INTERNSHIP PROPOSAL

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Thesis possibility after internship: YES
Funding: YES funding: Ecole Doctorale. project prioritized by the laboratory

Continuous superradiant laser with a laser-cooled atomic beam

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 to bolster investigations of fundamental physical phenomena, such as the detection of low-frequency gravitational waves.

Recently, a new type of clock has been proposed: the active clock using superradiant lasing. Instead of shining a very stable laser 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 in a laser, cold atoms would be prepared in an excited state, then placed between two mirrors forming a cavity. The atoms then coherently emit light into the cavity mode. However, unlike a traditional laser, the light frequency will mostly be set by the atoms themselves, and not by the cavity. 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 Laboratoire de Physique des Lasers, we have built a prototype for such a cold-atom-based superradiant laser. We want to tackle the unresolved issue of sustaining continuously its emission, thus harnessing its full potential as a clock. This will be done using an effusive beam of strontium atoms inside a vacuum chamber, slowed, cooled, guided up to an optical cavity, there to emit light in a superradiant fashion. We will investigate the light properties to understand how the emitters synchronize their oscillations, and how the light coherence is related to correlations between all atomic emitters.

The internship will be experimental research. The construction of the apparatus is nearing completion: the optical cavity is installed in the vacuum, and the laser system is functional. The Master student will be in charge of laser cooling and guiding atoms into the cavity, observing the first signs of collective interaction between the atoms and the light field in the cavity, and ultimately detecting superradiant emission. This implies implementing optical setups to shape and guide laser light onto the atoms, performing cavity-enhanced spectroscopy, and characterizing small superradiance signals in beat note spectroscopy. This work can then be continued into a PhD project, in which various superradiant emission regimes will be investigated, and the spectral and correlation properties of the light and of the atoms characterized. In collaboration with metrology experts, we will contribute to assessing the metrological interest (i.e., "performance" criteria to act as a clock) of atomic-beam continuous superradiant lasers.

Our group runs three experiments dedicated to the study of collective phenomena between atomic spins or dipoles. The two other experiments study quantum degenerate gases of interacting spinful atoms. The trainee will develop his work in connection with the entire team, developing a general culture in atomic physics and many-body physics.

References: [1] H. Liu et. al., PRL 125, 253602 (2020). https://arxiv.org/abs/2009.05717
[2] Laburthe-Tolra et al, SciPost Phys. Core 6, 015 (2023)

Condensed Matter Physics:	YES	Soft Matter and Biological Physics:	NO
Quantum Physics:	YES	Theoretical Physics:	YES