Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

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Internship location: LPS Orsay
Thesis possibility after internship: YES
Funding: NO

Topological surface states for the implementation of a Landau-level laser

The study of topological materials has become one of the major issues in modern condensed-matter and quantum physics. It is thought that some 30-40% of all materials are indeed topological, i.e. their physical properties are governed by quantum geometry. One particular feature of topological materials is the emergence of remarkable surface states. In addition to the chiral metallic state, there may be other gapped states that are described in terms of a relativistic quantum-mechanical wave equation (Dirac equation) if the surface or interface is sufficiently smooth. In the presence of a strong magnetic field, these surface states are quantised into Landau levels that have recently been observed in transport and spectroscopic measurements at ENS-Paris, based on predictions from the LPS theory group.

Landau levels have since long been proposed for the implementation of a novel type of tunable laser in the THz regime, which is a particularly difficult regime for coherent light emission. However, these proposals have encountered severe obstacles due to rapid non-radiative relaxation processes that prevent a sufficiently long-lived population inversion. Very recent theoretical studies from our group indicate that these obstacles may to some extent be circumvented in topological surface states, within multi-level lasing systems. In order to corroborated these studies, a detailed study of the different life times of electrons in the associated Landau levels is required. This study, which combines analytical and numerical calculations is at the heart of the internship project. It is meant to be carried out in collaboration with Prof Ermin Malic, Marburg University, Germany, for the numerical studies as well as with several experimental groups, such as the THz-spectroscopy group at LPENS, Paris.

Condensed Matter Physics: YES Macroscopic Physics and complexity: NO
Quantum Physics: YES Theoretical Physics: YES