Development of a mixed optical and magnetic trap for cesium atoms

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We describe a novel trap design for cesium atoms referred to as a mixed optical and magnetic trap. Its principle is to combine a 1D vertical magnetic force and a 2D horizontal dipolar optical force to achieve a 3D trap suitable for Cs atoms in the lowest energy Zeeman state (6 2 S1/2, F=3, m F=+3). This property is of a particular interest in the context of the formation of a Bose-Einstein condensate by evaporative cooling. Indeed, the usual purely magnetic traps work for atoms in a ‘low field seeker’ state, the internal energy of which maybe converted into kinetic energy during an inelastic collision process, leading to supplementary heating and trap losses. In the case of Cs atoms, the excess of such inelastic collisions during the evaporative cooling prevented the occurrence of the BEC transition. Our optical and magnetic trap should overcome this difficulty.

We have built a two-cell set-up to ensure a fairly good vacuum environment in the lowest cell (nearly 10^{-11} Torr). The experimental procedure is as follows. In the upper cell, Cs cold atoms are prepared in a vapor cell Magneto-Optical Trap (MOT). After a cooling phase, about 10^9 atoms at 10 \mu K are released out of the MOT. The atomic cloud falls under the gravity to the lower cell, where it is trapped again in a second MOT. The atoms are then cooled down to a few micro-kelvins, and they are also tightly compressed by drastically increasing the MOT magnetic field gradient in order to improve the phase space matching between the MOT and the optical and magnetic trap. After switching off the MOT, the atoms are optically pumped into the (6 2 S1/2, F=3, m F=+3) state, and are transferred into the optical and magnetic trap.

A vertical magnetic field gradient (30 Gauss/cm) created by a pair of conducting bars and superimposed to a homogeneous vertical magnetic field B 0, provides a trapping force strong enough to compensate gravity at the altitude of the MOT. A Nd:Yag laser of 300 mm waist focused in the MOT confines the atoms horizontally. The characteristics of the optical and magnetic trap are as follows: vertically, the trapping potential is 500 \mu K to 1 mK deep, depending on the parameters of the magnetic system (current in the two bars, value of B 0,position) and oscillation frequency varies between 5 to 10 Hz. In the horizontal direction, the frequency is about 50 Hz and the depth is around 30 \mu K.

The trapping of atoms in such a device has been demonstrated and experiments are still in progress. We have observed the occurrence of spontaneous evaporative cooling in such a trap during the very first hundred milliseconds: actually, hot atoms are expelled by the radial magnetic field as soon as they reach a radius greater than the laser waist. We have observed more than 2 s lifetime with a few 10^6 atoms. These parameters should be improved to allow the evaporative cooling by microwave transitions between the (6 2 S1/2, F=3, m F=+3) state and the (6 2 S1/2, F=4) manifold.