Proposition de stage M2 / M2 Internship proposal

Date : 09/11/22

Responsable du stage / *internship supervisor*:

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Nom du Laboratoire / *laboratory name*: Institut de Physique de Nice (INPHYNI)

Code d'identification : UMR 7010 Organisme : UCA & CNRS

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Adresse / *address:* 17 rue Julien LAUPRÊTRE, 06200 Nice
Lieu du stage / *internship place*: INPHYNI, Campus Plaine du Var, Nice

Titre du stage / *internship title*: **Spontaneous emission within a 1D atomic lattice**

Résumé / *summary*

In the cold-atom group at INPHYNI, we are studying **collective effects** in the interaction of light with laser-cooled atoms. Among those phenomena, **superradiance** and **subradiance** correspond to the accelerated and slowed down decay of light scattered by ensembles of atoms, compared with the single-atom decay rate. In the recent years, we have studied super- and subradiance in disordered cold-atom samples, where the position of each atom is random [1-3].

Now, we want to study what happens when the atoms are trapped in a one-dimensional lattice made of a retro-reflected optical tweezer. In that configuration, the atomic density becomes modulated in space with a periodicity close to $\lambda/2$ (where λ is the wavelength of the transition), which creates a modulation of the refractive index induced by the atoms. This modulation opens a **photonic band gap**, i.e., a range of frequency where light cannot propagate, but only at a given angle determined by the Bragg condition [4]. Light incoming from the outside at the Bragg angle is reflected. One can tune the Bragg condition by adjusting the periodicity of the lattice via the laser wavelength.

The questions that we want to address now are: How is the scattering rate modified within the band gap? Is it superradiant or subradiant?

On the longer term, this system, which is a first step towards **resonant quantum metamaterials** [5], is very rich and could be used to create quantum-optical devices such as quantum gates (using electromagnetically-induced transparency, EIT, in a four-level scheme) or quantum memories (using for instance the predicted "selective radiance" effect [6]).

The internship is experimental. The student will set up a new laser that will have to be phased-locked to another laser in order to be used for EIT experiments or for implementing new cooling mechanisms (gray molasses or Raman sideband cooling) to improve the atomic density in the lattice. The new laser will be tested on the cold atoms and the student will thus work in team with the PhD student and the post-doc currently working on the setup.

References:

[1] Subradiance in a large cloud of cold atoms, Phys. Rev. Lett **116**, 083601 (2016).
[2] Superradiance in a large and dilute cloud of cold atoms in the linear-optics regime, Phys. Rev. Lett. **117**, 073002 (2016).
[3] Subradiance with saturated atoms: population enhancement of the long-lived states, Phys. Rev. Lett. **126**, 103604 (2021).
[4] Photonic band gaps in one-dimensionally ordered cold atomic vapors, Phys. Rev. Lett. **106**, 223903 (2011).
[5] Quantum matter built from nanoscopic lattices of atoms and photons, Rev. Mod. Phys. **90**, 031002 (2018).
[6] Exponential improvement in photon storage fidelities using subradiance and "selective radiance" in atomic arrays, Phys. Rev. X **7**, 031024 (2017).

Ce stage pourra-t-il se prolonger en thèse ? *Possibility of a PhD* **? : YES**

Si oui, financement de thèse envisagé/ *financial support for the PhD***: EDSFA**