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Collective spin waves in reconfigurable artificial crystals and magnonic meta-materials[1]

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Periodically nanopatterned ferromagnets have generated great interest in the research field of magnonics in that they support spin-wave (SW) nanochannels, allow for multi-directional emission of short-wavelength SWs via the grating coupler effect and form artificial crystals for SWs (magnons) in the GHz frequency regime. Allowed SW minibands and forbidden frequency gaps are not just tailored by the geometrical and material parameters, but reflect decisively the periodic order of the nanomagnets' remanent magnetization. Thereby a further degree of freedom is offered for controlling wave phenomena in solids compared to photonics and plasmonics. We investigated such so-called reconfigurable magnonic crystals (MCs) consisting of a one-dimensional (1D) array of permalloy nanostripes that allow one to vary the Brillouin zone boundaries, forbidden frequency gaps and number of SW minibands in one-and-the same device. When excited by a microwave antenna, an unexpected metamaterial property was found in that both reciprocal and nonreciprocal SW excitation occurred depending on the parallel and antiparallel alignment of magnetic moments in neighboring stripes. Such excitation characteristics are not found in natural materials. Switching an individual stripe from parallel to antiparallel magnetization in an otherwise saturated 1D MC modified the transmitted SW amplitude considerably offering SW control on the nanoscale. Combined with the grating coupler effect, periodically nanopatterned ferromagnets are expected to provide interesting building blocks for magnonic applications aiming at transmitting and processing information at microwave frequencies with spin waves.

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