L.6: Trapping cold atoms in an optical lattice

Cold atoms trapped in an optical lattice, generated by standing wave intensity pattern of interfering laser beams, mimic the electrons in a periodic potential in a solid. Therefore, atoms in optical lattice can serve as test bed to study and verify several condensed matter phenomena predicted theoretically, because of ease to control and alter lattice parameters. Several condensed matter phenomena such as Bloch oscillations, Landau-Zener tunneling, superfluid to Mott insulator transition, etc. have been reported using optical lattices. Recently, a laboratory in Laser Physics Applications Section, RRCAT has successfully demonstrated trapping of cold ^{87}Rb atoms in a one dimensional vertically aligned optical lattice formed by the superposition of a pair of Gaussian beams. The lifetime of the atoms trapped in this optical lattice has also been measured.

The atom trapping in optical lattice has been demonstrated using a double-MOT setup used for generation of ultra cold atoms (Figure L.6.1). The setup consists of two chambers (i.e. vapor chamber and ultra-high vacuum (UHV) chamber) connected through a differential pumping tube to facilitate different vacuum levels in these chambers. Conventional 3-D magneto-optical traps (MOTs) are prepared in these chambers, by first loading the vapor chamber MOT (VC-MOT) followed by the loading of UHV-MOT using VC-MOT cloud. The VC-MOT is formed from the background Rb vapor (generated from Rb dispensers). A red detuned push beam is used to transfer cold atoms from VC-MOT to load the UHV-MOT. Cold atom cloud in UHV-MOT has ~5x10^7 number of atoms at temperature of ~90 μK.

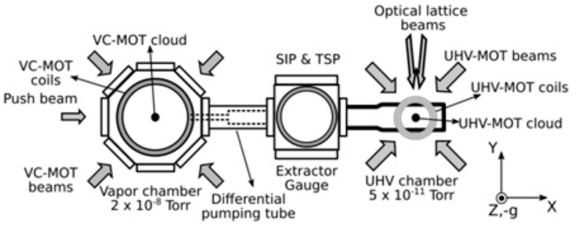


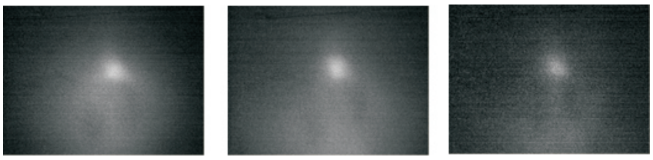
Fig. L.6.1: Schematic of the experimental setup for creating optical lattice of cold Rb atoms.

The cold atoms from the UHV-MOT are finally loaded in the optical lattice formed by a pair of Gaussian laser beams (as shown in Figure L.6.1). Two laser beams, each with power of ~55 mW and ~25 GHz red detuned from cooling transition of ^{87}Rb, are used as lattice beams. These beams are made to overlap just below the UHV-MOT position in the vertical plane at an angle of ~38°. This beam configuration formed a one-dimensional lattice in the direction of gravity with a lattice potential depth of ~ 40 μK and lattice spacing ~1.1 μm.

The CCD images of cold atom cloud from the UHV-MOT are captured in the absence as well as in the presence of the lattice beams. Figure L.6.2 (a)-(c) show the free expansion and fall of cloud under gravity in absence of lattice beams. Figure L.6.3 shows the atom cloud trapped in the optical lattice at different instants of time. The comparison of Figure L.6.2 and Figure L.6.3 clearly shows the trapping of atoms in optical lattice potential in the presence of pair of lattice beams, where (Figure L.6.3) the cloud does not fall under gravity in presence of optical lattice.

(a) (b) (c)

Fig. L.6.2: Images of cold atom cloud released from UHV MOT after (a) 20 ms, (b) 30 ms and (c) 40 ms in absence of optical lattice beams.



(a) (b) (c)

Fig. L.6.3: Images of cold atom cloud released from UHV MOT after (a) 20 ms, (b) 30 ms and (c) 40 ms in presence of optical lattice beams.

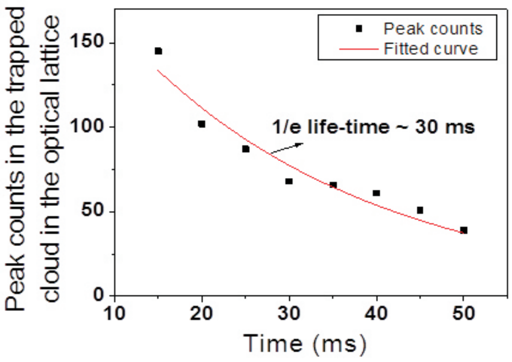


Fig. L.6.4: Measured variation of peak counts in CCD images of the trapped atom cloud in lattice with time. Continuous curve shows the best fit to the measured data.

The number of cold atoms decays exponentially with time as shown in Figure L.6.4. The 1/e lifetime of trapped atoms in the optical lattice is observed to be ~30 ms. Further work is in progress to improve the life time of cold atoms in optical lattice by increasing lattice trap depth and reducing the initial cloud temperature.

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