Resonant optical excitation of coherent magnons in nanometer ferromagnetic films

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The frequencies of electromagnetic waves within the visible range and magnons in ferromagnets are significantly different. However, the resonant optical excitation of coherent magnons can be achieved through the utilization of pulsed laser sources with ultrahigh repetition rates, presenting a competitive alternative to conventional microwave-based techniques at a considerably smaller scale. The efficiency of this approach is governed by the underlying mechanisms of optical excitation and the interplay among various dynamic processes induced by laser pulses, which are explored in the present work. The study focuses on layers of Galfenol, $Fe_{0.81}Ga_{0.19}$, of 5-100 nm thicknesses epitaxially grown on GaAs substrates. This material posess narrow ferromagnetic resonances in combination with strong magnetocrystalline anisotropy supporting the optical excitation of magnons [1]. The experimental setup employs a pump-probe scheme utilizing two asynchronously locked femtosecond laser oscillators. The pump pulse excites a Galfenol film at a repetition rate, f_L=10 GHz. The linearly polarized probe pulse is used to observe the response of the net magnetization using the polar magneto-optical Kerr effect. An external magnetic field, applied in the film plane, tunes the fundamental magon frequency, f_M. In the films of 5-20 nm thickness, at the resonant conditions, when $f_M = nf_L$ (n=1,2,3…), we observe harmonic non-decaying oscillations of the magnetization, which corresponds to the uniform magnon mode. In contrast, in thick films, this regime remains unachievable. By theoretical modeling, we identify the optically induced transient processes and parameters of the films, which determine the efficiency of the resonant optical excitation.

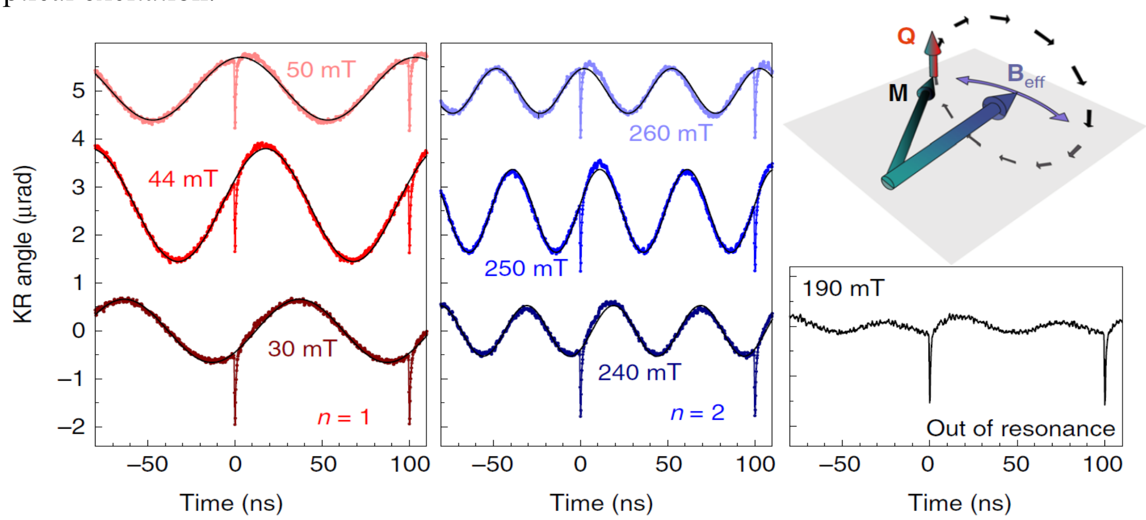

Fig.1 Magnon signals in time domain. Transient Kerr rotation signals measured in the vicinity of the first (left panel) and second (central panel) resonances and off-resonance (right panel). The amplification of the precession amplitude is induced by resonant driving of the precession **M** by the oscillating effective field $\mathbf{B}_{eff}$. The torque **Q** acting on the magnetization (see sketch at the top right) is maximal at the resonance conditions: $f = n_{f0}$.

[1] M.Kobecki et. al. Resonant thermal energy transfer to magnons in a ferromagnetic nanolayer. *Nat Commun* **11**, 4130 (2020).