Stabilization of terahertz quantum-cascade VECSELs

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Terahertz metasurface quantum-cascade (QC) vertical external cavity surface emitting lasers (VECSELs) are excellent candidates for frequency agile local oscillators and spectroscopic sources, that emit milliwatts to tens-of-milliwatts continuous-wave power with excellent beam power. We present the first high resolution studies of the free-running laser behavior of QC-VECSELs at 2.5 THz and 3.4 THz, and demonstrate phase-locking to a microwave reference, by using subharmonic Schottky-diode mixer instrumentation to downconvert the THz signal to a GHz intermediate frequency (IF). Feedback from reflections at the mixer are observed to have a strong influence on the free-running QC-VECSEL frequency stability as a result of efficient coupling to free-space compared to more typical ridge waveguide lasers. Instabilities in feedback result in free-running linewidths of tens of MHz. The QC-VECSEL IF signal is phase locked to a 100 MHz reference using the bias on the device as a means of error correction. Between 90-95% of the QC-VECSEL signal is locked within 2 Hz of the multiplied RF reference, and amplitude fluctuations on the order of 1-10% are observed, depending on the bias point of the QC-VECSEL. The bandwidth of the locking loop is ~1 MHz. Many noise peaks in the IF signal corresponding to mechanical resonances in the 10 Hz-10 kHz range are observed. These peaks are generally -30 to -60 dB below the main tone, and are below the phase noise level of the multiplied RF reference which ultimately limits the phase noise of the locked QC-VECSEL.

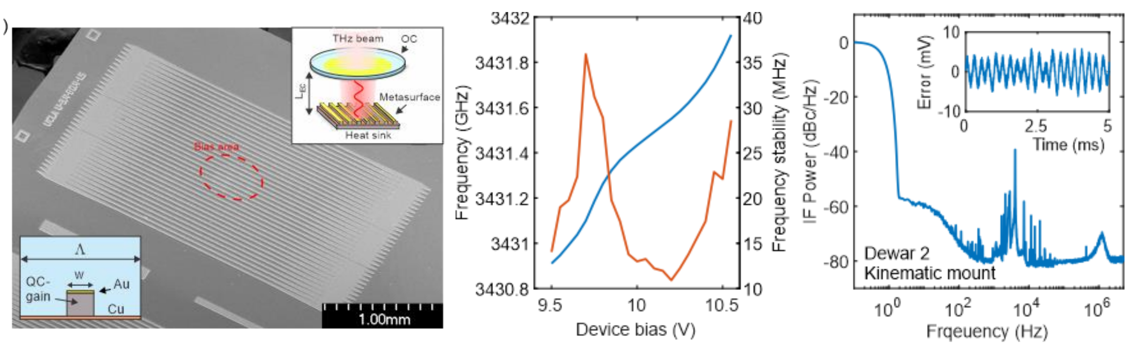

Figure 1. (left) SEM of the 3.4 THz metasurface. Insets illustrate a period of the metasurface, and the QC-VECSEL cavity. (center) Tuning characteristic and free-running linewidth of QC-VECSEL. (right) Phase-locked IF power spectrum and bias fluctuations.

[1] C. A. Curwen, J. H. Kawamura, Darren J. Hayton, Sadhvikas J. Addamane, John L. Reno, Benjamin S. Williams, and Boris S. Karasik, "Phase locking of THz QC-VECSELs to a microwave reference," https://www.techrxiv.org/articles/preprint/Phase_locking_of_THz_QC-VECSELs_to_a_microwave_reference/21893031/1 .

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