Towards the generation and fiber-link transfer of ultra-stable 895 nm signal for characterization of a microcell-stabilized laser

A.Gusching, I.Ryger, M. Abdel Hafiz, N. Passilly, J. Millo, R.Boudot
FEMTO-ST, CNRS, UBFC, ENSMM
Besançon, France
anthony.gusching@femto-st.fr

***Summary*—We report on the in-progress implementation and characterization of an optical setup aiming to generate an ultra-stable 895 nm signal, referenced to a cavity-stabilized laser, and to transfer it through a 30-m compensated fiber-link to a neighboring lab. This 895 nm signal will be used as a stable reference for the characterization of an external-cavity diode laser stabilized onto a Cs vapor micro-fabricated cell using dual-frequency sub-Doppler spectroscopy.**

Keywords—Microcell stabilized laser, optical fiber link; cavity-stabilized laser; Optical frequency comb;

I. INTRODUCTION

Microwave chip-scale atomic clocks based on coherent population trapping (CPT) have known a remarkable success by combining low volume, power consumption and a frequency stability about 100 times better than commonly-used quartz crystal oscillators [1]. However, these clocks suffer from stability limitations due to the frequency noise of the VCSEL they use and the presence of buffer gas pressure in the cell that causes frequency shifts.

Significant efforts have been then conducted over the last years towards the development of microcell-based optical frequency references. The two-photon transition of Rb atom at 778 nm was exploited in a microfabricated cell to demonstrate a stabilized laser with frequency stability at the level of a few 10^{-12} at 1 s, if use of a DFB laser source [1,2], and at the level of 2 10^{-13} at 1 s [3], with the use of a narrow-linewidth external cavity diode laser (ECDL).

In [4,5], we have started the investigation of an alternative approach based on dual-frequency sub-Doppler spectroscopy (DFSDS). In [5], we demonstrated a laser beatnote, obtained between a microcell-stabilized DFB and a microcell-stabilized ECDL, with an Allan deviation of 1.5 10^{-12} at 1 s, limited by the intermodulation effect from the DFB setup. However, the short-term stability budget, reported in [5], suggested that the microcell-ECDL is expected to exhibit a better short-term stability, below the 10^{-12} level at 1 s.

In this work, we present the in-progress construction of an optical setup targeting to generate and transfer through a short-distance compensated fiber link an ultra-stable 895 nm signal referenced to a cavity-stabilized 1542 nm laser. This signal will be used as an optical reference for the individual characterization of the microcell-stabilized ECDL. The present article is mainly focused onto the 30-m fiber link, used to connect two shortly-distant labs, and its residual phase noise characterization.

II. METHODS

The generation and fiber link transfer of the ultra-stable 895 nm signal is obtained with the approach described in Fig. 1. A 1542 nm laser is first frequency-stabilized onto a reference ultra-stable ULE cavity using the Pound-Drever Hall technique [6]. In a second step, a fiber-based optical frequency comb laser with a repetition rate of 250 MHz is phase-locked onto the cavity stabilized laser. The comb light is then sent into an optical frequency doubler and then injected into a non-linear fiber that provides a small amount of light power around 895 nm. An optical grating is used to improve light filtering at 895 nm. A local ECDL at 895 nm is then locked onto the comb-extracted 895 nm using an opto-electronic phase locked loop (OPLL), based on a FPGA-based digital board. This ensemble is mounted in a first lab, about 30 m distant from the lab where the Cs microcell-stabilized ECDL is implemented.

A fiber-link with Doppler-cancellation scheme was then implemented to transfer the cavity-stabilized 895 nm ECDL towards the second laboratory room. The principle of this compensated link is shown on Fig. 2 and is, in its architecture, comparable to the one described in [7]. It is based on a Michelson-type interferometer. The first arm is a free-space reference arm. In the second arm, the laser light is modulated at 110 MHz using a fibered acousto-optic modulator (AOM) and sent through a fiber link, at the output of which the light is reflected by a Faraday mirror. The reflected light, with doubled frequency modulation (220 MHz) is then superimposed with the light from the reference arm with a cube. Following a fast photodiode, the output 220 MHz signal is then down-converted to baseband through a FPGA-based PLL at the output of which a correction signal is generated and used to correct the laser frequency through the AOM frequency. These corrections permit to correct phase fluctuations along the fiber link transfer.

Once mounted, the comb-extracted 895 nm signal, at the output of the fiber link, will be coupled to the signal from the microcell-stabilized laser in order to produce a beatnote for analysis and evaluation of the performances of the microcell-stabilized laser.

III. FIRST RESULTS ON THE FIBER LINK

We measured the residual phase noise measured at 110 MHz at the remote end of the fiber link (out-of-loop noise), as depicted in Fig. 1. For first tests, this measurement was performed by replacing the 30 m long fiber by a short 20 cm fiber patch. Also, we note that the local ECDL in lab 1 is here not frequency-stabilized to the ultra-stable cavity but free-running. The beatnote generation between the AOM-based "short link" and the laser light extracted at the direct output of the laser was performed in free-space configuration. In this test, the arm that extracts light at the direct output of the laser is not compensated.

In this configuration, the residual phase noise of the fiber link, with a reduced 20 cm fiber patch, is about – 60 dBrad^2/Hz at 1 Hz and at the level of -110 dBrad^2/Hz at f = 10^6 Hz. These results are close to those reported in [7]. For comparison, the phase noise level of the fiber link, with short 20 cm fiber, is found to be significantly lower (more than 100 dB) than the microcell-stabilized lasers phase noise measured in [5]. The fiber link should then not be a limitation for the characterization of the microcell-stabilized laser.

Latest results linked to this work, hopefully including measurements of the microcell-stabilized laser, will be presented at the conference.

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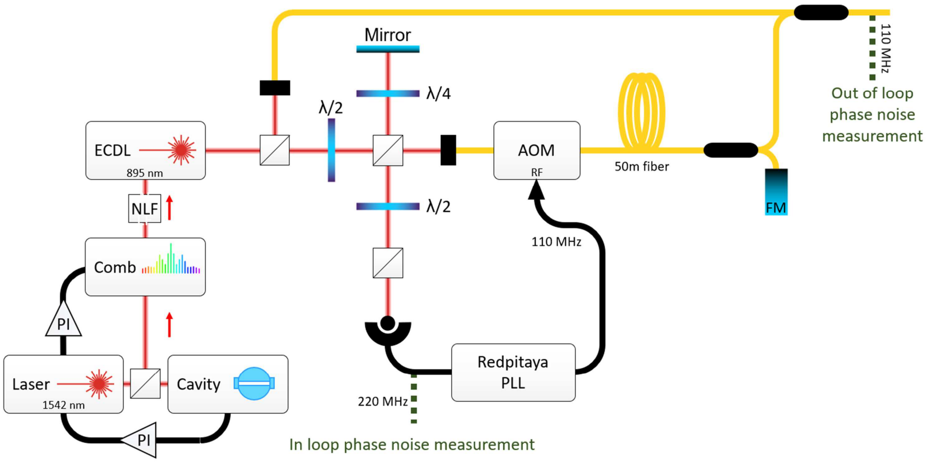

Figure 1: Simplified schematic of the generation and fiber-link transfer of an ultra-stable 895 nm signal, from a cavity-stabilized 1542 nm laser and fiber-based optical frequency comb. Ultimately, the 895 nm signal at the output of the fiber link will be used for producing a beat-note with the microcell-stabilized ECDL.