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# Design and development of frequency stabilized RF sources for modulating laser frequencies for laser cooling of Yb ions

S. Utreja [*1, 2], H. K. Rathore[1, #], P. Roy[1,2], S. Choudhury[1,2], M. Das[1, 2] and S. Panja*[1, 2]
(1) CSIR-National Physical laboratory, Dr. K. S. Krishnan Marg, New Delhi – 110012, India
(2) Academy of Scientific and Innovation Research (AcSIR), Ghaziabad – 201002, India
# Current affiliation: TCG CREST, Kolkata, West Bengal 700091, India
*email: panjas@nplindia.res.in

Frequency Modulation or amplitude modulation is a prerequisite for many of the state of the art quantum technologies, e.g., atomic clocks or optical frequency standard, quantum gravimeter, atomic gyroscope, quantum computers etc [1-2]. Optical atomic clocks based on the interrogation of single trapped $^{171}$Yb ion is emerging as one of the possible candidates for redefining SI Seconds as it provides excellent fractional accuracy as well as long term stability. For the production and laser cooling of ytterbium ions frequency modulated outputs of four lasers at different wavelengths, *i.e.*, ~ 399nm, 369nm, 760nm and 935nm respectively, need to be focused at the centre of a radio frequency ion trap. During the operation of laser cooling cycle all hyperfine splitted energy levels along with fundamental transition ($^2S_{1/2}$- $^2P_{1/2}$) of $^{171}$Yb ions are employed and similarly repumping of metastable states along with associated hyperfine states must be addressed for effective and closed cycle laser cooling of the ions.
For modulation of laser frequencies different kind of modulators are often used, like Acousto Optic Modulators (AOM) are commonly used for modulating frequency in MHz range. On the other hand, for addressing hyperfine split states Electro-Optic Modulators (EOM) [3] are frequently utilized those produces side bands in the GHz range in addition to the fundamental frequency. EOM consists of a crystal that changes its refractive index when an external RF voltage is applied and depending on the applied RF frequency ($\Delta\upsilon$), it generates additional frequencies around the fundamental frequency ($\upsilon_o$), *e.g.*, $\upsilon_o+\Delta\upsilon$, $\upsilon_o-\Delta\upsilon$, $\upsilon_o+2\Delta\upsilon$, $\upsilon_o-2\Delta\upsilon$. The EOMs require stable RF voltage for producing precise and stable sideband frequencies.

The present work describes about the design and development of frequency stabilized RF sources for driving EOMs for modulating laser frequencies to be used in the laser cooling experiments of Yb ions. Voltage-controlled oscillators (VCO) are used to generate tuneable frequencies and a phase-locked loop (PLL) has been used for stabilizing the frequencies generated by the VCO with respect to a reference signal generated from a direct digital synthesis (DDS) evaluation board. The generated output frequencies of these drivers are tuneable with a resolution of 10MHz, and the outputs are quite stable for driving EOMs. The drift in frequency and power for the output of the Rf driver is 120 KHz and 0.2 dBm in a day, which is quite suitable for the experiment. An optical setup is designed to generate and analyses beat signals and it has been observed that the beat frequency matches exactly with the applied RF frequency. Higher-order harmonics present in the generated RF signals have been suppressed that they have very less power compared to the fundamental and 1$^{st}$ harmonic frequencies.

**Keywords**: Frequency Modulation, RF Generation, Electro-Optic Modulators, Voltage-Control Oscillator,

**References: -**

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