L.1: Development of cold atom gravimeter for the measurement of gravitational acceleration

The value of earth's gravitational acceleration *(g)* changes from place to place depending upon structure of earth underneath. The accurate measurement of *g* on the earth's surface, using an accurate gravimeter, has applications in mineral explorations, study of geophysics, monitoring of seismic activities, space missions, etc. The accuracy of a gravimeter depends upon the fundamental method used for developing a gravimeter. Matter wave interferometry-based gravimeter, such as cold atom gravimeter (CAG), is an absolute gravimeter with high sensitivity, accuracy, and long-term stability.

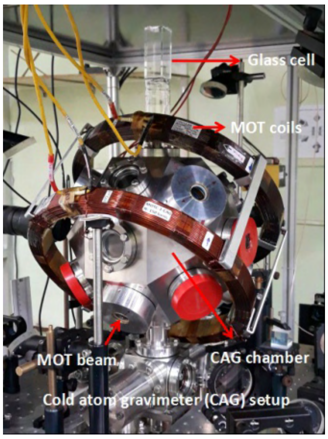

Fig. L.1.1: Photograph of the cold atom gravimeter at RRCAT.

At RRCAT, a cold atom gravimeter has been developed. The Doppler sensitive two-photon Raman transition based internal state atom interferometry is used for the measurement of *g*, when atoms are moving under influence of gravitational acceleration.

The cold atom gravimeter setup (Fig. L.1.1) has a magneto-optical trap (MOT) to cool and trap ^{87}Rb atoms. This is in [111] configuration of laser beam such that three pairs of counter propagating MOT beams are oriented in vertical direction with three-fold symmetry (Fig. L.1.2). Cold atoms from MOT are launched in the vertical direction to make a fountain. After the launch of atoms in fountain, the interferometric measurements are done by two-photon Raman excitation of ^{87}Rb atoms from hyperfine state F=2 to hyperfine state F=1 in the ground state. It is a Doppler sensitive technique that can sense the changing speed of atoms due to deceleration of *g*. When atoms are moving under influence of gravity *g*, and atoms undergo to a Raman pulse sequence of $\pi/2$-T-π-T-$\pi/2$, the population in F=2 after the pulse sequence is given as,

$$P_{|F=2\rangle} = \frac{1}{2}\left[1+\cos\left(\Delta\phi\right)\right]$$

where, $\Delta\phi = k_{eff} g T^2 - 2\pi\alpha T^2$ is net phase in the interferometer, with $k_{eff} \sim 2k$ as the effective wave-vector magnitude of two Raman beams, k is wave vector magnitude of each beam, T is separation between Raman pulses, and α is frequency chirp rate applied to Raman beam for compensating the changing Doppler shift due to gravitational acceleration.

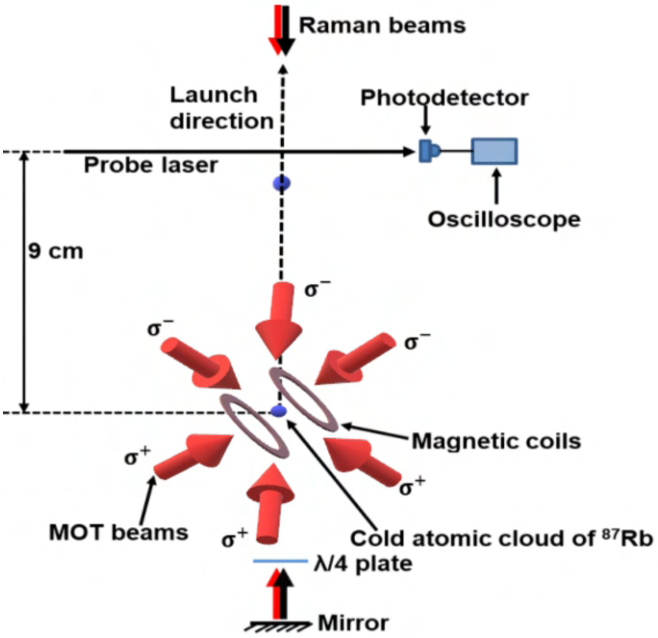

Fig. L.1.2. Schematic of cold atom gravimeter at RRCAT. Upper circle and dotted arrow shows launched cloud in upward direction.

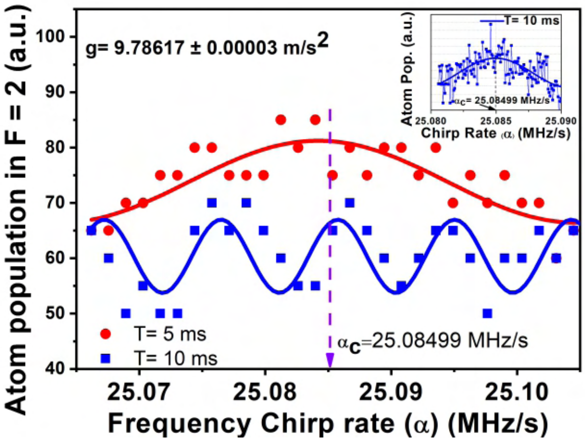

Fig. L.1.3: Interferometric fringes for different values of T.

Fig. L.1.3 shows the measured oscillations, i.e., interferometric fringes in the population in state F=2 with chirp rate α. By measuring the chirp rate for common peak to all values of T, we can measure the central chirp rate α_c for which $\Delta\phi$=0 and $g=\pi\alpha_c/k$. We measured α_c = 25.08499±0.000069 MHz/s, which gives the value of g as 9.78617±0.00003 m/s^2. The work is in progress to further improve the accuracy of the gravimeter.

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