PhD proposal

Title: Photon dynamics in a disordered cloud of Ytterbium atoms: towards Anderson localization

Keywords: **Cold atoms, light scattering, Anderson localization, disordered systems**

Scientific description:

The scattering of light on an ensemble of atoms connects many domains of physics, from **complex media** in mesoscopic physics to **quantum optics**. The resonant photons sent on a large sample of atoms can undergo multiple scattering events, and their wave-like behavior has to be considered to properly describe the physics of the system, and give rise to interesting phenomena such as Anderson localization. On the other hand, the atoms form an assembly of driven qubits that can interact through the dipole-dipole interaction which can drastically modify their excitation spectrum, and collective sub-radiant and super-radiant states can emerge.

The **localization of waves** addressed by Anderson in 1958 [1] is the following: when a wave is scattering in a disordered system with typical distance between scatterers on the order of the wavelength, interference effects fully trap the wave excitation inside the system. This has been observed with acoustic waves [2] and matter waves [3], but never with light waves so far. In cold atoms, several experiments have been performed with rubidium atoms, but the microscopic details of the light-matter interaction, in particular the polarization of light and the short-range interactions between atoms, were detrimental.

The experimental setup that we work on can create **large sample of cold ^{174}Yb atoms** (10^9 atoms at a temperature of a few microkelvin). These atoms have a J=0 ground state, which brings a huge advantage over Rb atoms, and recent theoretical findings suggest that the observation of Anderson localization of light could be within reach by applying random energy shifts to the atoms thanks to a far-detuned speckle light pattern [4].

The goal of the PhD thesis is to explore the scattering of photons in such atomic samples and to determine whether Anderson localization of light can be observed there, and how to probe it. It has a large experimental part, but numerical work can also be performed to better understand the physics that we investigate.

References:

[1] P. W. Anderson, *Absence of Diffusion in Certain Random Lattices*, Phys. Rev. **109**, 1492 (1958)
[2] Hu *et al.*, *Localization of ultrasound in a three-dimensional elastic network*, Nature Phys. **4**, 945 (2008)
[3] Chabé *et al.*, *Experimental Observation of the Anderson Metal-Insulator Transition with Atomic Matter Waves*, Phys. Rev. Lett. **101**, 255702 (2008)
[4] L. Celardo, M. Angeli, F. Mattiotti, R. Kaiser, *Localization of light in three dimensions: a mobility edge in the imaginary axis in non-Hermitian Hamiltonians,* EPL 145, 42001(2024)

Techniques/methods in use: Lasers, cold atoms
Applicant skills: Experiments in optics and laser physics, basic knowledge of atomic physics
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