PROPOSITION DE STAGE DE M1 - ICFO

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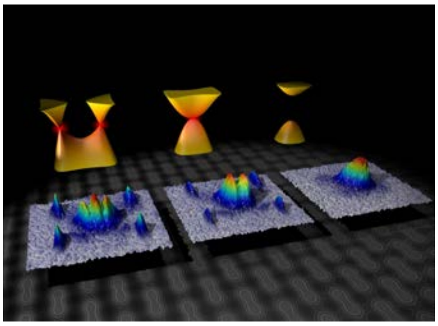
Ultra-cold fermions in optical lattices

In recent years ultra-cold atomic gases have emerged as a novel platform for the study of quantum many-body systems, giving access to phenomena originally studied in condensed-matter in a novel and highly controlled setting [1]. In this context, degenerate Fermi gases trapped in the potential created by interfering laser beams are a particularly clear example. By replacing the electrons by atoms, and the crystalline structure of solids by an optical lattice, these systems indeed provide the cleanest quantum « materials » that can be studied in the laboratory [2]. Fermions in optical lattices therefore appear as ideal test systems for studying the physics of strongly correlated materials. Indeed, after the first observation of a fermionic Mott insulator [3], the experiments are now starting to reach the regime at which the spin degree of freedom orders as well [4], opening the possibility to study quantum magnetism in the near future. Furthermore, these systems also offer the intriguing opportunity of reaching extreme parameter regimes which are not accessible in the solid-state context.



An example of extreme parameters that can be easily realized in cold atom systems : fermionic potassium atoms loaded in a tunable honeycomb lattice mimic the physics of graphene, but can also access a regime where the two Dirac points merge, annihilating each other [5].

Our group is currently setting-up at ICFO a new experimental apparatus specifically adapted to the production of ultra-cold potassium Bose and Fermi gases in complex optical lattices, with the long term goal of exploring magnetic phases in this setting.

During the internship the student will work on the construction of the experiment and the achievement of quantum degeneracy together with a PhD student and a postdoc. Quantum gas experiments involve a broad range of cutting-edge experimental techniques [6], including optics, ultra-high vacuum, electronics, and computer control. Depending on the skills and interests of the student, possible M1 projects are the set-up of a frequency stabilized laser system, the assembly and characterization of an ultra-cold atomic source (2D magneto-optical trap), the generation and stabilization of magnetic fields, the design and construction of an imaging system or the construction of an optical trap for the atoms.

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[3] R. Joerdens, N. Strohmaier, K. Guenter, H. Moritz and T. Esslinger, Nature **455**, 204 (2008).
[4] D. Greif, T. Uehlinger, G. Jotzu, L. Tarruell, and T. Esslinger, Science **340**, 1307 (2013).
[5] L. Tarruell, D. Greif, T. Uehlinger, G. Jotzu and T. Esslinger, Nature **483**, 302 (2012).
[6] W. Ketterle, D. S. Durfee, and D. M. Stamper-Kurn, arXiv:cond-mat/9904034
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