

One of the major themes of condensed-matter physics has been the discovery and classification of miscellaneous phases of matter. Historically, it was believed that characterization of states through the principle of spontaneous symmetry breaking and local order parameters can give a universal description of all kinds of states. The discovery and understanding of quantum Hall states open up a new era of condensed-matter physics: topological quantum states of matter.

In the last 40 years, we have witnessed the emergence of many types of topological states and topological phase transitions. Particularly significant effort has been devoted to searching and characterizing topological semimetal phases in the past few years. Topological semimetals are characterized by bulk band crossings in their electronic structures, which are expected to give rise to gapless electronic excitations and topological features that underlie exotic physical properties. The most famous examples are Dirac and Weyl semimetals, in which the corresponding low-energy fermionic excitations are direct analogues of relativistic particles in quantum field theory.

Unique topological nature of topological semimetals promise many novel properties, such as protection from back-scattering, monopoles, and Fermi arcs on the surface. Moreover, the research interest in materials with linearly dispersing bands is fuelled by their technological potential for exploiting the relativistic nature of the Dirac and Weyl fermions in high-speed electronics.

A research project **Detection of relativistic fermions in topological semimetals with magnetostriction** addresses a fundamental problem related to experimental investigations of Weyl and Dirac quasiparticles: First-principles calculations and angle-resolved photoemission spectroscopy measurements can point towards new materials with nontrivial band topology. However, other experimental signatures of relativistic fermions are often subtle and indirect, since in these materials conventional, massive charge carriers exist as well. Hence, new experimental methods for determining the relativistic character of the quasiparticles are highly desirable to set the stage for investigations of their relevance for electronic applications.

Our proposal draws attention to the magnetostriction that in a nonmagnetic semimetal results from the interaction between the electron and elastic degrees of freedom in a crystal, and thus it is determined by the change of the charge-carrier density in an intense magnetic field. Furthermore, for a multiband material with multivalley structure, such as semimetals or degenerate semiconductors, this directional dependent thermodynamic quantity is greatly enhanced due to a band overlap and an electron redistribution between the bands at the switching-on of magnetic field. Employing a theory of the magnetostriction for topological semimetals developed by our collaborators, we have recently demonstrated that measuring the field-induced length change in the quantum limit, one can clearly distinguish between the relativistic and conventional electrons owing to cardinally different contributions from the linearly crossing and trivial parabolic bands when relativistic fermions are confined at the zeroth Landau level [T. Cichorek et al. arXiv:2106.06062].

The main research task is intended to study relativistic quasiparticles in topological semimetals using the magnetostriction as an experimental probe. We propose comprehensive investigations of the angle-dependent field-induced length change of selected representative TSMs with bulk band crossings sufficiently close to the Fermi energy, and hence giving rise to robust gapless electronic excitations. Our second intention, which constitutes the main experimental challenge of the project, is to explore effect of uniaxial stress on the magnetostriction. Because this thermodynamic quantity is sensitive to the position of the Fermi level, we plan to study magnetostrictive effects when the enclosed nodes will be tuned under uniaxial tension to the Fermi level, and thus to search for new physics. In a wider context, the observation of large and strongly anisotropic length changes under magnetic fields can be relevant for future Weyltronic devices, since strained thin-films might be realized using a magnetostrictive stress.