Functionalization of THz Quantum Cascade Lasers

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Laser action is normally initiated by the amplification of spontaneous emission. As spontaneous emission is a random process, the carrier phase of a laser is different each time a laser is turned on. As a consequence, it is not possible to measure the time-resolved electric field of a free-running terahertz (THz) laser using standard coherent detection techniques (such as electro-optic or phoconductive sampling).

We have shown that it is possible to fix the carrier phase of a quantum cascade laser (QCL) by using injection seeding. Terahertz pulses with a fixed phase, generated using photoexcited interdigitated photoconductive antennas, are injected into the QCL cavity and coincide with the gain of the QCL being turned on rapidly to avoid gain clamping (gain switching). The externally injected THz pulses are greatly amplified through multiple passes and can initiate laser action (instead of the spontaneous emission) and set the carrier-phase. Consequently, as well as the generation of large THz fields, this enables the electric field of the laser emission to be measured as a function of time, from initiation of lasing to the steady-state lasing regime using coherent sampling techniques. The phased-resolved field of the QCL is thus directly measured in the time-domain. This work enables the laser emission to be measured in the time domain and the QCL to be used as a powerful source for THz time-domain spectroscopy. We also use this scheme to imprint a fixed phase relationship between the multiple longitudinal modes of a THz QCL, resulting in the emission of ultrashort THz laser pulses. We will also discuss how electro-optic sampling can be used for analysing the emission of actively modelocked QCLs, including metal-metal THz quantum cascade lasers operating at 77K.