A Rb microcell frequency reference based on two-photon transition at 778 nm

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Modern communication and navigation systems can significantly benefit from the integration of compact atomic clocks. In this domain, microcell vapor cell optical clocks based on the Rb atom Doppler-free two photon absorption (TPA) at 778 nm are attractive candidates. Best prototypes have shown frequency stability levels of 1.8×10^{-13} at 1 s, averaging down to the 10^{-14} range[1,2].

In this work, we present the in-progress development at FEMTO-ST of a Rb microcell TPA optical reference. The latter uses an external-cavity diode laser (ECDL) at 778 nm and an AOM for controlling the laser power. The laser beam is sent to a Rb MEMS cell[3] and reflected back using a dichroic mirror. TPA fluorescence photons at 420 nm are detected with a photomultiplier, at the output of which the resonance signal is obtained. The laser is stabilized onto the Rb^{87} $F_g=2$, $F_e=4$ transition.

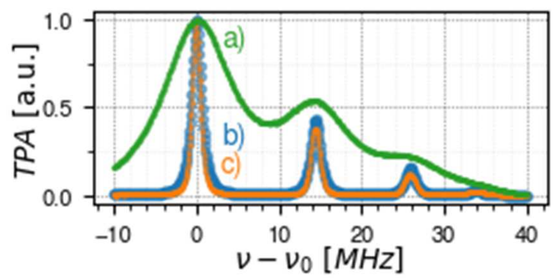

Fig. 1: Normalized TPA fluorescence emission signal as a function of laser detuning from Rb^{87} $F_g=2$, $F_e=4$. Traces a,b,c): microcell before NEG activation, microcell after activation, and high purity reference glass blown vapor cell.

In such an experiment, the purity of the Rb cell is crucial to benefit from the narrow natural linewidth of the two-photon transition (~300 kHz). We started to investigate cell atmosphere purification through the inclusion of passive non-evaporable getters[4] (NEGs). Preliminary results show, for some cells exhibiting a relevant initial concentration of impurities, an effective reduction of excess residual gas after activation of a NEG, as confirmed by narrowing of the TPA resonance (see Fig. 1). In this case, TPA resonances with a total linewidth of 1.4 MHz, including a Lorentzian component of 850 kHz, are obtained. Studies are still in progress to improve the cell inner atmosphere and increase the yield of cells qualified for TPA experiments.

Frequency measurements of the Rb TPA microcell reference against an ultra-stable cavity optical reference show a stability of $\sigma_y = 7 \times 10^{-13}$ at 1 s and $\sigma_y = 9 \times 10^{-14}$ at 100 s, in good agreement with a measured phase noise of +47 $dBrad^2/Hz$ at 1 Hz for the microcell-stabilized laser. The short-term performance is currently limited by the photon shot noise and intermodulation effect from the laser FM noise. Latest results and progress will be presented at the conference.

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[4] M. Hasegawa, R.K. Chutani, et al., "Effects of getters on hermetically sealed micromachined cesium-neon cells for atomic clocks", Journal of Micromechanics and Microengineering 23, pp.055022 (2013).