Cavity-enhanced non-destructive detection of atomic populations in Optical Lattice Clocks

Rodolphe Le Targat, Ulrich Eismann, Chunyan Shi, Jean-Luc Robyr, Jérôme Lodewyck

LNE-SYRTE, Observatoire de Paris, Paris, France

Email: rodolphe.letargat@obspm.fr

In Optical Lattice Clocks (OLCs), an ultrastable laser probes a high quality factor atomic "clock" transition. The large number of neutral atoms addressed simultaneously opens the way towards unprecedented statistical uncertainties: the fractional stability could ultimately reach 10^{-17} at one second when the clocks are solely limited by the atomic Quantum Projection Noise. Recently, a new generation of ultrastable lasers led to demonstrated stabilities as low as a few 10^{-16} at one second[1,2,3].

An alternative approach to improve the stability is to detect the atomic populations in a non-destructive way, by measuring the phase shift induced by the atoms on a weak off-resonant laser beam[4]. The recycling of the atoms reduces drastically the dead time between each spectroscopy phase, and decreases significantly the sampling of the frequency noise of the ultrastable clock laser. We will present our strategy to implement a cavity based non-destructive detection: in our scheme, far detuned sidebands are resonantly coupled to an optical resonator, they are phase shifted by the atoms before being compared to the carrier reflected by the cavity and used as local oscillator.

We will compare this approach with the free space Mach-Zehnder interferometer approach we presented in [4]. We show how the signal-to-noise ratio is enhanced by the cavity effect, possibly allowing to reach a detection resolution better than the Quantum Projection Noise. Finally we discuss the implementation of this detection scheme in an operational OLC, as well as the possible impact of this technique on the uncertainty budget.

Taking full advantage of the stability potential of OLCs must be compatible with demonstrated uncertainty budgets, on the path to a possible redefinition of the second. Future works therefore include inter-comparisons of the two LNE-SYRTE strontium OLCs with different detection systems and various duty cycles to further support the agreement at the 10^{-16} level demonstrated recently[5].

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