L.7: Enhanced loading of cold atoms in a Krypton magneto-optical trap with hollow Zeeman slower beams

Laser cooling of noble gas atoms in the metastable state has applications in many research fields including cold atoms collisions, ionization physics, nanolithography and atom trap trace analysis (ATTA) for applications in geophysics, archeology and monitoring low level nuclear fission activity.

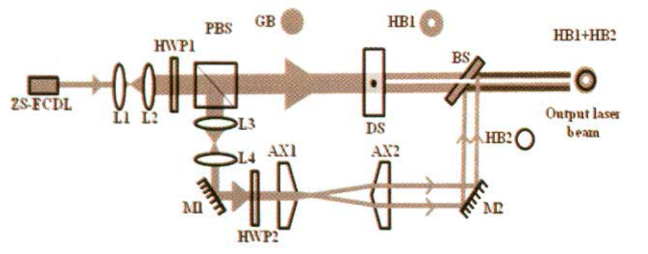

Fig. L.7.1: Schematic of experimental setup for the generation of hollow beams. ZS-ECDL: Zeeman slower-extended cavity diode laser, L1, L2, L3 & L4: Lenses of appropriate focal lengths, HWP1 & HWP2: Half wave plates, PBS: Polarizing beam splitter cube, GB: Gaussian beam, DS: Dark spot on the transparent glass plate, BS: Beam splitter, M1 & M2: Mirrors, AX1 & AX2: Axicon lenses, HB1: Hollow beam generated using the dark spot, HB2: Hollow beam generated using the axicon lenses.

A magneto-optic trap (MOT) setup to cool and trap noble gas Krypton atoms has been developed at the Laser Physics Applications Section, RRCAT. These noble gas Krypton (^{84}Kr) atoms in the lowest excited metastable state ($5s[3/2]_2$) have lifetime of nearly 40 s. The excitation to this metastable energy state is accomplished by inductively coupled RF discharge (frequency ~30 MHz). The laser cooling of metastable state ^{84}Kr atoms (denoted as ^{84}Kr* atoms hereafter) requires a wavelength of ~ 811.5 nm to drive the cooling transition between states $5s[3/2]_2$ and $5p[5/2]_3$. Prior to MOT formation, the ^{84}Kr* atoms emanated from discharge source are decelerated using a Zeeman slower device comprised of a laser beam and spatially varying magnetic field. The variation of the magnetic field in the Zeeman slower is kept in such a way that the Zeeman shift in the atomic transition frequency compensates the Doppler shift in the laser frequency for a moving atom. Thus, the laser beam interacts nearly resonantly to the atoms throughout the length of the Zeeman slower, and leads to slowing of the atomic beam effectively for the loading of the MOT. The MOT is formed by applying three pairs of counter propagating laser beams in the presence of a quadrupole magnetic field. The atoms trapped in the MOT are cooled to a temperature of few hundreds of micro-Kelvin. In the present work, we have used hollow beams instead of a generally used Gaussian beam in the Zeeman slower of our setup. A significant enhancement in the number of atoms trapped in the ^{84}Kr-MOT was observed with the hollow beams in the Zeeman slower, as compared to the number obtained with a Gaussian beam. In the experiments, two hollow laser beams of different dark diameter and ring width were used in the Zeeman slower of our atomic-beam-loaded Krypton MOT. Fig. L.7 .1 shows the schematic of the experimental setup for the generation of hollow beams. The first hollow beam (HB1) was generated using a dark spot in the path of a Gaussian beam. The second hollow beam (HB2) with variable diameter was produced by taking a part of laser beam and passing it through a pair of axicon lenses (with cone angle of 176°) mounted on a calibrated translation stage. Using the combination of these two hollow beam as a Zeeman slower beam, the observed enhancement in number of atoms in the MOT was more than ~50% with respect to the number observed with a Gaussian Zeeman slower beam of same power as shown in Fig. L.7.2.

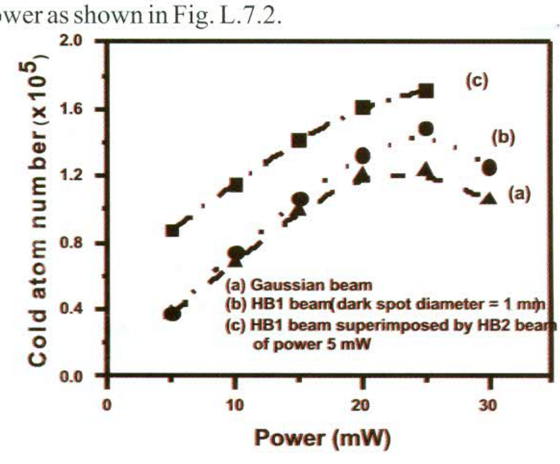

Fig. L.7.2. The measured variation in the cold atom number in the MOT with the power of the Zeeman slower laser beam. The curve (a) is for power in the Gaussian beam and the curves (b) and (c) are for the power of the hollow beam HB1. The curves (c) shows the variation in the number with the power in HB1 beam in presence of the HB2 beam of 5 mW power.

This enhancement in the number of atoms in the MOT is attributed to more efficient cooling of the off-axis atoms in the atomic beam and reduced destruction of the cold atom cloud as compared to the Gaussian beam. This work is published in J. Exp. Theo. Phys. 146, 464 (2014) by S. Singh, V. B. Tiwari, S. R. Mishra, H. S. Rawat.

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