Detection of relativistic fermions in topological semimetals by magnetostriction measurements

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Detection of Dirac or Weyl fermions in topological semimetals remains often elusive, since in these materials conventional charge carriers exist as well. Here, we draw attention to the magnetostriction, i.e., to the field-induced length change, which results from the interaction between the electron and elastic degrees of freedom in a diamagnetic crystal. Using the prototype Weyl semimetal TaAs as an example and performing measurements at low temperatures, we show that this thermodynamic quantity can be an effective probe of the massless quasiparticles in Weyl semimetals, if the Weyl points lie near the Fermi level. In this situation, even in moderate magnetic fields, which are too weak to confine large groups of massive quasiparticles at their zeroth Landau levels, the magnetostriction contains a linear-in-field term that identifies the presence of relativistic fermions. Specifically, a firm evidence for Weyl fermions is found with the measurements along the [001] direction where the largest length changes are observed. By contrast, the longitudinal expansion along the [100] direction is by an order of magnitude smaller in the highest field applied of 16 T, and this a-axis magnetostriction experiences immense changes from large positive to large negative values with minute deviations of the applied magnetic field from the [001] direction [1]. In addition to this, we discuss the longitudinal and transverse magnetostriction of the topologically trivial semimetal LuAs with a cubic structure [2] to demonstrate that subtle parameters characterizing not only Weyl electrons but also trivial charge carriers can be extracted from the magnetostriction measurements.

Our study shows how dilatometry can be used to unveil Weyl fermions in candidate topological semimetals. In a broader perspective, detection of relativistic quasiparticles in candidate topological materials with the magnetostriction can set the stage for their further investigations, and the observed anisotropic magnetostrictive stress can be relevant for future high-field Weyltronic devices.

References:

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