Striking effects of quantum transport in disordered media

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The internship is part of the development of quantum simulators using cold atoms, in particular through modulation in time of the experimental parameters. Using this technique beyond the perturbative regime, our group adresses questions related to the behavior of many-body wavefunctions in complex media and to quantum transport.

Our experiment is based on Bose Einstein condensates trapped in a 1D optical lattice, whose phase and amplitude are precisely controlled in time. Our group, in collaboration with G. Lemarié et B. Georgeot from Laboratoire de Physique Théorique in Toulouse, has recently shown the properties of a new type of tunneling effect assisted by delocalised quantum states. Unlike ordinary tunneling, this new type of tunneling effect exhibits resonances when one varies the parameters. Theses resonances were predicted in the 90's [1] but had never been observed before our recent experiments.

A second striking property of this tunneling effect is its range : transport can occur beyond the nearest neighbor. Additionally, this range can a priori be controlled through a well-chosen modulation profile [2]. The first objective of the internship will be to show these remarkable properties of quantum transport. This work opens up new perspectives for quantum simulators with cold atoms, which were limited to problems where only tunneling between nearest neighbors could be taken into account.

The second objective of the internship concerns also striking effects of quantum transport. More precisely, it deals with the localisation of matter waves in a disordered potential. The disorder is here simulated by the modulation in time of the optical lattice. Multiple wave interference effects can take place in these media and induce forward scattering. This phenomenon was predicted recently [3] but has never been observed in position space.

The PhD thesis that we propose in the wake of these experiments will address questions related to quantum phase transitions and the realization of Hamiltonians with various topological properties.

References

[1] S. Tomsovic, and D. Ullmo, Phys. Rev. E **50**, 145 (1994).
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[3] T. Karpiuk et al. Phys. Rev. Lett. **109**, 190601 (2012) ; G. Lemarié et al. Phys. Rev. A **95**, 043626 (2017).