Terahertz lasers based upon amplifying reflectarray antennas

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1. Extended Abstract

The reflectarray antenna has been widely used in the microwave and mm-wave spectral region to replace the functionality of curved reflectors with planar equivalents by spatially engineering the reflection phase across the planar surface. A similar structure for high power generation in the mm-wave is the grid amplifier/oscillator, which allows quasi-optical spatial power combining from an array of antenna-coupled transistor amplifiers.

We report on the development of a terahertz quantum-cascade metasurface laser, which combines elements of both reflectarray antennas and grid oscillators for the goal of achieving high power in combination with an excellent beam pattern [1]. This has been a particular challenge for terahertz (THz) quantum-cascade (QC) lasers, because they typically use sub-wavelength metallic waveguides that resembles scaled down microstrip transmission line. The key enabling element is the so-called active reflectarray metasurface, which is made up of a sub-wavelength spaced array of microcavity antennas. Each antenna (which resembles an elongated microstrip patch) is loaded with GaAs/AlGaAs quantum-cascade active material. When current is injected, incident THz radiation is reflected and amplified; this can then be made part of an external cavity laser. Essentially, power is combined from stimulated emission originating in all of the constituent microcavities.

We have currently demonstrated a variety of reflectarray metasurface lasers between 2.5-4.4 THz. In many cases, high power in combination with circular, Gaussian profile beams is obtained. Notable achievements include record slope efficiencies of 0.33 photons/electron, pulsed power levels of 140 mW at 77 K in pulsed mode, and continuous-wave power levels of 7 W at 77 K in pulsed mode). In another device, by spatially varying the microcavity dimensions to create a parabolic reflection phase profile, a “flat-optic” hemispherical laser cavity is obtained. In this device, a near-diffraction limited beam pattern with M^2 = 1.3, 27 mW and a record high brightness of 1.86×10^6 $\mathrm{Wsr^{-1}m^{-2}}$ is obtained.

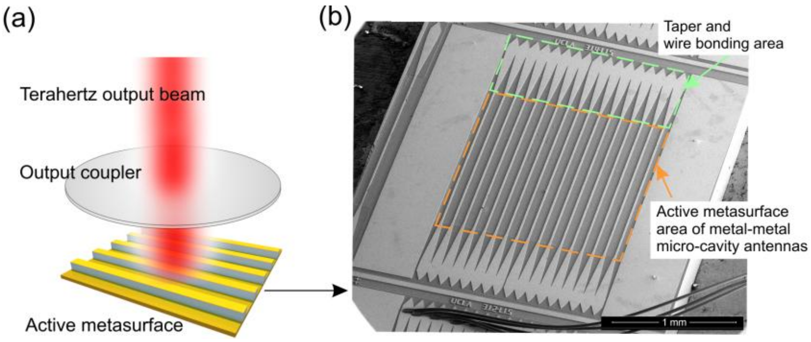

Figure 1. (a) Schematic of reflectarray metasurface terahertz quantum-cascade laser based upon the VECSEL concept. (b) SEM image of antenna array with tapered lossy terminations to prevent self-oscillation.

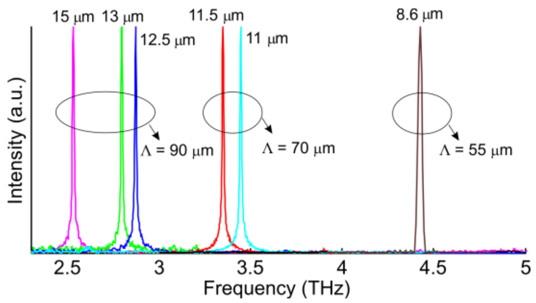

Figure 2. Measured lasing spectra for some demonstrated QC-VECSELs based on various metasurfaces designed with different ridge widths (see labels above each spectrum) and period Λ fabricated on different active QC-laser materials.

[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.,* vol. 107, p. 221105 2015.