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Topological Phonon Hall Effect

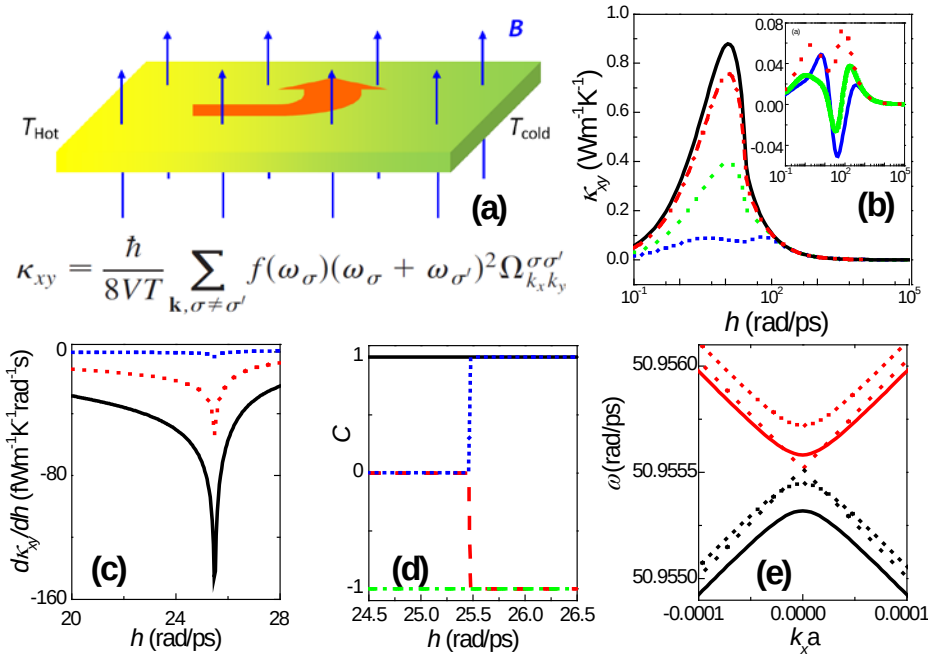

Figure.1 Topological phonon Hall effect.

Phonon Hall effect, a marriage between phononics and Hall effects, is opening the door for controlling phonons by a magnetic field. Traditionally we thought that we cannot manipulate the phonons by the external magnetic field because of the absence of Lorentz force. Therefore it is a big surprise that Strohm *et al.* found the PHE -- applying a magnetic field perpendicular to the heat flow in an insulating sample, a temperature difference appears in the third perpendicular direction [1], as shown in Fig. 1(a). Various Hall effects of electrons possess elegant topological interpretations in terms of geometric Berry phases, which provide a deep and unified understanding of basic transport properties of electrons. However, because phonons as neutral quasi-particles have distinct nature from electrons, the topological interpretation of Phonon Hall Effect (PHE) is not obvious and is still lacking even after five years of the experimental observation of itself.

In a recent work, physicists from National University of Singapore have successfully depicted the elegant topological nature of PHE. They obtain an exact general expression for phonon Hall conductivity (PHC) in terms of the Berry curvature of phonon band structures (as shown in Fig.1 (a)), whose topology is characterized by the integer Chern numbers. Such formula of topological PHE can also apply to the magnon Hall effect which reported in Science very recently [2]. Nonmonotonic and even oscillatory dependence of PHC on the magnetic field is predicted as well, as shown in Fig1. (b). Furthermore, they find that the PHE is not quantized; however, the quantization effect, in the sense of discontinuous jumps of topological Chern

numbers, manifests itself as the anomalous singularity of the first derivative of PHC with respect to the magnetic field, as shown in Fig1. (c) and (d). The underlying topological mechanism of the anomalous singularity is explained as a consequence of the phonon band crossing, as shown in Fig1. (e).

Publication:

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Reference:

[1] C. Strohm, G. L. J. A. Rikken, and P. Wyder, Phys. Rev. Lett. **95**, 155901 (2005).
[2] Y. Onose, T. Ideue, H. Katsura, Y. Shiomi, N. Nagaosa, and Y. Tokura, Science **329**, 297 (2010).