Strong coupling of phonons and antiferromagnetic magnons mediated by terahertz cavity photons

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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-polariton frequencies into the terahertz (THz) range [2]. In this range, many dielectric excitations like phonons, vibrational modes of molecules, plasmons in two-dimensional electron gases, etc, are characterized by higher light-matter coupling rates than those of magnetic excitations because of their high dipole moments. 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, excitations of different natures.

We used magnon in nickel oxide (NiO) owing to its low damping, and controllable frequency in the range of 0.7–1.0 THz using temperatures above 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 consists of parallel- plane slabs of both materials, placed next to each other at a well-controlled gap, forming a tunable Fabry-Pérot-type cavity. The frequency of the magnon was controlled by the temperature of the NiO crystal in the range of 270–450 K, while frequencies of cavity modes were controlled by changing the gap between the crystals in the range of 0.2–6.0 mm. We used a time- domain THz spectrometer to measure reflection spectra, collected as a function of NiO temperature and distance between the slabs. Thus, as a function of distance, we observed narrow avoided crossings of cavity modes with the magnon, and much broader avoided crossings with the phonon at 0.92 THz (phonon-polaritons). At around T = 360 K, where the magnon frequency was close to that of the phonon, and at distances between the slabs where one of the cavity modes was also at the phonon frequency, we observed polariton modes simultaneously coupled to the phonon in the ceramics sample and the magnon in the NiO crystal.

In comparison to pure phonon-polaritons, phonon-magnon polaritons are about 10% more split and their linewidths are narrower, which is, respectively, due to a higher number of all matter oscillators in the cavity, and narrower linewidth of magnons than that of phonons. Such states are tripartite phonon-magnon-polariton modes that share properties of a cavity mode, the magnon that has magnetic dipole moment only in its pure form, and the phonon that normally has electric dipole moment only. This hybridization is possible without directly interfacing the two materials, at distances up to a few mm long.

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