Broadband Metasurface External-Cavity THz QC-Lasers

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Abstract— Terahertz quantum-cascade lasers are high-power, compact sources of THz radiation that have potential to operate as local oscillators for THz heterodyne receivers. However, practical implementation has proved challenging due to difficulties in THz-QCL power extraction, poor beam patterns, and limited tunability – all resulting from the subwavelength, metallic waveguides used as laser resonant cavities. A new architecture has been demonstrated that solves many of these problems; the quantum-cascade vertical-external-cavity surface-emitting-laser (THz QC-VECSEL) [1, 2]. The THz QC-VECSEL uses an amplifying, reflective metasurface composed of a subwavelength array of antenna-coupled microcavities loaded with quantum-cascade gain material. When feedback to the metasurface is provided by an external mirror, the resulting Fabry-Perot cavity forms an external cavity laser that has demonstrated a near diffraction limited beam with very high power and slope efficiency. Furthermore, the QC-VECSEL is naturally suited for tunability by adjusting the length of the external cavity. By using piezoelectric actuation, we have demonstrated single-mode tuning of a QC-VECSEL over 250 GHz at ~3.4 THz [3]. However, this tuning range is limited by the bandwidth of the metasurface which is made up of a single resonant microcavity. Here, we further demonstrate metasurfaces with enhanced bandwidth made up of coupled microcavity resonators. We demonstrate continuous tuning over more than a terahertz, between ~2.85-3.9 THz, however, multimoding is consistently observed as a result of the external-cavity free-spectral-range being smaller than the gain bandwidth of the metasurface. A narrow beam is emitted (~5x5°), and a peak power of ~15 mW is observed at 77 K.

[1] L. Xu, C. A. Curwen, P. W. C. Hon, Q.-S. Chen, T. Itoh, and B. S. Williams, "Metasurface external cavity laser," Appl. Phys. Lett. 107, 221105 (2015).
[2] L. Xu, C. A. Curwen, D. Chen, J. L. Reno, T. Itoh, and B. S. Williams, "Terahertz metasurface quantum-cascade VECSELs: Theory and Performance," IEEE J. Sel. Top. Quantum Electron. 23, 1200512 (2017).
[3] C. A. Curwen, L. Xu, J. L. Reno, T. Itoh, and B. S. Williams, "Broadband continuous tuning of a THz quantum-cascade VECSEL," 2017 Conference on Laser and Electro-Optics (CLEO).