Phase-locking THz QC-VECSEL local oscillators using diode mixers and sources

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***Abstract*—The output frequency and phase of an external cavity quantum-cascade laser is phase-locked to an RF reference via two techniques: 1) down conversion with a diode harmonic mixer and locking to 100 MHz reference using the laser as a voltage tunable oscillator, and 2) directly injection locking the laser using the output of a 2.5 THz diode frequency multiplier source.**

Keywords—quantum-cascade laser, phase-locking

Terahertz quantum-cascade lasers (QCLs) are compact, semiconductor sources of coherent, milliwatt level radiation in the 2-5 THz frequency range. They are excellent candidates as local oscillators for heterodyne receiver arrays, and have been used as such in the upGREAT instrument on SOFIA, and the upcoming GUSTO balloon mission; observing neutral oxygen at 4.74 THz in both cases. However, limited beam quality and cryogenic operating temperatures of QCLs can make systems bulky and difficult to align. One design strategy for improving performance is to build the QC gain material into a vertical-external-cavity surface-emitting laser (VECSEL). QC-VECSELs have demonstrated excellent beam patterns, broad frequency tunability, and high continuous wave operating temperatures [1]. However, to achieve high spectral resolution from a heterodyne receiver, the output frequency of the VECSEL must be locked to a more stable frequency reference. Here, we demonstrate phase-locking of the VECSEL to a diode frequency multiplied RF source in two different ways. The VECSEL operates at 77 K and outputs ~1 mW of power.

In the first phase-locking approach, we down convert the output of a 2.5 THz QC-VECSEL to a 2 GHz IF using a harmonic diode mixer [2]. The mixer is pumped with an 840 GHz LO chain, and the 3rd harmonic mixes with the signal from the VECSEL. The IF is further down converted to 100 MHz and fed into a phase-lock loop (PLL) with a quartz reference. The error signal from the PLL controls the bias on the QC material, which acts as a frequency tuning mechanism. The phase noise of the locked VECSEL is shown in Fig. 1(b).

For the second phase-locking approach, we use the same 840 GHz LO chain, but we replace the mixer with a diode tripler source capable of outputting ~15 µW of power at 2.5 THz. This power can directly injection lock the QC-VECSEL with the RF source. The VECSEL is particularly suited to such an approach as it is easier to couple power in the large aperture of the VECSEL cavity than the sub-wavelength sized facet of a ridge-waveguide device. The locked spectrum, is shown in Fig. 1(c). The advantage of the injection locking approach is that the VECSEL output power is more stable than the first approach, but the downside is that it requires a diode frequency multiplier source, which becomes increasingly difficult at higher THz frequencies.

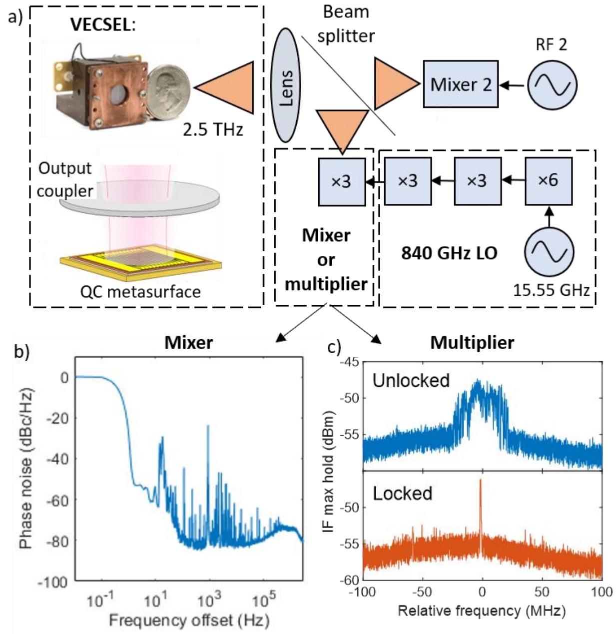

Fig. 1 a) Block diagram of experimental setup. b) Phase-noise when QC-VECSEL is locked to 3rd harmonic mixer. c) Locked vs. unlocked spectrum when injecting power from 2.5 THz tripler.

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