Ultrafast Nonlinear Conversion of Magnons in an Antiferromagnet

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Propagating magnons, or spin waves, have recently attracted a lot of interest as strongly interacting potential information carriers, which do not generate Joule heating. In antiferromagnetic materials the frequencies of the magnons lie in the THz range, compared to the GHz range in ferromagnets, allowing for orders of magnitude faster information processing in antiferromagnets [1]. The first experimental demonstration of generation and detection of the coherent propagating magnons in an antiferromagnet was very recently reported [2]. The breakthrough is based on using nanoscale confinement of the laser pump pulse to excite magnons, and selective detection of them is achieved by scattering of another probe pulse. In this work we capitalise on this discovery to harness strong nonlinear coupling between magnons and realise ultrafast converter of quasi-uniform spin precession into propagating magnons with higher frequencies (energies) and wavenumbers (momenta). Our discovery enables control over the spin waves, required to make them suitable for information processing in the form of logic gates [3]. We demonstrate supressing or amplifying of THz propagating magnons, mimicking the operation of a transistor. To this end, we perform a double pump - probe experiment. The first pump pulse launches spin dynamics, which are modulated and transformed by the second pump. The dynamics are probed magneto-optically, using the detection mechanism reported in [2]. From the 2D spectrum of the dynamics, we find that the amplitude of the detected spin wave can be controlled by the delay between the pumps. This amplitude modulation is intrinsically nonlinear, as we observe the features at (f_k, f_k) frequencies (interference), and around (f_0, f_k) frequencies (nonlinear conversion), where f_k is the finite-k component of the freely propagating spin wave, and f_0 is the frequency of the uniform spin precession. Using the Lagrangian formalism for describing nonlinear spin dynamics [4], we can show that our experiment can be interpreted as conversion of the quasi-uniform spin precession to the finite-k magnon modes by a second light pulse. The converter enables ultrafast modulation of spin waves in an antiferromagnet, which is a major milestone in THz magnonics.

References:

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