Study of light interacting with dense and cold atomic gases is an active area of experimental and theoretical research. The subject is deceptively simple, with in many cases light from a single weak probe beam scattering from a small cloud of cold atoms. However, under most realistic situations, the atoms in such a sample interact not only with the incident field, but also with the light scattered by all the other atoms. The ensembles can then be viewed as many-body systems. There are a number of physical situations in which cooperative interactions have important influence. These are tied to changes in process rates or to the distortion of the scattering processes line shapes in the cooperative regime. They include negative effects that optical dark states have on cooling atoms or diatomic molecules, atom counting in 2D or 3D cold atomic gases, precision time keeping, and quantum level sensor development. Although a wide range of phenomena have been studied, the majority of these have been concerned with light scattering on nearly closed atomic transitions for which the inelastic Raman transitions have been considered negligible. In most cases there has also been the possibility of quasielastic Rayleigh scattering, but largely the associated Zeeman redistribution has also not been studied in detail. The main interest in our studies is how observables for the various optical processes are changed by cooperative interactions among the atoms in the sample.

In this paper we present benchmark lower density results from counting measurement which serves as an estimator of the number of atoms in a cold atom sample at MOT densities and temperatures. In our measurements, about $10^8$ atoms are accumulated in the ground $F = 2$ level of $^{87}$Rb. A probe laser is directed through the atomic sample, is tuned near the $F = 2 \rightarrow F' = 2$ transition, and the transmitted light intensity detected as a function of time. The observed time evolution is quite closely exponential. The rate obtained from the exponential evolution is dependent on atom density, detuning and pump power. The detuning dependence is illustrated in the figure. There the red diamond data points correspond to forward scattering of the probe light, and the blue circular data points represent the rate for time evolution of the fluorescence. The slower rate for the fluorescence is likely due to the influence of multiple scattering contributing to the fluorescence signals.

For this data, there are then two open channels, one to the $F = 2$ and one to the $F = 1$ ground level. On average it takes two photons to move an atom from the initial $F = 2$ level to the $F = 1$ level. As these two levels are well separated energetically the $F = 1$ level is a dark state for the incident probe beam. With accurate energy calibration of the photodiode response, the integrated signal from the photodiode yields the number of atoms in the sample. It has been claimed that this result is independent of detuning, laser intensity and atomic density. However, this argument ignores the potential role of multiple scattering.

In this talk we summarize and discuss the results of the studies described above, with particular attention to atom counting data as measured in the combination of forward and sideways scattering in the system time evolution.

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