Characterization of the Phase-Noise induced by an Optical Frequency Doubler

Marion Delehaye[1], *Pierre-Yves Bourgeois*[1], *Jacques Millo*[1], *Lucas Groult*[1], *Ahmed Bakir*[1], *Rodolphe Boudot*[1], *Enrico Rubiola*[1], *Emmanuel Bigler*[1], *Vincent Giordano*[1], *Yann Kersalé*[1] *and Clément Lacroûte*[1]

1. *FEMTO-ST, TF Dpt., CNRS-ENSMM-UBFC, 26 ch de l'Epitaphe, 25030 Besançon, France*

State-of-the-art optical atomic clocks have attained short-term fractional frequency stabilities in the low 10^{-16} range [1,2]. This has been made possible thanks to improved performances of the clock lasers, which are pre-stabilized using ultra-stable Fabry-Perot (FP) resonators [3] Many of the last-generation optical clocks rely on frequency doubling via second harmonic generation (SHG) to produce the laser clock frequency [4,5], where the pump laser used for SHG is stabilized to the ultra-stable FP resonator. It is therefore necessary to ensure that the SHG setup does not degrade the beam fractional frequency stability.

Bulk crystals and periodically poled (PP) crystals have been used and characterized, and it has been shown that they introduce very low phase noise, at the price of a poor SHG efficiency [6-8].

Here we employ and describe fiber-coupled PPLN waveguides to perform the frequency doubling from a commercially-available laser diode at a wavelength λ = 871 nm to the clock frequency of Yb^+ at λ = 435.5 nm. These modules are both compact, highly-efficient, and avoid the use of an enhancement cavity. We report SHG efficiencies up to 117.5 % /W.

We measure the phase noise induced by the SHG with a Mach-Zender interferometer and a novel noise rejection technique and observe a relative phase noise as low as -40 $dBrad^2$/Hz at 1 Hz, which makes them compatible with the best up-to-date optical clocks and ultra-stable cavities.

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