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Stabilizing a SiGe BiCMOS Transmitter on a Molecular Absorption Line

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***Abstract*—In many applications, highly stable frequency references are desired which at the same time take up little volume and consume little power. Transmitters and receivers in SiGe BiCMOS technology can be realized on chip-scale, working at in the THz/Millimeter-wave range where many molecules have strong rotational transitions. We stabilized a SiGe BiCMOS transmitter on a rotational transition of carbon monoxide, reaching stabilities of <10^{-10} at 100 s integration.**

I. INTRODUCTION

HIGHLY accurate and stable frequency references are needed in many fields, for example communication, navigation or sensing. Additionally, these frequency references should be of small size and low-cost, the latter to make large-scale production possible. Quartz crystal oscillators often lack a sufficient long-term stability whereas atomic clocks are expensive or large. A CMOS on-chip molecular clock has already been presented where a CMOS transmitter was stabilized on an absorption line of carbonyl sulfide [1].

In our experiments, we use an integrated transmitter (TX) and heterodyne receiver (RX) in SiGe BiCMOS technology. We stabilize the TX frequency onto a rotational absorption line of carbon monoxide (CO) at 230.538 GHz. The TX and RX are described in detail in [2, 3]. They both use a voltage-controlled crystal oscillator (VCXO) as internal frequency reference. Their frequencies are controlled by fractional-N phase-locked loops and can be tuned between 225 GHz and 255 GHz.

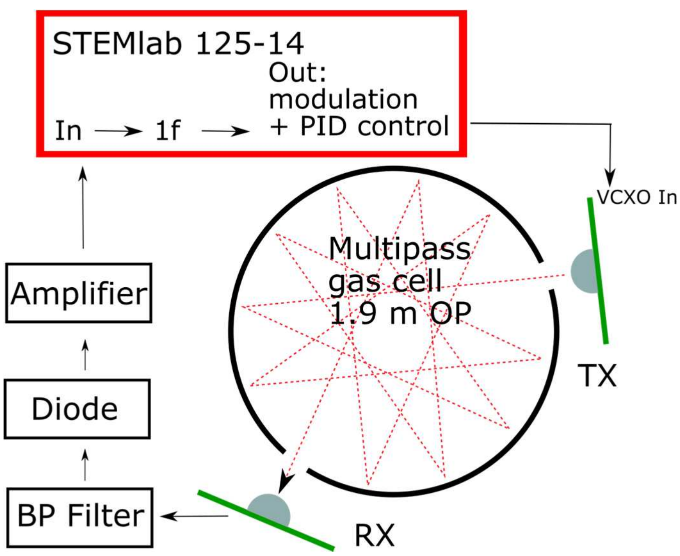

Fig. 1. Scheme of the absorption spectroscopy setup including the control loop for the stabilization of the TX frequency.

A scheme of the absorption spectroscopy setup is shown in Fig. 1. The TX frequency is modulated and the radiation passes a 1.9 m multipass gas cell [4]. At the RX, the incoming radiation is mixed with the RX's local oscillator frequency which is set to f_{TX}+IF. The intermediate frequency (IF) is then detected and rectified with a diode and amplified with an external amplifier. We use a very compact Red Pitaya STEMlab 125-14 as lock-in amplifier to demodulate the signal and obtain the first harmonic (1f) signal. This is used as the error signal of the PID control which is also executed with the STEMlab board. The control signal is fed to the TX's 100 MHz VCXO to increase the frequency stability based on the molecular absorption.

II. RESULTS

In Fig. 2, the Allan deviation (overlapping Allan deviation, cf. [5]) of the stabilized TX frequency is shown. The measurement was performed with CO at 10 Pa pressure. For comparison, we also show the Allan deviation of the free-running VCXO. The TX frequency reaches a stability of <10^{-10} at 100 s integration time which is two orders of magnitude better than the free-running VCXO. The slope of the Allan deviation below 100 s follows a $t^{-1/2}$ behavior (white noise), superimposed by a raising at 40 s which most likely originates in a periodic structure with low frequency in the dataset. The Allan deviation reaches its minimum at 300 s and then starts to rise as long-term drifts begin to affect the stability of the setup.

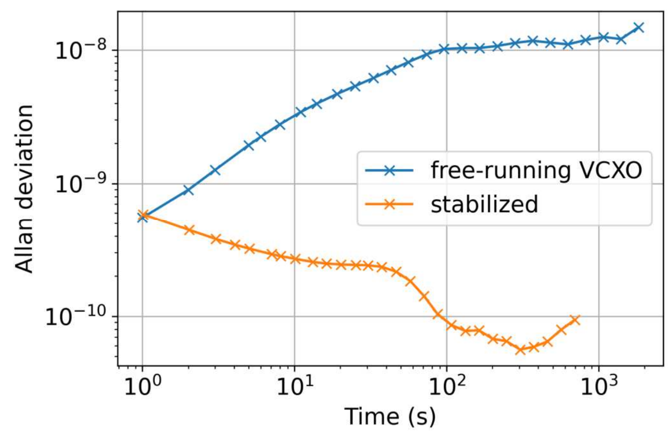

Fig. 2. Allan deviation (of the normalized data) of stabilized measurements with CO as well as of the free-running TX VCXO.

III. SUMMARY

We successfully stabilized a SiGe BiCMOS TX on a CO absorption line. The frequency stability of the stabilized TX is <10^{-10} @ 100s, with a minimum ~6×10^{-11} at 300 s. As next steps, we will eliminate setup-specific influences on the stabilized frequency and use Doppler-free spectroscopy to achieve an even narrower transition line to further improve the stability.

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