Analysis of THz-QCL pulses in the time-domain using superconducting direct detectors

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Terahertz frequency quantum cascade lasers (THz-QCLs) are compact solid-state sources of coherent THz radiation over the frequency range 1–5 THz. Due to the high output power, narrow linewidths and broad range of emission frequencies, QCLs have numerous potential applications as radiation sources for imaging and spectroscopy within biomedical or security scenarios, or as local oscillators in heterodyne mixing schemes. Although THz QCLs are known to exhibit sub-nanosecond dynamic behaviour, transient laser emission on these time-scales cannot be resolved by commercially-available Ge or InSb bolometers, owing to the large detection time-constants.

We present the time-domain analysis of fast pulses emitted by a quantum cascade laser operating at ~3.1 THz using superconducting THz detectors made from either NbN or $YBa_2Cu_3O_{7-\delta}$ (YBCO) thin films. The QCL emission was studied as a function of QCL bias voltage and excitation pulse length. The ultra-fast response from our superconducting detectors allows resolution of nanosecond-time-scale dynamic laser effects. This enables the QCL transfer function (output power vs. QCL drive current) to be determined, based on correlation of the time-dependent emission of radiation with current flow in the QCL, under different QCL bias conditions. From the transfer function, specific QCL parameters were determined including the threshold and cut-off currents. We show that this transfer function differs from that obtained using bolometric detectors that respond only to the integrated pulse energy.