Highly stable master laser for the interrogation of SYRTE's Sr and Hg optical lattice clocks

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In the context of optical clocks, which need better probing lasers to reach there quantum projection noise limit, many efforts have been carried out over the past years to improve the performance of Fabry-Perot cavity stabilized cw lasers.These systems now reach a fractional stability of a few 10^{-16} near 1s timescale [1]. However, cavity length changes due to the thermal motion of the mirror atoms pose a severe limit to this performance.
LNE-SYRTE is investigating a different approach that has recently been demonstrated to potentially achieve tenfold higher laser stabilities[2]. In this technique, the frequency discriminator to stabilize the laser is generated by burning spectral transmission lines into the inhomogeneously broadened absorption spectrum of rare-earth ion dopants in a crystalline matrix. At cryogenic temperatures, these ions are well shielded within the host and the transition is widely decoupled from thermo-mechanical noise. This allows for homogenus transmission line-widths of 1 kHz or less. Based on this spectral hole-burning technique we are developing a laser system with a proposed fractional short term stability of less than 10^{-16} and a residual drift of less than 10 mHz/s. This laser will serve as a master for the interrogation lasers of three different optical clocks. In particular, this comprises two strontium optical clock systems at 430 THz (698 nm) and one mercury optical clock system at 1.2 PHz (266 nm)[3]. The phase stability of the master at 258 THz (1160 nm) will be transferred to the different clock wavelengths by means of an optical femtosecond frequency comb[4].

We report on the current status of the project and discuss implementations for further improving the system .We use the well-known Pound Drever Hall technique to pre-stabilize a first 1160nm wavelength laser to a Fabry-Perot (FP) cavity with a finesse of 100 000, and a FSR of 3.15 GHz. This is to reduce short term frequency fluctuations as well as the laser drift that would otherwise smear out the hole-structure during the burning process. The laser has now a stability of minus than 10^{-13} at 1s and a linewidth of 50Hz. Its frequency is constantly monitored against a femtosecond frequency comb in a neighboring laboratory using a Doppler cancelled fiber link. The laser's frequency is therefore imposed by the available TEM00 FP cavity modes. However these achievable optical frequencies do not necessarily correspond to the $^7F_0 \rightarrow {}^5D_0$ transition in Eu that is used for spectroscopy after frequency doubling to 580nm wavelength. Hence, we implement an offset phase lock to a second laser which permits to bridge this gap and further allows us freely tune the laser frequency across the absorption spectrum enabling narrow-linewidth hole burning spectroscopy of Eu:YSO cryogenic crystal.

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