SEMINAR
FACULTY OF TECHNICAL PHYSICS
POZNAN UNIVERSITY OF TECHNOLOGY
and
POLISH PHYSICAL SOCIETY
(The POZNAN BRANCH)

Poznań, 5th April 2018

Abstract

Laser spectroscopic characterization of the nuclear-clock isomer ^{229m}Th

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The thorium isotope 229 possesses a unique, low-energy nuclear isomeric state (denoted ^{229m}Th) at about 7.8 eV [1,2]. This fact has stimulated the development of novel ideas in the borderland between atomic and nuclear physics. For example, the isomer could be used as an optical nuclear clock, using a γ-transition as a reference - instead of a transition in the electron shell – which offers many advantages [3, 4]. Another application of this system can be a sensitive probe of temporal variations of fundamental constants.

Many experimental attempts to induce and detect an optical excitation of this isomer have failed. The nuclear moments of the isomer ^{229m}Th have been estimated from nuclear structure models. Apart from the spectroscopic determination of the nuclear spin and indirect measurements of the excitation energy [1,2], no experimental data on the nuclear properties of the isomer have been available until recently. Using recoil ions from the decay of ^{233}U as a source of ^{229m}Th, electrons emitted from the internal-conversion decay of the isomer in neutral thorium were detected [5] and the half-life for this process was measured [6].

The availability of the isomer through recoil ions provides a way to measure the unknown nuclear properties of ^{229m}Th via laser spectroscopy of electronic transitions. In this presentation we report the optical detection of ions in the ^{229m}Th isomeric state and of the resolved hyperfine structure (HFS), which arises from the interaction of the isomer nucleus with the valence electrons.
This measurement yielded the first experimental determination of the nuclear moments and the mean square charge radius of the isomer [7]. Our results constitute a key issue in the ongoing experimental search for the direct optical excitation of the nuclear transition, as well as the future nuclear clock operation.

This work was supported by European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement number 664732 (nuClock), from DFG through CRC 1227 (DQ-mat, project B04) and TH956-3-2 and from the LMU Department of Medical Physics via the Maier–Leibnitz Laboratory.

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