L.3: Laser cooling and trapping of noble gas Krypton atoms

Laser cooling of noble gas atoms in the metastable state is of great importance to many research fields including cold atoms collision and ionization physics in the excited state, nanolithography and atom trap trace analysis (ATTA). The ATTA is a useful technique to detect rare (or low abundant) isotopes for applications in geophysics, archeology and monitoring low level nuclear fission activity.

A magneto-optic trap (MOT) setup to cool and trap noble gas Krypton atoms has been developed and made operational recently at the Laser Physics Applications Section, RRCAT. This is the first successful demonstration of a noble gas atom trap in the country. The MOT for Kr atoms requires different setup than that required for alkali gas atoms. The noble gas atoms are cooled and trapped in the metastable excited state, hence state preparation is the first step for cooling and trapping of these atoms. After the atoms are prepared in the excited state, they are transported to a chamber having appropriate vacuum for MOT formation. The pre-cooling of atoms is also required using a Zeeman slower device before loading the MOT. The MOT is formed by applying three pairs of counter propagating laser beams in the presence of an inhomogeneous magnetic field. Atoms trapped in the MOT are typically cooled to a temperature of few hundreds of micro-Kelvin.

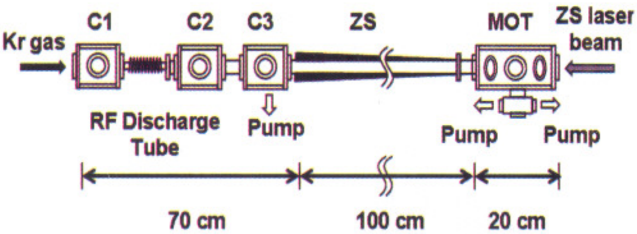

Fig. L.3.1: Schematic of experimental setup for cooling and trapping of Kr atoms. C1: Kr gas inlet chamber, C2: observation chamber, C3: pumping chamber, ZS: Zeeman Slower, MOT: magneto-optical trap.

We have demonstrated laser cooling and trapping of noble gas Krypton (^{84}Kr) atoms in the lowest excited metastable state ($5s[3/2]_2$) having 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 $5p[5/2]_3$. The even isotopes of metastable noble gas atoms however do not have a nuclear spin and therefore they do not have any hyperfine structure. Consequently, re-pumping laser beam is not required for cooling of these even isotope atoms. Fig. L.3.1 shows the schematic of the experimental setup for cooling of Kr* atoms which consists of various chambers with pressures varying successively from $\sim10^{-3}$ Torr to $\sim10^{-8}$ Torr. A Zeeman Slower (ZS) which produces spatially varying magnetic field over a length of around one meter is connected between pumping chamber and MOT chamber to slow down Kr* atoms to within the capture range of the trap. Finally, the cold atom cloud of Kr* atoms is formed in the MOT chamber.

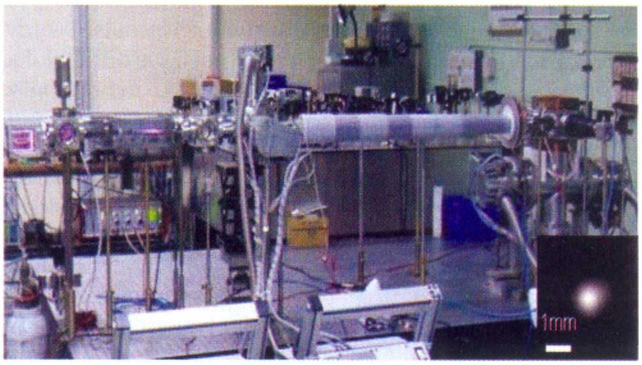

Fig. L.3.2: Experimental setup for cooling and trapping of Kr atoms. The inset shows the CCD fluorescence image of cloud of cold Kr atoms.*

The photograph of the experimental setup for cooling and trapping of Kr atoms is shown in Fig. L.3.2. The inset of Fig. L.3.2 presents a photograph of the fluorescence image of the trapped Kr* atoms cloud in the MOT. Nearly 10^5 atoms at temperature of around ~300 μK were trapped in the Kr*-MOT. The characterization and optimization of the Kr*-MOT is in progress.

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