Magnon-phonon interaction and its manifold manifestations in an optically excited ferromagnet

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The renewed interest in the interaction of acoustic and spin waves, or phonons and magnons, is stimulated by several reasons. First, modern technologies are capable of producing complex magnetic structures with atomic precision and allow controlling the dispersions, spatial profiles, lifetimes, and other parameters of these collective excitations [1,2]. At the same time, state-of-the-art experimental techniques enable direct monitoring of their dynamics in the time domain. It makes observable various manifestations of magnon-phonon interaction, even those that recently seemed elusive [3,4]. Second, the modern IT industry is searching for a new hardware basis to replace CMOS technology for rapidly developing artificial intelligence [5]. Both magnons and phonons are being considered alternatives to charge transfer and their specific advantages can be further extended by magnon-phonon interaction. This coincidence of interests stimulates extensive studies.

The objective of this lecture is to address both fundamental and applied aspects of magneto-phonon interaction research. The lecture will be constructed around ultrafast optical experiments with magnetic ferromagnetic/semiconductor nanostructures [6]. The design of the structures, namely the use of phonon Bragg mirrors, the spatial patterning of the ferromagnetic layers, and the combination of these approaches allow controlling of the main parameters of the phonon and magnon eigenmodes. In the pump-probe experiments performed in conventional and asynchronous optical sampling schemes, the coherent response of each subsystem to ultrafast optical excitation is detected with picosecond time and submicron spatial resolutions. In the first part of the lecture, we will discuss the mechanism of magnon-phonon interaction and how it is manifested in the transient signals. In the second part, we will consider how a coherent mixture of phonons and magnons can be used for neuromorphic tasks at the hardware level [7].

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