Aktuelle Fragen
der Nanophysik

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Ultrafast magnetoacoustics of metallic nanostructures

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Ultrafast magnetoacoustics focuses on the interaction of coherent acoustic phonons and magnons in magnetic materials [1]. Using femtosecond laser pulses to excite and probe the coherent response of the lattice and magnetization, we visualize the effects induced by their interaction in the time domain. In our studies, we work with metallic ferromagnetic nanostructures, which can be produced with state-of-the-art growth and post-growth technology and allow considering the real-life application perspective of obtained results. To match the phonon and magnon wave vectors and adjust the main parameters of the optically excited phonon and magnon modes, we use spatial surface patterning and phononic Bragg mirrors and waveguides. This enables fine control of magnon-phonon interaction, from the selective coupling of two localized phonon and magnon modes with the formation of a coherent hybridized state [2,3] to generating multi-mode propagating wavepackets characterized by extreme volatility [4] illustrated in Fig. 1. In the present talk, we will overview these and other effects and discuss their possible applications, e.g., for neuromorphic computing.

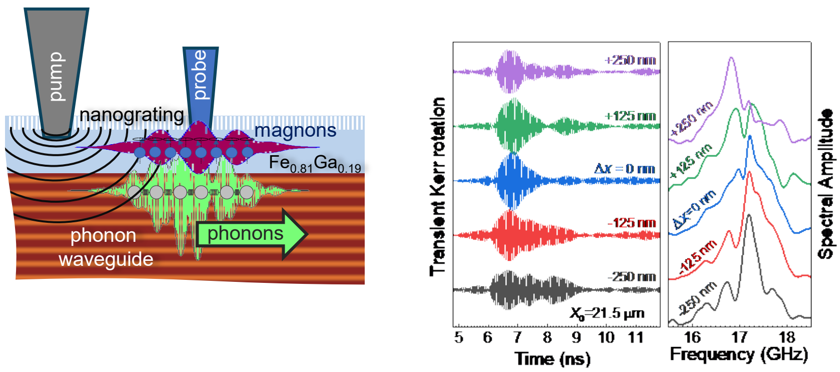

Figure 1. Schematic of the experiment with (Fe,Ga) nanograting deposited on a semiconductor phonon waveguide. The multimode coherent phonon wavepacket generated by the femtosecond pump pulse propagates in the waveguide and drives the magnon modes of a ferromagnetic nanograting. As illustrated in the right panel, the resulting coherent magnon-phonon mixture possesses extreme spatial-time volatility. The waveform and spectrum of the transient Kerr rotation signal measured by the linearly polarized probe at the distance $X_0 = 21.5\ \mu m \pm \Delta X$ are pronouncedly modified by the relative shift of the probe beam at a distance of only 125 nm, which is 20 times smaller than the pump laser spot diameter [4].

References

[1] A. V. Scherbakov et al., Ultrafast magnetoacoustics in Galfenol nanostructures, *Photoacoustics* **34**, 100565 (2023).
[2] F. Godejohann et al., Magnon polaron formed by selectively coupled coherent magnon and phonon modes of a surface patterned ferromagnet, *Phys. Rev. B* **102**, 144438 (2020).
[3] A. V. Scherbakov et al., Hybrid coherent control of magnons in a ferromagnetic phononic resonator excited by laser pulses, *Phys. Rev. Research* **6**, L012019 (2024).
[4] D. D. Yaremkevich et al., On-chip phonon-magnon reservoir for neuromorphic computing, *Nat. Commun.* **14**, 8296 (2023).