Femtosecond nonlinear coherent manipulation of the magnon spectrum in antiferromagnetic α-Fe_2O_3

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A future data-processing technology based on ultrafast opto-magnonics in antiferromagnetically-ordered materials bears the potential to overcome limitations of nowadays computation schemes. Such concepts promise to scale the rates of operation from the low-GHz to the multi-THz regime due to the intrinsic nature of high-energy modes in antiferromagnets (AFM) in the absence of major energy-dissipations. It has recently been suggested that employing ultrashort laser pulses allows to fully exploit the remarkable potential of AFMs since they enable the generation, control and detection of spins with temporal resolution shorter than the characteristic timescales of the spin system [1].

So far, successful approaches to optically induce ultrafast spin dynamics in AFM rely on either direct excitation of low-frequency one-magnon modes close to the center of the Brillouin zone [1,2] or indirect excitation of high-frequency two-magnon modes at the edges of the Brillouin zone via impulsive stimulated Raman scattering [3]. The latter one has already provided fundamental insights into these high-wavevector modes [4] although the excitation mechanism, being non-resonant, does not allow a massive direct generation of high-energy magnetic quasiparticles.

Here, we plan to directly excite pairs of zone-edge magnons by resonantly pumping the two-magnon mode in Hematite (α-Fe_2O_3) with a high-field laser source operating in the multi-THz regime. This unprecedented pumping induces an utterly unexplored magnetic regime in which tons of energy from the laser pulses are deposited exclusively in the exchange interaction by activating an immense ensemble of zone-edge magnons. Predictions of strongly nonlinear magnetic phenomena triggered by this photoexcitations have been reported [5].

The ability to tune the photon energy and spectrum of our mid-infrared laser source is crucial as it allows us to explore a resonant and non-resonant excitation of the 2M mode. This experiment disclosed a coherent coupling of the photodriven high-energy magnons to zone-center modes. The regime of interaction can be driven to an extremely nonlinear limit in which the spectrum of zone center modes is substantially modified. Our results have already revealed the ability to strongly manipulate the magnonic dispersion relation on the femtosecond timescale via purely magnetic processes without any involvement of the lattice.

References:

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