Terahertz quantum-cascade lasers

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The main challenge for the space THz program is solid-state local oscillators that can meet space qualifications in terms of output power levels and power efficiencies. Semiconductor electronic devices (such as frequency multipliers) are limited by the transient time and *RC* roll-off to below 2 THz. Conventional semiconductor photonic devices (such as bipolar laser diodes) are limited to above 10 THz even using small-gap lead-salt materials. Transitions between subbands in semiconductor quantum wells were suggested as a method to generate long wavelength radiation at customizable frequencies. However, because of difficulties in achieving population inversion between narrowly separated subbands and mode confinement at long wavelengths, THz lasers based on intersubband transitions were developed only very recently. The first THz quantum cascade lasers were developed based on a chirped superlattice structure. Recently, taking a completely different approach, we have developed THz quantum-cascade lasers based on resonant-phonon-assisted depopulation and using metal-metal waveguides for mode confinement. The band diagram of the QCL structure is illustrated in Fig. 1(a). Based on the combination of these two unique features, we have developed many THz QCLs with record performance, including a maximum pulsed operating temperature at 147 K (Fig. 1(b)), a maximum cw operating temperature at 97 K (Fig. 1(c)), and the longest wavelength (~141 μm) QCL to date without the assistance of magnetic fields (Fig. 1(d)). We will present more details and perspective at the symposium.