RF injection locking of THz metasurface quantum-cascade-VECSEL: effect of cavity length variation

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Quantum-cascade (QC) lasers are ideally suited for high-resolution, high speed spectroscopy techniques in terahertz (THz) spectral region. Their inherently high optical nonlinearity promotes the generation of spontaneous frequency combs via four-wave mixing in Fabry-Pérot or ring QC-lasers, based on which THz dual-comb spectroscopy has been demonstrated. Besides that, THz QC-laser has recently been implemented in the vertical-external-cavity surface-emitting laser (VECSEL) architecture, which is considered as a great candidate for THz frequency comb or mode-locking operations.

Here, we demonstrate RF injection locking in THz metasurface QC-VECSEL for the first time. An intra-cryostat focusing VECSEL cavity design is applied to reduce the intra-cavity diffraction loss and enable continuous wave lasing at 3.4 THz in an external cavity length over 30 mm (Fig. 1(a)). RF current modulation is applied to the QC-metasurface at a frequency close to the cavity round-trip frequency. Under weak RF power, pulling and locking of the round-trip frequency to the injected RF signal has been observed with locking bandwidth characterized using Adler's equation; Under strong RF power, broadening of the lasing spectrum with a maximum observable bandwidth around 110 GHz has been demonstrated under an injected RF power of 20 dBm (Fig. 1(b)). Injection locking phenomenon using metasurfaces with different gain/dispersion and tunable external cavity lengths has also been explored, taking the advantage of design flexibility of the VECSEL configuration. This experimental setup is suitable for further exploration of active mode-locking in THz QC-VECSELs.

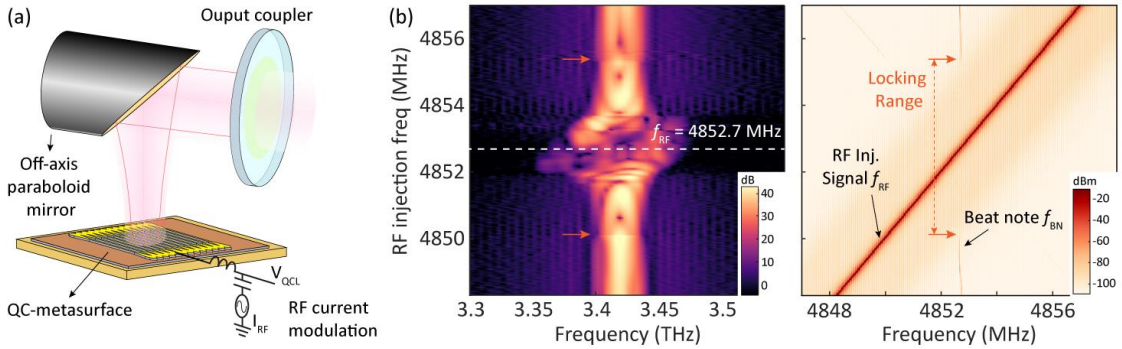

Figure 1. (a) Schematic of the QC-VECSEL based on an intra-cryostat focusing cavity design. (b) Lasing spectral broadening is observed under constant RF power of 20 dBm. The corresponding beat note map shows beat note locking to the injected RF signal with the estimated locking range pointed out by the red arrows.