**Internship offer**

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| **Laboratory: Laboratoire de Physique des Lasers (LPL)****Director: Anne Amy-Klein****Address: 99 av. Jean-Baptiste Clément, 93430 Villetaneuse, France** |
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**Continuous-wave superradiant laser**

**Scientific project:**

Atomic clocks are vital components for many applications in our modern society, such as the operation of GPS and the synchronization of telecommunication networks. Clocks are also used as powerful tools to bolster investigations of physical phenomena, such as the detection of low-frequency gravitational waves or the search for dark matter. Recently, a new type of clock has been proposed, the *active clock using superradiant lasing*.

This clock would use a completely new scheme: instead of shining a very stable laser light onto ultracold atoms to probe the atom resonance frequency (and thus measure time), the clock would operate by letting the atoms themselves emit light. Much like the working principle of a laser, ultracold atoms would be prepared in an excited state, then placed between two mirrors forming a cavity. The atoms will then coherently emit light into the cavity mode. The laser frequency will mostly be set by the atoms themselves, and not by the, here relatively unstable, cavity. Unlike a traditionnal laser, the light coherence will be set by a *collective synchronization of the atomic dipoles* with each other - a process called *superradiance*. Thus, in addition to its significance as a new clock architecture, this system is interesting from a fundamental point of view: it is an example of an open-dissipative system in which correlations of quantum nature may naturally arise.

In the team Magnetic Quantum Gases (GQM) of the Laboratoire de Physique des Lasers, we are building a prototype for such an *ultracold-atom-based superradiant laser* [1]. In particular, we want to focus on tackling the unresolved issue of operating such devices in a continuous manner, meaning the emitted light will no longer form a burst but rather a continuous wave, thus harnessing superradiant lasers’ full potential as clocks. This will be done using an effusive beam of strontium atoms inside a vacuum chamber, that we will slow, cool, and guide up to the mode of an optical cavity. There we will make atoms emit light in a superradiant fashion. We will investigate the light properties to try and understand how the establishment of coherence is related to the many-body entanglement that can occur between all atomic emitters.

The internship will be of experimental nature. The construction of this new apparatus is underway. Depending on progresses, the future student will be in charge of laser cooling and guiding atoms into the superradiant laser cavity, observing the first signs of superradiant emission, and investigating the properties of the emitted light. This implies implementing optical setups to shape and guide laser light onto the atoms, locking lasers on atomic absorption signals or optical cavities, detecting small signals via modulation-transfer spectroscopy and cavity-enhanced spectroscopy.

Our team is composed of three professors, two CNRS researchers, one PhD student, one postdoc, and one research engineer. We currently have two separate, already running experiments to study the collective properties of ultracold gases with exotic spins when in the quantum regime. We welcome every year one or more trainees on one of our experiments. Each time, we proposed an individualized work subject to the trainee, work that they could develop in autonomy while being put in connection with the rest of the team and its scientific projects.

**Group webpage and recent publications:** <http://www-lpl.univ-paris13.fr/gqm/>

**Reference:** [1] H. Liu, S. B. Jäger, X. Yu, S. Touzard, A. Shankar, M. J. Holland, and T. L. Nicholson, *Rugged mHz-Linewidth Superradiant Laser Driven by a Hot Atomic Beam*, Phys. Rev. Lett. **125**, 253602 (2020). <https://arxiv.org/abs/2009.05717>

**Methods and techniques:**

The internship will involve several methods pertaining to the domains of optics, electronics, and atomic physics. The internship will also deal with laser cooling of atoms, and the principles of lasers and superradiant lasers.