Dissipative atom optics with a cold metastable helium beam

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We use a bright, cold and ultra-collimated beam of metastable helium atoms in the $\{2s\}^3S_1$ state to study the momentum transfer between light and atoms with sub-recoil precision. The setup uses four separate laser cooling stages to produce a slow ($v_{||} = 247$ ms^{-1}) and monochromatic ($\Delta v_{||}/v_{||} = 1.5 \times 10^{-2}$ rms) spin-polarized He* beam with a transverse rms velocity spread of less than 9 mm s^{-1}. Combined with a two-dimensional position-sensitive metastable atom detector, placed 2 m downstream of the interaction region, this setup allows us to study the interaction with 1083 nm light with an overall rms resolution of 0.13 photon recoils.

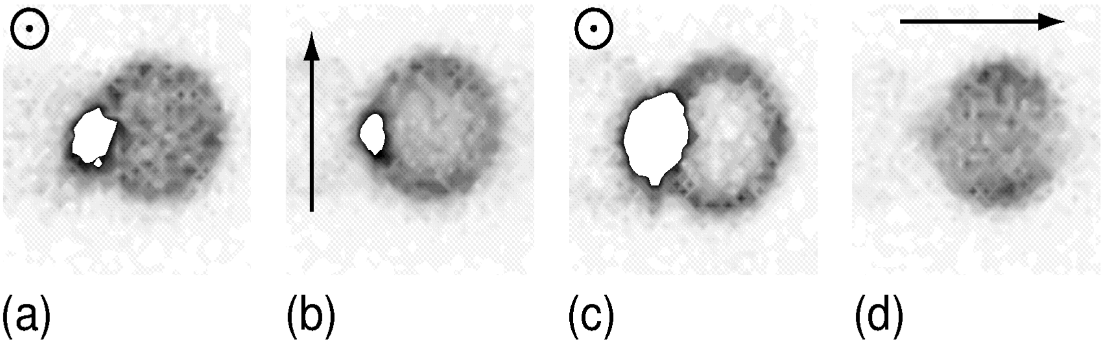

Figure 1: Two dimensional projections of the angular radiation distributions of electric dipole radiation observed in atomic recoil for (a-b) a σ-transition and (c-d) a π-transition. The arrows indicate the orientation of the quantization axis.

Using a Na Bose-Einstein condensate, of which the momentum distribution could be displayed with an optical imaging technique, Kozuma *et al.* [1] were able to map an angular radiation distribution, produced by spontaneous emission, into a two dimensional atomic pattern. This was done in the context of atomic Bragg diffraction and no further effort was made to study these patterns in more detail. The high quality of our atomic beam combined with a Stern-Gerlach type of magnetic substate analysis allows a more detailed look at these patterns. Two main types of emission patterns, associated with decay via either a π or a σ electric dipole transition, can be identified [2]. Both patterns were independently measured (see figure 1) and were found to be in excellent agreement with theory.

In the second experiment we use atomic Bragg scattering [3] to produce a high precision coherent atomic beam splitter. Up to eighth order Bragg scattering, with a corresponding splitting angle of 6 mrad, was realized. Due to the high quality of the atomic beam even higher diffraction orders can be addressed. At this moment we are, however, limited by the available laser power. In the near future we plan to use three of these beam splitters to produce an atomic interferometer with a very large enclosed area (6000 mm^2) and a macroscopic maximum path separation (6 mm). We also measured the Pendellösung oscillations in the splitting ratio [4] as a function of laser intensity for fifth order Bragg scattering. The oscillations clearly show the transition from a pure ten-photon process to a predominantly two-photon process.

Finally, the influence of a single spontaneously emitted photon on the coherence in the motional state of an atom is investigated. In our case atoms undergo spontaneous decay *during* the Bragg scattering process, unlike in a previous experiment [5], where the atoms decay *outside* the light field. The adiabatic evolution of the atomic state vector during Bragg scattering acts a probe that measures the degree of coherence after spontaneous decay.

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