Cooperatively enhanced light transmission in cold atomic matter

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The general optical properties of aggregated matter differ significantly from those of individual nuclear or atomic scatterers. In the case of a dilute and optically thin gas of atoms the response of the system to applied monochromatic electromagnetic radiation is well understood. However, upon increasing the atomic density, the quantum optics of such systems develops correlated characteristics. This is especially true in cold atomic gases, where coherence shared between applied and scattered fields, and the atoms comprising the samples, can be robust to environmental decoherence. Among those phenomena mediated by spatial disorder, Anderson localization of light and random atomic lasing are areas of current investigation. Because of the global coherence that can be generated in cold atomic ensembles, an optically excited ensemble can be considered a single entity, and the system described by a collective of atomic superpositions. One possible representation of these is the super and subradiant states introduced by Dicke. Although superradiant states have been observed and studied by many investigators, experimental research on the relatively fragile subradiant states has been much more limited. Recent work, for instance, has shown that, through off-resonance optical excitation of an atomic system, a so-called timed-Dicke state may be created. Such a collective excitation distributed through the sample as a whole, can demonstrate one-photon superradiance. Further, the timed-Dicke state may be mixed through so-called Fano couplings into subradiant modes, which may then be experimentally observable. In order to fully realize the potentially rich physics embodied in these systems requires a fuller experimental and theoretical exploration of their basic optical properties. In that direction, we report here enhanced transmission in measurements of the spectral dependence of forward light scattering by a high-density and cold ensemble of $^{87}$Rb atoms. This phenomenon, which is a result of dipole-dipole interaction induced cooperative light scattering in the atomic sample, implies a significant departure from the traditional density dependence of the transmitted light as embodied in the Beer-Lambert Law. Absolute values of the density-dependent forward light scattering cross-section are extracted from the measurements.

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