Phase Locking of 3.5-THz and 4.7-THz Quantum-Cascade Lasers Using a Schottky Diode Harmonic Mixer

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Abstract—High frequency accuracy and stability are important requirements for local oscillators in terahertz heterodyne spectrometers. We report on a phase-locked loop for quantum-cascade lasers (QCLs) operating at 3.5 and 4.7 THz, two very important frequencies in atmospheric science and astronomy. The QCLs are locked to the multiplied output of a frequency synthesizer using a Schottky diode harmonic mixer.

I. INTRODUCTION

Terahertz (THz) quantum-cascade lasers (QCLs) are of great importance as local oscillators (LOs) in high-resolution heterodyne spectrometers [1, 2]. These spectrometers are commonly used for astronomical and atmospheric observations in the THz range [2, 3]. The frequency resolution of such a spectrometer depends on the frequency stability of the QCL LO. Typically, the linewidth of a free-running THz QCL is on the order of 10 MHz. With special efforts regarding stabilization of temperature and driving current, it can be lowered to a few MHz. Stabilizing the frequency becomes even more challenging when the QCL is operated in a mechanical cryocooler, where vibration noise is intrinsically present.

In general, a powerful method for frequency stabilization of a radiation source is phase locking to a reference source. However, application of this method to THz QCLs faces two major problems: both, reference sources and mixers, are not readily available at THz frequencies. Mixers are a key part of the phase-locked loop (PLL), since they generate the difference frequency of the QCL and the reference source. We report on a PLL for QCLs operating at 3.5 and 4.7 THz, at which the hydroxyl radical, and atomic oxygen, respectively, have transitions. Both species are important in atmospheric science and astronomy, and several heterodyne spectrometers are currently in operation or under development for airborne and spaceborne missions [2, 4].

II. RESULTS

The QCLs which are frequency stabilized by the PLL are mounted in a compact, low-input-power Stirling cooler from AIM Infrarot-Module GmbH. They are designed for frequencies of 3.5 and 4.7 THz. The active medium has been developed for continuous-wave operation, high output powers, and low electrical pump powers. Both QCLs are based on single-plasmon waveguides with Fabry-Pérot resonators. The cavities are sufficiently short so that single-mode emission is obtained over most of the driving current range. The beam of

the QCL is formed with dedicated optics into an almost Gaussian profile. The free-running linewidth of the QCLs amounts to a few MHz. A simplified scheme of the QCL stabilization with PLL is shown in Fig. 1(a). The PLL is based on a Schottky diode harmonic mixer and a multiplier source, which pumps the harmonic mixer. The output frequency is tunable from about 570 to 610 GHz with more than 3 mW of output power. The Schottky diode harmonic mixer generates the sixth and eighth harmonic for phase locking of a 3.5-THz and a 4.7-THz QCL, respectively. Details of the design of the harmonic mixer are described in [5,6]. With this setup, phase locking was achieved for both frequencies [Fig. 1(b)].

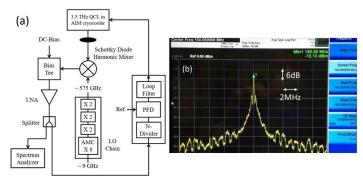


Fig. 1: (a) Scheme of the PLL setup and (b) locked signal obtained from the 3.5-THz QCL and the multiplier source.

III. SUMMARY

In summary, we demonstrate a PLL for THz QCLs operating at 3.5 and 4.7 THz. This paves the way for a QCL LO with a very high frequency accuracy and stability.

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