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Single Trapped $^{171}Yb^{+}$ for Optical Frequency Standards

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An optical clock or frequency standard based on the interrogation of an atomic transition in the optical domain, operates at ~ 10^{14} Hz is capable of providing orders of magnitude better accuracy than the present primary standard of frequency or time operating in the microwave range. Optical transitions of an ions, confined within a radio frequency ion trap and laser cooled to ~mK temperature, provides better long term stability since they are free from Coulomb and intra-atomic interactions. Optical frequency standards have been realized with several ions, *e. g.*, $^{199}Hg^{+}$, $^{171}Yb^{+}$, $^{115}In^{+}$, $^{88}Sr^{+}$, $^{40}Ca^{+}$, $^{27}Al^{+}$ and among those $^{171}Yb^{+}$ has multiple ultra-narrow optical transitions suitable for serving as frequency standards [1-2]

At CSIR-National Physical Laboratory, New Delhi we are working towards developing the first optical frequency standard of India with a single trapped Ytterbium (^{171}Yb) ion where the ultra-narrow octupole transition $\left|{}^2S_{1/2}; F=0, m_F=0\right\rangle - \left|{}^2F_{7/2}; F=3, m_F=0\right\rangle$ of laser cooled single $^{171}Yb^{+}$ will be probed at 467 nm [3-4]. A Paul trap of end-cap type has been designed and constructed for the confinement of single $^{171}Yb^{+}$. An effusive oven has been developed and used for producing low divergent Yb-atomic beam is placed within an ultra-high vacuum (UHV) chamber. The Yb-ions are produced at the centre of the trap by photoionization using a pair of lasers at 399 nm and 369.5 nm. Kinetic energy of the ion will be reduced by implying laser cooling to confine it within sub wavelength spatial extension, which will cancel out the first order Doppler shift. Multiple scattering from the $\left|{}^2S_{1/2}; F=1\right\rangle - \left|{}^2P_{3/2}; F=0\right\rangle$ strong transition at wavelength 369.5 nm will be used for laser cooling the ion. A closed cooling cycle requires pair of repumping lasers of wavelength at 935 nm and 760 nm, respectively, for depleting ions from the metastable states.

At the end of laser cooling ion will be optically pumped to the $F=0, m_F=0$ state for driving the transition at wavelength 467 nm. The probe laser for interrogating the ultra-narrow transition for frequency standards need to be stabilized within sub Hz spectral linewidth. This will be obtained by Pound-Drever-Hall technique by using a high finesse special ultra-stable Fabry-Perot cavity. Imaging a tiny fluorescence as signal from a single ion will require high resolution optics. Finally, an optical frequency comb requires for referencing the precisely measured frequency and operating this as a frequency standard.

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