Post-doctoral position:

Quantum transport with delocalized Floquet states

Scientific objectives

The Cold Atoms group at the LCAR laboratory at the Université Paul-Sabatier in Toulouse is investigating quantum simulation with ultracold atoms in time-modulated optical lattices. In a recent publication [1], we have demonstrated experimentally how quantum transport can be mediated by a delocalized state, in the context of an amplitude-modulated quantum pendulum. This was investigated by placing a Bose Einstein condensate in a time-dependent 1D optical lattice, in a parameter range for which the corresponding classical phase space is made of stable islands surrounded by a chaotic sea. The chaotic sea encapsulates delocalized Floquet states (DFS) that play a key role in the coherent quantum transport between islands, and explain the resonances that we have observed in the transport.

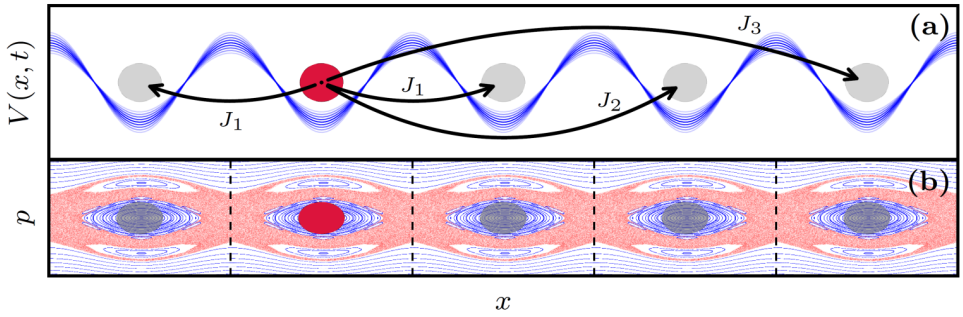

Figure 1: (a) Sketch of the system, showing the chaos-assisted hoppings J_n between regular islands, centered on the sites of the amplitude-modulated lattice (in blue), on which atoms are loaded. (b) Phase space (position x, momentum p) representation. Regular islands (in blue) are embedded in the chaotic sea (in red).

The aim of the two-year post-doc that we offer is to pursue our experimental effort on the amazing properties of delocalized Floquet states in various transport contexts:

1) The first goal consists in demonstrating the long range property of the coherent coupling between islands mediated by a DFS, in a regime similar to [1] (see Fig. 1). We have theoretically investigated several experimental techniques that can be envisioned to extract quantitatively the coupling coefficients between islands depending on their relative distance. This work is of interest for the field of quantum simulation as it shall enlarge the class of accessible problems to problems that involve long range couplings. (e.g Bose glasses).
2) The second goal is to investigate the role of interactions in DFS assisted transport. One may wonder how interactions modify the transport properties, and how to best account for that effect. One possibility is to describe transport in the time-modulated 1D lattice by a tight binding Hamiltonian, in which case a Bose-Hubbard model for interactions may be relevant. This open question is currently under theoretical investigation with our collaborators from the LPT (Laboratory of Theoretical Physics) in Toulouse. Experimentally, it will be explored by varying dramatically the number of atoms and the external confinement in our experiment to change interactions. In this

new range of parameters, our experiment shall behave as a testbed for interaction-induced decoherence models.
3) The third goal is to reach the strongly interacting regime, where a few atoms lead to a significant interaction energy, and study how quantum transport with DFS is then modified. This is so far an untouched domain, which should be accessible experimentally by adding an extra optical lattice on our setup with the appropriate time-dependent controls.
4) A fourth direction of research will be to investigate the role of DFS in coupling stable islands that are no longer static, but can themselves exhibit classical transport ("ratchet" behaviour). We are currently in the early stage of modelling the system in such a regime.

[1] *Chaos-assisted tunneling resonances in a synthetic Floquet superlattice,*
M. Arnal, G. Chatelain, M. Martinez, N. Dupont, O. Giraud, D. Ullmo, B. Georgeot, G. Lemarié, J. Billy and D. Guéry-Odelin to appear in Science Advances (arXiv: 2003.10387 [cond-mat.quant-gas]).

Profile: Candidates should hold a PhD in quantum optics or cold atoms experimental physics, with a solid grasp on theoretical aspects.

Position details: We offer a 24 months fixed term contract starting in early 2021, with a per annum salary from 25 000 € to 36 000 € depending on the seniority. The research will take place on the campus of Université Paul-Sabatier, in the south of the vibrant and history-rich city of Toulouse, at the heart of the South-West of France.

Group web site: https://www.quantumengineering-tlse.org

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