Terahertz quantum cascade lasers and real-time T-rays imaging

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The terahertz frequency range (1-10 THz) has long remained undeveloped, mainly due to the lack of compact, coherent radiation sources. Semiconductor electronic devices (such as transistors) are limited by the transient time and *RC* roll-off to below 1 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, lasers based on intersubband transitions were developed only recently at THz frequencies. The THz quantum-cascade lasers (QCL) hold great promise to bridge the so-called "THz gap" between conventional electronic and photonic devices.

Based on two novel features, namely resonant-phonon-assisted depopulation[1] and metal-metal waveguides for mode confinement,[2] we have developed many THz QCLs with record performance. They include by not limited to: a maximum pulsed operating temperature of 164 K and a maximum cw operating temperature of 117 K,[3] the longest wavelength (~160 μm, 1.9 THz) QCL to date without the assistance of magnetic fields,[4] and ~250 mW power level.[5] Using a high-power THz QCL and a 240×320 focal-plane array camera, we are now able to perform real-time THz imaging at video rate, that is, taking movies in "T-rays".[6] These rapid developments indicate great potentials for THz QCLs in various applications. We will present more detailed results and our perspective at the workshop.

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