URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

Spin Polarized Light for improving the accuracy of the second Cs atomic fountain clock at NPLI

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CSIR-National Physical Laboratory is the National Measurement Institute of India established through the act of parliament which establishes and maintains the Primary standards of SI units and their derived units for the traceability and quality measurements in the country. The Primary definition of the SI unit of time is defined in terms of energy difference between the two hyperfine ground states of Cs^{133} atom i.e., $6S_{1/2}$;|F=3, mF=0> and $6S_{1/2}$;|F=4, mF=0 >.

A Cs atomic fountain clock has been developed at CSIR-NPL which is the primary standard for the realisation of the SI unit Time “second”. Only 9 countries have developed this technology till now around the world. Our first atomic fountain clock has contributed to the BIPM with fractional uncertainty of $2.5^* \, 10^{-15}$. A second generation of atomic fountain clock is being developed with improved uncertainty to 10^{-16}. In this aspect we want to implement the optical pumping [1,2,3] for increasing the atomic population in a particular required state (|F=4, mF=0 >) for increasing the signal to noise ratio instead of letting them to blow out before microwave interrogation as they are in other required states (|F=4, mF≠0 >). By implementing this spin polarisation through optical pumping, the signal to noise ratio will be increased many folds, and also the cold collisional shifts bias will be reduced which is the major contribution in measurement of the frequency accurately [4].

This paper discusses the theoretical modelling and transient state solution for the implementation of the optical pumping in a 25level system of Cs^{133} atom by density matrix formalism solving the 625 Optical Bloch equations (Linear coupled differential Equations). This approach is basically a semi classical approach using the master equation

$$\frac{d\rho}{dt} = -\frac{i}{h}[H\ \rho] + \Delta_{relax}\gamma$$

This equation gives the evolution of the population of the atoms in different atomic states of the system considered, including the relaxation mechanism considered for modelling. By solving the Optical Bloch equations of the 25level system which include the Zeeman sublevels of the mentioned states i.e., |Fg=4>, |Fg=3> and |Fe=4> the transient solution of the system is studied.

The results and discussion include the selection of the transition states, the laser beams required, the effect of polarisation, intensity, magnetic field strength on the population of atoms in the required state and most importantly the time needed for the interaction of the atoms with the photons.

References

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