Terahertz emitters based on intersubband transitions

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By properly engineering subband levels and intersubband scattering rates, terahertz (THz) unipolar lasers may be developed based on intersubband transitions in multiple quantum well (MQW) structures. In order to achieve this goal, electrically pumped multi-level systems were designed and fabricated using coupled quantum wells in GaAs/AlGaAs heterostructures, and many (=150) such quantum-well structures are cascade connected to increase the emission power levels and to improve the mode confinement factor. The THz emission power was coupled out of the device from the surface using a metallic grating. The emission spectra were resolved using an external Fourier transform infrared spectrometer. Under appropriate biases, one structure emits THz radiation as a result of diagonal (or interwell) intersubband transition. The emission spectra showed a peak at 2.57 THz, which is close to the designed emission frequency of 2.7 THz. The FWHM emission linewidth is as narrow as 0.5 THz, indicating a high quality of the heterostructure interface and a good uniformity of the well widths. The emission linewidth remains approximately constant up to 80 K device temperature. In another structure in which the radiative transition is vertical spatially (or intrawell), the emission spectra showed a peak with an even narrower (0.24 THz) linewidth at the designed frequency of 5 THz.

In great contrast to mid-infrared quantum-cascade lasers, for THz emissions below the longitudinal optical (LO) phonon energy, LO-phonon scattering of hot electrons and electron-electron scattering are dominant in intersubband relaxation processes. Both scattering processes depend sensitively on the carrier concentration and pumping levels. Thus, optimization for a high-degree of intersubband population inversion requires a delicate trade-off among various device parameters, such as doping concentration and coupling strengths between quantum wells. Furthermore, mode confinement is more difficult to achieve at longer THz wavelengths than at mid-infrared frequencies. In order to effectively confine the mode and greatly reduce the cavity losses, we have successfully developed a process to fabricate metallic waveguides by using wafer bonding and selective etching. This metallic waveguide structure will be important for THz lasing.