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Time-resolved measurement of heating effects in a terahertz quantum cascade laser using an NbN superconducting detector

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The requirement for cryogenic cooling (currently to below 200 K [1]) in terahertz quantum cascade lasers (THz QCLs) has led to great interest in analyzing and improving their thermal properties. Most thermal studies infer the internal QCL temperature from changes in the emitted THz power [2]. However, heat-extraction occurs on microsecond time-scales [3] that cannot be resolved by bolometric or pyroelectric THz detectors.

We present direct observations of pulse-to-pulse THz power reduction from a 3.1-THz QCL using a superconducting NbN detector with a ~ 165 ps response time. The QCL was driven by current pulses with variable duty-cycle and repetition rate, and the THz beam was focused with two parabolic mirrors onto the detector. Coupling to the detector was enhanced by an integrated 0.5–4 THz log-spiral antenna, and a silicon lens. Fig. 1(a) shows a time-resolved THz power measurement for a QCL driven by 500 kHz, 20% duty-cycle pulses. The pulse-separation is too low for the laser to return to thermal equilibrium with the heat sink, leading to pulse-to-pulse THz power reductions. Fig. 1(b) shows that the THz power decreases both faster and more severely when the driving-current pulse length increases. These direct time-resolved observations of pulse-to-pulse heating can be used to determine time-constants for heat-extraction; the QCL thermal resistance; and the anisotropy in thermal conductivity, and could also be applied readily to studies of ultrafast modulation and mode-locking in QCLs.

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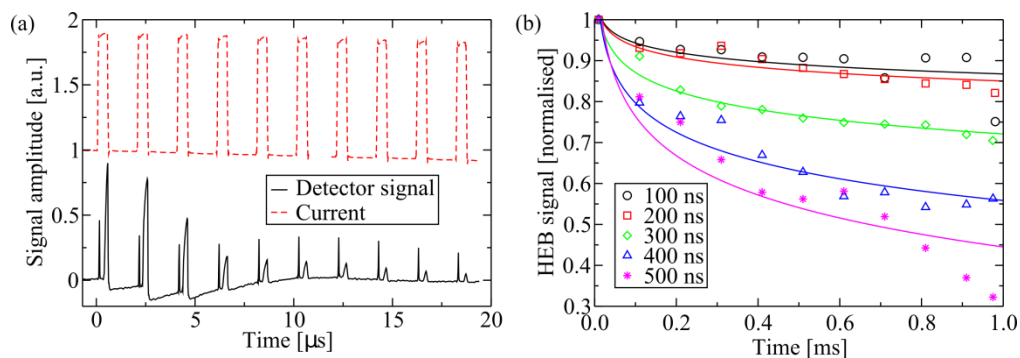


Fig. 1: (a) Normalised QCL driving current and detector response for 12.9 V, 500 kHz, 20% d.c. pulses at 45 K. (b) Time-averaged detector response at 15 K for 12.9 V, 500 kHz pulses of varying time pulse width. Solid curves show logarithmic regressions to the measured data.

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