Call for PhD position

'Fault-tolerant quantum computing tools with neutral atoms'

About IOGS:

Founded in 1917, the Institut d'Optique - Graduate School is a world leader in higher education, research and innovation in optics and photonics. IOGS trains physics Engineers, Masters students, and some of the most innovative PhDs in business and academia. At the heart of networks of excellence, its international influence is grounded in the quality of the training it provides and its research and technology transfer. IOGS is a member of Paris-Saclay University, with three campuses of excellence in Paris-Saclay, Bordeaux and Saint-Etienne. The research center is composed of three laboratories with international influence, including Laboratoire Charles Fabry in Paris-Saclay.

About LCF:

Laboratoire Charles Fabry (LCF) is a joint research unit between Institut d'Optique – Graduate School and the French CNRS (Centre national de la Recherche Scientifique). Research at LCF covers a broad spectrum of topics in both fundamental and applied photonics and quantum physics. With 43 permanent researchers, working with doctoral students and post-doctoral fellows and supported by technicians and administrative staff, LCF includes about 130 people. The fundamental research carried out at LCF over the past 25 years has laid the scientific foundations for the creation of Pasqal in 2019.

About Pasqal:

Founded by a team of scientists and former students from LCF, Pasqal has quickly established itself as a leader in the quantum computing landscape, exploiting the technology of laser-controlled neutral atoms. With around 300 employees worldwide, Pasqal continues to grow as it drives the transition from academic breakthroughs to practical quantum computing applications.

Proposed PhD topic:

Quantum computing is a new paradigm in the field of high-performance computing. Harnessing the laws of quantum physics, Quantum Processing Units (QPUs) are expected to solve complex optimization problems using less calculation time and power than their classical counterparts. There is currently a strong international momentum in this field, with both academic and industrial players striving to build QPUs using different architectures and technologies.

PASQAL develops neutral-atom based QPUs, using an innovative technique pioneered by the group of A. Browaeys and T. Lahaye [1] at Laboratoire Charles Fabry. Neutral atoms are cooled and trapped in configurable, defect-free arrays of optical tweezers. Interactions between the atoms, that are at the heart of the quantum computing schemes, are triggered by exciting the atoms to Rydberg states [2].

An outstanding challenge of nowadays QPU is to reach high-fidelity quantum operations, as imperfections ultimately limit the type and quality of calculations that can be performed on a QPU. A promising track for solving this issue is to use quantum error correction [3] (analogous to error correction in classical systems) in order to realize fault-tolerant quantum computations, meaning that a calculation is performed correctly even in the presence of errors in the system.

The goal of this PhD is to develop the required technological features for performing fault-tolerant quantum computing [4]. The first tool to develop is gates operation, comprising the all-to-all connectivity via in-circuit atom movement, and optical addressability for local gates. Then, mid-circuit readout will also be implemented for realizing quantum error correction. Once these are implemented, some proof of concepts of quantum error correcting codes, as well as fault-tolerant quantum computation, will be explored. The aim is to participate into a large project which includes (1) understanding, simulating and developing new quantum features, (2) designing systems to achieve them, and (3) implementing and assessing their performances in one of Pasqal's QPU. The work mainly consists of knowledge developments regarding quantum processes, associated technical solutions and their application onto a functioning QPU.

This PhD project will involve both experimental and theoretical developments, which will be carried out in close interaction with the Pasqal and LCF teams, as well as their collaborators (e.g. at INRIA). On the gates side, the aim is to improve their fidelity. Various options will be explored, from increasing the laser power and frequency stability, to implementing optimized gates protocols. Novel types of gates protocols will also be explored. On the addressability aspects, the implementation and improvement of atom movement will be explored. In particular, optimal atom movement protocols combining movement with dynamical decoupling sequences will be explored. Another important aspect is the ability to combine all of these developments in order to implement logical qubits. This aspect will be central to this topic, and will require knowledge development on both the hardware details, and the theoretical conception of logical encodings. For this, various logical encodings as well as the ability to optimally implement them and characterize them on the hardware will be studied.

[1] A. Browaeys and T. Lahaye, Nature Physics 16, 132–142 (2020).
[2] P. Scholl et al., Nature 595, 233 (2020)
[3] P. Shor, Phys. Rev. A 52, R2493 (1995)
[4] D. Bluvstein et al., Nature 626, 58 (2024)

PhD Supervision :
- At LCF : Dr. Antoine Browaeys
- At Pasqal: Dr. Pascal Scholl

What we offer:
- A dynamic research environment at a renowned laboratory, in very close collaboration with a dynamic and expending start-up (co-supervision by a researcher from LCF and one from Pasqal)
- A significant research budget to support your PhD project
- Opportunities for professional development and collaboration

Qualifications:
- A master degree in one of the following fields: laser-matter interaction, quantum physics, optics
- Strong analytical and problem-solving skills
- Excellent communication and teamwork abilities