Light in mesoscopic ensembles of atoms

Sébastien Lucas*[1], Sergey Skipetrov[1], and Christian Miniatura[2]

[1]Laboratoire de physique et modélisation des milieux condensés – Université Grenoble Alpes, Centre National de la Recherche Scientifique - CNRS – France

[2]Institut de Physique de Nice – Université Nice Sophia Antipolis (1965 - 2019), Centre National de la Recherche Scientifique, Université Côte d'Azur – Avenue Joseph VALLOT Parc Valrose 06100 NICE, France

Abstract

In a dense and large ensemble of atoms, the atoms couple via the electromagnetic field and their individual atomic states hybridize into collective atomic states. These collective resonances can be largely de-tuned from the atomic resonance frequency and exhibit enhanced decay-rates (super-radiant states), lifetimes several orders of magnitude greater than the one of single atoms (sub-radiant states) and even Anderson localization.

We study numerically the collective modes of ensemble of atoms randomly placed on a plane in the middle of a Fabry-Pérot cavity whose boundary conditions allow only for one TM propagative mode. Such geometry decouples the in-plane excitations (TM) from the out-of-plane excitations (TE), allowing to study the impact of the scalar or vectorial nature of the light on Anderson localization. Due to the cavity, the coupling between atoms via the TM modes resembles the one of a 2D scalar problem, with a near field dipole-dipole interaction inherited from the 3D nature of the problem. This allows to tune the effective dimensionality of the problem with the density of scatterers, giving rise to a localization transition. Additionally, although not able to support transport in an empty cavity, TE modes allow short range interaction between atoms that can restore transport at high enough densities, giving rise to a different localization transition.

*Speaker