M2 Internship proposal (2022/2023)

Unité de recherche : **Laboratoire Physique de l'Ecole Normale Supérieure (LPENS, UMR 8023)**

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Etablissement de rattachement : **ENS, SU, CNRS, UPC**

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A PhD thesis starting from september 2023 is planned

Weyl and Dirac fermions in topological heterostructures : a magneto-optical and quantum magneto-transport investigation

Weyl and Dirac electrons have attracted tremendous interest as they mimic relativistic high-energy particles. The properties of these electrons are governed by physical laws that resemble relativistic equations and as a result, condensed matter and relativistic physics have emerged as tightly related fields. A striking example is the discovery of topological insulators, which are insulating in the bulk but exhibit a metallic chiral state at their boundaries. These massless states obey the Weyl equation and display a relativistic energy-momentum relation. As such, these states are a hallmark of relativistic physics inherent to topological matter and with the advent of topological systems, they have been coined "topological interface states". They display a distinct chirality with the electron spin locked to its momentum, which is protected by time reversal or crystalline symmetry. This led to the discovery of novel phenomena such as the quantum spin Hall and quantum anomalous Hall effects and opened up the doors for novel physics and device applications.

In order to investigate Weyl and Dirac states, we propose the following experiments :

- Investigation of the relativistic spectrum in smooth topological heterojunction. Here, we will probe the relativistic states in artificially graded heterojunction based on PbSnSe and reveal the emergences of a new relativistic energy spectrum that features a massless Weyl fermion coexisting with massive Dirac fermions at a single interface. A single topological heterojunction made of only one interface supports just one massless chiral state with definite chirality. It displays a massless Weyl-like linear energy-momentum relation independently of the interface width.

- Weyl fermions observation. For this purpose, three-dimensional narrow-gap ferroelectric topological insulators are needed. While the gaps of PbSnTe and PbSnSe are well-known for a wide range of Sn content and temperature, the energy gap of the quaternary alloys with the Ge incorporation needs to be characterized. This will yield the critical point of band inversion in Ge-doped ferroelectric topological insulators for a wide range of Ge contents and temperature.

The experimental techniques will be magneto-spectroscopy in the THz and MIR domain and quantum magneto-transport under high magnetic field up to 17 teslas, in the temperature range 1.6-200K.

The high quality studied heterostructures will be grown by molecular beam epitaxy ans structurally characterized (XRD, STM, ARPES…) by our collaborators at the Johannes Kepler University in Linz (Austria).

Both good experimental and theoretical skills are required for this internship.