Post-doctoral position:
Quantum control and matter wave transport
at LCAR, Toulouse

Scientific project

The Cold Atoms group at the Laboratoire Collisions Agrégats Réactivité in Toulouse uses Bose-Einstein condensates (BEC) of Rubidium placed in a tunable optical lattice to investigate questions of quantum control and quantum simulations. In recent years, we have investigated the resonances of chaos-assisted tunnelling, mediated by Floquet states delocalized over the "chaotic sea", in an amplitude modulated lattice [1]. A similar mechanism should lead to effective long-range tunnelling between localized islands of regular trajectories [2]. In parallel, we have applied the tools of optimal control theory to the manipulation of the BEC wavefunction, and demonstrated our ability to control the full quantum state, and characterize the result [3,4].

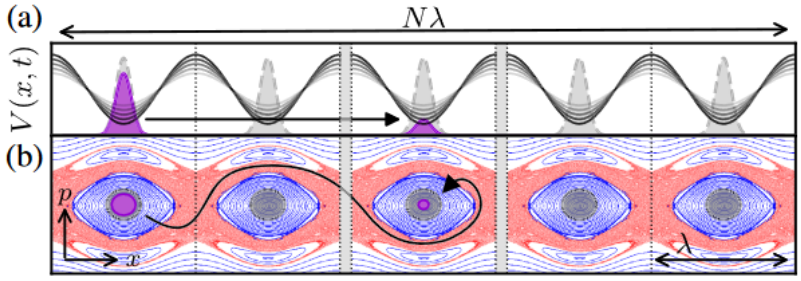

Figure 1: (a) in an amplitude modulated lattice, a wavefunction initially at the bottom of a well can be effectively coupled to distant sites by long-range tunnel couplings. (b) This can be interpreted (on a stroboscopic phase portrait) as a coupling between regular classical islands (blue) mediated by states in the chaotic sea (red). Adapted from [2].

We are offering a ***two-year post-doctoral position (ANR funded), to start in 2024***, to drive current experimental development in these two research directions, as well as to lead the development of the next generation of the experimental setup:

- The realization of a lattice system with long range couplings is a near term goal, with several protocols envisioned to characterize it. This would open a new class of models to quantum simulation. In that context the impact of interactions on the couplings will be studied in collaboration with the Laboratoire de Physique Théorique (Toulouse).
- We are looking to extend the use of quantum optimal control to optimal parameter estimation or sensing. This can be done for example by maximising the distance between final states after controlled evolution for two values of the parameter (e.g. lattice depth or force). A related question is the extension of the state-to-state control of [3] to the optimal realization of unitary operations in a finite Hilbert subspace (qudit gates), with applications in quantum calculation.
  Optimal control can also be fruitful in the context of quantum simulation, with the ability to prepare specific Floquet states, or tailor effective dynamics optimally.

- A new experimental setup is being developed in the new laboratory space delivered in 2022. The candidate will have a leading role in the construction of this setup, which aims at improved performance, stability and optical access. This will open the way to future investigations with better in situ characterization, higher dimensionalities, and interactions that can be brought from the mean-field to the strongly interacting regime.

References

[1] M. Arnal *et al., Chaos-assisted tunneling resonances in a synthetic Floquet superlattice,* Science Advances **6** :eabc4886 (2020)
[2] M. Martinez *et al., Chaos-Assisted Long-Range Tunneling for Quantum Simulation,* Phys. Rev. Lett. **126** 174102 (2021)
[3] N. Dupont *et al., Quantum State Control of a Bose-Einstein Condensate in an Optical Lattice,* PRX Quantum **2**, 040403 (2021)
[4] N. Dupont *et al., Phase-space distributions of Bose–Einstein condensates in an optical lattice: optimal shaping and reconstruction,* New J. Phys. **25,** 013012 (2023)
[5] N. Dupont *et al., Emergence of tunable periodic density correlations in a Floquet-Bloch system,* accepted in PNAS (2023)

Project setting: The LCAR laboratory is located on the campus of Université Paul-Sabatier, on the south edge of the vibrant and history-rich city of Toulouse, at the heart of the South-West of France. The research, in particular the development of a new experimental setup, will take place in the brand-new physics building (delivered in February 2022). The team benefits from in-house support in the development of mechanical and optical designs, as well as computer interfacing and control. Within the LCAR, the candidate will have opportunities to exchange with other teams focussed on quantum technologies, researchers from the broader FERMI research federation, and multiple opportunities for collaborations (with the nearby Laboratoire de Physique Théorique, or with the network of collaborators of the team)

Profile: We are looking for a highly motivated candidate with an expertise in cold atoms, atomic physics or quantum optics with a solid grasp on theoretical aspects. An experience in building a cold atoms setup is appreciated.

Position details: We offer a 24 months fixed term contract starting in early 2024, with a per annum salary from 25 000 € to 36 000 € depending on the seniority. Extensions can be envisioned through applications to local and national/EU funding.

Interested candidates can contact Prof. David Guéry-Odelin (dgo@irsamc.ups-tlse.fr)
Group web site: https://www.quantumengineering-tlse.org
Laboratory address: Laboratoire Collisions Agrégats Réactivité, UMR 5589,
Université Paul Sabatier, Bâtiment 3R4
118 Route de Narbonne, 31062 Toulouse