Progress on a Highly Compact Cesium CPT Clock Based on a Dual-Frequency VECSEL

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***Abstract*—We developed and tested a miniature optical bench to implement a cesium CPT clock based on a Vertical External Cavity Surface Emitting Laser (VECSEL) that provides two orthogonally polarized frequencies separated by a difference of 9.2 GHz. This work presents characterizations of the miniature optical power stabilization set-up as well as preliminary investigations of the VECSEL properties.**

Keywords—dual-frequency VECSEL, cesium, CPT

I. Introduction

One of the promising solutions for cesium (Cs) compact clocks is based on Coherent Population Trapping (CPT), where atomic interrogation is usually carried out by two phase-locked lasers with a frequency difference of 9.192 GHz for ^{133}Cs [1] or by an externally-modulated beam at half this frequency [2]. These laboratory clocks show frequency stability of few 10^{-13} at 1 s of integration time, but their dimensions are not suitable for on-board applications yet. In order to reduce the size and complexity of these systems, we propose to implement a highly compact clock based on a dual-frequency dual-polarisation VECSEL (DF-VECSEL) associated to a miniature optical bench with similar clock frequency stability and drastically reduced size.

II. Results

A miniature clock optical bench (i.e. less than 10 L for the physics package) has been designed and developed in collaboration with the French company Kylia. The clock optical and optoelectronic functions are implemented with discrete micro-optics assembled with a robust bonding technology (Fig. 1). The power stabilization stage adjusts the transmission of an acousto-optic modulator (AOM) comparing the signal to a voltage reference. This set-up has been extensively characterized with a monomode laser. The Relative Intensity Noise (RIN) of the laser is reduced by more than 20 dB at low frequencies and reaches a level below -155 dB/Hz between 100 Hz and 100 kHz, close to the voltage reference noise used for the lock loop (Fig. 2).

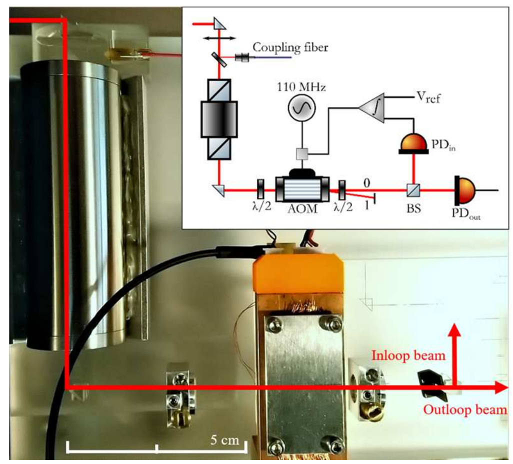

Fig. 1: Miniature optical bench for the optical power stabilization. AOM: Acousto-optic modulator; BS: Beamsplitter; PD: Photodetectors.

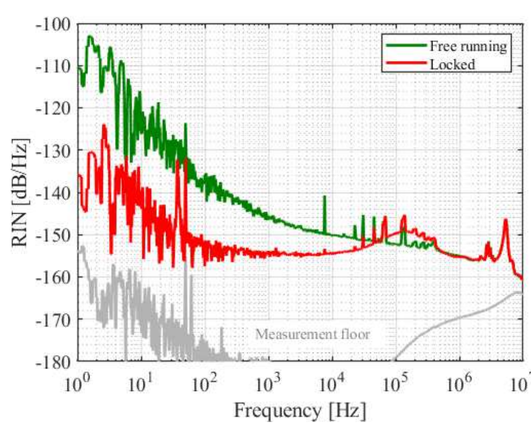

Fig. 2: Relative intensity noise of a monomode laser beam. Grey line: measurement floor.

The mid-term relative power fluctuations remain below 10^{-5} over 3 h of integration time when the stabilization is on (Fig. 3).

Discrepancies between outloop and inloop optical beams stability are explained by thermal drift of optical coatings.

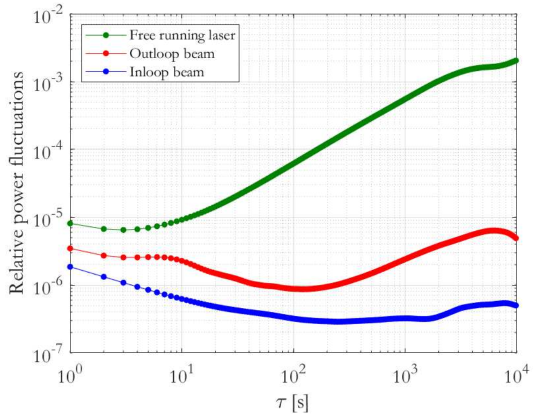

Fig. 3: Relative power stability of the laser beam. Inloop beam: signal use for the stabilization; outloop beam: exploitable light for the clock.

The industrial DF-VECSEL prototype under study (Fig. 4) to inject the clock bench provides two linearly polarized orthogonal modes at 852 nm with adjustable frequency difference around 9.2 GHz. An optimized architecture of the pumping scheme has been developed to obtain in-phase correlated intensity noises between the two modes as well as low noise transfer from the pump laser to the VECSEL eigenstates [3]. First measurements show in-phase correlations between the two frequencies with a degree of correlation above 0.6 (Fig. 5).

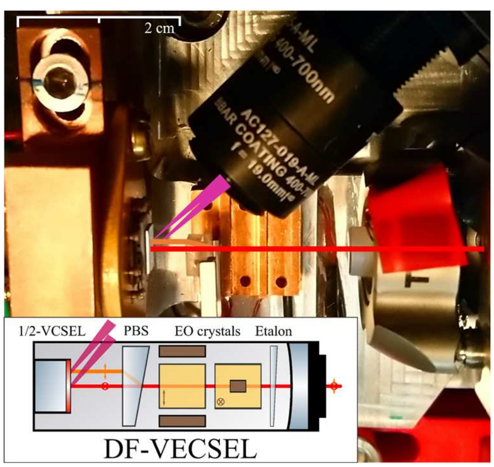

Fig. 4: Design of the dual-frequency VECSEL. Red (resp. orange) beam represents the x-polarized (resp. y-polarized) mode. Purple beams are for pump laser. PBS: Polarizing beamsplitter; EO: Electro-optic crystals.

III. DISCUSSIONS

The miniature power stabilization stage shows robust performances that are comparable to usual laboratory set-up. These results are compatible with clock stability aimed at short and mid-term [4].

Mechanical stability of the cavity elements is now crucial to ensure in-phase correlated eigenstates of the DF-VECSEL. Under these conditions, optical power fluctuations reduction can be maximized.

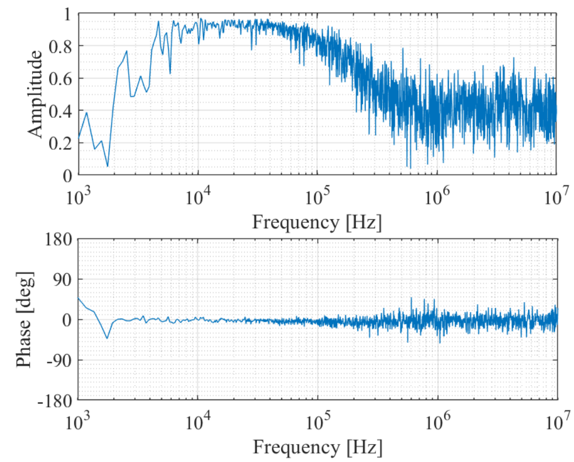

Fig. 5: Amplitude and phase of intensity noise correlation between the two polarizations emitted by the VECSEL.

IV. CONCLUSIONS

We developed the first stage of a miniature optical bench for a Cs CPT clock. The optical power stabilization demonstrated great reduction of the fluctuations.

We also started the implementation of a prototype of the DF-VECSEL, emitting in-phase correlated modes at 852 nm.

Optical power stabilization of the dual-frequency VECSEL is now in progress. Analysis of laser beams correlation and its impact on the power stabilization performances will be conducted. RIN reduction and mid-term power stability will be presented at the conference.

ACKNOWLEDGMENT

This work was partly supported by the french RENATECH network. Acknowledgment for ANR and french MoD for their support within CHoCoLA Project.

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