Phonons with magnetic character

Hiroki Ueda

SwissFEL, Paul Scherrer Institute, Forschungsstrasse 111, 5232 Villigen, Switzerland

A phonon is a collective elementary excitation in a crystal and describes an excited state in quantum mechanics with the modes of atomic vibrations. This quasi-particle can interact with another type of excitation, leading to its mixed character. Such an interaction dominates a coupling among correlated degrees of freedom in ultrafast timescales. Here, I focus on two cases where a phonon possesses a magnetic character or angular momentum. (1) A chiral phonon involves rotational atomic vibrations, inducing an orbital angular momentum. Our study on a chiral crystal, quartz, by means of resonant inelastic X-ray scattering with circularly polarized X rays demonstrated the presence of chiral phonons [1]. We disclosed that circularly polarized X rays couple to chiral phonons at general momentum points, which allows us to measure chiral phonon dispersion. (2) An electromagnon is a polar phonon whose wave function hybridizes with that of a magnon and is a characteristic excitation in magnetoelectric multiferroics. We revealed its real-time dynamics by performing two time-resolved X-ray diffraction experiments [2]. Following a coherent excitation of an electromagnon mode, time-resolved resonant X-ray diffraction clarified its magnetic response while time-resolved non-resonant X-ray diffraction observed its phononic response. Combined dynamics disclosed how the electromagnon is excited.

[1] H. Ueda et al., Nature 618 946-950 (2023).
[2] H. Ueda et al., Nat. Commun. 14, 7778 (2023).