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Hybridization of terahertz phonons and magnons in disparate and spatially-separated material specimens

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In the regime of strong light-matter coupling, polariton modes are formed that are hybrid light-matter excitations sharing properties of both, an electrodynamic cavity mode and a matter mode. In the recent decade, magnon-polaritons have been intensively researched using ferromagnetic materials in the microwave range, with potential applications for quantum technology and sensors [1]. Exploring antiferromagnets raises magnon frequencies into the terahertz (THz) range [2]. In this range, there are many excitations like phonons or plasmons. Recently, we reported on the cavity-mediated coupling of magnons in two distant slabs of antiferromagnets [3]. Here, we report on the cavity-mediated coupling of phonons and magnons.

We used magnon in nickel oxide (NiO) owing to its low damping, and controllable frequency near 1.0 THz at room temperature. We report on the coupling of its magnon mode to a phonon mode at 0.92 THz in CuB_2O_4 ceramics. Our experimental setup consisted of parallel-plane slabs of both materials, placed next to each other at a well-controlled gap, forming a tunable Fabry-Pérot-type cavity. Frequencies of cavity modes were controlled by changing the gap between the crystals in the range. We used a time-domain THz spectrometer to measure reflection spectra, as a function of NiO temperature and gap. We observed narrow avoided crossings of cavity modes with the magnon, and much broader avoided crossings with the phonon at 0.92 THz. At around T = 360 K, where the magnon frequency was close to that of the phonon, we observed polariton modes simultaneously coupled to the phonon and the magnon.

In comparison to pure phonon-polaritons, phonon-magnon polaritons are more splitted and their linewidths are narrower. Such states are tripartite phonon-magnon-polariton modes that share properties of a cavity mode, the magnon that has magnetic dipole moment, and the phonon that has electric dipole moment. This hybridization is possible without directly interfacing the two materials, at distances up to a few mm long.

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