Coherent backscattering of light by cold atoms

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The situation of a wave propagating through a random scattering medium is fairly common in nature (seismic waves, light in fog, ...). Understanding the rules of wave propagation in such media may have some interesting applications e.g. in medical imaging or in mesoscopic physics.

In the process of multiple scattering, the wave's initial direction of propagation (and its polarization, in the case of an electromagnetic wave) is rapidly scrambled, and the propagation can be seen as a random walk inside the medium. Thus, a diffusion picture seems appropriate in this problem. However, it is well known that interference phenomena can drastically affect the propagation in a dense random medium. An extreme situation is that of "strong" (or Anderson) localization, where the diffusion coefficient vanishes and the wave is "trapped" inside the medium. Another manifestation of interference effects in multiple scattering, observable in many samples (white paper, milk, biological tissues, ...), is the so-called coherent backscattering (CBS). The constructive interference between reverse scattering path in the sample yields an enhanced scattered intensity within a narrow angular range around the exact backscattering direction (known as the CBS cone). If the single scattering contribution to the detected intensity can be rejected, the intensity at the tip of the cone, in the "helicity preserving" polarization channel, is twice that of the background (i.e. far away from the backscattering direction). The angular width of the CBS cone is inversely proportional to the transport mean-free path of the wave in the sample. This is now a well-studied phenomenon, which has been has been observed in a variety of classical scattering systems.

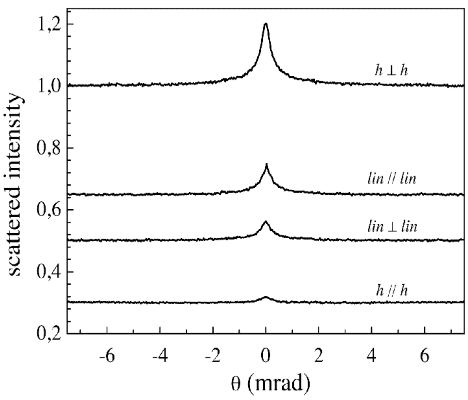

Figure 1: CBS cones from a laser-cooled rubidium sample in various polarization channels.

We have observed for the first time coherent backscattering of light from a sample of laser-cooled rubidium atoms. This is an interesting new situation, because atoms exhibit some unusual properties as scatterers of light (highly resonant scattering cross-section, internal structure, saturation effects, ...). Indeed, we observed for the atomic CBS signal marked differences with what is reported from classical samples. In particular, the intensity enhancement factor is much smaller than two even in the helicity preserving channel (see Fig. 1). This is due to the rubidium atom's internal (Zeeman) structure : because of the different Clebsch-Gordan coefficients, the amplitudes of the reverse light paths interfering to produce the CBS cone are imbalanced, yielding a reduced contrast of the interference. The observed enhancement factors in the various polarization channels are in good agreement with the theory.

In this communication, we discuss these results as well as some other produced by our experiment. Further studies will include the effect of sample geometry, saturation, laser frequency, and of an externally applied magnetic field.