Stabilization of terahertz quantum-cascade lasers by near-infrared optical excitation

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Frequency and power stability is an important requirement for a local oscillator (LO) in a heterodyne spectrometer. For terahertz (THz) quantum-cascade lasers (QCLs) employed as an LO, passive stabilization can be realized by keeping the driving current and operating temperature as stable as possible [1]. In this way, an LO frequency stability of a few MHz in a mechanical cooler is achieved for the 4.75-THz channel of the German Receiver for Astronomy at THz frequencies (GREAT). This is sufficient for typical astronomic observations. However, for resolving very narrow spectral details in the atmospheres of the Earth and other planets, a linewidth of less than 1 MHz is desirable. Besides frequency stability, power stability of the QCL is important, since the pump power stability mainly limits the Allan time for bolometric mixers.

Previously, we have demonstrated how near-infrared excitation can be exploited for light-induced frequency tuning of THz QCLs [2]. Here, we show how this effect in combination with the tuning of the QCL driving current can be used to realize simultaneous frequency and power stabilization. For the experiments, a QCL emitting at 3.1 THz is mounted in a mechanical cryocooler (Ricor, K535). An optical fiber is positioned close to the QCL for near-infrared illumination. A methanol gas cell, a Ge:Ga photoconductive detector, and a lock-in amplifier with integrated PID capabilities (ZI, UHF) are used for modulation (1f) spectroscopy and frequency locking. A second Ge:Ga photoconductive detector is used for power monitoring and, in combination with a second PID loop, for power locking. Figure 1 depicts experimental results for such an active stabilization, where the QCL driving current is used for frequency locking and the near-infrared illumination for power stabilization. In the free-running case (1), the frequency varies by almost 20 MHz associated with cooler vibrations, and the output power varies by 0.1% [root-mean square value (rms)]. For simple frequency locking (2), frequency variations are reduced to 240 kHz [full width at half maximum (FWHM)], while output power variations increase to 0.4% (rms). In case of simultaneous frequency and power stabilization, variations of 260 kHz (FWHM) and 0.03% (rms) are obtained, respectively. More details can be found in [3]. The advantage of our method is that both parameters (frequency and output power) can be controlled on the same short time scale, since the related current and illumination tuning effects are physically fast processes. This allows for an efficient compensation of detrimental power variations in case of frequency locking and vice versa. The approach might be adopted for a heterodyne receiver by using a subharmonic mixer and a multiplied microwave reference for frequency locking.

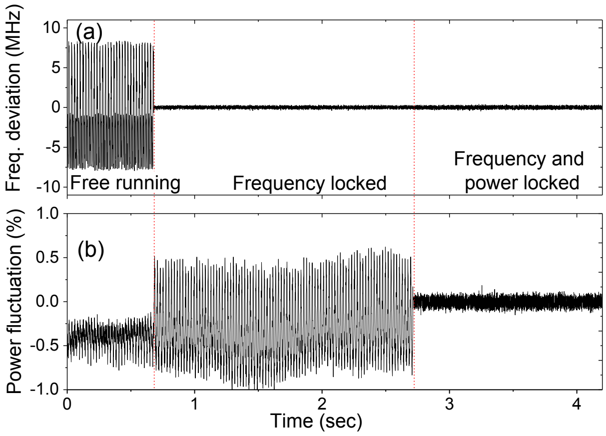

Fig. 1: (a) Frequency and (b) output power stability for the three cases: free running, frequency locked, frequency and power locked.

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