Frequency stabilization of 3.5-THz and 4.7-THz quantum-cascade lasers by a phase-locked loop

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***Abstract*—We report on a phase-locked loop for quantum-cascade lasers operating at 3.5 and 4.7 THz. These frequencies are particularly relevant in atmospheric science and astronomy. The QCLs are locked to the multiplied output of a frequency synthesizer using a Schottky diode harmonic mixer. The resulting linewidths are in the order of a few Hz.**

Keywords— frequency stabilization, phase-locked loop, terahertz, quantum-cascade laser

I. Introduction

Terahertz (THz) quantum-cascade lasers (QCLs) are of great importance as local oscillators (LOs) in high-resolution heterodyne spectrometers [1, 2], which are commonly used for astronomical and atmospheric observations [2, 3]. The frequency resolution of such spectrometers depends on the frequency stability of the QCL-LO. An optimal stabilization of temperature and driving current allows for a resolution of a few MHz.

Phase locking to a reference source is a well-known approach for inreased stabilization. However, application of this method to THz QCLs faces two major problems: Both, the reference sources and the mixers, are not readily available at THz frequencies. The mixer, which generates the difference frequency of QCL and reference source, is a key part of the phase-locked loop (PLL). We report on a PLL for QCLs operating at 3.5 THz and 4.7 THz. These are two important frequencies, because the hydroxyl radical, OH, and atomic oxygen, O, have transitions at these frequencies. Both species are significant for 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 mechanical cryocooler. 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 have a single-plasmon waveguide with a Fabry-Pérot resonator. The resonators are sufficiently short so that single mode emission over most of the driving current range of the laser is achieved. The beam of the QCL is formed with dedicated optics into an almost Gaussian profile. The free running linewidth of the QCLs is a few MHz. 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 570 GHz 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 QCL and a 4.7-THz QCL, respectively. With this setup, phase locking was achieved for both frequencies (Fig. 1).

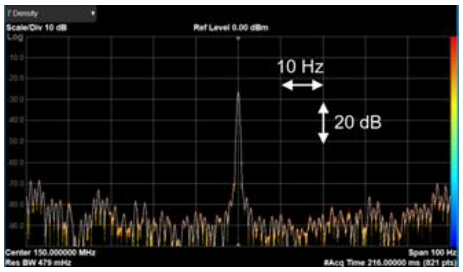

Fig. 1. Locked signal obtained from a 4.7-THz QCL and a multiplier source.

References

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