Near-resonant light scattering by small clouds containing a few cold atoms

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The scattering of light by particles is one of the processes that we encounter in our everyday life. This process is presently at the focus of many studies in numerous systems, such as nanoparticles, quantum dots or any random media. Cold atoms are also good candidates to study these phenomena because of their versatility. Examples are the recent observation of Anderson localization [1] and coherent backscattering in cold atom samples [2]. Here, we present results with small and dense clouds of cold atoms of the study of collective scattering effects.

In the absence of interactions between the atoms, Dicke's theory [3] predicts that particles with an inter-particle distance shorter than the wavelength of the light exhibit a collective (or cooperative) behaviour with respect to the light excitation, leading for example to super-radiance or sub-radiance phenomena. This picture is greatly modified when interactions are taken into account and no general theory exist to describe the situation where both collective scattering and interactions are present. We have studied both experimentally and theoretically the problem of near-resonant light scattering in a microscopic sample containing from 1 to 400 atoms leading to density as high as 10^{14}at/cm^3. In this regime, resonant dipole-dipole interactions play a crucial role, a situation largely unexplored so far. Experimentally, we have first studied the behaviour of the atomic sample under excitation around the atomic resonance. Our measurements indicate large collective effects with only a few atoms.

To explore further possible super- and sub-radiant effects, we have then performed a temporal analysis of the scattering of light. We started by studying the scattering of a wave-packet of light by a single atom. This leads to the so-called Wigner time-delay, which arises when scattering photons close to the resonance of a scatterer. In our case it reaches values as large as several tens of nanoseconds at resonance, due to the small line-width of the resonance [4]. Going to several atoms should lead to a modification of the Wigner time-delay because the collective effects broaden the resonance of the atomic sample.

Reference:
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