavior of the magnetic susceptibility versus external magnetic field $\chi \parallel (H)$ and $\chi \perp (H)$ at $H < 10$ kOe and highly anisotropic temperature dependencies of the magnetic susceptibility $\chi \parallel (H)$ and $\chi \perp (H)$ at low magnetic field $H = 100$ Oe is associated with different magnetic ordering of Nd^{3+} (Ce^{4+}) rare earth magnetic ions and copper ions at different orientations of the external magnetic field with respect to the conducting planes of CuO_2.The presence of the residual short ranged antiferromagnetic ordering of copper ions even in the over doping region leads to magnetic anisotropy in the conducting planes. Effects of Nd moment are included particularly in the low temperature regions [1].

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The application of unsupervised learning to the AC susceptibility data of High-Temperature Superconductors

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This work gives an insight if clustering technique applied to the dataset consisting of about 1000 measurements of High-Temperature Superconductors using the AC susceptibility method, will allow to recover known and unknown relationships (features) between different types of high-temperature superconductors and their superconducting properties, which depend on type of superconductor, sample preparation method and sample preparation conditions like sintering and annealing. The dataset was simplified by using a Convolutional Autoencoder and the Bag of Words (BOW) representation. The k-means and DBSCAN (Density-based spatial clustering of applications with noise) methods were used for clustering. The obtained results were visualised by the t-SNE algorithm (t-Distributed Stochastic Neighbor Embedding). As a result, a single AC vs temperature measurement is represented by only five numeric values.

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Estimation of Critical Temperature of High- Temperature Superconductors using machine learning approach

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The critical temperature T_c of a High-Temperature Superconductor (HTS) is often the most significant parameter of a prepared HTS sample. The T_c value can be estimated from magnetoresistance and AC susceptibility vs temperature measurements. Estimation of T_c is a time-consuming task. This task is also hard in cases when significant noise is present or unphysical contributions from laboratory equipment are apparent in a measurement. To deal with these issues we developed a method of estimation of critical temperature T_c using a machine learning approach. Our algorithm utilises one artificial neural network (ANN) for finding a relevant part of measurement for T_c estimation task based on the shape of the measurement. The second ANN estimates T_c using the regression technique. The ANNs were trained on a dataset consisting of more than 1000 AC susceptibility vs temperature measurements. The performance of the algorithm is shown and compared to a standard approach. Our solution can be extended for finding other parameters, which are derived from the shape of a measurement curve.

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Superconductivity in calcium-decorated hexagonal boron nitride monolayer

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In the present communication, we study the most important thermodynamic properties of novel calcium-decorated h-BN monolayer in the phonon-mediated superconducting state [1]. The analysis is motivated by the fact that the discussed material exhibits the highest superconducting critical temperature among alkali-doped h-BN structures, which is well above the temperature of liquid helium. The presented investigations of the thermodynamic properties are performed within the Eliashberg formalism [2], according to the expected strong-coupling character of the considered superconducting state. In particular, we calculate the thermodynamic properties of the superconducting state that allows us to quantitatively determine values of the characteristic dimensionless parameters i.e. the zero-temperature energy gap to the critical temperature, the ratio for the specific heat, as well as the ratio corresponding to the zero-temperature magnetic critical field. The obtained result are expected to provide interesting contribution toward further development of the two-dimensional hexagonal superconductors aimed at relatively high critical temperatures [3].

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Critical temperatures of the model of hard-core bosons on a square lattice in the Bethe approximation

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We consider the inclusion of short-range correlations for a two-dimensional model of hard-core bosons[1] on a square lattice within the Bethe approximation for clusters of 2 and 4 sites. Hamiltonian of the model of hard-core bosons has the following form:

$$\mathcal{H} = -t \sum_{\langle i,j \rangle} \left(b_i^+ b_j + b_j^+ b_i \right) + V \sum_{\langle i,j \rangle} n_i n_j - \mu \sum_i n_i, \tag{2}$$

where $b^+, (b)$ - hard-core boson creation (annihilation) operators, $n_i = b_i^+ b_i$ - operator of the number of hard-core bosons at a site, t and V - transfer integral and parameter of charge-charge correlations between nearest neighbors, μ - chemical potential required to take into account the condition of constant boson concentration.

We obtain explicit equations for the critical temperatures of charge and superfluid ordering for 2- and 4-site Bethe clusters and explore their solutions for various V/t ratios.

It is shown that the short-range correlations lead to the appearance of a critical concentration of bosons, limiting the region of existence of charge-ordered phase. For superfluid ordering, taking into account short-range correlations reduces the critical temperature to zero values at half filling.

The phase diagram of the model is constructed with allowance for phase separation, and it is shown that taking into account short-range correlations within the Bethe approximation quantitatively approximates the form of the phase diagram to the results of the quantum Monte Carlo[2].

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Magnetic phase transition in multiferroic $Sr_{1-x}Ba_xMn_{1-y}Ti_yO_3$ (with $x \geq 0.43$ and $y \geq 0$) system - specific heat studies

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The $Sr_{1-x}Ba_xMn_{1-y}Ti_yO_3$ multiferroics are the subject of intensive research, because in them, the same Mn ions are responsible for both the antiferromagnetic and the ferroelectric ordering. Thus, a strong coupling between electric and magnetic order parameters can be expected. The specific heat studies were performed for a series of ceramic samples differing in Ti and Ba content, over the temperature range 2 – 395 K, in magnetic field up to 5 T. The magnetic contribution was determined by extracting the lattice contribution (estimated by mixing the Debye and Einstein models) from the total specific heat measured and it was analyzed carefully. It was found that for majority of the studied compositions, the anomaly accompanying the magnetic phase transition is symmetric and a small thermal hysteresis of its appearance on heating and on cooling the sample is observed. This evidences the 1st order character of this transition. This effect was interpreted as the result of a strong coupling between the electric and magnetic degrees of freedom (a large change of electric polarization at the magnetic transition was reported in [1]). Specific heat anomalies were approximated by the Lorentz functions and the latent heat related to the magnetic transitions was assessed.

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Competing Kondo and RKKY interactions at the presence of crystal field effects in the compound $CeSi_{1.2}Ga_{0.8}$

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We present the thermoelectric power, electrical and thermal conductivity, magnetic and specific heat measurements for the intermetallic compound $CeSi_{1.2}Ga_{0.8}$. This composition belongs to the series $CeSi_{2-x}Ga_x$, which exhibits divers ground states and different crystallographic structures depending on the substitution level x [1-4]. It has been previously suggested that for $0.0<x<1.3$ the compounds crystallize in the α-$ThSi_2$ type structure and for $0.7<x<1.3$ [1,2] they order ferromagnetically [3,4]. Our complementary studies for $x = 0.8$ reveal that it is a complex system due to the Kondo scattering competing with the RKKY interactions. Moreover, the Seebeck coefficient shows not only an anomaly related to the magnetic transition, but also a wide maximum at about 100 K related to the crystal field effect. The case of $x = 0.8$, which has not been studied previously, is of special interest as it is at the crossing of the characteristic temperatures, i.e. $T_{\mathrm{ord}} \approx T_{\mathrm{K}} \approx 10$ K [4]. We provide the analysis of the temperature dependence of the Seebeck coefficient and electrical resistivity within the two band model, moreover the influence of the crystal electric field on the characteristic energy scales is also discussed. Our analysis of the magnetic field dependence of the specific heat and magnetization indicates that the magnetic order is not ferromagnetic but rather ferrimagnetic due to the evident presence of an antiparallel magnetization component.

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Impurity band features formed by Mn in InSb

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It has been shown that transport and magnetic properties of the impurity band formed in InSb by nonmagnetic (Ge) and magnetic (Mn) acceptors radically differ within metal−insulator transition (MIT) at temperature below 4K on the insulator side of MIT while the critical concentration of MIT (N_c=$2 * 10^{17} cm^{-3}$) is the same both in InSb(Ge) and InSb(Mn) crystals [1,2]. These findings were unexpected if we take into account the fact that both acceptors demonstrate the equal acceptor activation energy value E_c=9meV. The revealed in experiments Colossal Magnetoresistance, the Anomalouse Hall effect and especially uniaxial stress effects can be the evidence that Jahn−Teller distortions caused by Mn ions are responsible for the unusual magnetotransport and magnetic p−InSb(Mn) properties. Here, from the Hall constant and conductivity studies performed over the temperature range 0,3−280K, in the magnetic field up to 10 T for p−InSb(Mn) samples with $N_{Mn} = 5 * 10^{16}$-$2 * 10^{17} cm^{-3}$ it was revealed that inside the forbidden gap of InSb (E_g=0,23eV) the impurity band forms supernarrow gap semiconductor with the energy gap from 0 to 1meV depending on manganese concentration. In contrast to high mobility electrons in InSb ($1,5 * 10^4 cm^2/Vsec$) both the mobility of electrons and holes in impurity band did not exceed $10 cm^2/Vsec$. At $N_{Mn} > 2 * 10^{17} cm^{-3}$ the metal type conductivity and at $N_{Mn} < 5 * 10^{16} cm^{-3}$ the hopping type conductivity were observed. Thus, the formation of internal gap in impurity band is possible despite random distribution of manganese impurity in InSb single crystal.

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Interplay of excitonic correlations with quantum spin hall effect and superconductivity

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It has been proposed that in band-inverted electron-hole bilayers the excitonic correlations arising due to Coulomb interactions lead to phase transitions from a trivial insulator phase to an insulating phase with a spontaneously broken time-reversal symmtery and finally to a non-trivial quantum spin hall insulator phase as a function of increasing electron and hole densities. Importantly, in contrast to the standard paradigm of topological phase transitions,the trivial insulator phase is connected to a quantum spin Hall insulator without an energy gap closing appearing in the fermionic spectrum. Here, we show that it is possible to realize Majorana Zero Modes (MZMs) in the time-reversal symmetry broken phase in the presence of proximity-induced superconductivity in the absence of magnetic field. We demonstrate that the Majorana zero modes can be detected in superconductor/time-reversal symmetry broken insulator/superconductor Josephson junctions through the measurement of a 4π Josephson current. For a better understanding of our numerical results, we develop an effective low-energy theory in the presence of time-reversal symmetry breaking order parameter and obtain analytically the Majorana zero modes and the Andreev bound states localized at the junction using a scattering-matrix formalism. We find a good agreement between the numerical and analytical results in the limit of weakly-broken time-reversal symmetry.

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The metal-induced gap states localization and superconducting qubit decoherence at low-dimensions

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In the present communication we report studies on the local properties of the metal-induced gap states (MIGSs) that may become localized at the low-dimensional Josephson junctions, cause magnetic flux noise and consequently lead to the decoherence of the corresponding qubit modalities. These investigations follow similar earlier bulk considerations [1, 2], toward disambiguation of the decoherence effect and the validation of its universal character. Herein, the theoretical analysis is conducted within the complex band structure method [3, 4] for an arbitrary low-dimensional junctions, to arrive with the most fundamental and general observations, respectively. Specifically, the presented communication discusses in details the behavior of the MIGSs in the momentum space, with respect to the potential fluctuations at the junctions and under moderate electron-electron interactions. Such assumption allow us to conduct our analysis in agreement with the seminal proposal of Choi et al. [1], that relates magnetic flux noise to the MIGSs localization. In what follows, this study attempts to provide direct relationship between the MIGSs behavior, known aspects of the superconducting qubit decoherence and the intrinsic properties of the low-dimensional Josephson junction. As a results, the general trends in terms of the superconducting qubit decoherence at low-dimensions are expected, to simultaneously reinforce plausibility of the previous related studies.

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Competing orders in a frustrated Heisenberg model on decorated square lattice

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We have investigated the classical ground states in two dimensional decorated square lattice (which is a square-octagonal dual lattice, structurally equivalent to CaV_4O_9 and can be realized in a two dimensional cut in a hollandite lattice) analytically, followed by a confirmation by a classical monte carlo study where we obtained the phase diagram considering three different types of Heisenberg couplings J_1, J_2 and J_3. We have obtained three different phases in the frustrated regime. First one is uncorrelated AFM chain phase with infinitely degenerate ground state where there is no long range order. In this phase we have investigated the role of thermal and quantum fluctuations in fixing the degeneracy. Without considering the role of fluctuations, noncollinear ground states can exist in this phase. But the consideration of the fluctuation terms in the free energy favours for collinear spin orientation in this phase. But still there is no long range order. However the degeneracy reduced to 2^N where N is total number of vertical and horizontal chains. The other phases are Neel phase and sublattice Neel phase where in the sublattice Neel phase, individual sublattices form the neel order. We have also studied magnon excitation in all the phases. In the Neel phase the excitation spectrum consists of two band crossings which form two non-trivial Dirac nodal loops which remain protected by symmetry. Along with these two nodal loops for every choice of J_2 there will be a value of J_3 for which we can observe an another nodal loop along the zone boundary which is not protected by any symmetry and will be gaped out for other choices of $(J_2/J_1, J_3/J_1)$. Sublattice Neel phase also consists of symmetry protected band crossing at all the high symmetry points. We have also studied the valance bond solid, Plaquette RVB phases using mean field theory. The minimization of ground state energy favours three different regions of parameter space, which we have considered, for three phases (plaquette-RVB, VBS-1 and VBS-2). The triplon excitations consist of gap through out the parameter space which has confirmed stability of these phases.

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The influence of a further-neighbour spin-spin interaction on a rotating magnetoelectric effect in a spin-electron model with a doubly decorated square lattice

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Exact analytical calculations have been used to study the influence of a further-neighbour spin-spin interaction on a rotating magnetoelectric effect in a hybrid spin-electron model on a doubly-decorated square lattice. The special attention has been focused on a ground-state analysis and a thermal behaviour at a quarter- and a half-filled case. It was found that the competition between the non-zero spin-spin interaction, electron hopping and applied electric field gives rise to novel spatially (an)isotropic magnetic states, whose frontiers are influenced by a spatial orientation of an applied electric field. It is shown that the thermal stability of spontaneous long-range order can be enhanced by a rotating magnetoelectric effect, which may result in an enhancement of the critical temperature. The further-neighbour spin-spin interaction may cause a striking magnetic reentrance with either two or three consecutive critical points for both studied electron fillings.

Magnetic suscetibility studies of the $(Cr_{84}Re_{16})_{100-x}V_x$ alloy system

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The temperature dependence of magnetic susceptibility, $\chi(T)$ is a suitable measurement in determining the magnetic ordering temperature, obtaining information regarding density of states [1], as well as to detect the presence of localised moments [2]. In accordance with previous studies on $Cr_{100-u}Re_u$ alloys [3], $\chi(T)$ measurements of the $(Cr_{84}Re_{16})_{100-x}V_x$ alloy system exhibit anomalies at Néel temperature T_N associated with the onset of the antiferromagnetic (AF) spin-density-wave (SDW) state. These anomalies become more pronounced as x increases. T_N determined from $\chi(T)$ measurements are in close agreement with T_N obtained from the measurement of temperature dependence of electrical resistivity, $\rho(T)$. Prominent broad deep minima are observed in $\chi(T)$ upon cooling below 100 K followed by low temperature upturns for samples with $x = 10.9$ and $x = 12.4$ which may be attributed to a Curie tail arising from oxide impurities [4]. A second anomaly, not associated with T_N, but having the same trend, is observed at a temperature $T_o < T_N$ for alloys with $x = 0$, 1.3, 2.4, 4.4, 5.7 and 6.9. T_o observed in the $x = 0$ alloy has value 309 $\pm$ 2 K which is very close to 308 K, the transition temperature of AF Cr_2O_3 [5]. The presence of Cr_2O_3 was confirmed using neutron diffraction study of the $Cr_{84.7}Re_{15.3}$ alloy [6]. However, the value of T_o obtained from $\chi(T)$ decreases with an increase in x indicating that the oxide is most likely a V doped oxide of Cr having the formula $(Cr_{100-\delta}V_\delta)_2O_3$. x dependence of T_N obtained from $\rho(T)$ and $\chi(T)$ measurements were fitted with a power law yielding $x_c = 10.47 \pm 0.03$, the critical concentration at which antiferromagnetism (AFM) disappears. It is therefore evident that the low temperature upturns for samples with $x = 10.9$ and $x = 12.4$ is associated with the $(Cr_{100-\delta}V_\delta)_2O_3$ oxide. Curie-Weiss (CW) behaviour in the $(Cr_{84}Re_{16})_{100-x}V_x$ alloy system was tested by plotting χ^{-1} as a function of T and fitting the CW equation [2] to the experimental data above T_N. A positive gradient of the fit confirms CW behaviour [7] which was observed in the $x = 5.7$, 10.4, 10.9 and 12.4 alloys suggesting the existence of local moments at $T > T_N$.

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Thermodynamic features of the 1D dilute Ising model in the external magnetic field

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The dilute Ising model is one of the basic models in the theory of magnetic systems with quenched or annealed disorder [1]. Despite the absence of ordering at finite temperatures, one-dimensional spin systems exhibit a number of interesting phenomena such as magnetization plateaus, pseudophases, and pseudo-transitions. Previously, we considered the features of local distributions in our model [2]. In this work we show the behavior of the system in a magnetic field.

We use the $S = 1$ pseudospin formalism to describe our system. For a given lattice site, the states with the pseudospin projections $S_z = \pm 1$ correspond to the two magnetic states with the conventional spin projections $s_z = \pm 1/2$. The state with $S_z = 0$ corresponds to charged nonmagnetic state. The Hamiltonian of the system is

$$H = -J \sum_i S_{z,i} S_{z,i+1} + V \sum_i P_{0,i} P_{0,i+1} - h \sum_i S_{z,i} - \mu \sum_i P_{0,i}, \qquad (3)$$

where $S_{z,i}$ is a z-projection of the on-site pseudospin operator, $P_{0,i} = 1 - S_{z,i}^2$ is the projection operator on $S_z = 0$ state, J is the exchange constant, V is the intersite density-density interaction, h is the external magnetic field, μ is the chemical potential.

We use the transfer-matrix method applied to Hamiltonian (1) to explore the ground state and the evolution of our system with the temperature. We get the dependences of thermodynamic quantities on temperature and concentration of impurities, which allow us to calculate the entropy change in the applied magnetic field. We explore the ground state diagram of the system in the external magnetic field and the magnetic entropy change caused by the frustration in the ground state.

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The influence of double-exchange and Heisenberg interaction on the magnetization processes in rare-earth tetraborides

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We present a complex model for a description of magnetization processes in rare-earth tetraborides. The model is based on the coexistence of two subsystems, and namely, the spin subsystem described by the XXZ Heisenberg model and the electronic subsystem described by the generalized Hubbard model on the Shastry-Sutherland lattice. Moreover, both subsystems are coupled locally by the anisotropic double-exchange interaction, which besides the usual J_z term of the Ising type takes into account also the J_{xy} term representing the spin-flip processes. The model is solved numerically using the Lanczos/truncated Lanczos method and the special attention is paid on a description of individual and combined effects of the double-exchange interaction J_{xy} and the Heisenberg J'_{xy} interaction on the stabilization of magnetization plateaus with fractional magnetization. We have found that the J_{xy} and J'_{xy} interaction terms exhibit fully opposite effects on the stability of the main 1/2 and 1/3 plateau phases. While the J_{xy} interaction destroys the 1/2 plateau and stabilizes the 1/3 plateau, the $J'xy$ interaction stabilizes the 1/2 plateau and destroys the 1/3 plateau. Combined effects of both terms lead to several different scenarios, but for physically the most interesting case, J_{xy} and J'_{xy} small (corresponding to the real situation in rare earth tetraborides) we observe a significant suppression of the 1/3 plateau and the stabilization of 1/2 plateau in accordance with experimental measurements in these materials.

Slow Magnetic Relaxation in a S=1/2 copper-based mononuclear complexes

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We have studied the spin dynamics in complexes $Cu(abpt)_2(dca)_2$ and $\{Cu(abpt)_2(dca)_2\}_{0.5}\{Cu(abpt)_2(H_2O)_2(NO_3)_2\}_{0.5}$ (abpt = 4-amino-3,5-di-2-pyridyl-4H-1,2,4-triazole, dca = dicyanamide), which consist of isolated molecules with spin $S = \frac{1}{2}$ with a small antiferromagnetic exchange interaction of -0.4 K.

Measurements of AC susceptibility in the range 0.1–2 T suggest the presence of field-induced slow magnetic relaxation in the copper complexes similar to single-ion magnets [1]. The field and temperature dependence of the relaxation time τ were extracted from Cole-Cole diagrams. An increase of the relaxation time was observed with the increasing magnetic field up to 1 T followed by its decrease. Such slowing down of the relaxation up to magnetic fields even 3 T was observed in V(IV)-based complexed [2], above which a direct process dominates and the relaxation is accelerated. Subsequently, AC susceptibility was measured over a wide range of temperatures to determine the dynamic properties of the compounds. The magnetic relaxation characteristics obtained in the compound under study indicate an interesting example of the slow magnetic relaxation, where the temperature dependence of the one-phonon direct relaxation process is renormalized under the influence of the phonon-bottleneck (PB) effect.The study of the field dependence and temperature dependence of the sample for different crystallite size allowed to elucidate the origin of the PB effect to be due to the thermal contact between the sample and its surroundings, so-called spatial PB effect. A possibility to suppress the observed PB effect gives the opportunity to extract also the typical frequency of the phonons participating in the Raman process, which is effective at higher temperatures.

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Phase diagram of spin-1 condensate with quadrupole degrees of freedom in a magnetic field

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We obtain and justify a many-body Hamiltonian of pairwise interacting spin-1 atoms, which includes eight generators of the SU(3) group associated with spin and quadrupole degrees of freedom. It is shown that this Hamiltonian is valid for non-local interaction potential, whereas for local interaction specified by s-wave scattering length, the Hamiltonian should be bilinear in spin operators only (of the Heisenberg type). We apply the obtained Hamiltonian to study the ground-state properties and single-particle excitations of a weakly interacting gas of spin-1 atoms with Bose-Einstein condensate taking into account the quadrupole degrees of freedom [1]. It is shown that the system under consideration can be in ferromagnetic, quadrupolar, and paramagnetic phases. The corresponding phase diagram is constructed. The main characteristics such as the density of the grand thermodynamic potential, condensate density, and single-particle excitation spectra modified by quadrupole degrees of freedom are determined for different phases.

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The effect of an uniaxial single-ion anisotropy on the quantum and thermal entanglement of a mixed spin-(1/2,S) Heisenberg dimer

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An exact analytical diagonalization method is used to study the quantum and thermal entanglement of the antiferromagnetic spin-(1/2,S) Heisenberg dimer with the help of a concept the negativity. Under the assumption of non-zero uniaxial single-ion anisotropy affecting the higher spin-S ($S>1/2$) entities only, the ground-state degeneracy $2S$ is partially lift and the ground-state is two-fold degenerate with the total magnetization per dimer $S-1/2$ ($1/2-(2S \mod 2)/2$) for the easy-axis (easy-plane) anisotropic single-ion anisotropy. It is shown that the maximal quantum entanglement is reached for the antiferromagnetic ground state of a mixed spin-(1/2, S) Heisenberg dimer with an arbitrary non-integer spin-S atom, regardless of the easy-plane single-ion anisotropy. Contrary to this, the degree of a quantum entanglement in a mixed spin-(1/2,S) Heisenberg dimer with an integer spin-S atom for the easy-plane single-ion anisotropy, exhibits a decreasing tendency with an obvious spin-S driven crossing point. It is furthermore shown that the increasing spin-S magnitude is a crucial driving mechanism for an enlargement of a threshold temperature above which the thermal entanglement vanishes. As a result, the easy-plane single-ion anisotropy together with an enlargement of the spin-S magnitude, is other significant driving mechanism for an enhancement of a degree of the thermal entanglement in a mixed spin-(1/2,S) Heisenberg dimer.

Magnetocaloric effect in alternating-spin Cu(II)/Mn(II)-based complexes

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Magneto-thermal properties of alternating-spin (1/2-5/2) coordination complexes with a general formula $Cu(L)_iMnCl_4$, where $i = 2$ for L = men, bmen, and dmen, and $i = 1$ for L = dac, dpc (men = N–methyl–1,2–diaminoethane, bmen = N,N'–dimethylethylenediamine, dmen = N,N-dimethylethylenediamine, dac = 1,8-diallyl-1,4,8,11-tetraazacyclotetradecane, dpc - 1,8-dipropyl-1,4,8,11-tetraazacyclotetradecane). The structure of the compounds consists of covalent chains with alternating Cu(II) and Mn(II) ions for L = men and bmen, while covalent Cu(II)-Mn(II) dimers for L = dmen, dac, and dpc are formed. Measurements of magnetic susceptibility revealed the presence of a long-range order (LRO) in the complexes with L = bmen and dmen at ≈45 K. For complexes with L = men and dpc the LRO appears at 1.6 K and 3 K, respectively. A magnetocaloric effect was studied by the measurement of isothermal magnetization curves and the maximum change of the magnetic entropy during isothermal magnetization of the system was obtained close to 1.8 K for all complexes despite the magnetic ordering observed at much higher temperature in some of the studied complexes. Very high value $-\Delta S_M = 37$ JK^{-1}kg^{-1} at ΔB = 5 T was estimated for complex with L = bmen, which is even higher than for some spin clusters with high-spin Mn(II) ions only [1]. The analysis of the n exponent of $-\Delta S_M \sim B^n$ dependence close to the LRO temperature gives an insight into the critical behavior of the spin system [2,3].

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Galois symmetry of energy levels of the XXX model for the case of octagonal two-magnon states on the generic star of quasimomentum

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We consider the factor v of the characteristic polynomial $w^H(x)$ of the Heisenberg Hamiltonian $\hat{H}$ of the XXX model, corresponding to the generic star $\{k = \pm 1, \pm 3\}$ of quasimomentum k for octagonal ($N = 8$) magnetic ring in the two-magnon sector. This factor is recognized as the fourth degree polynomial with integer coefficients, indecomposable over the prime number field $\mathbb{Q}$ of rationals. We demonstrate the physical meaning of the corresponding Galois group as the group of permutations of eigenenergies between the quasimomenta entering the generic star of the Brillouin zone of octagon. In particular, we point out the role of intersection of this group with Galois group of the cyclotomic field, responsible for the translational symmetry of octagon. Bound and scattered two-magnon eigenstates are identified by their spectra.

Finite-size scaling at a topological quantum phase transition

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At quantum phase transition (QPT) properties of the ground state of the quantum system change drastically due to quantum fluctuations which are most clearly pronounced at zero temperature. Although many approaches have been proposed to examine QPTs, to locate critical points and to calculate values of critical exponents, an important question still remains: *Is it possible to explore the critical behavior of a system at QPT by examining the change of its ground state* $|\Psi_0\rangle$ *in a critical region, especially when there is no possibility to identify an order parameter nor to establish a pattern related to symmetry breaking?* Still, there exists a quest for new approaches, based on scaling and renormalization to search and characterize QPTs. We propose such an approach based on a topological charge Finite Size Scaling. We start by defining the topological charge: $\eta_T = \langle\Psi_0|W|\Psi_0\rangle/L$, with W being winding number and L - system size, respectively. Subsequently, the well-known quantum phase transition in the ground state of an antiferromagnetic spin-$\frac{1}{2}$ Heisenberg chain with nearest and next-nearest-neighbor interactions is re-investigated from this perspective. Finite Size Scaling of $\langle\Psi_0|W|\Psi_0\rangle$, $\langle\Psi_0|W|\partial_\lambda\Psi_0\rangle$, $\langle\partial_\lambda\Psi_0|W|\partial_\lambda\Psi_0\rangle$ leads to the accurate value of critical coupling $\lambda_c = 0.2412 \pm 0.0007$ and to the value of subleading critical exponent $\nu = 2.000 \pm 0.001$.

Generalized Heisenberg-Type Magnetic Phenomena in Nickel-Lanthanide Dinuclear Units Assembled in Coordination Polymers by Dicyanomide Ligands

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A new family of $3d$-$4f$ coordination polymers containing the dimeric units Ni^{2+}-Ln^{3+}, where the lanthanides Ln = Eu (**1**), Gd (**2**), Tb (**3**), Dy (**4**), Ho (**5**), has been synthesized in a current search for new single-molecule magnet (SMM) materials [1]. Its magnetic properties have been established by DC and AC magnetometry and explained quantitatively by comprehensive phenomenological modelling. Single-crystal X-ray diffraction study has shown that the lanthanide atoms occupy a nine-coordination site with Muffin-like geometry and individual Ni^{II}-Ln^{III} units are linked by dicyanamide anions. Beside paramagnetic compound **1**, **2**-**5** exhibit intra-unit ferromagnetic $3d$-$4f$ interactions favourable for a large spin ground state. Due to the easy-plane anisotropy driven energy structure that is unpropitious for the SMM behaviour, a slow field-induced relaxation of magnetization has been observed only in compound **4**. However, a substantial energy barrier U_{eff}/k_B = 26.2 K against spin reversal has been established below 6 K and experimental support for the scenario of the relaxation phenomenon in systems with the Kramers ground state doublet and hyper-fine interactions has been provided. The materials studied provide excellent test-beds for validation of generalized Heisenberg-type model as a tool to simulate the $3d$-$4f$ complexes that was hypothesized in a pioneering DFT approach [2].

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Effect of proton irradiation on magnetic properties of two-dimensional Ni(II) molecular magnet

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The broad capability of the molecular magnetic materials emerges from the variety of available systems with unique properties that can be altered by external stimuli such as temperature, pressure, light irradiation, or sorption of guest molecules. Although not popular in the field of molecular magnetism, ion irradiation is the other approach for tailoring the material's parameters. Energetic particles expose solids to the high-density local energy deposition, leading to non-linear and threshold effects that may create new materials with novel properties.

In particular, the irradiation-induced defects may give rise to the magnetism in initially non-magnetic materials and modify the magnetic properties of a system with a non-zero magnetic moment, especially when strong magneto-structural correlations are present. The studies of the response of thin films and bulk samples to ion irradiation show there is a possibility to alternate such parameters as the critical temperature, g-factor, or coercivity by energetic particles deposition. However, no systematic studies can be found regarding the effects of ion irradiation on molecular magnetic materials.

Here we examine the magnetic properties of 2D coordination polymer based on nickel sulfate and a 1,3-phenylenediamine ligand that was irradiated with 1.9 MeV protons using fluences ranging from $5 \cdot 10^{13}$ p $\cdot$ cm^{-2} to $2 \cdot 10^{15}$ p $\cdot$ cm^{-2}. The samples irradiated with the high fluence showed an increase in magnetization saturation up to 200 percent and the reduced coercive field to even 10 percent of the reference level. Simultaneously, the critical temperature remained the same ($T_c = 24.5$ K) regardless of the received radiation dose. The IR spectroscopy showed that the overall structure of the studied compound was preserved after proton irradiation, and only minor changes are present in the local structure.

Signature of field-induced spin ice state and evolution of structural and magnetic phase on La substitution in disordered pyrochlore oxide Dy_2Zr2O_7

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$Dy_2Zr_2O_7$ exhibits $Dy_2Ti_2O_7$ type high temperature magnetic field induced spin freezing near $\sim$ 10 K in ac susceptibility measurements [1]. The magnetic heat capacity of $Dy_2Zr_2O_7$ shows a correlation peak at 2 K, but no residual entropy was observed. The low-temperature magnetic entropy at 5 kOe field is R[ln2 - 1/2ln(3/2)] which is the same as for the spin ice state. Substitution of non-magnetic, isovalent La^{3+} for Dy^{3+} gradually induces the structural change from highly disordered fluorite to stable pyrochlore phase through a biphasic mixture of both. We observed that the higher La compositions ($1.5 \leq x \leq 1.9$), show spin freezing ($T \sim 17$ K) similar to the field induced spin ice freezing for low La compositions ($0 \leq x \leq 0.5$), and the well-known spin ice systems $Dy_2Ti_2O_7$ and $Ho_2Ti_2O_7$. The low temperature magnetic state for higher La compositions ($1.5 \leq x \leq 1.9$) culminates into spin glass state below 6 K. The Cole-Cole plot and Casimir-du Pré fit shows narrow distribution of spin relaxation time in these compounds.

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Magnetic investigations of a single crystal of spin chain

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The large single crystal of $[Co(NCS)_2(4\text{-}(3\text{-phenylpropyl})pyridine)_2]_n$ chain coordination polymer was synthesized. Its magnetic properties prove an almost Ising-type magnetic anisotropy with a magnetic easy axis nearly along Co-N_{ligand} bond, as predicted by single-ion *ab initio* calculations. Contrary to the powder sample [1], for the single crystal, two different magnetic relaxation processes are observed. Despite the system is ferromagnetically ordered (T_c = 3.39 K), one of the processes displays a crossover of relaxation time, indicating single-chain magnet (SCM) behavior. Dominant close to T_c, the second, faster process is assigned to spin-wave excitations. The origin of SCM relaxation was explained based on micromagnetic Monte Carlo simulations. They revealed that only chains at the borders of 3-dimensional domains for which the dipolar field cancels have their contribution to the ac magnetic susceptibility. To support the investigations of the SCM behavior, a magnetically diluted counterpart $[Co_xCd_{1-x}(NCS)_2(4\text{-}(3\text{-phenylpropyl})pyridine)_2]_n$ (x = 0.013) was used. It behaves as a single-ion magnet and its pathways of relaxation of single Co(II) spins are Raman, direct, and quantum tunneling processes. These processes were taken into account in the improved approach of the analysis of the SCM relaxation in $[Co(NCS)_2(4\text{-}(3\text{-phenylpropyl})pyridine)_2]_n$.

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Non-chiral spin frustration versus local unfrustrated spin chirality in an exactly solvable spin-electron planar model of inter-connected trigonal bipyramids

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In this work, an interplay between a non-chiral spin frustration and unfrustrated spin arrangement with sings of local chirality in a mixed spin-electron model on a regular two-dimensional lattice constituted of identical inter-connected bipyramidal units is rigorously examined within the dos Santos and Lyra's concept of the spin frustration [1]. The model is designed to belong to a class of bond-decorated lattices, which are exactly solvable by means of the decoration-iteration mapping transformation [2]: the common vertices of the plaquettes are occupied by the Ising spins of the magnitude 1/2, the rest ones, forming triangular clusters oriented perpendicularly to plaquette's axes, are available for mobile electrons (each cluster for 2 electrons), and the exchange interactions merely between the nearest lattice sites are allowed.
The analysis of obtained numerical results shows that the ground-state phase diagram of the considered spin-electron model contains two different macroscopically degenerate quantum phases, namely the spontaneously ordered ferro- or ferrimagnetic phase (FM) with signs of local chirality (left- and right-handed) in each one-third-filled electron triangle and the disordered frustrated (FRU) one. While the sponateously ordered FM phase is completely unfrustrated, both the Ising and electron sub-lattices are frustrated within the FRU phase. Specifically, the Ising spins at nodal lattice sites are completely free to flip between up and down states, while the electron pairs delocalized over triangular cluster of each bipyramidal unit underlie a quantum superposition of six intrinsic antiferromagnetic and three non-magnetic ionic states, which implies the spin frustration of the electron sub-lattice in terms of dos Santos and Lyra's concept [2]. The observed non-chiral spin frustration in electron sub-lattice and the spontaneous arrangement ordering with local chiral features persist also at finite temperatures. Of course, both they are gradually vanishing with increasing temperature. The spin frustration of mobile electrons is always completely suppressed by strong thermal fluctuations after exceeding a certain frustration temperature. The reverse trend can be observed only near the ground state boundary FM–FRU. In this region, up to three consecutive frustration temperatures indicating the thermally induced destruction, re-creation and definitive destruction of the non-chiral spin frustration in electron sub-lattice can be found.

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Spin-Wave Transport in Lateral Arrays of Magnonic Structures

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The traditional approach in semiconductor microelectronics is based on the use of a charge of current carriers, at the same time, the use of elementary quanta of magnetic excitations and spin waves as carriers of information signals allows the creation of a new generation of electronic devices - magnonics, reducing the magnitude of thermal fission and size, as well as increasing their functionality [1]. Magnonics devices have advanced capabilities due to the control of the properties of spin waves through various influences (for example, changes in the external magnetic field, electric field, heating, etc.), in contrast to vacuum and semiconductor microwave devices. It should be noted that magnon devices can easily be combined with a sufficiently large number of semiconductor integrated technologies. The use of multilayer magnetic microstructures based on films of yttrium iron garnet having a record low damping of spin waves seems to be important for the development of basic elements of magnonics and their formation in the so-called "magnonic networks" [2-3].

Using numerical studies based on the finite element method and micromagnetic simulation, we studied the propagation dynamics of surface magneto-static waves in a system of lateral YIG waveguides.

Structure is consisting of parallel-oriented magnetic stripes obtained using the laser scribing method from a YIG film 10 μm thick located on a gallium-gadolinium garnet substrate. The distance between magnetic microwaves is 40 μm. The length along the long side of the waveguides was 8 mm. Spin waves were excited using a microstrip antenna 1 μm thick and 30 μm wide. The structure is placed in an external static magnetic field, $H = 1200$ Oe, changing at an angle ϕ.

To demonstrate the control modes of the intensity of the spin-wave signal with a change in the magnetization angle, a numerical simulation was performed based on the solution of the Landau – Lifshitz equation.

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Influence of the demagnetizing field on the spin-wave softening in bicomponent magnonic crystals

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In bi-component magnonic crystals (MCs) demagnetizing field occurs around interfaces between a matrix and inclusions. As it is already shown this field strongly influences the spin-wave spectrum including the position and the width of band gaps and their response to the change of the external magnetic field [1, 2]. Here, we show its effect on the reversal of the mode order in the spectrum. The reversal of modes means that the modes which are excited mostly in the material with higher saturation magnetization have lowest frequencies then modes excited in the material with low saturation magnetization. We address this effect to the mode-dependent softening of spin waves resulting from the growing influence of the demagnetizing field while the external magnetic field lowers. The effect gives a possibility of tuning the concentration of spin-waves in one of the constituent materials – the matrix or scattering centres – by the external magnetic field. As an example, we study planar bi-component MCs consisting of cobalt inclusions in permalloy matrix, as well as Py inclusions in Co matrix. We show that in both cases lowering external magnetic field drives down in the spectrum these modes which are excited mostly in Co. Moreover, the concentration of such modes in Co is enhanced.

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A parametric model for global thermodynamic behaviour of ultrasonic attenuation in magnetic field

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The ultrasonic attenuation and velocity variations are theoretically investigated near the Curie temperature of ferromagnet under an application of magnetic field. The temperature, frequency and magnetic field dependence of acoustic properties of ferromagnet near a critical point is given. A parametric representation is used to describe a crossover from critical to classical region far away from the critical point. The crossover scaling functions are determined for sound attenuation coefficient and dispersion. We compare the proposed crossover model with experimental ultrasonic data for manganese phosphide MnP and find good agreement between theory and experiment.

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High-temperature Magnetodielectric $Bi(Fe_{0.5}Mn_{0.5})O_3$ Thin Films with Checkerboard-Ordered Oxygen Vacancies and Low Magnetic Damping

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The possibility of affecting the magnetic properties of a material by dielectric means, and vice versa, remains an attractive perspective for modern electronics and spintronics. Here, we report on epitaxial $Bi(Fe_{0.5}Mn_{0.5})O_3$ hin films with exceptionally low Gilbert damping and magnetoelectric coupling above room temperature (<400 K). The ferromagnetic order, not observed in bulk, has been detected with a total magnetization of 0.44 μ_B/formula units with low Gilbert damping parameter (0.0034), both at room temperature. Additionally, a previously overlooked check-board ordering of oxygen vacancies is observed, providing insights on the magnetic and dielectric origin of the multifunctional properties of the films. Finally, intrinsic magnetodielectric behavior is observed as revealed by the variation of dielectric permittivity well above room temperature. These findings show the possibility of electric-field-controlled magnetic properties, in low Gilbert-damping-based spintronic devices, using single-phase multiferroic materials.[1]

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Resonance modes of periodically structuralized microwave magnetic elements

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Here we consider a flower-like structure of a resonator consisting of six elliptical elements, referred to as petals, made from a magnetic material. The petals are positioned with their centers at the corners of a regular hexagon. Using numerical simulations (CST Studio) we examine the effect of different radial orientation of petals. We study resonance modes with a specific distribution of the electromagnetic field within the resonator as well as the effect of the rotation of petals on the field distribution. The mode character is crucial to understand the behavior of the frequency spectrum. E.g., the rotation of petals influences significantly the frequency of the lowest mode only, while the other frequencies are almost unchanged and this effect is directly related to the profile of modes. The system studied is a promising candidate for a component of an integrated detection system for applications in magnetic resonance spectroscopy and related detection techniques.

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Crystallographic, magnetic and magnetocaloric properties in Yb-based alloy

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In the last decades, intermetallic materials have attracted a lot of attention due to their intriguing properties. Systematic research of rare earth elements based on Eu, Ce and Yb, their combination and preparation of alloys and compounds offers very interesting physical results as high temperature superconductivity, quantum criticality or heavy-fermion behaviour, recently published e.g. [1, 2]. Particular classes are Yb-based alloys and compounds that show long-range magnetic order in the low temperatures range. More suitable objects for advanced materials are those which are ideal for magnetic refrigeration. Mentioned phenomenon based on the magnetocaloric effect is often more environmentally friendly and offers high energy efficiency than the refrigeration system's existing on the base of conventional gas compression e.g. [3]. Nowadays, it is essential to find other alternatives for refrigeration. To explore Yb-based magnetic material with extended the working temperature span with magnetic entropy changes, $Yb_{0.5}Gd_{0.5}Ni_5$ alloy has been prepared. The crystallographic structure, magnetic and magnetocaloric properties were studied. XRD patterns of the studied alloy shows two phases. The main phase belongs to $CaCu_5$ type crystal structure with *P6/mmm* space group as whole RNi_5 (R-rare earth) [3]. The presence of the second phase will be described in details. From the isothermal magnetization data, a magnetic entropy changes $-\Delta S_M$ was determined by a formula using the Maxwell's thermodynamic relations, and a broad maximum at $\sim$ 24 K is observed. The most remarkable fact is the asymmetric shape of maximum with a tail at higher temperatures. It can be explained due to the spin fluctuations effect [4]. It means that alloy and compounds with multiple magnetic transitions might create new materials to attain magnetic refrigeration technology in a broad temperature range compared to classical materials. Further study of $Yb_{0.5}Gd_{0.5}Ni_5$ alloy involving a full suite of physical properties, which are in progress, will be explained. The investigation of new intermetallic materials suitable for magnetic refrigerant opens the possibility of being more environmentally friendly, which recommends this alloy for possible future applications.

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Magnetocaloric effect in spin-glass-like $GdCu_4Mn$ compound

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Materials based on Gd with magnetic frustration may have high magnetocaloric application potential. $GdCu_4Mn$ crystallizes in hexagonal $CaCu_5$-type structure with space group $P6/mmm$ (no 191, Pearson symbol: $hP6$). Obtained from x-ray diffraction pattern lattice parameters for our sample are equal to $a = 5.1140(3)$ Å and $c = 4.1513(3)$ Å. Due to the structural disorder (random distribution of Cu and Mn atoms on $2c$ and $3g$ positions) a spin-glass-like behavior is observed in this material at low temperatures. In addition to the standard measurements of dc magnetization and ac magnetic susceptibility, the spin-glass state was confirmed by the memory effect and relaxation behavior. The lack of long-range ordering was demonstrated by electronic transport and specific heat measurements. For a change in magnetic field from 0 to 5 T maximum values of the isothermal magnetic entropy change (ΔS_M), relative cooling power (RCP), and adiabatic temperature change (ΔT_{ad}) are equal to -1.3 J/(kg K), 125 J/kg, and 0.5 K, respectively.

Modulation of the spin-wave amplitude through dynamic charge-mediated magnetoelectric coupling

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We present new mechanism for manipulation of the spin-wave amplitude through the use of the dynamic charge-mediated magnetoelectric effect in ultrathin multilayers composed of dielectric thinfilm capacitors separated by a ferromagnetic bilayer. Propagating spin waves can be amplified and attenuated with rising and decreasing slopes of the oscillating voltage, respectively, locally applied to the sample. The way the spin accumulation is generated makes the interaction of the spin-transfer torque with the magnetization dynamics mode-selective and restricted to some range of spin-wave frequencies, which is in contrary to known types of the spin-transfer torque effects. The interfacial nature of spin-dependent screening [1] allows to reduce the thickness of the fixed magnetization layer to a few nanometers, thus the proposed effect significantly contributes toward realization of the magnonic devices and also miniaturization of the spintronic devices.

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Edge ferromagnetism of graphene oxide

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Graphene oxide (GO) is the starting material for producing a wide variety of other graphene-related materials that may inherit some of its properties. For this reason, in particular, the origin of the observed ferromagnetic hysteresis loops in GO [1] requires an explanation. The possible ferromagnetic impurities in GO [2] can be eliminated. The intrinsic ferromagnetism of GO is more interesting. Until now, it has been postulated that this magnetism can be cause by hydroxyl groups [3], a specific distribution of epoxy groups [4] resulting in the appearance of a large number of covering defects or magnetic moments arising due to the mixed sp^2-sp^3 hybridization [5]. However, the exchange interaction between randomly distributed magnetic moments attributed to the proposed surface defects in the monolayer GO should result in the antiferromagnetic order [6].

In this report, results of SQUID magnetometry and ferromagnetic resonance (FMR) studies of magnetic properties of the monolayer GO of a high purity [7] are presented. We used three types of GO. GO paper was obtained by drying the "as purchased" GO suspension. The second type of GO was obtained from suspension irradiated by ultrasound for several hours. The third diluted sample consisted of the monolayer GO flakes deposited on the spectrally pure MgO powder. We found that ultrasound irradiation slightly increases ferromagnetism of the produced GO paper and decreases the paramagnetic contribution. We also found that the mass magnetization of the diluted sample is twenty times higher than that of the GO paper. We studied impact of atmospheric gases on GO properties and showed that contact with air decreases magnetization of the GO paper and removes completely the FMR signal of GO flakes deposited on MgO. Additionally, the shape of the FMR line of GO and its temperature evolution are similar to those observed in graphene [8]. We concluded that the intrinsic ferromagnetism of GO is due to ordering of dangling bonds (broken σ bonds) at zigzag edges.

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Ferromagnetism of graphene-related materials: Methods and conditions for its identification

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Magnetic moments in graphene can be due to defects such as edges, vacancies or functional groups covalently bounded to carbon atoms on a graphene surface. According to theoretical predictions, these moments can be magnetically ordered [1,2]. Ferromagnetic ordering of the edge states on the zig-zag edges [3] was foreseen theoretically and observed by ferromagnetic resonance (FMR) [4]. Surface magnetic moments located in one sublattice interact ferromagnetically, while an interaction between moments located in two sublattices has antiferromagnetic character [5]. Low mass magnetization makes it difficult to observe ferromagnetism in graphene-related materials. Carbon atoms on zig-zag edges in graphene constitutes a small part of the total number of atoms. For the surface magnetic moments generated by covalent functionalization, using in particular hydrogen atoms, situation is more complex. A significant ferromagnetism is expected for one-side hydrogenated graphene [6], which is difficult to obtain and unstable. Hydrogenation of materials consisted of graphene or graphene oxide flakes inevitably leads to two-side functionalization resulting in a formation of ferromagnetic domains as well as nonmagnetic graphane-like regions. Detection of ferromagnetism in such materials requires sensitive methods such as SQUID or FMR recorded using EPR spectrometers.

In this report, we present data proving the existence of ferromagnetic order in graphene, graphene oxide and reduced graphene oxide. We analyze peculiarities of magnetometry and FMR in these materials. Additionally, an origin of para- and diamagnetic contributions revealed in field dependences of magnetization is discussed. We also demonstrate the crucial role of the strength of magnetic field in temperature dependences of magnetization. Finally, we point significant differences between FMR signals of the ordered zig-zag edge states and of the exchange-coupled magnetic moments located on the graphene surface in one sublattice.

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Skyrmion formation in magnetic nanodots

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Magnetic skyrmions are circular domains surrounded by a single chirality domain wall. They are characterized by a small size and robustness against the external perturbations, which makes them attractive for modern memory-storage devices and as information carriers. Understanding the stability of magnetic textures in multilayer patterned dots would make a significant step towards skyrmion-based applications. Here, we report the observation of skyrmions in nanopatterned nanodots composed of multilayers. We have examined the stabilization of various magnetic states, such as single domain state, skyrmion state, horseshoe-like domain structure, and worm-like domain structure, formed in submicron-sized dots (diameter 150-525 nm). In particular, we show that the stack of six repetitions of Pt/Co/Au is enough to stabilize the skyrmion state inside the dot at room temperature. Furthermoe, we have found that the magnetic field generated by the magnetic force microscope tip can significantly affects the magnetization state of the nanodots, even lead to the formation of skyrmion. Micromagnetic simulations explain the evolution of the magnetic state during magnetic force microscopy scans and confirm the possibility of the magnetic skyrmion formation.

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Observation of Griffiths-Phase like behaviour in polycrystalline $LaFe_{0.5}Mn_{0.5}O_3$

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Transition metal perovskite with generic formula ABO_3 remained to be a potentially functional material since last few decades having a wide range of applications. Nowadays partially doped (both A and B site) comes up with intriguing features which bring out rich physics. Particularly rare earth Manganites is an interesting compound in this series with unique properties like spin reorientation, colossal magnetoresistance (CMR), Metal-Insulator Transition (MIT), spintronics applications. Griffiths Phase(GP) is one of the interesting behaviour observed in the doped manganites. The underlying reason for manganites to exhibit GP behaviour is the inheritance of quenched disorder. We report the magnetic study of pure $LaFe_{0.5}Mn_{0.5}O_3$ polycrystal prepared by solid state reaction in air. It crystallizes in orthorhombic structure ($Pnma$) with $\chi^2 = 1.79$ without the presence of any secondary phases. Magnetic measurements reveal Griffiths Phase like behaviour in half doped Orthomanganites $LaFe_{0.5}Mn_{0.5}O_3$ in the range 276 K to 314 K having antiferromagnetic Neel temperature 276 K ($\theta_{CW} = -27K$), which was further confirmed by modified Curie Weiss behaviour($\chi^{-1} = (T/T_C^R - 1)^{1-\lambda}$), using power-law susceptibility exponent (λ)[1]. Generally, GP arises due to quenched disorder where small ferromagnetic clusters form having short-range magnetic order. Magnetization is a non-analytic function of H and T in the GP region[2]. Inverse susceptibility vs Temperature behaviour shows a sharp downturn around Neel temperature where Curie Weiss law is not fitting and this is a primary indication of Griffiths Phase[3]. Above the onset temperature of GP ($T_G = 314K$) Curie Weiss law, as well as the analyticity in magnetization, are restored again. The ferromagnetic clusters are being ordered with the application of magnetic field and susceptibility also increases as evidenced from inverse susceptibility vs Temperature behaviour at different magnetic fields(100 Oe, 500 Oe, 10 kOe). Non-analyticity also being suppressed with the application of magnetic field. In order to have further confirmation, $\mathrm{Log}_{10}(\chi^{-1})$ vs $\mathrm{Log}_{10}(T/T_C^R - 1)$ plot was also taken. Linear fitting at Griffiths Phase(GP) and Paramagnetic(PM) regions give the value of the susceptibility exponents (λ_{GP}=0.99 and $\lambda_{PM} = 0.09$), indicating a strong presence of Griffiths Phase[4].The presence of dominant ferromagnetic behaviour at a lower temperature is evidenced from the spontaneous magnetization (M_S) obtained from Arrot plot at different isotherms.

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NONLINEAR DYNAMICS OF SPIN WAVES IN PLANAR MAGNETIC-CRYSTAL MICROSTRUCTURES

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Magnon waveguides formed from thin magnetic films with a low linear attenuation coefficient are a functional unit of any complex integrated magnon network [1,2], since it is possible to create interconnects and transmission lines between the functional nodes of information processing on their basis signal [3]. A theoretical, numerical and experimental study of the spatial-frequency selection of the spectrum of magnetostatic surface waves (MSSW) in a two-dimensional tangent magnetized magnon crystal lattice, which is a film of yttrium iron garnet (YIG), with a two-dimensional array of grooves on the surface. The possibility of the formation of transverse-limited beams of surface magnetostatic waves in the case when the frequencies of the input microwave signal coincide with the frequencies of the Bragg band gaps in the magnon-crystal lattice is shown. The features are investigated and the mechanisms of spatial-frequency selection are revealed during the propagation of MSSW in the magnon-crystalline structure. The results can be used to organize a spatially distributed information signal processing system based on magnon networks, as well as an element for spatial-frequency filtering of signals in the microwave range of radio waves [4]. In this work, we present the results of a numerical study of the linear and nonlinear properties of a structure consisting of two two-dimensional magnon crystals, each of which is formed by creating a groove structure on the surfaces that is periodic in two directions. Two films are placed so that the rows of grooves are arranged one above the other, forming a multilayer irregular periodic structure. Based on the micromagnetic simulation of two coupled two-dimensional magnon-crystal lattices, the optimal parameters for the effective excitation and propagation of spin waves are determined, and the frequency selective properties of such a structure will be determined. A model of a multiplexer based on a system of two two-dimensional magnon crystals has been developed, which can be used to develop a real device, which, in turn, can be used to develop telecommunication networks. The possibility of frequency-spatial selectivity and the formation of waveguide channels is shown. in the investigated three-dimensional structure. The formation of adjacent waveguide channels for spin waves is possible when the frequency of the input signal falls into the frequency range of the Bragg band gap of the MC.

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Tuning all-optical magnetization switching efficiency by laser pulse wavelength variation

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Magnetization manipulation remains an indispensable tool in both, basic research, and application development [1]. Energy transfer from the electron system to the spins provides the basis for the response dynamics triggered by optical laser excitation determining the speed of ultrafast magnetization processes. In magnetic storage development, granular FePt gained special interest for heat-assisted magnetic recording [2]. In the meantime, writing experiments by single laser spots point to an asymmetric writing per laser shot. This was consistently observed by different research groups [3,4,5,6]. The interplay between the involved processes requires further investigation, opening further questions about the extension and possibilities for all-optical writing as a general mechanism. In the current understanding of interaction in ultrafast excitation and heating, the influence of magnetic dichroism and the presence of the inverse Faraday effect jointly work as forces causing magnetization reversal. We calculate the switching rates for individual FePt nanoparticles in ab-initio calculations of the optical effects (inverse Faraday effect and magnetic dichroism induced heating) included in thermal modelling. The latter then provides switching rates for the ensembles. We can trace the different processes from the beginning of the laser pulse impact [4]. This theoretical description allows us to optimize the required number of shots to reverse the magnetization of FePt nanoparticles and pinpoints how to optimize the all-optical writing by tuning the laser fluence and wavelengths. First experiments show, that tuning wavelengths requires simultaneous fluence adjustment due to the increased photon absorption for larger wave lengths.

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Scattering of spin waves in the single-mode and multi-mode ferromagnetic waveguide

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Most of the research involving the skyrmion-waveguide system has focused on the stabilization, dynamics, and motion of the skyrmion within the waveguide. However, in our work we decided to present a slightly different approach, we studied the propagation of spin waves in a waveguide under the influence of a skyrmion located above the waveguide.

Assuming magnetization along the waveguide, we investigate the backward volume magnetostatic spin-wave modes via micromagnetic simulations how the spin waves excited in the waveguide are affected by the heterogeneity of magnetization in the nanodisk with a skyrmion, placed above the waveguide. Based on the obtained results we conclude that in a single-mode and a multi-mode waveguide, the introduction of skyrmion into the system influences the propagation of spin waves, e.g. causes scattering into other modes. The scattering process depends on the frequency and the eigenspectra of the spin-wave oscillations in the skyrmion.

By examining the dipole coupling between the spin-wave and the dynamics of the skyrmion, we observed the conversion of incident homogeneous mode to the quantized by width spin-wave modes. Interestingly, at a low frequency, we observed the skyrmion-induced magnetic field heterogeneity reflects the spin-wave energy in the waveguide, creating a reflected mode with two nodal lines. The presented mechanism of spin-wave mode conversion in a ferromagnetic waveguide can be useful for nanoscale control of the propagating spin waves.

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Observation of two-step laser-induced demagnetization process in Ni-Mn-Sn Heusler alloy film

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The ultrafast magnetization dynamic processes are investigated in a broad timescale range for different laser pump fluences in Ni- and Mn-rich Heusler alloy film of $Ni_{54.3}Mn_{31.9}Sn_{13.8}$ composition using time-resolved magneto-optical Kerr effect (TR-MOKE) in perpendicular magnetic field geometry. For all fluences used, two distinct types of magnetization dynamics of different timescales: ultrafast up to 2 picoseconds (range I) and slower from 2 ps to hundreds of ps (range II), were observed. The description of the two-step de- and remagnetization processes were performed on the basis of microscopic three-temperature model (M3TM) [1] in the frame of extended eM3TM model [2]. In transition from I to II timescale range, the model parameters: electron-lattice coupling g_{el} and demagnetization rate R decreases over two order of magnitude but weakly depend on the fluence. The calculated spin-flip probability a_{sf} decreases over one order of magnitude as well. The reasons for demagnetization slowing down effect observed in the Ni-Mn-Sn film in range II are related with lowering of the exchange interaction and Curie temperature proximity [2]. The model parameters g_{el}, R and a_{sf} in range I are of the same order as in Ni metal and can be explained through the electron-phonon-mediated spin-flip scattering processes [1].

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Dimerized nature of magnetic interactions in the S = 1/2 quantum antiferromagnet $Cu(en)_2SO_4$

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Previous studies of metal-organic compound $Cu(en)SO_4(H_2O)_2$ (*en* = ethylenediamine - $C_2H_8N_2$) revealed that this quasi-one-dimensional polymer structure represents realization of the S =1/2 Heisenberg antiferromagnet on the zig-zag square lattice with alternating intralayer interactions J/k_B = 3.5 K and J' = 0.35 J [1]. The compound undergoes a phase transition to the ordered state at 0.93 K. The substitution of water by *en* leads to the formation of very similar structure, namely $Cu(en)_2SO_4$. Our preliminary studies of powder sample indicated significant strengthening of exchange interactions and no fingerprints of any phase transition which suggests some kind of dimerization as a result of different distribution of alternating exchange interactions [2].

This work focuses on the study of magnetic susceptibility and magnetization of a single crystal in the field applied along the b axis. The temperature dependence of the magnetic susceptibility was measured in the ZFC mode in the temperature range from 2 to 300 K in the magnetic field 1 T. An analysis of the susceptibility within the Curie-Weiss law indicates the antiferromagnetic nature of the exchange coupling between magnetic ions with zJ/k_B = -6.4 K. Considering the structure of this material, the formation of magnetic dimers can be expected. Correspondingly, very good description of data was achieved using the Heisenberg antiferromagnetic dimer model with intradimer coupling J/k_B = -5.52 K, interdimer coupling $z'J'/k_B$ = -2.7 K and g = 2.12. The energy gap in the spin excitation spectrum was estimated $\Delta/k_B \approx$ 11 K and corresponding critical field $B_c^b \approx 7.8$ T required for closing the gap. The dimerized nature of magnetic interactions was also confirmed by isothermal magnetization data which manifest qualitatively the same behaviour as the aforementioned dimer model. The possibility of further low temperature experiments in the closed gap regime is discussed to obtain more detailed concept of magnetic interactions in this interesting compound.

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Effect of electronic configuration of substituents for manganese and nonstoichiometry defects on the properties of $La_{0.7}Sr_{0.3}Mn_{0.9}{}^{57}Fe_{0.05}Me_{0.05}O_{3+\gamma}$ (Me = Zn, Mg) manganites

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Structural and magnetic characteristics of $La_{0.7}Sr_{0.3}Mn_{0.9}{}^{57}Fe_{0.05}Zn_{0.05}O_{3+\gamma}$ and $La_{0.7}Sr_{0.3}Mn_{0.9}{}^{57}Fe_{0.05}Mg_{0.05}O_{3+\gamma}$ manganites containing Mössbauer isotope ^{57}Fe are investigated and compared. The Zn^{2+} and Mg^{2+} ions have almost identical radii (0.74 and 0.72 Å), but different configurations of electron shells ($3d^{10}$ and $2p^6$, correspondingly). Ceramic samples were sintered in air at 1473 K. They were then exposed to heat treatments at 1223 K and partial pressure of oxygen in the gas phase of $P_{O2} = 10^{-1}$ Pa, 10^{-8} Pa, and 101.3 kPa, which ensured the production of manganites with stoichiometric oxygen content ($\gamma = 0$), with $\gamma < 0$ (containing anion vacancies) and $\gamma > 0$ (containing cation vacancies), respectively. All synthesized manganites have rhombohedral crystal structure. Mössbauer spectroscopy data correspond to Fe^{3+} ($3d^5$) ions. Non-stoichiometry index (γ) is calculated from the data on unit cell volume according to algorithm proposed earlier [1,2]. The following values of γ are obtained: γ = -0.005; 0.000; 0.007; 0.008 for Zn-containing manganites (ZnM), and γ = -0.022; 0.000; 0.002; 0.005 for Mg-containing manganites (MgM). ZnM have essentially higher values of magnetization, Curie point (T_c), and narrowest temperature interval (ΔT) of "ferromagnetic-paramagnetic" transition as compared to MgM. Their structure can be considered as more homogeneous, which corresponds to a lower value of quadrupole splitting (QS). Manganites annealed in oxygen have the narrowest ΔT, apparently due to vacancy mechanism of cation diffusion that smooths out spatial variations of the composition. Magnetization and T_c of ZnM increase in general with increasing the oxygen content, showing a plateau in the intermediate range of γ. MgM have similar dependence of T_c on γ, but their magnetization has a maximum at $\gamma = 0$ and a sharp decline at $\gamma = 0.005$, although QS at latter point is minimal. The results obtained indicate that different effect of Zn^{2+} and Mg^{2+} ions on electromagnetic characteristics of manganites is largely determined by the configuration of their electron shells.

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Mutual magnetostatic coupling between the saturated ferromagnetic stripe and a nanodot

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One of the main research directions in magnonics focuses on the excitation of short wavelength spin waves. Recently, a few approaches have been proposed, but with some limitations, like a weak efficiency of the transducing energy, which further limits the development of magnonic applications. One promising upcoming solution is to use an inscribed skyrmion in a nanodot in the proximity of the spin-wave conduit, but such a system has a lot of variables and needs extensive optimisation.

In this paper, we narrow the scope and focus on the system composed of a nanodot with a varying magnetic state placed on the top of a ferromagnetic stripe. The waveguide is magnetically saturated along its length and it is separated from the nanodot by a thin spacer. We select the nanodot with the specific geometry and size, i.e., Pt/Co/Ir circular layers with a diameter of 300 nm, possessing a strong enough interfacial Dzyaloshinskii-Moriya interaction (DMI), which allows for the formation of a stable skyrmion.

When relaxing this system, a *spin-dot-shadow* is created in the waveguide, meaning the magnetization below the nanodot deviates from their saturated magnetization direction, because of the dipolar coupling with the skyrmion. Interestingly, the spin-dot-shadow in the waveguide mutually influences the magnetization inside the nanodot and affects the shape of the skyrmion. In our example, the skyrmion's core expends and becomes egg-shaped under the influence of the waveguide. The analysis is repeated for many values of the DMI, to demonstrate that it is the principal factor in the resulting texture in the nanodot, which allows to control the skyrmion circular shape deformation, and thus the coupling between skyrmion dynamics and the spin waves in the waveguide.

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Revisiting structural, magnetic and electronic properties of $CaCoSi_nO_{2n+2}$ series.

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In a public space[1] there are several reports of materials with general stoichiometry $CaCoSi_nO_{2n+2}$. For n=2 it is a known pyroxene $CaCoSi_2O_6$[2,3]. However, not much is known about materials with n=3 and n=4, which seem to be analogous to known pigments $CaCuSi_nO_{2n+2}$.

In this study several attempts were carried out to synthesize those phantom materials and it was found that they do not exist as a single phase. A quantitative XRD analysis revealed that their stoichiometry is correct but the formula should be written as $CaCoSi_2O_6$ + (n-2)SiO_2. Similar qualitative conclusions were drawn from investigation of magnetic (DC magnetometry) and electronic properties including XPS and Si K edge XANES. Additionally, ab initio DFT calculations were carried out to get insight into electronic structure of the base system and compare them to XAFS results. The apparent influence of the excess of SiO_2 on magnetic properties of this "series" can be understood in terms of presence of secondary phases like $Ca_2CoSi_2O_7$, which form when the starting materials are not homogenized properly. Addition of surplus SiO_2 suppresses their formation leaving clear signature from $CaCoSi_2O_6$, which also can be synthesized from stoichiometric mixture using proper techniques.

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Self-imaging of spin waves in thin, multimode ferromagnetic waveguides

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The Talbot effect, called also a self-imaging, has been known in linear optics since the 19th century and has found various technological applications. Self-imaging is also a property of multimode waveguides, that can be used to create advanced logic circuits also in magnonics. After our successful demonstration of this effect for spin waves using micromagnetic simulations [1] in infinitely wide systems (with periodic boundary conditions), it is time for real-size systems that can be used in future magnonic devices. At this conference, I would like to present a family of out-of-plane magnetized ferromagnetic waveguides, in which, as a result of combining Talbot effect and multimode interference, regular self-imaging of patterns characteristic for the near diffraction field occurs and they are created at equal distances away from a number of sources (single-mode waveguides). Using micromagnetic simulations I demonstrate systems with various parameters such as: number of sources, width of the system and distance between the sources (which in this case is an analog of a diffraction grating constant) to analyze and compare the obtained interference fields in terms of possible application. In many cases, interesting effects can be observed and, especially in the near diffraction field, patterns similar to the theoretical images known as „Talbot carpets", which is particularly interesting due to the possibility of applying this effect in systems with higher damping. The object of my interest are also analogous in-plane magnetized systems, with additional effects due to anisotropy. The self-images created in the waveguides were analyzed in systems with a low Gilbert damping constant, and it seems that this effect can be used experimentally with great efficiency, e.g. in yttrium iron garnet materials.

From the conclusions of the described research, it can be distinguished, among others, that the self-imaging effect for spin waves occurs in systems of finite dimensions, multimode interference transfers and duplicates the near diffraction field to further, repeatable distances from the sources and it is possible to control this effect by selecting an appropriate geometry and parameters. It gives a lot of application possibilities, as well as ways of manipulating and adapting the effect to specific needs. The obtained results help to better understand spin-wave interference and diffraction processes due to the use of a number of coherent spin-wave sources and I believe my findings open an avenue to practical application of the Talbot effect in future magnonic devices.

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Crystal-field states of the Sm^{2+} ion in topological Kondo insulator SmB_6: specific heat studies

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Topological Kondo insulator SmB_6 exhibits the hybridization gap of 20 meV, but experiments like temperature dependence of the magnetic susceptibity and of the specific heat with a very large extra specific heat with a large maximum (about 10 J/K mol) at 50 K point to the existence of in-gap localized states of the debated origin [1,2]. We have attributed [3] these states as originating from the the Sm^{2+} ion which can be theoretically revealed by calculations within the spin-orbital $|LSL_zS_z>$ space, with L=3 and S=3. The in-gap states originate from the 49-fold degenerated quasi-atomic term ^7F ($4f^6$) which becomes split by the cubic crystal-field (CEF) and the finite spin-orbit interactions. These interactions competite with each other - the six-order cubic CEF interactions produce the 7-fold degenerated ground state whereas the spin-orbit interactions, even of the weakest one, produce a singlet (J=0) ground state. The derived CEF and spin-orbit parameters produce the lowest singlet state at 0 K with an excited triplet at 89 K and a next triplet at 215 K. Such states are within the 20-meV hybridization gap.

Our approach is very similar to the one used by us in description of 3d compounds (CoO, NiO) [4,5], where the spin-orbit coupling is taken relatively weak - it is in contrast to the standard approach used for rare-earth ions with the quantum number J as the good quantum number. This similarity is due to a fact that the orbital quantum number L=3 for the Sm^{2+} ion is the same as for the Co^{2+} or Ni^{2+} ions.

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Peculiarities of magnetic properties and electronic structure in Mn_2YAl (Y = Ti, V, Cr, Mn, Fe, Co, Ni) Heusler compounds

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Some Heusler alloys demonstrate properties of half-metallic ferromagnets (HMFs) [1] and spin gapless semiconductors (SGSs) [2]. These two classes have a significant difference: there is no energy gap near the Fermi level for the spin up current carriers in HMF, whereas in SGS the gap is being zero. However, the electronic band structure is the same in HMF and SGS for spin down: both the materials have a gap [1,2]. Since in X_2YZ Heusler compounds Y-elements are 3d-transition metals [3], it is of great interest to follow experimentally the changes in the electronic and magnetic properties of the Mn_2YAl Heusler alloys system, when varying Y in the sequence Ti, V, Cr, Mn, Fe, Co, Ni. The main purpose is to compare the results obtained from the electronic band structure calculations and investigate a possible proximity to HMF- and/or SGS-states in the Mn_2YAl system. An elemental analysis was carried out by using a FEI Company Quanta 200 scanning electron microscope equipped with an EDAX X-ray microanalysis unit. The temperature dependences of the electrical resistivity were obtained in a wide temperature range from 4.2 to 1000 K. The field dependences of the magnetization were measured in the fields up to 50 kOe at $T = 4.2$ K. The calculations of the electronic structure and magnetic properties of Mn_2YAl were performed in generalized gradient approximation within the Quantum-Espresso software package [4]. As a result, the experimental study showed a good agreement with the electronic band structure calculation. The energy gap parameters and the current carrier spin polarization vary significantly depending on the number of valence electrons, which is reflected in the change of their electrical and magnetic characteristics. Some features in the electronic and magnetic properties of Mn_2YAl Heusler alloys may indicate conditions close to the HMF or SGS states. A high degree of charge carriers spin polarization makes it possible to use these materials in the development of spintronic devices.

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Magnetic interactions and spin dynamics of the ^{53}Cr in the orthosilicate host crystals

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Recently, much attention has been paid to finding ways of practical implementation of various algorithms of quantum informatics. An active search is carried out of quantum systems for practical implementation of quantum computers. To transfer quantum information over long distances and create a universal quantum computer, quantum memory devices capable to remember and to reproduce quantum information are needed. Rare-earth impurity ions with a nonzero nuclear spin in oxide crystals (in particular, the yttrium orthosilicate Y_2SiO_5 (YSO)) are widely studied [1-5] as a possible material basis for practical implementation of quantum memory in optic range. In the field of quantum computing, significant progress has been associated with the creation of systems of coupled quantum bits (Q-bits) based on superconductor devices. The characteristic operating frequencies of superconducting qubits lie in the microwave range. Therefore, a quantum memory for the quantum computers should also operate in the microwave range.

In this work, we measured the orientation dependencies of the EPR spectra of ^{5}3Cr impurity monoisotopic ions in YSO and determined principal values and orientations of the principal axes of the D-tensor that determines anisotropy of the electron levels of trivalent chromium in YSO single crystal. Values of isotropic g-factor and the energy of the hyperfine interaction between electron and nuclear spins were also determined. Temperature dependencies of spin-lattice relaxation time and memory phase time were measured and estimated.

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Magnetic structure of the Mn_2GaC thin film (MAX phase) - ^{55}Mn Nuclear Magnetic Resonance study

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Mn_2GaC ternary compound belongs to the rich family of materials, known as the MAX phases. It presents an atomically laminated structure stacked along the hexagonal c-axis, where the Mn-C-Mn stacks are interleaved with the atomic layers of gallium. It is magnetically ordered with the critical temperature of the order-disorder transition of 507 K. At around 214 K this compound undergoes a first order phase transition, and the magnetic structure below the transition point turns out to be complex. The experiments of unpolarized neutron reflectometry have shown the features of antiferromagnetic order with periodicity of two unit cells, in consistence with the AFM$[0001]^A{}_4$ structure proposed from the theoretical calculations [1]. On the other hand, a nonzero magnetic remanence suggests long range ferromagnetic correlations [2]. In this work we used Nuclear Magnetic Resonance (NMR) technique to shed some light on the low temperature magnetic structure. We present the results of ^{55}Mn NMR experiment carried out on a 100 nm film sample at 4.2 K in zero field and in the external field up to 1T, as well as their implications on the microscopic magnetic order. Presence of a non-collinear magnetic structure inferred from NMR analysis will be discussed in the light of the latest theoretical magnetic ground-state search, assuming a biaxial in-plane strain, using Heisenberg Monte Carlo simulations [3].

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Investigation of the soft mode behavior in superconducting Heusler $LiPd_2Ge$

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$LiPd_2Ge$ is a type-I superconductor with transition temperature $T_c = 1.96$ K. It belongs to the rich Heusler family of more than a thousand compounds which exhibit all kind of physical phenomena. $LiPd_2Ge$ was recently synthesized and characterized experimentally as well as with DFT calculations [1]. In this work we investigate observed phonon anomalies using *ab initio* computations. Acoustic phonons are strongly softened and become imaginary at Γ-K near vector $\boldsymbol{q}$=(1/3,1/3,0). It is worth noting that isoelectronic $LiPd_2Si$ and $LiPd_2Sn$ show similar behavior. $LiPd_2Ge$ has highest T_c and strongest softening, which suggests that the soft mode enhances superconductivity. Many other reported Heusler compounds show phonon anomalies, which is also observed experimentally. We examined whether distorted or modulated structures are favorable. Fermi surface nesting could be another explanation for phonon softening, especially considering the presence of Pd atoms for which the Kohn anomaly is well known. We calculated generalized susceptibility function to look for features indicating Fermi surface nesting. Then we probed potential energy surface by calculating energy of cells with distorted atoms along phonon eigenvectors. Resulting curve deviated from a parabola expected for a harmonic potential as it had a double well structure.

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Identification of magnetic anisotropy axes using thermomagnetic Nernst effect

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Thermomagnetic and thermoelectric effects are attractive due to their potential applications involving the direct conversion of waste heat into electrical energy [1]. Currently, only a few thermoelectric effects can be applied in ultra-low-power thermoelectric generators and transducers. The most widespread are semiconductor devices exploiting Seebeck-Peltier-Thomson effects. Thermomagnetic effects like Nernst [2], Ettingshausen [3], or spin-Seebeck [4] are still under scientific study. The Nernst effect is one of the thermomagnetic effects that can be also potentially used in direct converters of thermal energy into electrical energy [5,6]. The state of the art of research on the Nernst effect will be presented. The paper will show experimental research and discussion of results showing the influence of magnetic anisotropy of soft magnetic structures on the thermomagnetic Nernst effect [7]. The effect was investigated in several samples made of high magnetic permeability Fe-containing alloys. The samples with 20x4x0.2mm were tested in a transverse arrangement, i.e. in which the magnetic field vector was applied transversely to the temperature gradient [8]. The studies were performed for several values of temperature in the range from 293K to 320K. The experimental results reveal a significant impact of structural and micromagnetic order on electric field potential caused by the presence of the Nernst effect.

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Temperature dependant heterogeneous magnetic properties in Cr-Fe-Mn alloys

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This study focuses on $Cr_{74}Fe_{21}Mn_5$ and $Cr_{83}Fe_{14}Mn_3$ alloys prepared by arc-melting. The actual concentrations of the individual elements were verified using electron microprobe analyses within an error of ± (3%, 2%, 0.5%) for Cr, Fe, Mn, respectively, in both alloys. ZFC and FC magnetization show that both alloys change from a paramagnetic phase at high temperatures to a spin-glass state at low temperatures signalled by a sharp downturn in the ZFC data. Temperature dependant hysteresis shows that the alloys become ferromagnetic below 100 K. Further analysis of the magnetization reveals that there exist intermediate competing antiferromagnetic and ferromagnetic phases resulting in heterogeneous magnetic states in the system [1]. The magnetic ordering is sensitive to the Fe content where both alloys exhibit deviation from the Curie-Weiss behavior, with a positive Curie constant, indicating a ferromagnetic exchange interaction. The alloys re-enter into a disordered phase, suggesting that the ferromagnetism and the re-entrant spin-glass phase arise because of the presence of Fe in an antiferromagnetic Cr-Mn matrix. The Curie temperature (T_C) (97 and 70 ±5K), Néel temperature (T_N) (249 and 174 ±5K), spin glass transition temperature (T_g) (8 and 7 ±1 K), and Curie constant (θ) (215 and 130 ±1K) for $Cr_{74}Fe_{21}Mn_5$ and $Cr_{83}Fe_{14}Mn_5$, respectively, are derived from the magnetization studies. These findings show that these magnetic phase transitions are connected to spontaneous symmetry breaking and the appearance of discontinuities in the physical properties of the system [2,3].

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Magnetic properties, electronic structure and stability of Heusler alloys $Mn_{2-x}Fe_{1+x}Al$

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Heusler Mn-based alloys are being intensively studied because of complex magnetic properties [1], spintronic applications, electronic structure and band-gap design. We present an investigation of the electronic structure and magnetic properties of the novel composition $Mn_{2-x}Fe_{1+x}Al$. It was found to be stabilized in a cubic β-Mn-type crystal structure with an antiferromagnetic ordering of the Mn and Fe magnetic moments for x = 0.5, similar to the recently reported Mn_2FeAl Heusler alloy [2]. The detailed theoretical study was done to obtain the optimized atomic positions for $Mn_{1.5}Fe_{1.5}Al$ in the β-Mn-type structure for the first time. The calculated total magnetic moment is found to be 1.76 μ_B per formula unit of $Mn_{1.5}Fe_{1.5}Al$. The magnetic ordering in this configuration is composed of the ferro and antiferromagnetically arranged Mn ions, being antiferromagnetically ordered mostly in the 8c-type positions. The average magnetic moment of Mn, Fe and Al are 3.1 (Mn2) and 2.2 (Mn1) μ_B, 0.7 and 0.2 μ_B, correspondingly. These contributions of the Mn ions give the largest contributions to the densities of states and magnetic properties of the $Mn_{1.5}Fe_{1.5}Al$ Heusler alloy. The calculations for the Mn-Al alloys show that with the occupation of the 12d positions with Al results in the decreasing total magnetic moment with the total moment equal to zero in some cases. Our theoretical calculations demonstrate the complex character of the magnetic properties and electronic structure of the Heusler $Mn_{2-x}Fe_{1+x}Al$ alloys.

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Ising-like model for the two-step spin-crossover systems: Static properties with magnetic field effects using cluster variation method

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We investigate the static properties of a two−sublattice Ising−like Hamiltonian for spin-crossover (SCO) systems in the presence of an external magnetic field. Self−consistent equations are obtained using cluster variation method in the lowest approximation. From the solutions of these equations, we present high−spin state fraction vs. temperature and magnetic field variations for various values of the degeneracy ratio between high−spin and low−spin states (r). It is shown that two metastable and one unstable (or saddle) branches in the SCO region are displayed in the $r > 1$ case while the metastable states disappear and only one saddle point occurs when $r = 1$. However, only stable states are obtained at high temperatures outside the SCO region. The comparison of our results to other theoretical treatments is also given.

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Crystal-field electronic structure in $CeMg_3$, $CeIn_3$ and PrO_2

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We have analyzed magnetic and electronic properties of three compounds, $CeMg_3$, $CeIn_3$ and PrO_2, with an aim to compare their low-energy discrete electronic structure and the underlying charge distribution. In all these compounds rare-earth ions have one f electron - due to this fact these compounds can be treated as good examples from a pedagogical point of view. All of them form a cubic structure. Two cerium compounds have Γ_7 Kramers doublet ground state and the excited quartet Γ_8. In PrO_2, the quartet Γ_8 is the lowest. By analysis of the strength of the fourth-order CEF interactions (B_4) we would like to answer about i) the origin of the crystal-field splitting, and ii) the role played by conduction electrons. We have got consistent understanding of magnetic and electronic properties of $CeMg_3$ including the theoretical description of the λ-type peak at T_N and the value and the direction of the Ce magnetic moment. We try to determine the charge distribution in the unit cell. Our atomistic approach offers consistent theoretical description of paramagnetic and (antiferro)magnetic state of these compounds being the atomic-scale basis for heavy-fermion and/or Kondo phenomena.

Electronic structure and magnetic properties of $Gd_3Cu_3Sb_4$.

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In this presentation we show the results of electronic strucuture calculations for $Gd_3Cu_3Sb_4$, where we suspected non-collinear magnetic structure. Such non-collinear structure was earlier reported for analogue compound $Ce_3Cu_3Sb_4$. We also show the results of X-ray photoelectron spectroscopy measurements and compare them with results of our calculations. Our magnetization and magnetic susceptibility measurements are also interpreted on the basis of our calculation results. We found that this compound exhibits complex antiferromagnetic order below 51 K.

Mössbauer study of YFe_2Ge_2

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The YFe_2Ge_2 crystallizes isostructural to the AFe_2As_2 (A = Ca, Ba, Eu, K) iron-pnictide parent compounds and superconductors. Superconductivity with T_c = 1.8 K is strongly dependent on the sample quality and disorder caused by Fe atoms deficiency on the Fe site. The coexistence of ferromagnetic and stripe-type antiferromagnetic spin fluctuations within the Fe plane was recently found by neutron scattering. ^{57}Fe Mössbauer spectroscopy measurements were performed versus temperature down to 1.5 K for the YFe_2Ge_2 powdered single-crystal sample grown out of Sn flux. Spectra at room temperature (RT) and 80 K have a shape of broadened pseudo-single line with the quasi-continuous distribution of quadrupole doublets. A distribution is caused by the spatial modulation of the electric field gradient, which can be interpreted as a consequence of the incommensurate modulation of the charge density on the Fe nuclei, i.e., the charge density wave (CDW). The isomer shift at RT is equal to 0.34 mm/s, which is significantly less than 0.43 mm/s for $BaFe_2As_2$. It means that *d*-electrons density is significantly lowered in YFe_2Ge_2 in comparison to non-superconducting parent compound $BaFe_2As_2$. Hence, the system can be considered as strongly hole-doped, similar to KFe_2As_2 superconductor. Spectra at 4.2 K and 1.5 K are significantly broadened due to the spatial modulation of a weak hyperfine magnetic field with the average values about 1.3 and 1.5 Tesla, respectively. The magnetic nature of the spectra close to the ground state can be interpreted as a consequence of the spin fluctuations and indicates that the system is close to magnetic instabilities.

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Antiferromagnetic spin chains formed in novel TCNQ-based organic magnets

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The work devoted to the study of two novel genuine organic anion-radical salts (ARS) [N-Me-Dipy](TCNQ)$_2$CH$_3$CN (**1**) and [N-Xy-iQn](TCNQ)$_2$ (**2**), where TCNQ = 7,7,8,8- tetracyanoquinodimethane, N-Me-Dipy = N-methyl-2,2'-bipyridine, and N-Xy-iQn = N-(p-xylene)-isoquinoline, is presented.

In the past few decades molecular low-dimensional conducting materials have attracted much interest, in particular, electrical (conducting or semiconducting properties), magnetic and spectral. The uniqueness of ARS TCNQ is in a combination of electroconductivity and the ability to form magnetically ordered structures. Such structures are interesting primarily because, even though they do not have metal ions, and still exhibit magnetic properties in the role of the acceptor molecule.

The crystallographic data indicate the formation of $(TCNQ)_2^{\bullet -}$ anion-radical π-dimers in the synthesized ARS carrying spin S = 1/2. The analysis of the TCNQ bond distances allowed the estimation of the charge distribution that suggests the formation of magnetic stacks along the crystallographic a-axis. Magnetic measurements of prepared ARS were performed in a temperature range from 1.8 to 350 K in magnetic fields up to 7 T using a SQUID magnetometer. Both studied ARS display an antiferromagnetic (AFM) behavior.A broad maximum in the temperature dependence of the susceptibility was observed at ∼280 K for ARS **1** and described by a model of uniform spin chain with exchange interaction J/k_B = - 440 K, which agrees with a uniform spacing of TCNQ π-dimers in the stacks. On the other hand, an exponential-like decrease of susceptibility with decreasing temperature for ARS **2** suggests strong spin chain dimerization due to the complicated stacking of TCNQ π-dimers along the a-axis. A model of AFM alternating bond (or dimerized chain) spin chain with S =1/2 was used for the analysis. The energy gap in the excitation spectrum of the spin chain induced by dimerization was estimated from the analysis of susceptibility as Δ/k_B = 1322 K with exchange interaction alternation parameter α=0.195. In both systems, low-temperature behavior is affected by a very small fraction (less than 2%) of uncoupled or end-chain spins displaying simple paramagnetism.

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Zak phase for spin waves in one-dimensional magnonic crystals

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The dispersion relation of a one-dimensional magnonic crystal is composed of the sequence of the non-overlapping bands. The calculation of the Zak phases [1,2] for the bands below the selected gap allows identifying if the gap is supportive to the existence of edge modes [3] in terminated structures. In this work, we have calculated Zak phases for magnonic crystal operating in exchange regime, composed of the two alternatively repeated magnetic layers. An expression for the dispersion relation of such magnonic crystals has been derived and the corresponding Bloch function has been found. We determined the Zak phases of the successive bands by analyzing the symmetries of the Bloch in a centrosymmetric unit cell, at the edges of bands (i.e. for the wavenumbers in the center and edges of the Brillouin zone). For this, we have used an important result from J. Zak's work [1] for 1D one-dimensional crystals with inversion symmetry [1], which were generalized to a magnonic system. In conclusion, we have presented a general approach for studying the topological properties of Bloch bands in 1D magnonic crystals in an exchange regime.

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Substitutions' impact on the Curie temperature in Cantor alloy's derivatives

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Multiprincipal element alloys stand for promising materials with a wide range of possible applications *e.g.* in mechanical engineering. One of the most known representatives is the high entropy alloys (HEA). They benefit from composing of several components, which leads to the high-temperature stabilization and variability of their properties. Magnetism and magnetic ordering represent important properties, which the application potential depends on. Not only are they important by themselves, but they influence other properties as mechanical ones. We discuss the enhancement of the magnetism given by nonmagnetic *p*- and *d*-substitutions in the well-known Cantor alloy based on the ab-initio calculations. Although the parent alloy is composed of magnetic 3*d* elements, it does not bear noticeable magnetic behavior. Employing the TB-LMTO-ASA method, which allows for an effective including of disorder within the framework of CPA, we describe magnetic exchange interactions in the substituted alloys and determine their magnetic ordering temperatures based on the Monte-Carlo simulations as their knowledge is important for the estimation of their magnetic properties under the ambient conditions. We discuss the difference between the *p*- and *d*-typed substitutions and the most suitable composition to achieve ferromagnetic ordering above the room temperature.

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Electronic properties of chromium doped $Bi_2(Se,Te)_3$ topological insulators

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Three-dimensional topological insulators $(Bi,Sn)_2(Se,Te)_3$ have drawn a wide interest, because of their unusual physical properties, like symmetry protected surface states, and strong potential for applications in next-generation electronic, spintronic and quantum computation devices. Incorporation of magnetic impurities can lead to the merger between the symmetry protected surface states and the appearance of ferromagnetic order and thus provide a physical realization of the novel topological magneto-electric effect.

The aim of the presented work is to show the properties of Cr dopants in $Bi_2(Se,Te)_3$ and to explain their influence on the bulk and, most of all, on the surface states of host insulators. The calculations are performed in the framework of the density functional theory within relativistic variant of the local density approximation of exchange-correlation potential. Our results for bulk Bi_2Se_3 doped by Mn, Fe, Co and Ni have been presented in [1]. Here, the electronic structure of $Bi_2(Se,Te)_3$:Cr is analyzed and shows that Cr occurs mainly in 3+ charge state, while the occupied Cr levels reside just below the valence band of Bi_2Se_3.

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Effect of the magnetic anisotropy on magnons in the VSe_2 bilayer antiferromagnet

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The magnon properties in a two-dimensional antiferromagnetic bilayer magnetic system based on the ferromagnetic insulator VSe_2 is investigated. The both T and H-type bilayer stackings are considered within the Heisenberg model including additionally terms describing the single-ion anisotropy as well as the term that describes the effective in-plane anisotropies due to spin-orbit interactions. The applied magnetic field is also taken into account to split the degenerated magnon modes. Magnon energy spectra are derived from the eigenvalue problem for the bosonic system, obtained within an eight-dimensional Bogoliubov transformation combined with a Holstein-Primakoff transformation applied to the assumed model Hamiltonian. For numerical analysis the density functional theory (DFT) calculations were used to evaluate the single-ion anisotropy energy as well as the parameter describing the interlayer antiferromagnetic coupling in both the T and H phases. It is shown that an interplay between the in-plane and out-of-plane anisotropies modifies qualitatively the magnon behaviour in the vicinity of the Γ point. The evolution of the magnon modes due to the applied magnetic field is also discussed and their behaviour is explained for dispersion relations calculated along the high-symmetry paths in the Brillouin zone.

Impact of Kondo correlations and spin-orbit coupling on spin and orbital currents in two-orbital quantum dot

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Spin polarized transport through a quantum dot with spin-orbit interaction (SO) coupled to ferromagnetic electrodes is discussed in the strong correlation range in terms of nonequilibrium Green functions formalism within equation of motion method. Three types of spin-orbit coupling are considered: Zeeman-like, orbital-like and Rashba contributions. SO interaction opens off-diagonal spin-orbital transmissions and apart from current with spin component parallel to the polarization, also spin-flip currents appear. In consequence of mixing of spin and orbital channels the nonvanishing spin-opposite and orbital-opposite noise occurs. We also discuss the impact of SO on tunnel mangetoresistance and show that this interaction might change its sign.

Large voltage-tunable spin valve based on a double quantum dot

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In this communication the theoretical study of spin-dependent transport properties of a spin valve based on a double quantum dot setup is described. In the considered device each quantum dot is strongly coupled to a separate ferromagnetic lead, while the coupling between the dots is assumed to be weak. Using perturbation theory in the hopping between the dots, we have determined the current flowing through the system, its spin polarization and the tunnel magnetoresistance associated with the change of magnetic configuration of the leads from the parallel to antiparallel one. To calculate the spectrum of a quantum dot-ferromagnetic lead subsystem in most accurate manner, we have used the numerical renormalization group method. We show that the spin-resolved transport strongly depends on the magnitude and sign of the exchange field, which splits the double dot levels. Such a field, which can be controlled by gate voltages applied to the dots, plays a role similar to a local magnetic field. We demonstrate that in the linear response regime both positive and inverse tunnel magnetoresistance can be obtained. Moreover, in the nonlinear response regime, we predict a perfect spin polarization of the current and a greatly enhanced tunnel magnetoresistance. These effects can be observed when the exchange field is of opposite sign in each dot, which can be obtained by appropriate tuning of gate voltages. Our work reveals thus that double quantum dots strongly attached to external ferromagnetic leads can serve as efficient voltage-tunable spin valves characterized by high output parameters.

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Interplay of dark states and superconducting correlations in transport through quantum dot trimers

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The electronic transport through a hybrid triple quantum dot system is theoretically studied by means of the real-time diagrammatic technique. The central part of the system is arranged in a triangular geometry, with two quantum dots weakly coupled to metallic electrodes, while the third dot is proximitized by the s-wave superconductor. In particular, the focus is put on the regime where one- and two-electron dark states are formed due to the destructive interference of the electronic wavefunction. This effect greatly influences the transport through the system, leading to the current blockade, enhanced shot-noise and coherent population trapping. It is shown that the presence of the superconducting pairing correlations in the system leads to lifting of the dark state blockade and significantly reduces the shot-noise.
Moreover, the current oscillations due to the magnetic flux enclosed by the triangular structure and the influence of superconducting correlations are considered. It is predicted that for one-electron dark state the oscillations are strongly diminished while the current blockade is lifted, however when the system is in two-electron dark state regime, the oscillations of current suppression are conserved, yet for the doubled period of applied magnetic flux.

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The influence of the magnetic configuration on the charge current generated by the temperature gradient in the double planar ferromagnetic tunnel junctions

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The charge current generated by the finite temperature gradient applied to the double planar tunnel junctions with the ferromagnetic external electrodes and the central ferromagnetic layer is investigated in the spin polarized free-electron-like one-band model. The tunnel current induced both by the temperature gradient and the bias voltage is also analysed. Three different orientations of the magnetic moments in the ferromagnetic components of the junction are considered and the influence of the magnetic configurations on the tunnel currents is investigated. It has been shown that this influence can be enhanced in the junctions with the special thicknesses of the central layer due to the resonant electron tunnelling by the resonant states. The investigated tunnel currents are also sensitive to the central layer thickness, the average temperature of the junction, the barrier height, the spin splitting of the electron bands in the electrodes and the bias voltage applied to the junction.

Anisotropic magneto-thermal transport in Co_2MnGa thin films

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The full Heusler compound Co_2MnGa belongs to the family of Weyl-II-semimetals. Large anomalous Nernst effect has been observed in Co_2MnGa and it was attributed to non-vanishing Berry curvature of the Weyl-points making the material a promising candidate to study exotic transport phenomena. In this work we systematically measure anisotropic magnetoresistance (AMR) and its thermoelectric counterpart anisotropic magnetothermopower (AMTP) in Co_2MnGa thin-films. The data is modeled using a Stoner-Wohlfarth formalism as well as a symmetry-based phenomelogical model. Our findings show the presence of both crystalline and non-crystalline components in both magneto-transport phenomena. While the AMR is small in relative terms, the AMTP is large, which is discussed in the context of the Mott rule.

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Conversion of magnonic, electronic spin and charge currents in hybrid quantum dot

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We investigate thermal response of a hybrid system consisting of a quantum dot attached to magnetic insulators and magnetic metals. Both magnetic insulators and magnetic metals are assumed to be of ferromagnetic type. Magnetic insulators are sources of magnons, whereas magnetic metals are host for spin-polarized electrons. Generally, the considered system consists of two magnonic reservoirs and two metallic leads. However, the special cases with only two or three electrodes in different configurations are also studied. Here, we are interested in magnon current conversion to electric spin and charge currents, and *vice versa*. Magnon current is generated by temperature difference set to/in magnetic insulators and then converted to electronic spin and charge current by means of quantum dot. In turn, charge/spin current of electronic type induced by temperature gradient set between metallic leads can be transformed to magnon spin current. In the present work we model coupling between quantum dot and magnetic insulators by means of energy-dependent density of states which leads to energy-dependent coupling matrix element. The energy dependence is crucial for boson-like particles especially in low-energy limit where the lowest momentum states dominate the transport. As a consequence, one should consider explicit energy dependence of the density of states for magnonic reservoirs.

Moreover, taking into account many-body magnon interaction leads to temperature-dependent magnonic density of states, and thus, to asymmetry in couplings of magnetic insulators to quantum dot when temperature gradient is set between magnonic reservoirs.

This phenomenon can lead to asymmetric spin currents resulting in spin diode effect.

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Bilinear magnetorsistance in topological insulators: the role of spin-orbit scattering on impurities

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Bilinear magnetoresistance (BMR) is a new kind of spin-orbit-driven magnetoresistance effect that scales linearly with electric and magnetic fields. We considered BMR theoretically in surface states of 3D topological insulators. Assuming the minimal model of surface electronic states in TIs, we calculated BMR induced by the interplay of current-induced spin polarization and spin-orbit scattering on impurities. We present detailed characteristics of BMR and compare our results to those obtained for TIs with structural defects [1] and hexagonal warping [2].

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Graphene on the magnetic substrate with a domain wall

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Graphene is a two-dimensional material which is interesting for theoretical and experimental investigations. In this work, we present electronic band structure of a grahene deposited on a magnetic layer with a single sharp magnetic domain wall. To describe the system we also include Rashba spin-orbit coupling. The electronic structure includes the four bands with a bandgap proportional to magnetization M. From the Schrodinger equation we also find states localized at the domain wall, which appear inside the band gap. We observe strong oscillations of the spin density for low electron energy, with the spin along a direction parallel to the magnetic domain wall.

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Spin-orbit driven phenomena in Dirac fermions with Rashba spin-orbit interaction – transport characteristics at finite temperatures

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Spin-orbit driven phenomena, such as the spin Hall effect or current-induced spin polarization, enable electrical control of the spin degree of freedom and efficient spin-to-charge interconversion. Using the Matsubara Green function's formalism and the linear response theory, we considered the spin-orbit driven transport properties of Dirac fermions in the presence of weak Rashba spin-orbit interaction. Such a model may be used to describe transport properties of graphene and graphene-like 2D crystals beyond the zero-temperature limit. In the regime of weak Rashba coupling, we obtained analytical formulas describing the spin Hall effect and current-induced spin polarization and their thermal counterparts at arbitrary temperature. The considered model can be adapted easily to study many-body physics in Dirac-Rashba systems.

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Chiral Hall effect in the kink states in topological insulators with magnetic domain walls

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We investigate the chiral Hall effect due to topologically protected chiral kink states formed in 2D topological insulators at boundaries between domains with differing topological invariants [1]. Such systems include the surfaces of three dimensional topological insulators magnetically doped or in proximity with ferromagnets. We analyze the equilibrium charge current along the domain wall and show that it is equal to the sum of counter-propagating equilibrium currents flowing along external boundaries of the domains. In addition, we also calculate a dissipative current along the domain wall when an external voltage is applied perpendicularly to the wall. This effect is different from the anomalous Hall effect and we therefore named it the "chiral Hall effect".

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Room temperature ferromagnetism in Co-Cr and Fe-Cr co-doped ZnO nanoparticles

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The study focuses in particular on the effect of the transition metal (TM: Co-Cr and Fe-Cr) co-doping on the structural, optical and magnetic properties of ZnO. $Zn_{0.99-x}M_{0.01}Cr_xO$ (M=Co and Fe, $0 \leq x \leq 0.05$) nanoparticles were synthesized by the solution combustion method. Powder x-ray diffraction (XRD) analysis confirms all the samples has hexagonal wurtzite structures without any secondary phase present in the spectra. The average crystallite size (D) of $Zn_{0.99}Co_{0.01}O$ and $Zn_{0.99}Fe_{0.01}O$ was calculated using Scherrer's formula [1] and found to be 41±4 nm and 18±7 nm. In the case of $Zn_{0.94}Co_{0.01}Cr_{0.05}O$, D decreased to 23±7 nm, but for $Zn_{0.94}Fe_{0.01}Cr_{0.05}O$ it remains approximately unchanged at 16±7 nm. Transmission electron microscopy (TEM) images of the samples indicate that particles are in the nano-regime. It is found to be 50±1 nm for $Zn_{0.99}Co_{0.01}O$, but for other samples particles are agglomerated. Diffuse reflectance spectroscopy (DRS) analysis shows the optical band gap values are 3.302±0.005 eV and 3.293±0.006 eV for $Zn_{0.99}Co_{0.01}O$ and $Zn_{0.99}Fe_{0.01}O$, respectively, and slightly decreases (3.272±0.005 eV and 3.254±0.004 eV) with the increased Cr (0.05) ion doping concentration. A vibrating sample magnetometer (VSM) was used to obtain room temperature (RT) field-dependent magnetization (M - μ_oH) measurements. The M-H curves of all the samples are found to be hysteretic, which signifying RT ferromagnetism (RTFM). The RTFM is enhanced with Cr ion concentration which is antiferromagnetic in character. Maximum saturation magnetization, coercivities and remnant magnetization obtained for the samples are 0.665±0.01 emu.g^{-1}, 0.734±0.01 emu.g^{-1}, 142±2 Oe, 147±2 Oe and 0.103±0.01 emu.g^{-1}, 0.120±0.01 emu.g^{-1} for $Zn_{0.94}Co_{0.01}Cr_{0.05}O$ and $Zn_{0.94}Fe_{0.01}Cr_{0.05}O$, respectively. As compared to other TM co-doped ZnO such as Fe-Cu [2], Mn-Ni [3], Cu-Cr [4], the noticeable RTFM has achieved in the wurtzite structure of $Zn_{0.99-x}M_{0.01}Cr_xO$ (M=Co and Fe, $0 \leq x \leq 0.05$) nanoparticles. The correlation between structure and RTFM as a function co-doping concentration probed in these samples can helpful to manipulate the magnetic ordering in future diluted magnetic semiconductors studies.

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The effects of Cr and Ni Doping on the Structural, Optical, and Magnetic Properties of ZnO

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Zinc oxide (ZnO) is II-IV semiconductor, with a wide band gap (2.83 eV [1]). It has been the centre of much research in semiconducting material [2] as a candidate for the development of diluted magnetic semiconductors (DMS) [3] which exhibit multifunctional properties such as magnetic, semiconducting, and optical properties with potential application in spin-based electronics [1] and optoelectronic devices [4]. In these materials, a fraction of ions of the host material has been substituted for by magnetic ions (typically $3d$ transition metals) [2]. The *sp-d* exchange interaction between the charge carriers of the host and the dopant ions gives rise to unique structural, optical, and magnetic properties [5]. In the present work, we report the sol-gel synthesis of $(Zn_{1-x}Cr_x)O$ ($x = 0$, 0.005, 0.01, 0.03) and $(Zn_{1-(x+y)}Cr_xNi_y)O$ ($x = y = 0.005$ and $x = 0.025$, $y = 0.005$). The samples were calcined prior to characterization using X-ray diffraction (XRD), Transmission electron microscopy (TEM), Ultraviolet-visible (UV-VIS) spectroscopy, and Vibrating sample magnetometer (VSM). The hexagonal wurtzite structure of ZnO was confirmed from XRD data. The crystal size calculated using Williamson-Hall analysis [6] and were found to be between 73 nm and 99 nm. The crystal size increased with increasing Cr concentration from $x = 0.005$ to $x = 0.01$ followed by a decreased for $x = 0.03$. Doping ZnO with Cr and Ni decreased the crystallite size of ZnO from 90.59 nm to 83.49 nm for $(Zn_{0.97}Cr_{0.025}Ni_{0.005})O$ and 73.72 nm for $(Zn_{0.99}Cr_{0.005}Ni_{0.005})$. TEM revealed that the ZnO, as well as all the doped samples prepared in this study form agglomeration of the crystallites. The size of the band gap of ZnO decreased with increasing Cr concentration from $x = 0.005$ to $x = 0.01$, while the band gap increased with increasing Cr concentration to $x = 0.03$, contrary to previous reports. The simultaneous doping of ZnO with Ni and Cr decreased the optical gap. Low field ferromagnetism and high field diamgnetism was observed in all samples and they did not show magnetic saturation. Ferromagnetism in ZnO was attributed to the possible presence of oxygen vaccancies in the samples. In the doped samples, ferromagnetism originates from the $ZnCr_2O_4$ phase obserevd in XRD data and possoble formation of bound magnetic polarons (BMPs) as reported by other authors. High field diamagnetism observed was linked to the bulk like nature of the samples.

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Magnetotransport of LSMO grown on various buffer layers on STO

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$La_{2/3}Sr_{1/3}MnO_3$ (LSMO) is very promising for application in full oxide spintronics due to its colossal magnetoresistance, ferromagnetism at room temperature and half metallic properties. However, its properties are very sensitive to changes in stoichiometry (oxygen, La/Sr ratio), interface structure, temperature, as well as to the substrate and its crystallographic orientation, buffer layers and strain in the case of thin films. In particular, understanding and controlling magnetic properties of LSMO films are critical for implementation in the high speed and low power memory as a tunnel junction. It is proposed to create a tunnel junction with a large tunneling electroresistance (TER) and tunneling magnetoresistance (TMR), using a composite tunnel barrier of $BaTiO_3$ (BTO) and MgO between two LSMO electrodes. In such a case, the properties of upper LSMO layers may change due to their growth on MgO/BTO and BTO/MgO composite buffer layers. In this work, we present the influence of such buffer layers on the magnetotransport properties of an LSMO electrode. Our experiments were performed for the following set of buffers: MgO, BTO, MgO/BTO, BTO/MgO and a reference sample with no buffer layer, i.e. LSMO on $SrTiO_3$ (STO). We measured magnetoresistance, anisotropic magnetoresistance (AMR) and coercivity vs. temperature. For epitaxial LSMO grown directly on an STO or on a BTO buffer layer, magnetoresistance is relatively small. Double-buffer layers (with MgO) results in a polycrystalline structure. In the case of polycrystalline LSMO, scattering at the grain boundary is an additional source of magnetoresistance, which causes an increase in the magnetoresistance effect, especially at low temperatures. As expected, we measured higher low field magnetoresistance values for the buffer samples with respect to the reference sample. Regarding the dependence of magnetoresistance on temperature, the highest value of magnetoresistance was observed at a low temperature for LSMO/MgO/BTO/STO and LSMO/BTO/MgO/STO samples. The polycrystalline LSMO layers had a higher coercivity than the epitaxial reference sample [1]. Magnetoresistance vs. the applied magnetic field is qualitatively different below and above Curie temperature, and it is also different for epitaxial and polycrystalline LSMO. Interestingly, it correlates with the coercivity of the films. The AMR effect is predicted to occur for epitaxial LSMO samples and its absence indicates a polycrystalline structure. Consequently, we observed the AMR effect only for the LSMO/STO and LSMO/BTO/STO samples.

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Zero-bias Giant Rashba Spin-Orbit Coupling at Complex Oxide Interfaces

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Following the second law of thermodynamics, the Landauer's principle dictates a fundamental physical limitation for the switching energy of a complementary metal oxide–semiconductor (CMOS). A primary solution in breaking this limitation is to utilize the spin-orbit coupling (SOC) effect, as it allows easy manipulation of spin currents. However, this SOC effect is often quite weak, especially in the absence of external voltage biases. Here, a four-fold SOC enhancement at zero bias voltage and pronounced SOC evolution is reported in correlated $LaAlO_3$-$SrTiO_3$ heterostructures buffered by a carrier modulating $LaFeO_3$ layer. An entirely new approach has been used to provide evidence of generating Rashba SOC. Correlating the magnetotransport data with first-principles calculations and high-resolution electron microscopy, the results reveal its origin which lies in the asymmetric hybridization of the interfacial wavefunctions. The results open hitherto unexplored avenues of generating and controlling Rashba coupling to design next-generation two-dimensional electron system based spin-orbitronic devices.

Bilinear magnetoresistance and planar Hall effect in topological insulators

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Bilinear magnetoresistance and planar Hall effect [1-3] are two nonlinear transport phenomena that scale linearly with the electric and magnetic fields and appear in non-magnetic systems with strong spin-orbit coupling, such as topological insulators (TIs). Using the semiclassical Boltzmann theory and generalized relaxation time approximation, we considered in detailed the bilinear magnetoresistance and bilinear planar Hall effect in an effective model describing surface states of three-dimensional topological insulators. We focused, among others, on the role of magnetic impurities in both of these nonlinear effects.

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Role of chromium on structure, optical and magnetism of Cr doped ZnO nanoparticles

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The role of Cr incorporation into the ZnO were probed through investigations into the structural, optical and magnetic properties. Diluted magnetic semiconductors (DMSs), ZnO and $Zn_{1-x}Cr_xO$ (x = 0.03 and 0.05), were prepared by solution combustion method with glycine as fuel. Powder x-ray diffraction (XRD) results indicate that both the ZnO and $Zn_{1-x}Cr_xO$ (x = 0.03 and 0.05) have single hexagonal wurtzite structures, indicating that Cr ions substituted the Zn ions without influencing the structure. This is in agreement with previous theoretical and experimental results suggest that only Cr^{3+} ions substituted into Zn^{2+} sites without altering the structure [1, 2]. Following the Willamson-Hall approach [3], the crystallite size and microstrain of the samples were calculated and found to be be 42±2 nm for ZnO and it reduces to 33±4 nm in $Zn_{0.97}Cr_{0.03}O$, while lattice strain increased from 0.039±0.005% to 0.048±0.008%, respectively. Rietveld refinement analysis reveals that lattice parameters a and c of ZnO are well matched with standard data (PDF# 36-1451). The value of both a and c increases slightly for $Zn_{0.97}Cr_{0.03}O$ while a decrease was observed for $Zn_{0.95}Cr_{0.05}O$. Transmission electron microscopy (TEM) reveals that particle size of ZnO is 47±2 nm and for $Zn_{1-x}Cr_xO$ (x = 0.03 and 0.05) samples, particles are agglomerated. The optical bandgap obtained using diffuse reflectance spectroscopy was found to be 3.305±0.003 eV and 3.290±0.003 eV for ZnO and $Zn_{0.97}Cr_{0.03}O$, respectively. The field-dependent magnetization (M - μ_oH) measurements were carried out using a vibrating sample magnetometer (VSM) at 300 K. All the samples exhibits ferromagnetic behavior. In ZnO ferromagnetism at 300 K is due to different observed defects (oxygen and zinc vacancies). The $Zn_{0.97}Cr_{0.03}O$ showed the highest saturation magnetization and remnant magnetization are 0.664±0.01 emu.g^{-1} and 0.126±0.002 emu.g^{-1}, respectively, while $Zn_{0.95}Cr_{0.05}O$ sample exhibit a higher coercive field (23.7 mT) than that observed for $Zn_{0.97}Cr_{0.03}O$ sample (19.5 mT). The study of XRD and high resolution TEM (HR-TEM) confirms, all the samples are in wurtzite structure and the cause of magnetism is explained on the basis of complex interplay between the defects and Cr substitution at Zn sites [4].

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Vector Spin Capsule Neurons - Towards a Spintronic Vector Deep Learning Framework

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Spintronics has the potential to revolutionize computing and storage [1] for the beyond CMOS era. Spintronic and multiferroic phenomenon with spin transfer torque, all spin currents, spin based threshold operations and Rashba-spin-orbit effects provide a rich platform that allows complex signal processing [2]. Recently, a major breakthrough has been reached with the application of deep-learning [3] methods for artificial intelligence. However, the computing for AI and deep learning is increasingly dependent on scaling of Teraoperations/second and Teraoperations/watt. For the complete advancement of AI to its potential a breakthrough is required in computuing hardware itself [4,5].

Vector capsule networks [6,7] are an important evolutinary step towards vector deep neural networks where the vector nature of image information is comprehended in the neural network to overcome the "bag of features" problems in traditional scalar neural networks. Vector networks capture both the features of an object and its orientation to decide classification. Spin provides a natural fit for such a representation due to the vector nature of spin currents where the orientation is captured in the orientation of Spin and stength is captured in the magnitude of the spin current [8].

We describe the generalization of vectorial spin neurons with scalar, vector and tensor weights. We also describe the nature of vector neurons with scalar, vector and tensor weights. We show examples of neuron non-linear vector-valued sigmoid functions that allow back propagation. We also describe a physical method for implementing such vector spin devices [9].

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Thermal scanning probe lithography for nanoscale magnetic domain switching

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Thermal scanning probe lithography (t-SPL) uses a heatable ultra-sharp tip for nanoscale physical or thermal modification and simultaneous imaging of materials. The technology has proven its value as an enabler of new kinds of ultra-high resolution nanodevices as well as for improving the performance of existing device concepts [1]. The range of applications for t-SPL is very broad including ultra-high resolution 2D and 3D patterning. Nanometer-precise markerless overlay and non-invasiveness to sensitive materials are among the key strengths of the technology. In addition, an integrated laser write head has been introduced to increase the throughput of lower resolution patterning and to enable the fabrication of systems where feature sizes range from nanometers to millimeters [2].

Recently, t-SPL has been used to define nanoscale magnetic domains into arbitrary shapes and directions of magnetization by locally heating multilayer ferromagnetic/antiferromagnetic thin film stacks under an external magnetic field [3]. Accurate control over individual domain walls enables the creation of, e.g. vortex/antivortex pairs and Bloch lines, guiding spin waves and defining versatile, optics-inspired magnonic circuits for spin waves demonstrating engineered wavefronts, focusing and robust interference with nanoscale wavelength. [4]

In this poster, we demonstrate the abilities of thermal scanning probe lithography not only as a high-resolution nanolithography tool that can replace or complement electron beam lithography in challenging applications, but also as a versatile instrument for studying magnetic phenomena at the nanoscale.

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Micromagnetic investigation of domain wall morphology in perpendicular anisotropy microwires with anisotropy gradient and structural defects

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A reliable control of field or current driven dynamics of domain walls (DWs) in various magnetic conduits is crucial for prospective applications in senor, memory or logic devices [1]. Depending on technology involved the control may be realized, among others, by geometric constraints [1] or introduction of structural defects [2]. In the latter case an ion bombardment may be used to induce changes within a material that ultimately alter an effective anisotropy of the system and influence DW response to the field. The defects, in otherwise magnetically relatively homogeneous layers, locally change DW nucleation field and significantly affect their motion [2]. In this contribution we show micromagnetic analysis, using OOMMF software, of the DW propagation in $1\,\mathrm{nm}\times4\times1\,\mu m^2$ strips with a constant perpendicular magnetic anisotropy (PMA) gradient along their longer edges and randomly distributed defects of two kinds. The defects are either micromagnetic cells with zero magnetization or cells with PMA reduced by 3 % relative to the gradient background. The changes of the DW shape as it propagates along the strip are analyzed using image analysis, as a function of the number of both types of imperfections. Preliminary results show that if roughly 3 % of the cells have no magnetic moment convexity of the DW, defined as a ratio of its length to the distance between its terminals, approaches one, as opposed to the case with no defects. The anisotropy defects which locally decrease the PMA below the minimum value of the defect-free simulation lead to significant random contribution to the domain nucleation and in effect render the walls increasingly convex.

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Electronic structure and hydrogen absorption in Mg-Ni alloy thin films

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The strong interest in pure Mg and Mg-based alloys as hydrogen storage materials is associated with the fact that magnesium can absorb a large amount of hydrogen. Moreover, magnesium is abundant, light weight, and relatively not expensive [1]. Magnesium based thin film materials are subject of intensive studies due to a potential application as switchable mirrors and hydrogen sensors [1,2]. In this contribution we report on electronic structure and room temperature (RT) hydrogen absorption in Mg-Ni alloy thin films. Mg-based alloy thin films were prepared on transparent glass substrates at RT by UHV RF/DC magnetron co-sputtering. Before hydrogenation, all samples were coated with a 10 nm thick Pd layer. The chemical composition of all the layers and interface mixing between Mg-Ni and Pd layers were studied in-situ using X-ray photoelectron spectroscopy (XPS). Furthermore, the XPS valence bands were measured for all the prepared alloy thin films. Hydrogen absorption in Mg-Ni alloy thin films were studied at a pressure of about 1000 mbar using simultaneous optical transmittance and four-point resistivity measurements. Moreover, before and after hydrogen absorption the samples were characterised by Atomic Force Microscopy and high-angle X-ray diffraction (XRD). XPS measurements showed no surface segregation effect in freshly prepared Mg-Ni alloy thin films. On the other hand, successive measurements of the XPS Mg-2p, Ni-2p and Pd-3d peaks for Mg2Ni thin films covered by Pd layer revealed a formation of interface Mg-Pd alloy layer. Such an interface alloy layer can considerably influence on the hydrogen absorption in the Mg2Ni thin films [2]. Transmittance and resistivity measurements during hydrogen absorption showed that the 100 nm – Mg thin film covered by 10 nm Pd layer needed about 200 h for saturation. The MgNi and MgNi2 alloy thin films revealed no hydrogen absorption at RT. On the other hand, the fastest rise in transmittance was observed for Mg2Ni thin film covered by 10nm Pd. The transmittance of the sample with a thickness of about 200 nm reached 90 percent of the maximal value after 40 s of hydrogenation. The sample was completely loaded with hydrogen after about 20 minutes. RT hydrogen absorption in pure Mg and Mg2Ni alloy thin films was also confirmed by intense hydride reflections observed in the XRD patterns.

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Influence of NiO layers on Exchange Bias Coupling and Perpendicular Magnetic Anisotropy of Co layers

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Nowadays, magnetic multilayers consisting of oxide layers have been intensively investigated due to their crucial role in modification of magnetic properties of ferromagnetic (F) films. For example, it was recently shown that metal oxide (MO) layers may induce strong Perpendicular Magnetic Anisotropy (PMA) [1] and/or Dzyaloshinskii-Moriya interaction at the F/MO interface [2]. Both effects can also be controlled with antiferromagnetic oxides (AFOs) [3, 4], which also gives an additional degree of freedom to tune magnetic properties through exchange bias (EB) coupling.

Here, we focused on $NiO^b/Co/Au$ and $NiO^b/Co/NiO^t$ polycrystalline systems (the superscript b and t denote the bottom and top NiO layer, respectively) where PMA of Co layer and EB coupling between NiO and Co layers were investigated. For both systems, we found strong PMA of Co layers and strong EB coupling between Co and NiO [5]. The results for the $NiO^b/Co/NiO^t$ system are particularly interesting because the Co layer is only in contact with the oxide material. This shows that it is possible to achieve a strong PMA of the F layer replacing the heavy metals by AFOs. Moreover, the coercivity and the exchange bias (H_{EB}) field almost doubled in comparison to those observed for the $NiO^b/Co/Au$ and $Au/Co/NiO^t$ systems. This can be explained assuming an additive contribution of the NiO^b/Co and the Co/NiO^t interfaces to the effective EB coupling. Additionally, for $NiO^b/Co/Au$ and $NiO^b/Co/NiO^t$ systems, we demonstrated that after field cooling in moderate temperatures ($\sim$450 K) the PMA is enhanced due to an increase of surface contributions to the effective anisotropy. However, further field colling procedure up to 450 K enables to tune H_{EB} in a wide range without perturbing other magnetic properties of importance.

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Non-equilibrium steady state transport through quantum dot spin valves

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Transport through correlated nanostructures, such as quantum dots or molecules, has been under intensive research owing to the fascinating physics emerging at the nanoscale. In particular, a many-body effect resulting in an enhancement of the zero-bias conductance up to the quantum limit at low temperatures, known as the Kondo effect, is one among the main reasons for this increasing attention. Even though this effect could be theoretically explained using the Wilson's numerical renormalization group (NRG) under equilibrium, there is a need for reliable quantitative results for such systems in the non-equilibrium regime. In this communication, we theoretically investigate the non-equilibrium transport properties of a quantum dot-spinvalve, i.e., a quantum dot attached to two ferromagnetic leads, particularly focusing on the Kondo regime. We employ a hybrid NRG-time-dependent density matrix renormalization group approach that enables us to accurately resolve extremely low energy scales, while keeping the system out of equilibrium. We study the non-equilibrium steady state current, while probing the system under various parameters,such as lead spin polarization, temperature and applied magnetic field. The system when tuned to the particle-hole symmetry point, shows a finite zero-bias conductance peak, characteristic of the Kondo effect, and a reduction of the Kondo energy scale in voltage with rise in the lead spin polarization, which is quantitatively different from previous theoretical predictions for equilibrium systems. Moreover, a suppression of the Kondo resonance with increasing the lead polarization is observed when the system is detuned out of the particle-hole symmetry point, owing to the emergence of an exchange field in the system. Interestingly enough, for a particular value of applied magnetic field, the Kondo resonance can be restored. Our work provides quantitatively accurate results for nonequilibrium behavior of quantum dot spin valves that may serve as benchmark for future theoretical and experimental works.

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Magnetic properties of two-dimensional M2N3 (M-metal, N-non-metal) compunds.

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Using ab-initio methods we study structural, electronic and magnetic properties of two dimensional compounds with stoichiometry M2N 3 (M-metal, N=non-metal from groups 13-18 of the periodic table). Our study shows that structures with Cr, Ti, and Mn are stable, with significant binding energy. Also, such structures are semiconductors with narrow band gaps. We also show that above mentioned compounds have considerable magnetic moments. The negative values of magnetic anisotropy energy suggest, that these materials can maintain ferromagnetic ordering in non-zero temperatures with estimated Curie temperatures in the range of 30-130 K

Measuring interfacial Dzyaloshinskii-Moriya interaction in a Pt/Co/Pt structure dusted by Gd via asymmetric domain wall expansion

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Efficient manipulation of topological spin textures in multilayer stacks might be achieved by breaking spatial inversion symmetry at the interfaces. Such an approach could become important for spintronic applications. The symmetry breaking at interfaces increases chiral phenomena, which could yield new material properties. In ferromagnetic (FM) thin films, the chiral exchange interaction is known as interfacial Dzyaloshinskii–Moriya interaction (iDMI). So, manipulating the iDMI could provide a general route to tailor chirality in magnetic materials through interface engineering. In this study, the influence of a Gd dusting layer on PMA and iDMI was measured via asymmetric domain-wall expansion by Kerr microscopy in a Pt/Co/Pt base structure. The measurements show that the existence of the Gd dusting layer enhanced the iDMI, while the strong PMA of the system is preserved. We expect that this study could inspire future considerations about the influence of rare-earth-element dusting on magnetic properties and might open new strategies for Skyrmion stabilization in metallic FM systems.

The studies on phonons and magnons in $[CoFeB/Au]_N$ multilayers of different number of repetitions

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In $[CoFeB/Au]_N$ deposited on the silicon substrate, the interaction between spin waves and surface acoustic waves is observed by Brillion light scattering spectroscopy. We show that the magnetoelastic interaction in the dispersion relation can be achieved by changing the number of repetitions. As a result, the magnetoelastic interaction between SW mode and SAWs can be controlled (activated or deactivated) by the thickness of the magnetostrictive multilayer. It is also possible to control the character of magnetoelastic interaction by selection of the type of magnetic waves that take part in the magnetoelastic interaction.

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The studies on surface spin waves dispersion relations in $[Ni_{80}Fe_{20}/Au/Co/Au]_N$ multilayers with different direction of magnetization

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In $[Ni_{80}Fe_{20}/Au/Co/Au]_N$ deposited on the silicon substrate, the surface spin waves dispersion relations are observed by Brillion light scattering spectroscopy. The NiFe layer is characterized by in-plane anisotropy (magnetic easy axis in plane) while in the Co layer the direction of magnetization depends on the thickness of Co. We show that different dispersion relations for surface spin waves can be obtained by changing the thickness of the Co layer. The anisotropy of surface spin waves on surface of studied multilayers has also been shown.

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Higher-order interlayer exchange coupling in Nb-Fe and V-Fe multilayers

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Short-ranged interlayer exchange coupling play an important role in the properties and potential application of magnetic materials. However, the origin and nature of this interaction are not sufficiently clear [1]. In this contribution, we report results on the interlayer exchange coupling studies in (110) oriented Nb-Fe and V-Fe multilayers (MLs).The samples were prepared at room temperature (RT) on Si(100) wafers with an oxidised surface using UHV magnetron sputtering. A capping layer of 5 nm Pd was used to avoid oxidation of the top Fe sublayers and catalyse hydrogen absorption and desorption in the Nb and V sublayers. The chemical composition of all the layers was studied *in-situ* using X-ray photoelectron spectroscopy (XPS). The growth and interface mixing of the Nb-Fe and V-Fe bilayers were characterised *in-situ* by successive measurements of the XPS Fe-2p, Nb-3d and V-2p peaks for the samples with different sublayer thicknesses. Magnetic characterisation of the Nb-Fe and V-Fe MLs was performed in the temperature range 5-350K by successive hysteresis measurements using a Vibrating Sample Magnetometer in a magnetic field up to 9T. Moreover, RT hydrogen absorption in the Nb-Fe and V-Fe MLs was studied at a pressure of about 1000 mbar using four-point resistivity measurements. Results on XPS studies showed a limited interface mixing for the Nb-Fe and V-Fe bilayers deposited at RT. Furthermore, from the exponential variation of the XPS Fe-2p, Nb-3d and V-2p integral intensities with increasing layer thickness we conclude that the Fe, Nb and V layers grow homogeneously in the planar mode. The hysteresis loops revealed antiparallel alignment of the magnetic moments of the Fe sublayers and were fitted using bilinear (J1), biquadratic (J2) and cubic (J3) exchange constants. The interlayer antiferromagnetic coupling in the V-Fe MLs was also confirmed by magnetoresistance measurements. Results show that the biquadratic and cubic interlayer exchange coupling play an important role in magnetisation reversal of the Nb-Fe and V-Fe MLs. The higher-order interactions (J2 and J3) are especially important for Nb and V spacer thicknesses greater than 7 monolayers. Furthermore, the hydrogen absorption in the Nb and V spacer at RT below 1 bar can only suppress cubic interaction. The above effect is reversible and after hydrogen desorption the cubic interaction appears again. In conclusion, the cubic interlayer exchange coupling is sensitive to hydrogen absorption under mild conditions.

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Tailoring of magnetic anisotropy in Au/Co/Ni systems by plasma oxidation

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The exchange bias (EB) coupling has been intensively studied for many years in ferromagnet(FM)/antiferromagnet(AFM) thin film systems with perpendicular magnetic anisotropy (PMA). This significant attention is because of their potential use in many applications (e.g. magnetic random access memories, hard drive read heads, etc.) [1]. Nowadays, a new aspect of this interaction is broadly investigated, namely the role of this interaction in PMA enhancement. It has been shown in several systems (e.g. Fe/Mn [2], $(Ni_{80}Fe_{20})/Mn$ [2], Co/NiO [3]) that coupling between the FM and the AFM is an additional source of PMA for the FM films.

Here, we investigate how plasma oxidation (PO) influences the PMA and the EB coupling of Ti/Au/Co/Ni layered systems. After deposition, the sample was treated with oxygen plasma to oxidize the Ni layer. Our previous research indicates that this process leads to the formation of NiO on top of the Co/Ni system. As a result, a significant increase in the coercive field (H_c) is observed, which could be attributed to EB coupling. To verify this, we performed field cooling (FC) process in a perpendicular magnetic field ($H_\perp$) to induce the unidirectional anisotropy of the Co/Ni system. Measurements were carried out in high vacuum by using a liquid nitrogen cryostat. The samples were cooled down to $T = 78K$ at $H_\perp = 3kOe$. At this temperature, we found a shift of the hysteresis loop along the field axis (H_{EB}), which evidences EB coupling between the oxidized Ni and the Co/Ni bilayer. The FC process was repeated three times for an oppositely directed H to confirm that the shift direction is due to the EB coupling. Since the H_c and H_{EB} values depend on the AFM thickness, we deposited an additional NiO layer on top of the oxidized Ni layer. At low temperatures, we found higher values of H_c and H_{EB} than those of the sample with thinner NiO layer. Moreover, the H_{EB} is preserved even at RT which was not a case for samples without additional NiO layer. We also found that the effective anisotropy for such a system is strongly enhanced, which means that formation of a Ni/NiO interface by plasma oxidation constitutes a novel tool to tune EB coupling and magnetic anisotropy of thin Co (or ferromagnetic) films.

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The Magnetic Properties of Mn_5Ge_3 Grown on PMN-PT Thin Films

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It is of great importance to show the electric field manipulation of magnetic properties in the field of spintronics and memory devices. One approach for achieving voltage control of magnetization is to use a hybrid piezoelectric/ferromagnetic device in which a voltage applied to the piezoelectric induces a strain in the ferromagnetic layer, which in turn affects the magnetic properties. To control several physical properties of various as-grown functional ferromagnetic thin films, ferroelectric PMN-PT single crystals have been widely used as piezoelectrically active substrates [1-3]. It has been previously indicated that permanent strain on Mn_5Ge_3 induced by the growth on a substrate with the different lattice constant varies the magnetization and Curie temperature [4]. Since Mn_5Ge_3 has a strong magnetization at room temperature and the ability to control the magnetic properties by strain, Mn_5Ge_3 is a very advantageous material.

In this study, we examined the structural and magnetic properties of thin Mn_5Ge_3 films grown on PMN-PT (011) substrate by solid-phase epitaxy with various thicknesses of Ge and Mn layers. Sample growth was performed by Molecular Beam Epitaxy (MBE), under the pressure of 1 x 10^{-9} mbar. The samples were prepared by depositing Ge layer at around 150° C then Mn layer at RT followed by annealing for 20 min at 330° C to allow Mn atoms to diffuse into the Ge layer and form Mn_5Ge_3 structure. Insitu XPS measurements performed to investigate the electronic structure and atomic concentration of the elements. The relationship between the magnetic properties and Ge and Mn layer thickness was investigated by means of vibrating sample magnetometer (VSM) and Electron Spin Resonance (ESR) over a wide range of temperatures. All the samples are a ferromagnetic with a Curie temperature of 300° C. Lower Mn layer thickness led to smaller magnetization and higher coercive field. The highest squareness ratio (Mr/MS) of 0.55 is obtained for samples with the lowest Mn layer thickness, indicating that they have a single magnetic domain. Upon switching the ferroelectric polarization from P_{up} to P_{down}, we observe a relative change in the total magnetic moment of the films.

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Synthesis and Characterization of $Co_xNi_{1-x}Cr_2O_4$ ($0 \leq x \leq 1$) Nano Particles.

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$CoCr_2O_4$ is a spinel ferrimagnet that crystallizes in the space group Fd3m [1]. There are two clear magnetic phases associated with the compound: a collinear ferromagnetic phase below, T_C of about 94 K and a long-range conical spiral state at the spin-spiral transition temperature, T_S at about 27 K [2]. An additional first-order transition has been reported by several authors [3,4] T_L at about 14 K. The present study aims to synthesize $Co_xNi_{1-x}Cr_2O_4$ and to probe the physical and magnetic characteristics of these nanoparticles. $NiCr_2O_4$ has a normal cubic spinel structure within the space group of Fd3m at temperatures above 320 K and exhibits two magnetic transitions at $T_C = 74$ K and $T_S = 31$ K [5]. A magneto-structural transition at 74 K where the structure changes from tetragonal to an orthorhombic phase and magnetic transition from paramagnetic to ferromagnetic. The second transition at 31 K is because of the ordering of the antiferromagnetic component. The structural and magnetic phase transitions happen simultaneously in $NiCr_2O_4$. $NiCr_2O_4$ and $CoCr_2O_4$ are both spinels but each show unique properties; thus, it is thought by considering $Co_xNi_{1-x}Cr_2O_4$with $0 \leq x \leq 1$, the modification of the magnetic as well as structural properties can be probed. The $Co_xNi_{1-x}Cr_2O_4$with $0 \leq x \leq 1$ samples were synthesized by sol-gel technique, followed by calcination at different temperatures. The structural characterizations of these samples were studied by x-ray diffraction (XRD) patterns of the samples calcined at different temperatures ranging from 400 to 900° C indicate that the powders are of single phase. The crystallite size estimated by Williamson-Hall method is 5.734 nm for sample $Co_{0.75}Ni_{0.25}Cr_2O_4$ calcined at 500° C. The transmission electron microscope (TEM) was used to study the microstructure of the calcined powders. The particles are not uniform in size. The average particle size from TEM is 5.85 ± 3nm for the sample $Co_{0.75}Ni_{0.25}Cr_2O_4$ calcined at 500° C. Most of the particles have a bi-pyramidal shape. The magnetic behavior of composition $Co_{0.75}Ni_{0.25}Cr_2O_4$ synthesized by sol-gel technique calcined at different temperatures were studied. For $Co_{0.75}Ni_{0.25}Cr_2O_4$ calcined at 700° C determined T_C =79.4 ± 0.5 K which is less than previously reported T_C = 90.6 ± 0.9 K for $Co_{0.75}Ni_{0.25}Cr_2O_4$ synthesized by co-precipitation and calcined at 900° C [6]. The study reveals the modification of magnetic properties in accordance with calcination temperatures.

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Ferromagnetic resonance-induced spin pumping in CoFeB/Pd systems deposited on rigid and flexible substrates

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Broadband ferromagnetic resonance (FMR) has been used to investigate the dependence of the magnetic damping enhancement in CoFeB/Pd bilayer systems due to spin pumping. This study has been realized on a series of samples characterized by a fixed CoFeB thickness of 6 nm while the Pd thickness varies from 2 to 30 nm ($t_{\mathrm{Pd}} = 2, 4, 6, 8, 12, 20$ and 30 nm). This series has been simultaneoulsy deposited on two different substrates: a rigid one (Si) and a flexible one (Kapton). The results obtained from the analysis of the FMR measurements reveal show an exponential behaviour of the Gilbert damping as function of the Pd thickness in both kind of substrate. The experimental data was analysed using an anaytical model for spin pumping [1,2], which includes the effective spin mixing conductance of the CoFeB/Pd interface and the spin-diffusion length. The estimated values are around 6 nm^{-2} for both substrates whereas the diffusion length differs significantly between the two substrates (5.22 nm for Si sunbstrate and 1.11 nm for Kapton substrate). The obtained results demonstrate the efficiency of the possibility of tuning the Gilbert damping constant by a judicial choice of the nonmagnetic film, depending on the desired application.

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Magnetocaloric properties of $Ga_xFe_{3-x}O_4$ nanoparticles coated with chitosan

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The use of magnetic nanoparticles in magnetic fluid hyperthermia and a growing interest in nanotechnology cause development of variety of isostoichiometric materials of different shapes [1,2]. Small angles neutron scattering, as well as transmission and scanning electron microscopy measurements, confirm the change in shape of core and core-shell nanoparticles of gallium-iron oxides from parallelepiped to spherical ones [3,4]. According to magnetization and Mössbauer spectroscopy results, gallium-doped magnetite particles belong to very soft magnetic materials. Due to nano-size of core type particles, they exhibit a variety of superparamagnetic behavior versus temperature. The X-ray diffraction patterns confirm a single phase of the reverse spinel structure as the Massart synthesis result. Admixture in the form of trivalent gallium as a non-magnetic ion significantly modifies the magnetic ordering of ferrite. Calorimetric measurements disclosed large sensitivity of the specific absorption rates of electromagnetic radiation at 10^5 Hz frequency range versus ferrofluid concentration dispersed in water (10 mg/mL, 5 mg/mL, and 2.5 mg/mL). Magnetism of $Ga_xFe_{3-x}O_4$ with $0 < x < 1.5$ particles coated with chitosan was tested in external fields up to 1.3 T.

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Exchange bias coupling between Co and TbCo alloy layers with controlled concentration gradient

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The ability to tune the switching fields (H^S) of ferromagnetic layers (F) exhibiting perpendicular magnetic anisotropy (PMA) in a wide range is important for many spintronics applications. This is usually realized by exchange bias coupling in AF/F (AF-antiferromagnetic layer) bilayers. We have recently[1] shown that replacing the AF layer with a ferrimagnetic (FI) layer allows to tune the H^S of the F layer from minus to plus several kOe. This work investigates the exchange bias coupling between the F and FI layers, where the FI layer is an alloy. Here, we study F(Co)/FI(Tb-Co) and F(Co)/S(Au-tAu)/FI(Tb-Co) layered systems, where t_{Au} is the thickness of a Au wedge. For comparison with our previous studies, Tb-Co alloy layers with a well-defined c_{Tb} gradient parallel to the substrate's edge (x) were deposited. This was obtained by co-sputtering from Co and Tb targets, where the desired c_{Tb}(x) gradient was first calculated and then experimentally verified using energy-dispersive X-ray spectroscopy and polar magneto-optical Kerr effect measurements. In this work, we focus on a (Au-1nm/Co-0.8nm)$_3$/Au-t_{Au}/(Tb-Co-c_{Tb}) structure, in which changes of the c_{Tb} and t_{Au} occur along mutually perpendicular directions. This morphology allows us to determine the magnetization reversal as a function of c_{Tb} and t_{Au} values in a single sample. We found that the strongest interaction between F and FI occurs for c_{Tb} near the compensation point (c_{comp}) of the Co and Tb sublattices. For t_{Au}=0, c_{comp} is around the c_{Tb}=29at.% and it does not change up to t_{Au}=0.8nm. As t_{Au} increases above 0.8nm, c_{comp} starts to decrease and approaches constant (c_{Tb} = 22at.%) for $t_{Au}\geq$1nm. For $t_{Au}<$0.8nm, the top Co layer interacts more strongly with the Tb-Co alloy than with two other Co layers in the (Au/Co)$_3$ multilayers and undergoes magnetization reversal together with Tb-Co alloy. This means that the top Co layer is coupled to the FI layer and this causes an increase of the amount of Tb needed to compensate the Co sublattice. In the case when the top Co and Tb-Co layers are separated by a thick Au layer, the interactions between them are much weaker and the magnetization reversal of the top Co layer of (Au/Co)$_3$ takes place together with the other two Co layers. As a result, the compensation occurs at c_{Tb} = 22at.%, which is in good agreement with recent reports for Tb-Co film[2].

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Reversible ionic control of antiferromagnetic anisotropy

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Antiferromagnets (AFMs) are a ubiquitous class of magnetic materials, holding the promise of low-dissipation spintronic computing devices that can display ultra-fast switching, density scaling and robustness against stray fields[1]. However, magnetic sublattice compensation makes it difficult to detect and control AFM textures in a reversible and scalable manner via standard techniques[2].

We overcame this limitation by developing a novel ionic approach to reversibly tailor AFM anisotropy[3]. We focussed on the earth-abundunt AFM α-Fe_2O_3, which exhibits a spin-reorientation (Morin) transition between in-plane and out-of-plane configurations. Developing reversible control of AFM anisotropy in α-Fe_2O_3 is important for prospects in (i) topological spintronics[4,5] and (ii) magnonics[6,7]. Regarding the former, I will discuss our recent results where the Morin transition was exploited to stabilize a wide family of exotic AFM topological textures - half-skyrmions and bimerons - at room temperature. These topological textures have core sizes (of ≈ 100 nm) and can be scaled further with anisotropy tuning[4].

In this context, I will discuss our findings on ionic control of antiferromagnetism in epitaxial α-Fe_2O_3 films[3]. The catalytic-spillover process employs Pt nano-structures to hydrogenate the AFM films, thereby, driving pronounced changes in the anisotropy, Néel vector orientation and canted magnetism via local charge-doping. As H ions are very small and light, they can be added/removed from the host lattice, without significantly disturbing the overall structure. This allows our approach to be stable yet reversible[3]. Tailoring our work for future applications, we demonstrated reversible control of the room-temperature AFM-state by doping/expelling H ions in Rh-substituted α-Fe_2O_3. I will conclude by presenting the wider implications of our work, such as how AFM-state control could eventually be realized with E-fields[8] and translated to a wider variety of AFMs (e.g. orthoferrites, orthochromites)[9], enabling the construction of low-energy antiferromagnetic applications.

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Impact of the ferrogel fine structure on magnetic heating efficiency

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Agarose gel with nanoparticles of Fe_3O_4 was used as a tissue-mimicking material (TMM) for hyperthermia study, e.g. in [1]. Magnetisation of clustered nanoparticles is generally lower than spatially separated magnetic nanoparticles, cf. [2]. The goal of this study was to show how the nanoparticle are clustering inside the agarose gel structure and to relate it with the heating efficiency of ferrogel. To this end, two types of ferrogels were studied, with bare and PEG-coated nanoparticles. XRD patterns revealed the spinel structure and mean crystal diametr c/a $d = 8.9$nm. TEM images confirmed these results. FTIR confirmed the PEG content in PEG-coated nanoparticles. SQUID measurements revealed the superparamagnetic properties at room temperature, and besides, lower magnetization values of PEG-coated nanoparticles than bare ones. A comparison of the temperature increase under the influence of the same alternating magnetic field in both gels indicated a bit faster temperature rise for a gel containing PEG-coated nanoparticles although the magnetic saturation of the PEG-coated superpapramagnetic nanoparticles was 15% lower than for bare nanoparticles. The measured specific heat of both gels was indistinguishable. So, the Specific Absorption Rate (SAR) of the ferrogel with PEG-coated nanoparticles was greater than with bare nanoparticles. This result confirmed the influence of the fine structure of the nano-composite gel on the heating efficiency of the composite. The fine structure of two types of nanocomposites differed firstly in the spatial nanoparticle distributions and their locations. Secondly, they differed also in the strength and type of bonds between nanoparticles and the gel. For the first time, it was possible to observe in TEM images chiral clusters of nanoparticles, evenly densely packed and located inside agarose double helices. We underline that such clusters, probably bonded by electrostatic and van der Waals forces were stable under the action of the AC magnetic field, we observed only in the ferrogel with bare nanoparticles. PEG-coated nanoparticles did not form such clusters, they were more uniformly distributed and located outside double helices, rather inside the ice structure of water, and bonded to this structure by weak hydrogen bonds. We concluded that these differences in nanostructures were responsible for differences in heating efficiency.

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Comparison of the influence of superparamagnetic nanoparticles concentration and coverage on the alternating magnetic field thermal effect.

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The alternating magnetic field (AMF) causes the located in cancerous tissue magnetic nanoparticles (MNP) to dissipate heat, leaving the surrounding tissue intact, which is the basis for many biomedical technologies. One of them is magnetic fluid hyperthermia (MFH), a controlled technique of heating tissues to temperature from 41 to 46 °C exploiting magnetic fluids with Fe_3O_4 after injecting them directly into target tissues. The efficiency of MFH depends on the type of particles. The particles used in medical procedures must have high biocompatibility. For this purpose, they are usually coated with special coatings. Our goal was to investigate the effect of nanoparticle concentration and coverage in the tested samples on the efficiency of MFH.

The MNPs were produced by standard co-precipitation reaction of iron chlorides with ammonia water. To apply polyethylene glycol (PEG) coatings on the nanoparticles PEG was added during the process. For our research, two series of nanoparticles were produced: without (series 1) and with PEG coatings (series 2). Magnetic characterization, size, and composition of the nanoparticles produced were carried out based on X-ray diffraction (XRD), spectroscopy in Fourier transform infrared (FTIR), superconducting quantum interference device (SQUID), and transmission electron microscope (TEM). Magnetic fluids were prepared as oleic acid suspension of nanoparticles of the two series at concentrations of 5, 10, 20, 40 mg/ml. The volume of oleic acid in all samples was the same. Measurements of the temperature rise in all magnetic fluids were carried out within 3 minutes.

The results of the conducted experiments confirmed that the efficiency of MFH strongly depends on the concentration of fluids. The efficiency of the process increases with a higher amount of concentration. Besides, a fluid containing bare magnetic nanoparticles (series 1) had a greater temperature increase than those that contain particles with coatings PEG (series 2) in the concentration range from 5 to 40 mg/ml. To compare the heating properties of the Fe_3O_4 and Fe_3O_4-PEG nanoparticles, the specific absorption rate (SAR) was calculated for each sample $SAR = c_p \frac{\partial T}{\partial t}|_{t=0}$, where c_p is the specific heat of the sample and $\frac{\partial T}{\partial t}|_{t\approx 0}$ is the constant, i.e. the rate of temperature rise at the beginning of the process. The results indicate that the magnetic fluid containing nanoparticles with PEG heat up slower than fluids with bare nanoparticles. The reason for this is maybe the increase of "magnetic dead layer" width on the contact of nanoparticles with PEG, which was also confirmed by the worse magnetic properties of PEG-coated MNPs compared to bare MNPs.

Surface modification and magnetic study of widely Ga-doped magnetite nanoparticles

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In recent years, magnetic nanoparticles have been widely used in biomedicine for drug delivery, magnetic resonance imagining or hyperthermia [1,2]. Magnetites doped with *3d* ions, and Ga^{3+}: $Ga_xFe_{3-x}O_4$ with $0 \leq x \leq 1.4$, form a group of innovative materials [3-5]. Gallium nano-ferrites seem to be promising biomaterials that exhibit superparamagnetic fluctuations up to temperatures well above 315 K. X-ray and neutron diffraction, transmission electron microscopy, magnetization, and Mössbauer spectroscopy measurements were collected for nanoparticles synthesized by different methods. The reverse spinel structures of core and core-shell gallium ferrites have been confirmed as single phases. The in-site occupancy preference as a function of gallium dopant is discussed. The nanosystems have been quickly saturated disclosing neglectable coercive fields with the spontaneous magnetization at the range of 2 emu/g - 58 emu/g. Independently of the synthesis method, for the nanoparticles of gallium content $x > 0.8$, the superparamagnetic contribution becomes the dominant one.

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Enhancing Dzyaloshinskii-Moriya Interaction in Pt/Co/Pt structure by Gd dusting

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Stabilizing chiral spin textures in magnetic thin films is generally dependent on the interfacial Dzyaloshinskii-Moriya interaction (iDMI) along with the exchange interaction. Especially, enhancing iDMI in thin films with perpendicular magnetic anisotropy (PMA) such as Pt/Co/Pt multilayers is still a challenge. In this study, the influence of Gd layer dusting on PMA, iDMI, and exchange energy in Pt/Co/Pt structure is investigated by first-principles calculations. The magnetic properties of structures were investigated by Vibrating Sample Magnetometry and also via domain wall expansion by Kerr Microscope. We show that the existence of Gd dusting layer leads to an enhancement in iDMI, while the strong PMA of the system is preserved. The exchange energy of the system was also reduced by the Gd insertion to the interface. We anticipate that our study not only offers a rational design for controlling the strength of the iDMI, PMA, and exchange energy but also will inspire future considerations about the influence of rare-earth element dusting on magnetic properties.

Size Effect on Magnetic Properties of $MnCr_2O_4$ Nanoparticles

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Transition metal oxide spinels of the form AB_2O_4 have attracted a lot of interest because of the emerging interest in spin frustration, multiferroicity and critical point phenomena [1-2]. They have important applications in technology. This group of compounds has distinct tetrahedral (A) sites occupied by divalent cations and octahedral (B) sites populated by trivalent cations [3]. The physical properties of spinel oxides depend on the distribution of cations among the sites and the relative strength of the super-exchange interaction [4]. Among AB_2O_4 compounds, cubic spinel ACr_2O_4 oxides exhibit various significant physical effects, such as colossal magnetoresistance, multiferroicity, spin frustration and so on [5]. $CoCr_2O_4$ shows a magnetic transition from paramagnetic to ferrimagnetic and ferrimagnetic to spiral ordering as the temperature lowers and shows lock-in transition at low temperatures [2]. In this work, the size effect on the structural and magnetic properties of cubic spinel $MnCr_2O_4$ nanoparticles synthesized by the co-precipitation method is discussed [5]. The samples were calcined at different temperatures in the range 750°C - 1050°C. The average crystallite size of the synthesized nanoparticles was determined by powder X-ray diffraction (XRD), which showed an increase in particle size from 35.88 ± 0.01 to 55.53 ± 0.01 nm with an increase in calcination temperature. The lattice parameters of the nanoparticles decreased with an increase in calcination temperature. The average particle size was determined from the transmission electron microscopy (TEM) by fitting a Gaussian curve for the distribution of particles. Energy dispersive X-ray spectroscopy (EDS) confirmed Mn and Cr in the nanoparticles and selected area electron diffraction (SEAD) showed the crystalline nature. The optical spectra for $MnCr_2O_4$ nanoparticles was recorded using the UV-vis spectrometer. The Tauc model [6], was used to calculate the optical band gap that showed an increase in the value with increase in particle size. The magnetic properties as a function of temperature and magnetic field were measured using a vibrating sample magnetometer (VSM). Results showed $MnCr_2O_4$ nanoparticles have paramagnetic to ferrimagnetic transition at Curie temperature, T_C that ranges $42 \leqslant T_C \leqslant 46$ K followed by another transition at temperature T_S between 18 K and 21 K associated with the short-range spiral order. The observed anomaly will be discussed considering the change in lattice parameter

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Direct and multistage spin reversal in chains of magnetic nanoparticles

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Magnetic systems exhibiting well-defined sequences of stable states are useful in design of memory storage devices. We have studied the switching of magnetization in linearly arranged particles of different shapes under variations of the magnetic field (applied perpendicular to the chains). Several approximations appropriate for macrospins have been employed: from an extended Stoner-Wohfarth model by a 1D model of magnetic threads to the extensive micromagnetic calculations reflecting the actual shape of the particle [1, 2, 3, 4, 5]. A qualitative difference in behavior of infinite and finite chains has been observed. Whereas the infinite chains tend to switch the magnetization in a direct one-step manner, chains of finite number of particles turn out to exhibit a sequence of macrospin reversals giving rise to several intermediate configurations of well-defined magnetisations. Some of the reversal sequences turn out repeatable that make them promising models for many-stage memory elements.

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Tuned spin-textures at heavy metal/magnetic multilayered heterostructures

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Interface engineering to tune the sign and intensity of the Dzyaloshinskii-Moriya interaction (DMI) has received large attention in the last decade. It has important prospects for emergent spintronics applications that rely on the stabilization of chiral spin textures, such as the manipulation of magnetic domain walls (DWs) through spin Hall effect induced torques. As most magnetic materials are non-chiral, insertion of heavy metal layers is currently used to lift the degeneracy between left- and right-handed DWs. However, the delicate balance between magnetic exchange, magnetic anisotropies and DMI depends on the specific materials and the details of the structure.

We have recently proved the interest to replace conventional uniform magnetic layers such as Co by multilayered Co/Ni heterostructures, using Bi as a heavy metal. The heterostructure inhibits stacking faults that could significantly alter the magnetic anisotropy, and serves to stabilize configurations minimizing Heisenberg exchange in favor of a dominant DMI. Furthermore, Bi guarantees the homochirality of the system even under disordered distributions, that naturally emerge due to the strong tendency of Bi atoms to float on the surface. Here we explore the effect of replacing Bi by other heavy metals, namely Pt and Ir, with a lower trend to seggregate to the surface and a reduced lattice mismatch with respect to the Co/Ni multilayers. Both features favor the control over the finally grown heterostructure, enabling the design of multilayer stacks with tuned chirality.

Based on a density functional theory approach, we determine the influence of band filling effects, strains and heavy metal distributions on the balance of the relevant magnetic energies, identifying the conditions that enhance the DMI leading to chiral spin textures. Our results confirm the uniqueness of Bi to stabilize robust homochiral structures with dominant DMI, but also serve to identify interesting alternatives to tune magnetic handness by wiseful heterostructure design.

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Structural and Magnetic Properties of $DyCrTiO_5$ Nanoparticles

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Futuristic engineering science is searching for advanced magnetic materials with novel properties such as magnetization reversal (MR), magnetocaloric effect (MCE), spin switching (SS), and spin reorientation (SR) [1]. The compounds with the general chemical formula $R\mathrm{CrTiO_5}$ (R = rare-earth ions) crystallize in an orthorhombic structure with space group *Pbam*, isostructural to the $R\mathrm{Mn_2O_5}$ [1-3]. The interesting magnetic behavior observed in $R\mathrm{CrTiO_5}$ compounds is attributed to the presence of two magnetic sublattices [1-3]. However, there are very few reports on the physical properties of these compounds, and are primarily on bulk. From this family of compounds, $DyCrTiO_5$ is one of the most interesting materials to study because of the large magnetic moment of Dy as well as large magnetocrystalline anisotropy of $DyCrTiO_5$ [1]. Das *et al.* [1] discussed the magnetic properties of $DyCrTiO_5$ bulk samples that showed novel features, such as MR, SR, and exchange bias phenomenon because of the interaction between R^{3+} and Cr^{3+} [1]. The exploration of structural and magnetic properties of $R\mathrm{CrTiO_5}$ compounds in the nano dimension has not been reported to date. This report focuses on the synthesis of DyCrTiO nanoparticles using a simple and cost-effective sol-gel technique to explore the role of size on structural and magnetic properties. Subsequent calcination of the synthesized samples at 800 ^{o}C led to single phase particles. The crystal structure is confirmed from the Le-Bail profile fitting [1] of the x-ray diffraction (XRD) pattern. The $DyCrTiO_5$ nanoparticles crystallized in an orthorhombic structure having lattice parameters, a, b, c of 7.32, 8.64, 5.84 Å, respectively. The average particle size obtained from the transmission electron microscopy (TEM) is around 75 nm which is in line with the size estimated from the XRD using Scherrer equation. From the temperature-dependent magnetization measurement at 50 Oe magnetic field, the obtained T_N value is around 151 K. In contrast to the bulk form, $DyCrTiO_5$ nanoparticles do not show SR which should be observed below 37 K or the magnetic compensation [1]. In addition, the magnetization is suppressed when measured as a function of temperature with a probing field 50 Oe in the heating cycle of measurement. The observed anomalous properties are discussed considering the size effect.

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Magneto-dynamic properties of LSMO films on STO modified by buffer layers

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Manganite perovskites $La_xSr_{1-x}MnO_3$ (LSMO), generally referred as colossal magnetoresistance materials, high spin polarization and robust ferromagnetic order at room temperature. Recently reported possibility of tuning magnetic properties of LSMO by strain have attracted significant interest due to possible application of LSMO-based devices in spintronics. We have explored how strain induced changes in magnetic properties of LSMO can be controlled by MgO and $BiTiO_3$ (BTO) buffer layers deposited on $SrTiO_3$ (STO) substrate. Using Ferromagnetic Resonance (FMR) Spectroscopy and Vibrating Sample Magnetometry (VSM) we were able to test dynamic and static magnetic response, respectively. VSM measurements reveal that all the samples studied exhibit coercive field smaller than 100 Oe, which make them suitable for spintronic applications. The strongest magnetic properties is revealed by the LSMO/STO films. However, it is only slightly reduced in the LSMO films grown on MgO and BTO buffer. FMR spectra show a significant difference between LSMO/STO films and LSMO/(MgO,BTO)/STO heterostructures as well. The highest Gilbert damping constant is observed for LSMO films on MgO buffer, while the smallest one for the LSMO films deposited directly on STO. In all the cases damping coefficient is small, i.e. below 10^{-3}, which indicates superior quality of the films and long propagation length of spin waves of the order few micrometers.

Effect of Ce^{3+} Substitution at *B* site on Magnetic Phase Transitions in $CoCr_2O_4$ Nanoparticles

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$CoCr_2O_4$ belongs to the cubic spinel family where Co^{2+} occupies the tetrahedral *A* sites and Cr^{3+} populates the octahedral *B* sites [1]. Single crystals of $CoCr_2O_4$ undergo a paramagnetic to ferrimagnetic transition at $T_C = 93$ K, and subsequent lowering of the temperature leads to a conical spin state at 26 K (T_S) [1]. The appearance of ferroelectricity in $CoCr_2O_4$ has been ascribed to this spin modulation [1]. At 15 K, the compound shows the lock-in transition[1]. In polycrystalline $CoCr_2O_4$ spinel compounds, both ferrimagnetic and spiral magnetic orderings were observed at 94 K and 27 K, respectively, with missing lock-in transition [2]. The results of multiferroicity in $CoCr_2O_4$ were confirmed [3], where the conical-spiral ferroelectricity has been referred to as the interrelation of ferroelectric polarization, magnetization, and spiral wave vector [3]. The observed findings suggest that the nearest neighbor and isotropic antiferromagnetic *A-B* and *B-B* exchange interactions J_{AB} and J_{BB} compels the system to attain a "ferrimagnetic spiral", having spins located on the conical surfaces [3]. The occurrence of spiral ordering at 25 K has also been observed in $CoCr_2O_4$ nanoparticles (about 40 nm) without any lock-in transition [4]. The disappearance of T_S also occurred in undoped and Ni substituted $CoCr_2O_4$ thin films [5]. As a strong motivation of the importance of the spiral ordering and the exchange interaction, the present work aims at the substitution of rare-earth Ce^{3+} ion at Cr^{3+} site. A $Co(Cr_{0.95}Ce_{0.05})_2O_4$ compound was synthesized by the sol-gel technique. X-ray diffraction (XRD) studies of the sample calcined at 600 C, revealed pure phase. The crystallite size estimated from the XRD was approximately 9 nm. The average particle size calculated from the transmission electron microscopy (TEM), $D_{TEM} = 11 \pm 2$ nm. Electron diffraction patterns confirm the crystalline nature of the nanoparticles. Magnetization as a function applied field shows an increase in coercivity below T_C with subsequent lowering in temperature. Magnetization measured as a function of temperature indicated the ferrimagnetic $T_C = 86 \pm 1$ K which is lower and $T_L = 15 \pm 2$ K in agreement with the reported values for $CoCr_2O_4$. Interestingly the spiral ordering was smeared by the substitution of Ce at the Cr site. The present work envisages the impact of rare-earth ion substitution at the *B* site that can alter the exchange interaction in such a way that causes suppression of the spin modulation.

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Magnetic properties of ultrathin Co layers sandwiched between noble metals (Au, Pt, Ir)

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Ultrathin cobalt layers sandwiched between noble metals exhibit magnetic properties attractive for different applications. In particular in these systems relatively strong perpendicular magnetic anisotropy (PMA) can be obtained in Co thickness range of several monolayers. Moreover, for Pt/Co/Ir and Ir/Co/Pt systems strong Dzyaloshinskii-Moriya interaction (responsible for creation of skyrmions and domain walls with a given chirality) can be achieved [1]. Therefore, magnetic systems with structure X/Co/Y (X,Y = Au, Ir, Pt) are very important for applications in information technologies. We have investigated X/Co-wedge/Y (X, Y = Au, Ir, Pt) layered system deposited by magnetron sputtering on naturally oxidized Si substrate covered with Ti-4nm/Au-30nm buffer layer. The thickness of wedge shaped Co layer (tCo) was varied from 0 to 3.6 nm and the thickness of X and Y layers were 2 nm. The magnetic properties of nine systems (all combination of X/Co/Y) were characterized by measurements of magneto-optical hysteresis loops measured in polar configuration (P-MOKE) along the Co thickness gradient. On this basis we have defined tCo changes of: (i) coercive field HC(tCo); (ii) and squareness of the hysteresis loops (ratio of P-MOKE signal in remanence and saturation - ϕR/ϕS(tCo)); (iii) magnetic uniaxial anisotropy field. The Co thickness corresponding to spin reorientation transition, and volume as well as surface contributions to effective anisotropy constant were determined for each system. For selected systems the magnetic characterization was supplemented by determination of Dzyaloshinskii-Moriya interaction (using Brillouin light spectroscopy) and observation of magnetic domain structure evolution with magnetic field (using P-MOKE-microscopy).

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Magnetic-resonance-induced modification of mechanical properties of crystals

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Magnetoplastic effect (MPE) is known as changes of nonmagnetic crystal's mechanical properties due to magnetic impact, [1]. Recently its manifestations were found even under ultralow fields in the EPR scheme when the sample was exposed to the crossed fields, static (the Earth field $\sim$ 50 μT) and alternating field (1-3 μT) of some resonance frequencies $\sim$1 MHz, [1]. Here, we studied changes of dislocation mobility and the modification of microhardness in the NaCl crystal with the Ni impurity ($\sim$2 ppm). In our case, a series of rather narrow peaks of dislocation paths related to definite resonance frequencies were observed in the EPR scheme. In parallel, after exposure, a similar resonance decrease in the crystal microhardness was observed. The spectrum consisted of the two groups of softening peaks, nine ones in each group. These times we dealt with a memory effect, in which maximums of peaks were reached not immediately, but in 2-3 hours after the exposure. The necessary diffusion self-organization stage of the crystal with resonance transformed impurity centers to the new long-lived equilibrium metastable state needed a time. Then after the back transitions of those centers, the back diffusion processes provided weakening of the effect, the hardness slowly increased arriving at the initial level in a day. To check the magneto-activity of so small density of Ni impurities ($\sim$2 ppm), the same samples were used for an ordinary EPR analysis in the standard X-range (ν = 9.4 GHz) at 4.2 K for different orientations of a sample with the magnetic field vector. All obtained spectra correlated with each other, indicating the same elementary acts in all cases, the spin-dependent electron transitions during the magnetic exposure of samples. The studied resonance spectra of mechanical characteristics were related to specifics of MPE at ultra-low magnetic fields in the EPR scheme. The transformed Ni centers were under the action of not only external static magnetic field but also of local crystalline magnetic field (e.g. from Cl^- nuclei). In our case, the latter was $\sim$100 times higher than the external Earth field. The interaction of impurity electrons with those ligands created the splitting of states of "zero field" and the related series of resonance transitions providing the experimentally observed spectra.

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Electronic and magnetic properties of silicene monolayer under bi-axial mechanical strain: A first principle study

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The mechanical control of the electronic and magnetic properties of 2D Van-der-Waals heterostructures enables the development of spintronics-related technologies such as memory and quantum-computer devices.

Using the density functional theory, we investigated the structural, electronic and magnetic properties of silicene monolayer with substituted impurity atoms X (X=Fe, Co, and Cr), and under small biaxial strain ($|\epsilon| \leq 8\%$). Our results indicate that the X-doped silicene nanosheets are either magnetic metal or half-metal without strain. We will show that with the tensile strain increasing, the magnetic moment concerning the horizontal dimer substitution has sustained variations and preserves the metallic behaviour. However, it increases slightly through the monomer, and vertical dimer substitution and the system shows a weak semiconductor feature in $\epsilon \geq 8\%$. We will also show that the largest semiconductor band-gap is 0.4 eV at 8% tensile strain for vertical Fe-doped. Finally, biaxial compressive strain leads to emerging fluctuating changes in the magnetic moment, whereas monomer Co-doped disappears in higher strains. Meanwhile, the half-metal behaviour under the compressive strain transforms to a semiconductor for monomer Co and vertical dimer Cr substitution at -4% and -2%, respectively.

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Formation of Fano resonance in double quantum dot system

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Nowadays, after applying short-time voltage pulses or other sudden changes in system parameters it is possible to experimentally observe dynamic of charge in nanostructures under the non-stationary conditions. The ultra-fast time-resolved spectroscopy techniques enable real-time observation of, among others, how the system returns to equilibrium from excited states. Just recently the Fano resonance buildups were monitored in optical experiments using the spectrally resolved electron interferometry and the atto-second transient absorption spectroscopy [1].

Here, transient electron dynamics and the Fano resonance formation in transport through a two-QD system (DQD) in a T-shape geometry are analysed (neglecting Coulomb interactions). Electrical currents are derived by means of nonequilibrium Green functions, where their time dependencies are found by inverting the Laplace transform in the wide band limit. We assume that initially only one QD is coupled to two metallic electrodes under bias, and then suddenly the second QD is attached. This strongly modifies coherent transport: currents and conductances. Time evolution of the transport characteristics and electron dynamics are different for a weak and a strong inter-dot coupling (t_{12}) with respect to the dot-electrode coupling (Γ). When the dot-dot coupling is weak, $t_{12} \ll \Gamma$, electrons tend to occupy dot levels. One level is strongly hybridized with the electrodes, while the other one (on the attached QD) is localized and only weakly coupled to a conducting channel. Interference between these two conducting channels leads to a Fano anti-resonance with a characteristic dip in the conductance. Periodic oscillations of conductance are found, which are related with charge transfers between the QD and the electrodes. The oscillation frequency is inversely proportional to the relative position of the QD level to the Fermi level and their amplitudes decrease with time and bias. In the opposite limit, $t_{12} \gg \Gamma$, one can treat DQD as an artificial molecule and observe the time evolution of the conductance from the single peak structure into the double peak structure, which corresponds with bonding and antibonding orbitals. Now the dot-electrode charge oscillations are more pronounced, which leads to a change in the direction of the current flow and, consequently, a change in the sign of the conductance. Apart from the aforementioned oscillations one finds also rapid Rabi oscillations caused by coherent electron transfer between the DQD states. For some bias voltages we have found the superimposed modulations of the conductance amplitude originating from beating of the Rabi oscillations with the dot-electrode charge oscillations. In the large time limit the stationary solutions of Fano resonance are recovered.

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Magnetic reversal mechanism and domain pattern in thin films with perpendicular magnetic anisotropy for different angular orientation, shape, and arrangement of antidots

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Theoretical studies, especially micromagnetic simulations are powerful method in terms of investigation of a complex magnetic systems which are difficult to obtain in experimental techniques. Our work is focused on magnetic reversal and domain pattern formation in antidot arrays with perpendicular magnetic anisotropy. The effect of the lattice symmetry with different arrangement (triangular, square, quasicrystalline and random), antidot size, shapes (triangles, squares and crosses) as well as their angular orientation has been investigated. Simulations are performed by solving the Landau-Lifshitz-Gilbert equation and finding the system's energy minimum for model with intrinsic and extrinsic defects. Rotation of the antidots around their centers has an affect in coercivity values and also domain sizes especially in the systems with square and cross-shaped antidots. The results are discussed in terms of the local shape anisotropy and equilibrium positions of domain walls.

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Morphological characterization and electronic properties of pristine and oxygen-exposed graphene nanoribbons on Ag(110)

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Graphene nanoribbons (GNRs) are at the frontier of research on graphene materials since the 1D quantum confinement of electrons allows for the opening of an energy gap [1]. GNRs of uniform and well-defined size and shape can be grown using the bottom-up approach, i.e. by surface assisted polymerization of aromatic hydrocarbons [2]. Since the electronic properties of the nanostructures depend on their width and on their edge states, by careful choice of the precursor molecule it is possible to design GNRs with tailored properties [3]. Here, we characterize pristine and oxygen-exposed GNRs with mixed edge-site sequence (two zig-zag and one armchair) synthesized on Ag(110) from 1,6-dibromo-pyrene precursors. The electronic structure is investigated by scanning tunneling spectroscopy, and influence of oxygen exposure is revealed by scanning tunneling microscopy and photoemission spectroscopy. Our results demonstrate that oxygen exposure deeply affects the overall system by interacting both with the nanoribbons and with the substrate; this factor must be considered for supported GNRs under operative conditions.

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Ultrathin iron nitride films on Cu(001): Growth conditions vs. structure and electronic properties

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Iron nitrides exhibit interesting magnetic and electronic properties, making them promising for spintronic applications [1,2]. We studied ultrathin ($\leq$ 1 monolayer-thick) γ'-Fe_4N films grown on Cu(001) by sputtering the substrate with N^+ ions, depositing Fe and post-annealing in ultra-high vacuum (UHV). The relatively small lattice mismatch between the iron nitride and the copper support (in the $\sqrt{2}$ direction) results in an epitaxial growth [3]. In addition to the films prepared using the above-mentioned (and already-reported [4–5]) procedure, we also prepared iron nitride layers using the modified approach in which we switched the order of the preparation steps (Fe deposition$\rightarrow N^+$ sputtering$\rightarrow$UHV annealing). The results obtained using scanning tunneling microscopy (STM) and spectroscopy (STS) revealed differences in the structure (islands vs. continuous film) and electronic properties (work function, density of electronic states close to the Fermi level) of the films, which is believed to be related to the growth of either a pure γ'-Fe_4N (using the literature procedure) or a half-unit-cell Fe_2N form (using the modified approach).

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Structural flexibility of ultrathin iron oxide islands and films on Ru(0001)

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Iron oxides are the well-known magnetic materials which, depending on the crystalline phase, exhibit ferromagnetic or antiferromagnetic ordering. In the case of ultrathin (< 1 nm-thick) iron monoxide (FeO) islands and films, the structure and magnetic properties may be additionally determined by the limited thickness and the interaction with the underlying substrate. Such species are also prone to oxidation/reduction when subjected to oxidizing/reducing conditions, which is related to the different possible oxidation states of iron and the structural flexibility of nanometer-sized structures. We used scanning tunneling microscopy (STM), low energy electron diffraction (LEED) and X-ray photoelectron spectroscopy (XPS) to study the structural evolution of the FeO/Ru(0001) system upon exposure to atomic oxygen (oxidation) or high-temperature annealing under ultra-high vacuum (UHV) (reduction). The results revealed the transformation of FeO into an oxygen-rich ("FeO_2") or oxygen-poor ("Fe_2O") phase upon oxidation/reduction, respectively [1,2]. The experimental findings are supported by density functional theory (DFT) calculations on the crystallographic, electronic and magnetic structure of different iron oxide films on Ru(0001).

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Structural, thermal and magnetic characterization of Al-(Ni,Cr,Cu,Y)-Fe alloys

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Rapidly solidified aluminium alloys are promising materials which provide many beneficial properties compared to conventional Al-based alloys with crystalline structure. Better properties compared to crystalline alloys are resulted from chemical homogeneity and possibility to obtain unique structures like amorphous, quasicrystalline or nanocrystalline [1]. Improving of magnetic properties of these alloys have been described in the literature by many methods like f.e. primary crystallization of amorphous alloys [2]. Relatively good magnetic properties have been observed in Al-Fe-Ni [3] and Al-Fe-Cu [4] alloying compositions. The aim of the studies was characterization of structural, magnetic and thermal properties of aluminium alloys with Ni, Cr, Cu, Y and Fe additions. The samples were prepared with a different cooling rates by induction melting (master alloys), high-pressure casting (plates) and melt-spinning (ribbons). Phase identification was analized by X-ray diffraction method. The magnetic properties were examined using vibrating sample magnetometer and Mössbauer spectroscopy. Measurements of magnetic parameters were performed at room temperature and included field of coercive force (H_c), saturation magnetization (M_s), magnetic remanence (M_r) which were determined from hysteresis loops by vibrating sample magnetometer in magnetic fields up to 20 kOe. The ^{57}Fe Mössbauer spectra were measured at room temperature with a constant acceleration spectrometer with ^{57}Co:Rh source. Mössbauer spectra were fitted using doublets describing different local environments of a ^{57}Fe nuclide. The differential scanning calorimetry was conducted to determine the crystallization mechanisms of studied alloys.

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Thermodynamic equilibrium of large scale Monte Carlo magnetic simulations

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Magnetic simulations take an important place in the area of designing new magnetic materials required for different applications in modern technologies. In this aspect, the Monte Carlo methods are very interesting regarding the fact that they allow modeling complex magnetic systems not only in the basic state but also in realistic temperatures. It is well known that the key point of any applications of the Monte Carlo methods in statistical physics is the condition to keep thermodynamic balance expressed by the Boltzmann probability. Recently, we proposed an original supplementation of the cluster Monte Carlo methods that bases on an configuration entropy of some property (e.g. magnetic anisotropy) [1], which it enhances efficiency for finding minimum of free energy in magnetically multiphase systems. In order to analyze large scale magnetic systems we introduced scaling rules that allow simulating mesoscopic objects by a system with relatively low number of the so-called nodes[2]. This approach requires a redefinition of some parameters occurring in the system Hamiltonian (e.g. exchange integral parameter, spin value, anisotropy constant). The undiscussed problem may arise from the question how is the thermodynamic balance in the "enlarged" systems. The work refers to a set of Monte Carlo magnetic simulations supplemented by the scaling rules. We have tested the ferro-para transition in a function of the scaling factor, i.e., for the systems ranged from nano to meso in size. It turned out that the Curie point had significantly varied with the increasing system size and follows the rule of n^2 (where n is the scaling factor). In the presentation this effect is widely discussed and derived form analysis of the Hamiltonian redefinition proposed as the scaling rules.

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Monte Carlo calculations of Curie temperature of $Y_{1-x}Gd_x(Fe_{1-y}Co_y)_2$ pseudobinary system

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The $Y_{1-x}Gd_x(Fe_{1-y}Co_y)_2$ system belongs to Laves phases [1,2], which are binary close-packed structures with the chemical composition AB_2. Our main result is the dependence of the Curie temperature on the Gd and Co concentrations of the $Y_{1-x}Gd_x(Fe_{1-y}Co_y)_2$ system, obtained by fashioning the Heisenberg model Hamiltonian of the mentioned system with Monte Carlo simulations using parameters from the first-principles calculations. Furthermore, we investigate the dependence of exchange integrals on inter-atomic distance and study the behavior of total and partial magnetic moments as calculated from the first principles. For the $Y_{1-x}Gd_xFe_2$ system we reproduced the linear dependence of T_C on Gd concentration x and for the $Y(Fe_{1-y}Co_y)_2$ and $Gd(Fe_{1-y}Co_y)_2$ we reproduced the characteristic Slater-Pauling-like dependence of T_C on Co concentration y.

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Unravelling magnetism and microstructure in $SmCo_5$/Fe composites

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Magnetic nanocomposites $SmCo_5$/Fe were synthesized by high energy ball milling (HEBM) from $SmCo_5$ and 10 wt.% of α-Fe powders over various time up to 10 h. The X-ray diffraction patterns revealed dominated hexagonal 1:5 phase, the cubic α-Fe phase and 2:17 rhombohedral phase, all content modified over synthesis duration. By analysing XRD patterns, the significant decrease of crystallites size with simultaneous increase of lattice straining is confirmed. An evident reduction of particles size is noted from the microstructural analysis. The observed non-linear modification of magnetic parameters determined from hysteresis loops may be considered as the modification within the exchange-coupling strength induced by various synthesis time. The modification of the maximum energy product $(BH)_{max}$ is discussed. The room temperature Mössbauer spectra confirmed the magnetic character of Fe.

Structurally disordered $Ce(Fe_{0.9}Co_{0.1})_2$ metamagnet: electronic structure, magnetism and magnetocaloric effect

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Electronic structure, magnetic and magnetocaloric properties of $Ce(Fe_{0.9}Co_{0.1})_2$ alloy with the C15 cubic Laves phase are discussed. This well known metamagnet was synthesized by melt-spinning, which enabled formation of quenched-in structural disoder in the way reported by us for YCo_2 [1]. Subsequently, as-quenched ribbons were plastically deformed to cause further microstructural modifications and analyse their impact on magnetic and magnetocaloric properties. It is known that the crystal structure of the monocrystalline $Ce(Fe_{0.9}Co_{0.1})_2$ becomes distorted to rhombohedral symmetry at 90 K in zero magnetic field. While decreasing temperature, the process is accompanied with the magnetic phase transition from the ferromagnetic to the antiferromagnetic state. Due to structural disorder significant volume fraction of the deformed sample retains its ferromagnetism, while remained antiferromagnetic phase undergoes metamagnetic transition to the ferromagnetic state with applied magnetic field. Magnetic entropy change for the inverse magnetocaloric effect observed in the vicinity of antiferro-ferro transition is significantly reduced from about 1.45 J/kg K ($\Delta\mu_0 H = 2$ T) for melt-spun ribbon to about 0.15 J/kg K in plastically deformed sample. Moreover, in the framework of the Density Functional Theory we discuss the electronic structure of the alloy with antiferromagnetic and ferromagnetic ordering.

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DFT calculations of intrinsic properties of magnetically hard phase $L1_0$ FePt

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Due to its strong magnetocrystalline anisotropy, $L1_0$ FePt phase is considered a promising material for magnetic recording media and as a magnetically hard material that does not contain rare earth elements [1]. Although the magnetic properties of this phase have already been analyzed many times using density functional theory (DFT) [2], we decided to study it again using the full-potential local-orbital (FPLO) scheme [3]. In addition to determining the exact values of the magnetocrystalline anisotropy constants K_1 and K_2, the magnetic moments, the Curie temperature, and the magnetostriction coefficient, we focused on investigating the dependence of the magnetocrystalline anisotropy energy (MAE) on the magnetic moment values, which was made possible by using the fully relativistic fixed spin moment method [3]. These calculations also allow us to understand the discrepancies between the results obtained previously for different exchange-correlation potentials. The obtained calculation results are in good agreement with the experimental results.

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Magnetocaloric effect in binary Gd-Pb alloys

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The aim of present work was to study the phase composition, microstructure and magnetocaloric effect of binary Gd-Pb alloys. Samples were prepared by arc-melting of high purity constituent elements. The XRD studies were carried out using a Bruker D8 Advance diffractometer with Cu-Kα radiation and semiconductor detector Lynx-Eye. The microstucture and chemical composition of the samples were studied by scanning electron microscopy (SEM) using JEOL JSM 6610LV, equipped with an energy dispersive X-ray spectrometer (EDX). The XRD and SEM studies revealed biphasic structure built by pure Gd and secondary phase Gd-Pb. The magnetocaloric measurements revealed two maxima corresponding to two phases, which caused an increase of half width at half maximum of ΔS_M vs. T curve. The analysis of the temperature dependence of magnetic entropy change allowed to construct temperature dependence of exponent n.

Structure and magnetic characteristics of $Mn_{1-x}Fe_xNiGe$ $(0.05 \leq x \leq 0.30)$ solid solutions

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Intermetallic alloys and solid solutions having magnetostructural phase transitions are of interest for theory and practice due to the presence of magnetoresistance, magnetocaloric effect, magnetostriction effects. MnNiGe-based alloys and solid solutions are convenient model objects for studying static and dynamic distortions of the crystal lattice, since magnetostructural transformations of both the first and second kind realized in them [1]. The features of the relationship of magnetic properties and changes in the crystalline structure of solid solutions $Mn_{1-x}Fe_xNiGe$ $(0.05 \leq x \leq 0.30)$ are studied. It has been established that MnNiGe is an antiferromagnet with a Neel temperature $T_N \approx 346$ K. Substitution of Mn atoms with iron ones causing a decrease in the parameters of the MnNiGe unit cell leads to the emergence of a ferrimagnetic state and in some cases to a manifestation of ferromagnetic ordering of magnetic moments.

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Influence on the microwave characteristics of Y-type polycrystalline hexaferrite

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We report results from studies on the microwave properties of Y-type polycrystalline hexaferrite synthesized by sol-gel auto-combustion and used as a filler in a composite microwave absorbing material. The reflection losses of the Y-type hexaferrite powder dispersed homogeneously in a polymer matrix of silicon rubber were investigated in the 1–20 GHz range in both the absence and the presence of a magnetic field. We used a permanent magnet with a strength of 1.4 T with the magnetic force lines oriented perpendicularly to the direction of the electromagnetic wave propagation. In the case without magnetic field, the microwave reflection losses reached the maximum value of 34.63 dB at 6.19 GHz in the Ku-band, while applying the magnetic field resulted in a remarkable and rather unexpected change in these values, namely, a maximum value of 21.13 dB at 8.95 GHz. The sensitivity of the microwave properties of the composite material to the external magnetic field was manifested by a decrease in the attenuation of the reflected wave. Thus, at a fixed thickness tm of the composite, the attenuation peak frequency can be adjusted to a certain value either by changing the filling density or by applying an external magnetic field.

Keywords: Y-type hexaferrite, microwave properties, reflection losses, external magnetic field.

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Magnetic instabilities in $K_2Cr_3As_3$

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The magnetic response of a $K_2Cr_3As_3$ sample has been studied by means of dc magnetization measurements as a function of magnetic field (H) at different temperatures ranging from 5 K up to 300 K. Looking at the magnetic hysteresis loops m(H), a diamagnetic behavior of the sample has been inferred at temperatures higher than 60 K, whereas at lower temperatures the sample shows a ferrimagnetic behavior. Moreover, several spike-like magnetization jumps, both positive and negative, have been observed at certain fields in the range -1000 Oe $<$ H $<$ 1000 Oe, regardless of the temperature considered. The field position of the magnetization jumps has been studied at different temperatures, and their distribution can be described by a Lorentzian curve. Finally, a possible explanation of the microscopic mechanisms leading to the presence of these magnetization instabilities has been provided.

Optimization of the hard magnetic properties of MnBi alloy by minor Pd substitution

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MnBi alloys are of the highest importance nowadays due to the significant uniaxial magnetic anisotropy of its low-temperature phase (LTP), which crystallizes in a hexagonal NiAs-type structure. At above 600 K this ferromagnetic phase transforms into a paramagnetic high-temperature phase with a Ni_2In-type structure. Parent MnBi compound and Pd-substituted ($Mn_{50}Bi_{49}Pd$ and $Mn_{49}Bi_{50}Pd$) alloys were synthesized by melt spinning and further heat treatment. Minor addition of Pd stabilizes LTP when compared to parent MnBi compound. It is reflected in considerable increase of coercivity. Optimization of microstructure and domain structure should result in further improvement of hard magnetic properties.

The texture transition of shear bands in Goss grains during cold rolling in grain-oriented silicon steel

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Grain-oriented silicon steel is an important soft magnetic material for electromagnetic conversion and is widely used in transformers[1−2].The magnetic induction of grain-oriented silicon steel is determined by the sharpness of secondarily recrystallized Goss grains,which is originated from nucleation in the shear bands of cold rolled sheets[3].However,the microstructure and texture in shear bands is depended on the texture of deformed matrix and the rotation route of the deformed matrix[4−7].To clarify the formation mechanism of the shear band,the initial Goss grains with diffused angle along the ϕ_2 axis in the subsurface layer of the normalized sheet were selected to captured the microstructure evolution during the cold rolling.The quasi in-situ electron back-scatter diffraction(EBSD) method was used to track the texture transition of shear bands in Goss grains with different diffused angle along the ϕ_2 axis.It is found that the diffused angle along ϕ_2 axis of initial Goss grains decreased 1-3°during cold rolling, and ϕ_2 angle converged on 45°,which the grain orientation rotated towards {111}<112>. When {111}<112> deformed matrix texture was diffused along the ϕ_2 axis larger than 4°, the Goss orientation within the shear band was diffused along the ϕ_2 axis larger than 4°. The simulation of the rotation path and the shear band texture by the crystal plasticity simulation was consistent with the experiment.This study provides a beneficial guide to improve the sharpness of secondary recrystallization Goss texture and magnetic induction in the grain-oriented silicon steel.

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Magnetic and structural properties of rare-earth free permanent magnets Fe-Ni-Al

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Permanent magnets [1-6] are used in an impressive range of applications, from electromotors and loudspeakers to windscreen wipers, locks, microphones and toy magnets, computer hard-disk drives, wind generators, and hybrid-car motors. The performance of RE-TM intermetallics is difficult to beat, but rare-earth supplies have become a bottleneck in recent years, and there is active research in various directions. First, as emphasized by Skomski and Coey [7], the range of transition metal-rich rare-earth intermetallics is limited, but improving the energy product could be possible by suitable nanostructuring [7-8]. Second, a fundamental topic is the improvement of permanent magnet materials, by changing chemical composition and atomic structure. Along with rare-earth systems, some Fe-based alloys are some of the most promising candidates for rare-earth compounds for the production of permanent magnets. In this work we report on the results of investigation of magnetic properties Fe-Ni-Al system after severe plastic deformation by high pressure torsion.

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Influence of Nb and Mo substitution on the structure and magnetic properties of rapidly quenched $Fe_{79.4}Co_5Cu_{0.6}B_{15}$ alloy

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In the present work, comprehensive structural and magnetic studies of the vacuum- and air-annealed, followed by rapid quenching $Fe_{79.4}Co_5Cu_{0.6}B_{15}$ ribbons, modified by Nb and Mo (1,3,5 at.%) have been reported. All these alloys were firstly produced in the pure amorphous state via melt spinning technique, and then characterized by X-ray diffraction and differential scanning calorimetry methods. Based on these results, the annealing process has been optimized in the temperature range between 260 and 500°C towards improving the magnetic properties (saturation induction (Bs), coercivity (Hc), core power losses at 1T and 50 Hz ($P_{10/50}$)). The local and average crystal structures were investigated by the X-ray diffraction complemented by transmission electron microscopy observations proving the nanocrystalline phase embedded in the glassy matrix, however with the crystal growth rate restricted to only an early stage of crystallization. Additionally, the magnetic properties of air-annealed samples are compared against the vacuum annealed counterparts. Finally, the local crystal structure of the vacuum- and air-annealed alloys have been characterized by transmission electron microscopy.

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Effect of Co Substitution on Structure and Magnetic Properties of High Induction $Fe_{85-(x+y)}Cu_xCo_yB_{15}$ Metallic Glasses

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Previously, Rajat K. et al. presented results for $(Fe_{1-x}Co_x)_{84}(B_{1-y}Si_y)_{13}Nb_2Cu_1$alloys, that exhibit promising high induction >1.8T for sample with content of Co = 5 at% [1]. Similar results were also obtained for alloys $(Fe_{1-x}Co_x)_{79}Si_{8.5}B_{8.5}Nb_3Cu_1$ and $Fe_{80-x}Co_{20}B_x$ [2-3]. However, the literature lacks a description of the influence of a small Co substitution and the heat treatment process on the crystal structure and magnetic properties of the material.

In this work the effect of substitution of Fe by Co on the crystallization kinetics, crystal structure and magnetic properties of high induction(Bs>1,6T) $Fe_{85-xy}Cu_xCo_yB_{15}$ (x = 0.6, 1.2; y= 2.5, 5, 7.5) amorphous and nanocrystalline alloys was investigated. The amorphous alloys in the form of ribbons were obtained by melt spinning technique. The kinetics of the crystallization process were determined based on differential scanning calorimetry (DSC) measurements performed at heating rates from 10 to 100 °C/min. To obtain the best soft magnetic properties (Hc, Bs and Ps) at frequency 50 Hz, the wound toroidal cores were isothermally annealed in a vacuum for 20 minutes at a various temperatures based on DSC measurement. In addition, an annealing process in air at optimal temperature was also carried out to check the effect of surface oxidation on magnetic properties. The crystal structure of as-spun and annealed materials were verified by X-ray diffraction and transmission electron microscopy observations. The complex magnetic permeability in the frequencies 10^{6}-10^{9}Hz for the materials annealed at optimal temperatures was measured. Finally, all the results have been correlated to explain the Co substitution effect.

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Studies of the coercivity mechanism in the bulk nanocomposite Pr-Fe-B-type magnets

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Nanocomposite $Pr_9Fe_{50+x}Co_{13}Zr_1Nb_4B_{23-x}$ (x = 0, 5, 8) bulk magnets in the form of rods were produced by two-step process: the suction-casting rapid quenching technique and subsequent devitrification annealing. The rapid solidification resulted in obtaining the fully or partially amorphous structure of the rods depending on the B content in the alloy composition. Subsequent annealing at 983 K for 5 min caused formation of three crystalline phases: the hard magnetic $Pr_2Fe_{11.2}Co_{2.8}B$, the soft magnetic α-Fe and the paramagnetic $Pr_{1+x}Fe_4B_4$. Due to the initial composition of the alloys as well as diversity in the crystal growth dynamics of constituent phases some differences in the grain sizes were revealed. Particularly, the soft magnetic α-Fe phase had the finest grains of the average diameter of about 10 nm while for the $Pr_2Fe_{11.2}Co_{2.8}B$ phase the crystallites were much bigger with the average diameters ranging from 35 to 95 nm depending on the chemical composition of the alloy. Furthermore, all the annealed rods have shown the remanence enhancement. Moreover, the x=0 alloy rod exhibited the highest coercivity (of 950 kA/m) among all annealed rods of investigated alloys. In order to analyze the coercivity mechanisms in the annealed rods, the Kronmüller method was used [1]. Based on the hysteresis loops measured at the temperatures ranging from 25 K to 400 K, the temperature dependencies of coercivity ${}_J\mathrm{H}_C$, remanence polarization J_r and saturation polarization J_s, were determined. Furthermore, based on the $\mu_0\mathrm{H}_c/\mathrm{J}_s$ vs. $\mu_0\mathrm{H}_N/\mathrm{J}_s$ plots constructed using hysteresis loops measured at various temperatures, the microstructural parameter α and the effective demagnetization factor N_{eff} of the Kronmüller coercivity relation [2] were calculated. It also allowed to assess the magnetization reversal in the investigated specimens.

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Chemical synthesis of NdFeB particles with high (BH)max by modified reduction-diffusion method

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We prepared the NdFeB magnetic particles with high (BH)max using spray drying and reduction-diffusion (RD) techniques. The magnetic properties could mainly depends on the Nd2Fe14B phase purity, crystallinity and microstructure. To wards this direction, we report the cost effective and a facile chemical synthesis including spray drying and reduction-diffusion (RD) process with some modefications [1, 2]. Importantly, we invesigated the annealing effect for NdFeB oxide powders and it is very importane to control the final particles structural and magnetic properties. Different annealing conditions from700 to 1000 oC for annealing propcess of oxides were used. Among them, the 800 oC results the NdFeB particles with improved magnetic and structural properties. The NdFeB particles prepared using modefied RD process shows the high (BH)max of 14 MGOe, corcivity (Hc) of 3000 Oe, remanence (Mr) of 137 emu/g and saturation magnetization (Ms) of 151 emu/g. The Ms value was close to the bulk NdFeB (168 emu/g) [2]. This is attributed to the shape uniformity of NdFeB particles and phase purity with high crystallinity. Further more, as prepared Nd2Fe14B particles has been used to produce the sintered NdFeB magnets by vacuum annealing with lower doping content of NdHX particles.

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Additive manufacturing of soft ferromagnetic Fe6.5%Si annular cores: process parameters and magnetic properties

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Introduction: Additive manufacturing (AM) has been a rapid growth in recent decades. The parts produced by AM are first designed in a CAD program, conveniently stratified and then constructed, layer by layer, by a continuous material addition process. Many different kinds of technical approaches are used by AM machines (binder jetting, extrusion, laser melting). In the context of metallic parts production by AM processes, one of the most widely used is the Laser Beam Melting (LBM). In this process, thin layers of powder are selectively irradiated and melted by a laser source. AM LBM has been largely investigated for processing a range of metallic materials and improving their mechanical properties. However, in the case of ferromagnetic materials, the potential of this technology is marginally explored[1-2]. The goal of the present work is to show the impact of the process parameters on the magnetic properties of ferromagnetic (Fe6.5%Si) parts.

Experimental methods: A series of annular cores were manufactured by AM LBM (external diameter d_e = 25 mm, internal diameter d_i = 35 mm and height h_c= 6,2). The raw material employed was high-silicon steel powder with approximately 6.5% wt Si (commercially acquired –HL POWDERS), the LBM machine used was a Realizer SLM-250. The magnetic properties of the Fe-Si alloy under quasi-static conditions were determined using the hysteresigraph method described in IEC standards (AFNOR IEC 60404, 2004)[3] . A parametric study was performed by varying the LBM parameters : laser power q, laser beam diameter r_b, hatch-spacing h, layer thickness l and laser scanning speed v. 25 samples were manufactured using a combination of these parameters. For each sample, a measure of density was realized. Then a microstructural study was performed by optical microscopy and Electron Back Scatter Diffraction (EBSD).

Results: In a first step, the micro-structural study was used to identify the links between mechanical output variables (density, grain size) and the input parameters. This was possible by the use of a normalized energy [4] expressed as,

$$E_0^* = \frac{Aq}{(2r_b lv)(\rho c_p(T_m - T_0))}$$

where A is the surface absorptivity (0.3 and 0.8), ρ is the material density, c_p is the specific heat, T_m the melting point of the raw material and T_0 the initial temperature of the powder bed. Thus, a maximum density point was identified, which, in our case, corresponds to a density of ≈98.5%.

A second step was carried out to identify the influence of the normalized energy over magnetic properties. This study was focused on the annular parts with high densities ≥ 90% (six samples).

It was found that the normalized laser energy plays a major role on the final grain size and magnetic properties. For a higher injected energy, the average grain size increases and leads to a decrease of the coercivity H_c but also in an increase of the maximum and remanent induction (B_{max}, B_r).

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Magnetization reversal asymmetry in structured ferromagnetic nanoparticles with hard/soft areas

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Asymmetric hysteresis loops can be found in exchange-bias systems in which a ferromagnet is exchange-coupled with an antiferromagnet [1]. In purely ferromagnetic samples, such effects can occur due to undetected minor loops or thermal effects. While the exchange bias is long established in hard-disk read/write heads and diverse spintronics applications, minor loops are sometimes used for the calculation of first order reversal curves (FORCs). Reports about their technological relevance, however, are scarce. Here we report on micromagnetic simulations of sputtered nanoparticles with different structures and varying height, consisting of tessellations of a defined area. After saturating these nanostructures by a strong magnetic field pulse, several tessellations show distinctly asymmetric, horizontally shifted hysteresis loops, especially in the transverse magnetization component. We show the dependence of this asymmetry on the external magnetic field orientation and investigate the reliability of this effect for randomly oriented magneto-crystalline anisotropy axes per grain.

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Physical properties of the $Ti_{45}Zr_{38}Co_{17}$ nano-alloy and their amorphous hydrides.

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The amorphous and quasicrystalline Ti-Zr-Ni alloys have raised an interest due to the wide range of their potential applications. The large hydrogen uptake capacity makes the TiZrNi compositions promising candidates for hydrogen storage and battery applications. The $Ti_{45}Zr_{38}Ni_{17}$ compositions can be modified by substituting the other 3d transition metals for Ni, replacing Ni with Fe and Co. However, the basic properties of the Ti-Zr-Co alloys, including the magnetic properties, have not been extensively researched yet. The most interesting questions regarding magnetism at TiZrCo system are: a) why amorphous phase shows ferromagnetism? b) why quasicrystals phase can exhibit long-range magnetic ordering? The present work aimed to track the $Ti_{45}Zr_{38}Co_{17}$ phase transformation from the amorphous to the quasicrystalline/crystalline capturing change of magnetic properties. We succeeded in obtaining the amorphous $Ti_{45}Zr_{38}Co_{17}$ alloys with the full capacity of hydrogen. The amorphous phase is stable up to the temperature of 300^oC. During further heating, a quasi-continuous transformation to the i-phase occurs. Close to 500^oC, the reflections of the i-phase were well developed. Hence, the quasi-continuous character of the transition from the amorphous into quasicrystalline phase was evidenced. Structure of $Ti_{45}Zr_{38}Co_{17}$ started to evaluate from the i-phase into the w-phase above 500^oC, an additional transition close to 700^oC from the w-phase into the new cubic phase was noticed. The possibility of obtaining the amorphous but hydrided alloys with the hydrogen capacity exceeding 2.39 wt.% is extremely interesting in the context of hydrogen storage. The mechanically-alloyed, initially amorphous, $Ti_{45}Zr_{38}Co_{17}$ material undergoes the structural transformation into the quasicrystalline state, the i-phase is changed to the approximant w-phase, which is transformed into a cubic phase. The amorphous phase with its hydrides shows a ferromagnetic behavior. The quasi-phase is not magnetic at all structure, with a small addition of ferromagnetic phase.

Low-temperature magnetization behavior in rapidly quenched alloys Fe-Cu-Nb-Si-B

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The low-temperature magnetization behavior is one of the fundamental characteristics of the ferromagnet. The exchange interaction parameters can be derived from this dependence by using the spin-wave excitation theory. In this work, the low-temperature behavior of magnetization in rapidly quenched Fe-Cu-Nb-Si-B alloys ribbons of 9 different compositions was studied. The dependence *M(T)* was well-fitted by Bloch's law $T^{3/2}$, and the fitting parameters made it possible to calculate the values of the spin-wave stiffness and the mean-square range of the exchange interaction. The linear correlation between the spin-wave stiffness and the Curie temperature was found. Also, the first coordination sphere radii were calculated using the Bethe-Peierls approximation; the obtained values of the radii are close to the nearest neighbor distance of crystalline Fe.

The spontaneous magnetization value at 0K allowed to calculate the average magnetic moment per Fe atom. We have constructed the dependence of the atomic magnetic moment on the average number of electrons per atom for Fe-Cu-Nb-Si-B alloys by analogy with the Slater-Pauling curve for crystalline alloys. The obtained values well-fitted on the line drawn through the points with coordinates (26, $2.9\mu_B$) and (19.2, $0\mu_B$): the first point corresponds to the FCC structure of Fe with a ferromagnetic order, the second point corresponds to the filled argon shell minus two $4s$ electrons.

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Magnetization processes of fractal-like core-shell nanoparticles

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The paper refers to micromagnetic simulations of magnetization processes of fractal-like core-shell nanoparticles. The objects were generated by the 3D diffusion limited aggregation (DLA) algorithm that allows obtaining fractals with two kinds of magnetic phases – magnetically soft core and magnetically hard shell. Also, the opposite situation have been taken in to consideration. The simulations were carried out using the cluster Monte Carlo algorithm designed for spin continuous and multiphase magnetic systems [1,2]. The presented researches include different degree of branches development, different strength of the exchange coupling between the phases as well as different soft phase content. As it was shown, the influence of microstructure on the coercivity mechanism is a complex phenomenon. In the presented work the variability spectra of the used parameters (e.g. the spin value, the exchange integral parameter, the anisotropy constants and the phase compositions) allowed determining the so-called optimization curves regarding the maximum values of coercive filed as well as $|BH|_{max}$ parameter. The carried out analysis is widely discussed in a context of enhancement of hard magnetic properties for the particles with magnetically soft or hard core.

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Temperature-dependent magnetic and transport properties of gadolinium-dysprosium-iron-garnet (50% vol. GdIG, 50% vol. DyIG) composite.

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Gadolinium-iron garnet ($Gd_3Fe_5O_{12}$, GdIG) based materials attract growing interest, especially in the advanced electronic industry as waveguide optical insulators or memory devices, and microwave insulators, due to their outstanding magneto-optic properties. There are several recent literature reports regarding enhanced properties of the garnets in one of three forms: polycrystalline, monocrystalline and thin films. Current research efforts arefocused on doping of GdIG with other ions in order to enhance its properties, e.g., the introduction of yttrium ($Y_{3-x}Gd_xFe_5O_{12}$, YIG) or dysprosium ($Dy_{3-x}Gd_xFe_5O_{12}$, DyIG), which improve magnetic properties of gadolinium-iron garnets, where GdIG is a compensated ferrimagnetic insulator. The typical garnet synthesis route involves a solid-state reaction between rare-earth (III) oxide and iron (III) oxide (Fe_2O_3). Thus, although being effortless, such an approach has several disadvantages like extended and energy-consuming grinding or need for elongated sintering time (12h) at elevated temperatures (1400^oC). From the industrial-scale production point of view, developing novel, cheaper, and more efficient synthesis routes seems to be of peculiar interest. Additionally, such methods can possibly be further transferred to different types of garnet materials. A major contribution to these attractive properties, Fe ions, are localized in two different crystallographic sites; Fe^{2+} ions occupy the octahedral sites, where Fe^{3+} the tetrahedral sites formed by the nearest oxygen ions. The magnetic moment of Fe is coupled by two spin-antiparallel a-site and d-site Fe through super-exchange interaction. The magnetic moment of a rare-earth element introduced at the c-site is antiparallel to the iron atoms. GdIG/DyIG composite possesses three different magnetic temperatures: compensated (T_{comp}), the magnetocaloric effect (T_o) and the Neel (T_N). These temperatures are between the values of the pure GdIG and DyIG bulk. The composite GdIG/DyIG change from the insulator to semiconductor behavior with energy gap at 1eV, between T_{comp} to T_o. The aim of this work was to obtain dense polycrystalline gadolinium-dysprosium-iron-garnet material (50% vol. GdIG, 50% vol. DyIG) by a reactive sintering method based on a solid-state reaction between dysprosium-iron perovskite ($DyFeO_3$), gadolinium-iron perovskite and iron oxide and characterization of magnetic and transport properties the composite was performed.

A new composite soft magnetic material with ferrite coatings

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For the electrical industry an urgent task is to develop new soft magnetic materials, in particular composites. Composites in which filling components have metal-dielectric-metal (MDM) interaction are of greatest interest. Recent few years many research centers have been intensively researching soft magnetic composites (SMC) based on use of soft magnetic particles, usually based on iron, with an electrically insulating coating on each particle [1]. The carried out preliminary researches of a composite magnetic material based on iron ASC 100.29 and Atomet 1001HP powders, surface of which is capsulated by ferrite, have shown perspectives of their application in engineering. Unique specific parameters of a softmagnetic composite material - a magnetic induction of saturation 2.1 Tesla, work in a frequency range up to 100 kHz at Curie temperature from above 800°C allow to use it in high speed valve and valve-jet electromachines and as chokes and high-frequency transformers.

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Tuning of structure and magnetocaloric effect of $Mn_{1-x}Zr_xCoGe$ alloy (where x=0.03, 0.05, 0.07, 0.1)

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The aim of the present work was to study an influence of partial substitution of Mn by Zr in the MnCoGe alloys. The XRD studies revealed a coexistence of the orthorhombic TiNiSi-type and hexagonal Ni_2In- type phases. The Rietveld analysis showed that the changes in lattice constants and content of recognized phases are depended on Zr addition. Moreover, the occurrence of structural transformation was detected. This transformation was confirmed by the analysis of the temperature dependence of exponent n given in the relation $\Delta S_M = C \bullet (B_{MAX})^n$. A decrease of the Curie temperature with an increase of Zr content in alloy composition was detected. The magnetic entropy change was 6.93, 13.42, 3.96 and 2.94 J/(kg K) for $Mn_{0.97}Zr_{0.03}CoGe$, $Mn_{0.95}Zr_{0.05}CoGe$, $Mn_{0.93}Zr_{0.07}CoGe$ and $Mn_{0.9}Zr_{0.1}CoGe$, respectively. A significant rise of magnetic entropy change for sample doper by Zr (x=0.05) was caused by structural transformation.

Magnetic and magnetocaloric properties of promising materials for liquefaction cryogenic gases.

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Considerable progress in the development of materials for room-temperature magnetic refrigeration has renewed interest to the materials which are perspective for cryogenic gases liquefactions. Numerous studies have identified a large variety of materials which exhibit a sizable magnetocaloric effect (MCE) in a temperature region of interest, from 15 to 150 K [1]. Almost all these materials are rare-earth-based intermetallic compounds RTX, R_5T_4, R_3T, and RT_2 (R is a rare-earth metal, T is a 3d or 4d transition metal and X is the main group chemical element). Considering rapid development of superconducting magnets which can generate magnetic fields of 15 – 22 T, study of MCE in high magnetic fields is of considerable interest for the development of perspective technologies for cryogenic magnetic refrigeration. In this sense, there is a need to revisit magnetocaloric properties of the rare-earth-based intermetallic compounds and to study them in a wider range of applied magnetic fields. In this work we report on the results of investigation of magnetic and magnetocaloric properties of R_5T_4 alloy.

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Tuning the magnetocaloric response in Gd-rich amorphous alloys

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A highly tunable magnetocaloric effect was observed in melt-spun amorphous $Gd_{65}Fe_{15-x}Co_{5+x}Al_{10}Si_5$ (x = 0, 5, 10) alloys with different Fe/Co ratios. Their magnetic properties were compared with those of previously investigated "parent" $Gd_{65}Fe_{10}Co_{10}Al_{15}$ alloy. The glassy structure of the melt-spun samples was confirmed by X-ray diffraction (XRD) and ^{57}Fe Mössbauer spectrometry. Their Curie temperatures (T_C) were between 155 and 195 K and significantly increased with decreasing Co content. The highest value of the magnetic entropy change ΔS_M = 6.8 J/kg K was obtained for $Gd_{65}Fe_5Co_{15}Al_{10}Si_5$, when the magnetic field was changed from 0 to 5 T. Refrigerant capacity (RC) takes values close to 700 J/kg for the whole series of alloys. The occurrence of the second order phase transition and the conformity of the magnetic behavior with the mean field model were discussed on the basis of the analysis of the universal curves and the values of the exponent n.

Formation of solid solution in Cu and Co doped FeNi: theory and experiment

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FeNi-based alloys are well known as soft magnetic materials when crystallized in the regular structure (bcc, fcc) [1], but FeNi tetragonal ($L1_0$) phase exhibits hard magnetic properties [2]. In this work we calculated enthalpies of formation of FeNi in various structural states using Miedema's thermodynamic modeling [3], which has been already used with success for other Fe-based alloys [4]. We considered competition between solid solution and amorphous phase (also in near equiatomic compositions), which mimics solidification process. Moreover, the influence of Cu- and Co-doping on the enthalpy was evaluated. Possibility of vitrification was excluded on the basis of our calculations, confirming high probability of formation of solid solution in all mentioned cases. For Cu-doped alloys, enthalpy of formation of solid solution was decreased by Cu addition in broad range of compositions, while Co had almost negligible effect.

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A new way to generate a rotating magnetic field in the high frequency range

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The article describes a new method of generating a rotating magnetic field of high frequency. This new measuring system is built of a magnetic circuit consisting of a ferrite torus, inside of which there are three L_P windings wound on ferrite cores connected in parallel with C_P capacitors. Between the three rectangular voltage signals shifted by 120 angular degrees and the L_PC_P circuits, three serial L_SC_S circuits that constitute the band-pass filter circuit are connected. In this way, the system can be powered by both sinusoidal and square signals. This significantly reduces the cost of the entire device. The necessary conditions for the phenomenon of thermal energy released in a magnetic fluid placed in a high-frequency rotating magnetic field are given. The author presents the preliminary results of the calorimetric effect in a magnetic fluid caused by a rotating (RMF) and alternating (AMF) magnetic field. The same sample of the magnetic fluid with magnetite nanoparticles and the oil (as a carrier liquid) was influenced by both fields. The value of the heating rate temperature $(dT/dt)_{t=0}$ in the experiment and its dependence on the intensity of the magnetic field were determined. Taking into account the parameters of both experiments carried out under slightly different conditions, the intrising loss power (ILP) was calculated in order to compare their effects. The obtained results indicate that the effect in RMF is more than two times greater than in AMF. This allows a significant reduction in the mass of the magnetic material needed to produce a similar thermal effect in medical applications.

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Propagation of ultrasonic wave in magnetic Pickering emulsion under DC magnetic field

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Pickering emulsion is an emulsion stabilized by solid particles accumulated at the surface of droplets. It is also possible to create stable Pickering emulsion stabilized by ferromagnetic iron oxide nanoparticles to make them susceptible to magnetic fields [1]. Such type of emulsion has received great research interest in recent years because it has generated and hold promise for a variety of practical applications in fields such as medicine, the food industry, the oil industry, and biofuel processing. In the context of many applications, it is important to study the structural properties of particle-stabilized emulsions. However, their real-time characterization especially under external stimuli such as magnetic fields is generally challenging. We use a convenient method to control the properties of magnetic particle-stabilized emulsions using the ultrasound technique. In the experiments, we investigated the velocity and attenuation of ultrasound using ultrasonic spectroscopy based on FFT spectral analysis of the received pulses as a function of magnetic particle concentration and field intensity. By using consecutive action of ultrasound and electric fields we prepared oil-in-oil emulsions with droplets fully covered by magnetite particles. After the application of DC magnetic the structure of the emulsion alteration and this process was characterized by acoustic spectroscopy. The formation of chain structures by magnetite-stabilized silicone oil droplets affects the velocity and attenuation of ultrasonic waves, and this influence had depended on the concentration of magnetic nanoparticles, droplets size, and the intensity of the magnetic field. The parameters of magnetic emulsion can be monitored by broadband acoustic method.

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Magnetic anisotropy detection in a cobalt foil determined by means of a magnetoimpedance sensor

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Due to their soft magnetic properties and negative near-zero magnetostriction and high transversal permeability, Co-rich microwires are one of the most popular sensing elements used in magnetic sensors. In this work, the instrumentation of a magnetoimpedance sensor is presented, based on an amorphous Co-rich microwire as the sensing element, and by means of a microstrip transmission line. A 1mW (0 dBm) signal in the frequency range from 1 to 10 MHz was used to energize the sensor, where the magnetic field of the cobalt foil was detected by the magnetoimpedance sensor. The foil was rotated during the test, finding that the curve shift depends on the angle of rotation of the foil, but it is independent of the excitation frequency. The interaction between the sensor and the cobalt foil modified the magnetoimpedance response, which is related to the cobalt foil magnetization. Left-wise and right-wise shifts were observed in the curves; this behavior was correlated with the magnetic anisotropy of the foil. Additionally, the magnetoimpedance behavior of microwire and the foil were analyzed and correlated with spin rotation dynamics.

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Tuning the magnetocaloric response of $Gd_{7-x}Y_xPd_3$ ($2 \leq x \leq 6$) alloys by microstructural modifications

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We investigated the influence of microstructural changes on the magnetic and magnetocaloric properties of $Gd_{7-x}Y_xPd_3$ ($2 \leq x \leq 6$) alloys rapidly quenched by vacuum suction casting and melt-spinning techniques. Structural investigations were carried out using X-ray diffraction, while the microstructure was studied utilizing scanning electron microscopy. Quenched-in structural disorder determines magnetic and magnetocaloric properties in both series of alloys. For rc-cast samples two distinct magnetic transitions are visible. The peak at higher temperatures is related to the ferromagnetic/paramagnetic transition of the crystalline phase. In contrast, the peak observed at low temperatures is believed to be related to the ferro-para transition of the amorphous phase and/or a spin reorientation. In the samples obtained by vacuum suction casting (rc-cast), the grain size was estimated to be equal 30-70 nm, while for the $Gd_2Y_5Pd_3$ composition the grains were slightly larger (up to 80 nm). The $Gd_{7-x}Y_xPd_3$ alloys in the form of rapidly cooled cast exhibit the magnetic transition temperatures at 262 K, 242 K, 202 K, 153 K and 9 K, for ($2 \leq x \leq 6$) respectively. The Curie temperatures of melt-spun $Gd_{7-x}Y_xPd_3$ alloys are much lower compared to rc-cast samples. The melt-spun $Gd_5Y_2Pd_3$ orders ferromagnetically below 90 K, while $Gd_4Y_3Pd_3$, $Gd_3Y_4Pd_3$, $Gd_2Y_5Pd_3$ and GdY_6Pd_3 ribbons undergo the magnetic transformation at 65 K, 40 K, 25 K, and 9 K, respectively. For the rc-cast samples, a table-like magnetocaloric effect in a wide temperature range is observed. This table-like temperature dependence of magnetic entropy change (ΔS_m) is caused by the successive magnetic transitions of crystalline and amorphous phases. Ribbons exhibit almost doubled magnetic entropy change in comparison to rc-cast samples. For instance, the (ΔS_m) value for melt-spun and rc-cast $Gd_5Y_2Pd_3$ is equal to 6.31 $Jkg^{-1}K^{-1}$ and 3.64 $Jkg^{-1}K^{-1}$, respectively. Moreover, due to the large FWHM of the magnetic entropy change peak, both the melt-spun and rc-cast samples exhibit large refrigerant cooling power (*RCP*), reaching 466 Jkg^{-1} ($\Delta\mu_0 H$=5 T) for the rc-cast $Gd_5Y_2Pd_3$. *RCP* values are comparable to those of some potential magnetic refrigerants.

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Adaptive structure based on phononic crystals with embedded magnetic harvesters

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Phononic crystal, referring to structures consisting of periodic arrays of acoustic or elastic inclusion in matrix system. Phononic crystal structure has potential applications in the design of acoustic filters, waveguides, vibration isolators and noise suppressors [1]. In this work authors developed construction with periodically distributed matrix, which work as phononic crystal structure.

In this structure magnetic harvesters were embedded. Harvesters that were used based on magneto-mechanical phenomena. It is assumed that even in the case of low power and efficiency, they can be a valuable source of power supply [2]. Theses devices can also be efficiently used in wireless energy and information transfer using ultrasonic vibration.

The work presents a method of both power and information transmission through pair of rails with phononic crystal structure using novel system developed by authors. The solution allows to (electrically) feed sensors located in hardly accessible places of mechanical constructions with simultaneous half-duplex data transmission (e.g. measurement "question-response"), when conventional power supply (requiring e.g. electricity networks, storage batteries, batteries, etc.) is eliminated. The mechanism of power transmission consists in "sending" of mechanical energy through an actuator in a form of "pure" sinusoidal ultrasonic wave and next "receiving" it and transforming into useful electrical current by harvester with reverse magnetostriction induced by the mechanical resonance. To optimise transmission (the highest possible efficiency and acceptably low noise level), a properly designed phononic crystal matrix as well as software allowing to select the right type of an actuator, modulation and the recommended frequency band was developed. Additionally it is possible to determine resonance frequency for each construction which is to be used for information and power transfer.

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Multidimensional magnetovisual method for mapping of pre-magnetized geometric singularities subjected to mechanical loading in the elastic range

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This paper presents the latest generation of the magnetic scanner system called Magscanner-Maglab System (MMS) which enables the fast acquisition from three axis of magnetic sensors. In recent years attempts have been made to visualize the magnetic field by magnetovision cameras. New applications of the magnetovision system are connected with measuring the magnetic field around objects subjected to technological processing (cutting, laser ablation, electro-discharge drilling, micro-layer plotting, magnetic printing, etc.), in order to check its quality. Digital visualization is used by various systems (based on discrete sensors or a matrix of sensors) for the human optical perception of real physical effects.

The proposed method of evaluating magnetic field distribution around different objects is based on modified passive sensors and on the dedicated Magscanner-Maglab software which is compatible with industrial parametric CAD, NURBS or MESH systems. The measurement technique consists in acquiring a set of points belonging to equally distant planes, similarly as in tomography and 3D visualisation in CAD under standard IGES. Magnetovisual system could also provide visualization as multidimensional manifolds for a variety of flat and cylindrical scanned objects. MMS can be synchronized with a material testing machine for static loadings or fatigue tests of the samples. Now is capable of investigating the magneto-mechanical phenomena using vector-field distribution models in experimental mechanics as well as areas of plastic deformations and cracks in industrial processes.

The identification process of inverse magnetostriction (Villari effect) for a thin plate with a circular hole (the so-called Kirsch specimen), subjected to cyclic loading on elastic range was described. The concept of identification is based on multi-dimensional magnetic fields as magnetovisual datas to describe the mechanical state of sample (the strain field) in geometric singularities (edges of the sample) of pre-magnetized ferromagnetic materials. It should also be possible to generate a range of magnetic field distribution maps depending on the proposed Villari effect model. Therefore the Kirsch problem has been implemented in the MMS software using the elementary magneto-mechanical models described the Dipole Contouring Method one can obtain a 3D magnetic field distribution [1-2].

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Rapid demagnetization of Suction Casting Alloy cores for Energy Harvesting

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Energy Harvesting is mainly associated with transformation of different sources of energy commonly found in the environment, which are undesirable and usually suppressed, (e.g. noise, mechanical vibrations, heat etc.), or widely available (e.g. sunlight, wave energy, biochemical processes) to useful electric energy [1]. One type of such transformation base on immediate demagnetization of the magnet by a stroke following an explosion or other strong impulse of force. During this demagnetization magnet loses its magnetic properties and generates huge magnetic field impulse around it, which allows to charge high voltage capacitors with large capacity. From the past few years this issue is of great interest in military applications [2].

The paper presents the results obtained using the rapid demagnetization method in the case of a NdFeB magnet and new hybrid core. The developed core consisted of three basic elements: a NdFeB magnet, Terfenol-D and a developed metallic alloy prepared with a suction casting method. The main goal of proposing a new type of core in the event of rapid demagnetization is to partially replace the permanent magnet with another material in order to reduce the rare-earth material, while keeping the amount of generated electricity at a level that allows powering low-power electrical devices. To "capture" rapid change of magnetic flux a small number of coils around the core was made. However, a very low voltage level at a very high current required the use of specialized electronic transducers capable of delivering the appropriate voltage level to power the microprocessor system. To overcome this problem the circuit designed by authors which enabled voltage processing from low impedance magnetic circuits was used. The obtained results demonstrated the usefulness of the system to resonant frequencies up to 1MHz.

It should be noted that the estimated efficiency of transforming the impact energy and demagnetization of the core to electric current was only 0.01%. Therefore, the key challenge is to improve the energy transformation, which might be done by changes of core arrangement or harvester construction.

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$La_{0.80}Ag_{0.15}MnO_3$ magnetic nanoparticles for self-controlled magnetic fluid hyperthermia

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In our paper we report on synthesis, characterization and magnetic properties of colloidal suspension based on $La_{0.80}Ag_{0.15}MnO_3$ nanosized particles. Nanosized particles were prepared by the glycine-nitrate method. The proper magnetic properties with the Curie temperature of about $T_C = 318$ K and 323 K were obtained by annealing at 800°C in air or O_2 atmosphere. Powder XRD measurement at room temperature revealed that the particles crystallize in rhombohedral crystal structure, R-3c space group, and the average size of nanoparticles varies between 25 to 40 nm. SEM analysis revealed that the particles form aggregates. Ultrasonic treatment and mechanical milling in agate bowl was performed to favour their disaggregation. Nanoparticles were functionalized with anionic sodium dodecyl sulfate (SDS) or dextran as a surfactant in distilled water. In the case of SDS functionalized particles the water based colloidal suspension was prepared in a laboratory circulation mill MiniCer. Size distribution of sample after ball milling has unimodal distribution, with the size fraction from 40 to 120 nm. Zeta-potential after half year from preparation of sample remain stable, around -40mV ($\pm 1,5mV$). Particles size distribution of dextran functionalized sample varying from 20 up to 100 nm was narrowed by etching in citrid acid. Preliminary hyperthermia measurements indicate increase of temperature by high frequency measurements 808kHz/0.024T from room temperature to 38.1°C in 13 min. Both samples display superparamagnetic behavior and colloids have the same T_C as powder. Our study shows that the rise in temperatures by these nanoparticles could be safely controlled around Curie temperature T_C.

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Magnetocaloric effect in $CeSi_{1.3}Ga_{0.7}$ alloy

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The $CeSi_{1.3}Ga_{0.7}$ alloy is a ferromagnetic Kondo lattice belonging to the $CeSi_{2-x}Ga_x$ series, in which a competition between Ruderman–Kittel–Kasuya–Yosida (RKKY) and Kondo interactions is observed [1-5]. This material crystallizes in the tetragonal α-$ThSi_2$-type structure (space group $I4_1/amd$). The ferromagnetic phase transition is observed at the temperature of 10 K. We have investigated the physical properties of $CeSi_{1.3}Ga_{0.7}$ by measurements of the magnetic susceptibility, electrical resistivity, and specific heat.The analysis of the Arrott plot confirms the second order-type phase transition. The magnetocaloric effect parameters, i.e. the magnetic entropy change, ΔS_M, and adiabatic temperature change, ΔT_{ad}, were calculated using thermodynamic Maxwell's relations. The maximum ΔS_M value determined from the magnetic measurements is -5.9(1) J kg^{-1} K^{-1} at 10.9(5) K and the relative cooling power (RCP) value is 32(1) J kg^{-1}, both obtained for a magnetic field change of 5 T.

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Application of permanent magnet and magnetorheological fluid in the finger pads of a jaw gripper

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Soft grippers are constantly in the interest of researchers [1] due to their gripping properties and adaptability. On the other hand well-known kinematic structures of rigid grippers allow for precision and force exertion [2]. Still an undiscovered topic is the combination of these structures into a hybrid soft-rigid gripper using magnetorheological (MR) fluid [3]. This creates the potential to develop the subject of grippers equipped with setup that interacts with MR fluid and magnetic field sources capable of changing its properties. Solutions in this case include designs such as the universal jamming gripper [4] and cushions on the parallel jaw gripper [5].

This publication discusses the solution of a novel MR fluid cushion system which is a soft element that is flexible and mounted on a rigid jaw gripper. The MR fluid cushion setup structure is based on a permanent magnet inside a yoke, a spring unit and an MR fluid cushion made of thermoplastic polyurethane. This is an interesting application of magnetism to perform object manipulation tasks. In this case, changing the distance of the permanent magnet changes the properties of the MR fluid. When the cushion makes contact with the object to be grabbed, a magnetic field is applied to the system, resulting in a stiffening of its structure. Retracting the jaws moves the magnet away and weakens the magnetic field inside the cushion. The publication includes a description of a novel MR cushion setup along with finite element method studies for magnetic applications.

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Usage of MFAM Technology to determine the influence of the Earth's magnetic field on the diagnosis of steel wire rope

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Steel wire ropes used in roped transport devices are subjected to bending fatigue. According to the application area, steel wire ropes are often exposed to atmospheric influences, and the impact of corrosion is inevitable. Non-destructive damage detection is a critical way to assess damage states to guarantee wire ropes reliability and safety. Microelectromechanical systems (MEMS) have allowed magnetic field sensors with potential applications such as the automotive industry, navigation systems telecommunications, and non-destructive testing. Optically-pumped magnetometers (OPMs) have been developed since the 1960s. OPMs have generated renewed interest over the last 15 years due to their increased sensitivity when operated in the spin-exchange relaxation free (SERF) regime. The Geometrics' MFAM is a laser pumped caesium magnetometer module that measures the total magnetic field strength. It uses caesium atoms contained in a small, evacuated glass vapour cell as the sensing element. The paper presents the application of MFAM sensors for diagnostics steel wire ropes. The module features two sensors that can be used independently or as an intrinsic gradiometer. The examined cable is the 7x7+7x19W+IWRC steel wire rope type of 6,5 mm diameter, coated, with a metallic central core strand and crossed to the right. Cable construction is robust and widely used in the industrial field, mainly in lifting applications. The examination aims to check the influence of the Earth's magnetic field on the diagnosis of steel rope using MFAM Technology. The steel wire rope was placed in various configurations, changing its position - both geographically and magnetically. Under the rope, an MFAM Magnetometer (2 sensors: M1 and M2) was attached, which with the use of appropriate software, could move at a constant speed of 3 mm/s. There are recorded the measurement of the magnetic field around the rope over a measuring length.

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Coexistence of two kinds of superfluidity in Bose-Hubbard model with density-induced tunneling

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With use of the U(1) quantum rotor method [1] in a path integral effective action formulation and S=1 pseudospin mapping [2], we have analytically confirmed the mathematical similarity of the phase Hamiltonian and the extended Bose-Hubbard model with density-induced tunneling. Moreover, we have shown that the latter model exhibits two coexisting (single-particle and pair) superfluid phases. Phase separation of the two has also been confirmed, determining that there exists a range of coefficients in which only pair condensation, and not single-particle superfluidity, is present.

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Structure and magnetic properties of Ni- doped gehlenite glass microspheres

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The structural and magnetic properties of undoped and Ni-doped aluminate glass microspheres with gehlenite composition and of their polycrystalline analogues were studied. The concentration of Ni was 0.5, 1 and 3 mol. % . Glass microspheres were prepared by combination of solid-state reaction and flame synthesis. The detailed examination of morphology of the glass microspheres of all prepared composition by scanning electron microscopy (SEM) revealed no features indicating presence of crystalline phases. However, except of the sample GNi3.0 (3.0 mol. % of Ni), X-ray powder diffraction (XRD) detected traces of crystalline gehlenite in all other compositions. In samples crystallized at 1273 K for 10 h, XRD revealed the presence of gehlenite as the only crystalline phase. The finding was supported by SEM examination, which revealed morphological features characteristic for crystals. Raman spectroscopy of crystallized samples also confirmed the presence of gehlenite. Raman spectra of as-prepared glass microspheres differed significantly from the spectra of their crystallized counterparts. These indicate the role of aluminum as a network-forming element. Magnetic properties of the undoped and Ni-doped gehlenite microspheres and of their polycrystalline analogues were measured by Quantum Design SQUID magnetometer. Measurements showed complex magnetic behaviour of prepared glass microspheres, influenced by temperature, the magnetic field and content of Ni. The samples were diamagnetic or weakly ferromagnetic at 300 K, whereas paramagnetic or weak ferromagnetic behaviour was observed at 2 K. The influence of crystallization on magnetic properties was also investigated.

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Electronic Structure and Superconductivity of the High Entropy Alloy Sc-Zr-Nb-Rh-Pd

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In 2014, the superconductivity was discovered in the new type of materials - High Entropy Alloys (HEA), the alloys that are formed by mixing relatively large proportions of five or more elements. Since then, the superconductivity was found experimentally in many HEAs. However, the theoretical research concerning the electronic structure and the mechanism behind forming of the superconducting state is scant. HEAs are of high interest from material science point of view due to their unique properties such as high fracture toughness, ductillity and yield strength in extreme temperatures as well as resistance to corrosion and oxidation.

The superconductivity of Sc-Zr-Nb-Rh-Pd alloy was experimentally confirmed in 2018 and reported in [1]. This research investigates electronic structure of the Sc-Zr-Nb-Rh-Pd HEA by employing the Korringa-Kohn-Rostoker Coherent Potential Approximation method (KKR-CPA) and Density Functional Theory. The main purpose of this work was to analyze how well the KKR-CPA method can describe the electronic properties of HEAs. Similar computations were carried out in [2] for Ta-Nb-Hf-Zr-Ti HEA superconductor.

The results obtained in this work concern the McMillan-Hopfield coefficients, the density of electronic states around Fermi Energy and dispersion relations for different concentrations of the components in Sc-Zr-Nb-Rh-Pd HEA for which the formation of the superconducting state was observed. The computations also showed that the CsCl structure should be observed in this type of alloy, and the experimental data in [1] shows that this is indeed the case. Additionally, strong smearing of the electronic bands shows the significance of the chemical disorder in the properties of the alloy.

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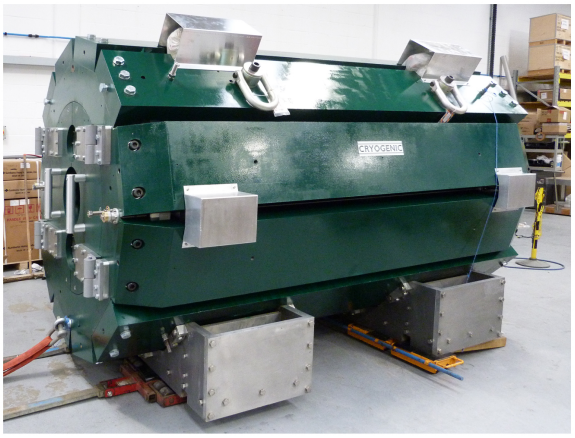
SCIENTIFIC EXHIBITORS

Larger Scale Cryogen Free Magnet Systems

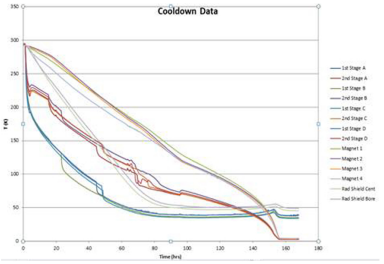
CRYOGENIC
CRYOGENIC LIMITED

Cryogenic 2.6 Tesla CFM Mu3e System

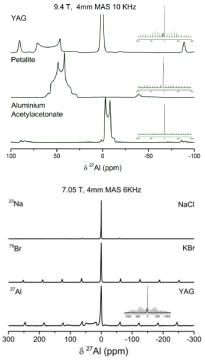


- 1 m diameter room temperature bore accessed by steel swing doors
- 2.6 T superconducting solenoid magnet
- Base homogeneity of <0.12% over a 1.3 m axial length
- Cooled by Four 1.5 GM Cryocoolers
- 27 tonne passive shield reducing stray field to 5 mT at 1 m

The magnet produces a homogeneous field profile over a large volume (Ø70cm x 200cm) The field is generated using four separately energisable circuits. Subtle changes in the field profile are possible by varying the currents in the four circuits.



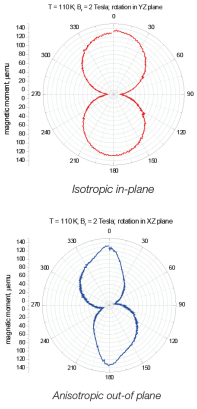
Cryogen free Solid State NMR



500 MHz / 600 MHz Wide bore and Narrow bore Magnets

Model	CFM-600 MHz
Maximum central operating field at 4K	14.1 Tesla
Equivalent Maximum Proton frequency	600 MHz
Shimmed central homogeneity	1 ppm over 10 mm sphere HHLW
Cryo-shims	Z1, Z2, X, Y, C2, S2, ZX, ZY
Long-term drift rate	≤ 0.1 ppm/hr
Room temperature bore	54 or 89mm diameter
Field Sweep	0 T to 14.1 T
Typical initial cool-down to operating temperature	70 hrs / 100 hrs
Actively Shielded	Yes
Field sweep coil	Optional

9T-2T-2T Vector System with VSM



- Completely Cryogen-Free
- Compatible with variety of applications
- Vertical magnetic field up to 9 Tesla
- Arbitrary 3D field rotation up to 2 Tesla
- VTI temperature range 1.6 K to 400 K
- Sample in isolated static gas chamber
- High-sensitivity VSM

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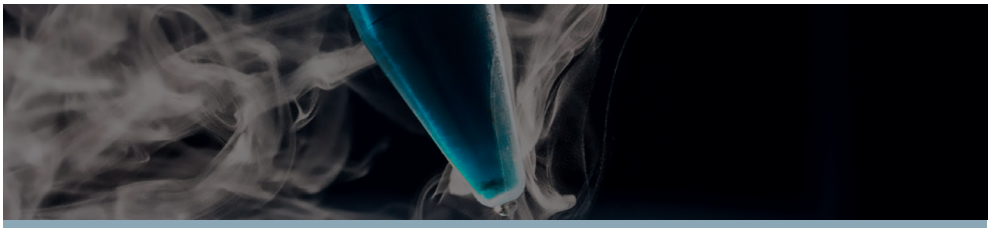
Cryogenics & magnetics news

Lake Shore Cryotronics and Quantum Design Europe have combined their cryogenic expertise and started a strategic partnership.

Quantum Design now provides Lake Shore's complete state-of-the-art product range:

- Cryogenic thermometry monitors, controllers, and sensors
- Cryogenic probe stations for on-wafer measurements
- VSM systems with 15 nemu sensitivity
- Turnkey Hall effect measurement systems
- The FastHall measurement instrument
- AC/DC current and voltage sources



Quantum Design GmbH, Piotr Dluzewski, +48 502 591 207, pdluzewski@qd-europe.com

As a member of the **SHI Cryogenics Group**, Sumitomo Cryogenics of Europe GmbH (SCEG) offers **innovative cryotechnical solutions** for a variety of industries. The products are not only used in the **research** and **medical industry**, but are also an integral part of the **semiconductor** and (optical) **coating** industry.

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New research opportunities through a dual-access procedure at the European Magnetic Field Laboratory

Strong magnetic fields provide unique opportunities for studying, modifying and controlling the state of matter.

To address the interest of researchers in Europe and worldwide with these opportunities, the European Magnetic Field Laboratory has been established (EMFL - http://www.emfl.eu/aboutemfl.html). The Laboratory consists of host institutions, which provide access to their infrastructures localized in France with two centers in Grenoble and Toulouse, in the Netherlands, and in Germany. The University of Nottingham, UK and the French Institute of Research into the Fundamental Laws of the Universe CEA, France are also the EMFL members.

Starting from 2019, the University of Warsaw officially joined the EMFL to represent the Polish research community, organized in The Consortium of Strong Magnetic Field Users. The Consortium currently includes:

University of Warsaw, Institute of Physics, Polish Academy of Sciences (PAS), Institute of High Pressure Physics PAS, Research Network Łukasiewicz: Institute For Microelectronics and Photonics, Institute of Molecular Physics PAS, Nencki Institute of Experimental Biology, PAS, Wrocław University of Research and Technology, and Institute of Low Temperatures and Structure Research PAS.

The access to the EMFL infrastructure is provided through a procedure involving calls for proposals twice a year (https://emfl.eu/apply-for-magnet-time/).

Recently, novel **Dual Access** procedure has been established within the frame of a EU-funded project. Scientists at an early stage of their research projects are welcome to apply.

Applications address both the first-step access to research equipment dedicated to the moderate-field range accessible with superconducting magnets and, in a following second step the access to the highest possible magnetic fields at the EMFL host infrastructures in France, Germany, and the Netherlands. Several partner laboratories in Europe are involved in the first step access. They are located in the University of Nottingham, UK; University of Oxford, UK; Universidad Autonoma de Madrid, Spain; University of Warsaw, Poland; Charles University, Prague, Czech Republic; National Institute of Chemical Physics and Biophysics, Tallinn, Estonia, and University of Salento, Lecce, Italy.

The expertise at those laboratories (https://emfl.eu/dual-access/) can be used to enhance the research potential of the community of researchers working in the field of magnetism and magnetic materials.

The Polish participation in EMFL is supported by the DIR/WK/2018/07 Grant from the Polish Ministry of Education and Science, the dual-access procedure is supported by the ISABEL project funded by the EU Horizon 2020 grant No 871106

A.Babiński, *Faculty of Physics, University of Warsaw, ul. Pasteura 5, 02-093 Warszawa*

The European Conference PHYSICS OF MAGNETISM 2021 (PM'21)

	Monday, June 28	Tuesday, June 29	Wednesday, June 30	Thursday, July 1	Friday, July 2	
$10^{15} - 11^{00}$	*Opening*					$10^{15} - 11^{00}$
$11^{00} - 11^{30}$	L.W. Molenkamp	P. Kuświk	D. Atkinson	R.A. Duine	A. Baumgartner	$11^{00} - 11^{30}$
$11^{30} - 12^{00}$	S. Tarucha	D. Niarchos	S. Mangin	B. Hillebrands	I. Weymann	$11^{30} - 12^{00}$
$12^{00} - 12^{30}$	C.Q. Jin	I. Škorvanek	R. Sánchez	J. van den Brink	T. Klimczuk	$12^{00} - 12^{30}$
$12^{30} - 13^{00}$	A. Bergman	D. Pinkowicz	S.-I. Yoo	A. Bonanni	A. Bianconi	$12^{30} - 13^{00}$
$13^{00} - 13^{30}$	*long break*	*long break*	*long break*	*long break*	*long break*	$13^{00} - 13^{30}$
$13^{30} - 14^{00}$						$13^{30} - 14^{00}$
$14^{00} - 14^{30}$	O-1-01, O-2-01, O-3-01 O-1-02, O-2-02, O-3-03	O-1-03, O-4-04, O-5-27 O-1-19, O-4-11, O-5-28	O-3-09, O-5-01, O-6-01 O-3-10, O-5-02, O-6-02	O-4-02, O-5-08, O-7-02 O-4-03, O-5-09, O-7-03	R. Puźniak	$14^{00} - 14^{30}$
$14^{30} - 15^{00}$	O-1-04, O-2-03, O-3-04 O-1-05, O-2-04, O-3-07	O-1-26, O-4-12, O-5-23 O-3-13, O-4-13, O-5-24	O-3-12, O-5-03, O-6-05 O-3-14, O-5-04, O-6-06	O-4-10, O-5-10, O-8-01 O-4-05, O-5-11, O-8-02	E. Demler	$14^{30} - 15^{00}$
$15^{00} - 15^{30}$	O-1-06, O-2-07, O-3-11 O-1-07, O-2-08, O-3-15	O-3-27, O-4-14, O-5-25 O-3-05, O-4-15, O-5-26	O-3-21, O-5-05, O-3-02 O-3-23, O-5-06, O-3-24	O-4-06, O-5-13, O-8-03 O-4-07, O-5-14, O-7-01	A.M. Oleś	$15^{00} - 15^{30}$
$15^{30} - 16^{00}$	O-1-11, O-2-09, O-3-16 O-1-18, O-2-10, O-3-18	O-3-06, O-4-16, O-5-21 O-3-08, O-4-17, O-6-03	O-3-25, O-5-07, O-3-19 O-1-28, O-4-18	O-4-08, O-5-16, O-1-09 O-4-09, O-5-17, O-1-17	G. Jackeli	$15^{30} - 16^{00}$
$16^{00} - 16^{15}$	*short break*	*short break*	*short break*	*short break*	*short break*	$16^{00} - 16^{15}$
$16^{15} - 16^{45}$	M. Zahid Hasan	B. Göbel	K. Ptaszyński	O-1-10, O-2-06	A. Dyrdał	$16^{15} - 16^{45}$
$16^{45} - 17^{15}$	T. Dietl	H. Jani	A. Francuz	O-1-14, O-5-18	G. Vignale	$16^{45} - 17^{15}$
$17^{15} - 17^{45}$	D. Kaczorowski	M. Heigl	M. Roman	O-1-16, O-5-19	E. Tsymbal	$17^{15} - 17^{45}$
$17^{45} - 18^{15}$	S. Bühler-Paschen	A. Ross	G. Cuono	O-1-23, O-5-20	*short break*	$17^{45} - 18^{15}$
$18^{15} - 18^{45}$	*short break* O-1-12, O-2-11, O-3-20	K. Szulc *short break* **Poster Session I**	R. Vieira *short break* **Poster Session II**	O-1-24, O-5-22 O-1-27, O-5-15 *short break* **Poster Session III**	A. Fert	$18^{15} - 18^{45}$
$18^{45} - 19^{15}$	O-1-13, O-2-12, O-3-33 O-1-15, O-2-13, O-3-22	P-1-01, P-2-08, P-4-09, P-3-07, P-3-28, P-5-09, P-5-28, P-6-14, P-7-01, P-1-02, P-2-09, P-4-10, P-3-11, P-3-29, P-5-10, P-5-29, P-6-15, P-7-02, P-1-03, P-2-10, P-4-11, P-3-12, P-3-30, P-5-12, P-5-30, P-6-16, P-7-03, P-1-04, P-2-11, P-4-12, P-3-13, P-3-31, P-5-13, P-5-31, P-5-33, P-7-04, P-1-05, P-2-13, P-4-13, P-3-14, P-3-32, P-5-14, P-5-32, P-6-19, P-7-05, P-1-06, P-2-14, P-4-14, P-3-15, P-3-33, P-5-16, P-6-01, P-6-32, P-7-07	P-1-08, P-2-15, P-4-15, P-3-16, P-3-34, P-5-15, P-6-02, P-6-20, P-7-08, P-1-09, P-2-16, P-4-16, P-3-17, P-3-35, P-5-17, P-6-03, P-6-21, P-7-09, P-1-10, P-2-17, P-4-17, P-3-22, P-3-36, P-5-18, P-6-04, P-8-05, P-7-10, P-1-11, P-2-18, P-5-35, P-3-23, P-5-01, P-5-19, P-6-05, P-4-18, P-7-11, P-1-12, P-4-01, P-3-02, P-3-24, P-5-04, P-5-20, P-6-06, P-6-24, P-7-12, P-2-01, P-4-05, P-3-03, P-3-25, P-5-05, P-5-34, P-6-07, P-6-25, P-8-01	P-2-02, P-4-02, P-3-04, P-3-18, P-5-02, P-5-22, P-6-08, P-6-26, P-8-02, P-2-03, P-4-03, P-3-05, P-3-19, P-5-03, P-5-23, P-6-09, P-6-27, P-2-04, P-4-04, P-3-06, P-3-20, P-5-11, P-5-24, P-6-10, P-6-28, P-6-17, P-2-05, P-4-06, P-3-10, P-3-21, P-5-06, P-5-25, P-6-11, P-6-29, P-5-21, P-2-06, P-4-07, P-3-08, P-3-26, P-5-07, P-5-26, P-6-12, P-3-01, P-2-07, P-4-08, P-3-09, P-3-27, P-5-08, P-5-27, P-6-13, P-6-31, P-4-19	*Summary* *Awards* *Closing* ISBN 978-83-956445-2-8	$18^{45} - 19^{15}$ $19^{15} - 19^{45}$ $19^{45} - 20^{15}$
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$19^{45} - 20^{15}$	O-1-22, O-2-16, O-3-30 O-1-25, O-2-17, O-3-32					

PM'21