Clock Laser Stabilisation on High-Finesse Cavities

O.Morizot, G.Hagel, D.Guyomarc'h, E. Bizri, M. Kamsap, C.Champenois, M.Houssin, J. Pedregosa, and M.Knoop

Université Aix-Marseille, CNRS, PIIM, Centre de Saint Jérôme, Case C21, 13 397 Marseille Cedex 20, France

Email: marie.houssin@univ-amu.fr

The present work is realized to take advantage of the electric quadrupole transition of calcium ions at 729 nm. This transition whose natural linewidth is below 200 mHz corresponding to a quality factor of 2×10^{15} is the support of a potential optical frequency standard[1, 2]. This very narrow line can also serve as a basis for multi-photon coherent processes like the three-photon coherent population trapping demonstrated in [3] which results in a dark line reference in the THz domain[4]. With all required wavelengths in the visible domain, calcium ions offer a premium choice to face technical issues.

The clock ultimate accuracy is expected to be met when the clock transition is probed in a single ion using quantum jump statistics, to the detriment of the measured frequency stability, limited by the quantum projection noise and expected to reach $2.5\times10^{-15}/\sqrt{\tau}$. The frequency stability can be increased by probing several ions under identical environmental and probed conditions. This could be realized on an ion ring trapped in a miniature multipole trap, like proposed in [5]. The built-up time of the clock signal is then reduced.

To ensure the frequency stability and precision of the local oscillator, the linewidth of the 729nm probe laser (clock laser) should reach the hertz level for duration at least as long as the interrogation time. The stabilisation of the laser consists of a Pound-Drever-Hall (PDH) lock onto an ultra-stable high-finesse ULE cavity. The cavity is mounted vertically and has an overall length of 150 mm. Optimization of the cavity design leads to an expected relative length variations below 10^{-14} under the influence of 1g-gravity acceleration[6]. An analysis of the different sources of noise shows that, for a regime superior to 100 mHz, the linewidth of the laser will not be limited by the cavity characteristics. Two identical cavity spacers have been realized. Silicon mirrors have been optically contacted onto the spacers, resulting in finesses of the order of 140,000 and 200,000 measured by a cavity ring-down method.

The clock laser is locked onto one reference cavity. Corrections are applied to a PZT actuator supporting a laser cavity mirror, an intra-cavity electro-optic modulator and an external acousto-optic modulator to assure fast feedback. Evaluation of the lock performances on the second cavity are underway and will be presented at the conference.

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