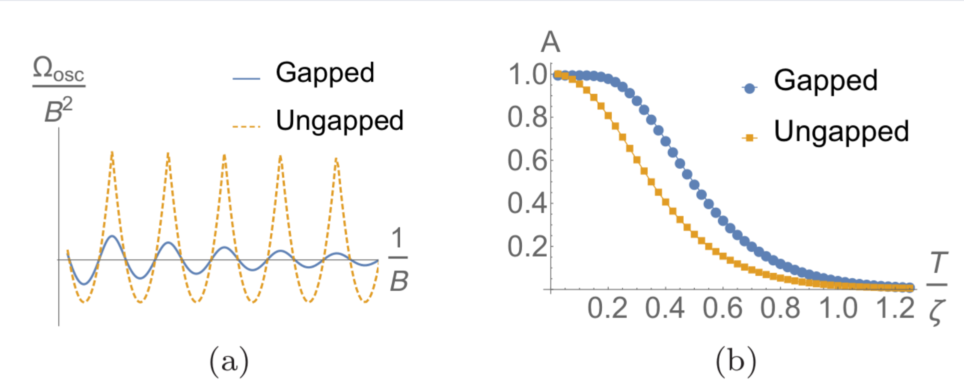
Quantum Oscillations in a Small-Gap Insulator

H. K. Pal, F. Piéchon, G. Montambaux, M. O. Goerbig (LPS), J.-N. Fuchs (LPTMC).

Quantum oscillations are a well-known technique in the study of electron systems in the presence of a magnetic field. They provide valuable information about the band structure of metallic systems by mapping out their Fermi surface. According to the generally accepted picture, the energy bands get partially quantized by the magnetic field into socalledLandau levels, and oscillations occur every time the Fermi energy crosses a Landau level. It comes therefore asa huge surprise that small-gap insulators can, under certain circumstances, also display quantum oscillations in the absence of a Fermi surface! This is, however, the case. Theoreticians, financially supported by the Labex PALM, have shown that in order to understand this unusual situation one needs to distinguish two classes of quantum oscillations. While those due to the pure Fermi surface, such as the Shubnikov-de Haas oscillations in the magneto-resistance, are absent in an insulator that has no quantum states available at the Fermi level, a second class of quantum oscillations requires taking into account the full Fermi sea, i.e. all states up to the Fermi level. Such a situation is for example encountered in de Haas-van Alphen oscillations in the orbital magnetization of an electron system. In this case, also an insulator can display quantum oscillations if the gap is locally inverted, e.g. when the conduction and valence bands overlap and are hybridized such that the valence band upper edge has the shape of a circle and plays the role of an effective Fermi surface.



The authors have theoretically studied quantum oscillations in small-gap insulators as a function of temperature, the gap size and asymmetry in the chemical potential (that is when the chemical potential is not situated precisely in the centre of the gap). Figure (a) shows the difference between an ungapped semimetal and a small-gap insulator with an inverted band structure. While the gap suppresses the oscillations, they remain clearly visible and survive upon increase of temperature [figure (b)] similarly to the case of quantum oscillations in a more conventional metallic situation. Furthermore, it was shown that the phase of the oscillations can be altered for an asymmetric chemical potential.

H. K. Pal, F. Piéchon, J.-N. Fuchs, M. O. Goerbig, G. Montambaux, *Chemical potential asymmetry and quantum oscillations in insulators*, Physics Review B 94, 125140 (2016)

Résultats obtenus dans le cadre du projet MAGNOSC financé par le thème 1 du LabEx PALM et porté par Mark Olivier Goerbig (LPS) et Christophe Texier (LPTMS).