Frequency tuning of terahertz quantum-cascade lasers by optical excitation

M. Wienold[1, 2], T. Alam[2], X. Lü[3], K. Biermann[3], L. Schrottke[3], H. T. Grahn[3], and H. W. Hübers[1, 2]

The ability to tune the frequency is an important requirement for a local oscillator (LO) in a heterodyne spectrometer. When employed as LO, terahertz (THz) quantum-cascade lasers (QCLs) are usually tuned by changing their driving current or temperature [1]. This yields a frequency tunability of a few GHz. In addition to the small frequency coverage, the output power of the QCL does not remain constant using this method.

Light-induced frequency tuning is an alternative approach which is based on the optical excitation of carriers in the QCL cavity. We demonstrate the feasibility of this approach by molecular laser absorption spectroscopy. For a 3.1-THz QCL, we obtain a frequency tuning range of about 40 GHz for continuous-wave operation, which represents a ten-fold improvement over the usually employed tuning by current.

In our experiments, we illuminated the back facet of a THz QCL with light from a near-infrared diode laser improving a recently reported approach by Hempel *et al.* [2]. For a well-defined excitation, we used a confocal microscope setup with a 10× objective lens. The largest tuning of almost 40 GHz was obtained by exciting the substrate underneath the QCL active region with a high-power multimode diode laser at 808 nm with up to P=3.5 W output power as shown in Fig. 1. Using a single-mode diode laser, we obtained for the same device a tuning range of more than 12 GHz with as little as 200 mW.

We explain the tuning effect by the excitation of an electron-hole plasma in the vicinity of the back facet, which locally changes the dielectric constant inside the QCL cavity. The calculated frequency shift follows a square root power dependence as shown in the inset of Fig. 1, which is also observed experimentally [3].

In addition to wideband laser absorption spectroscopy, the method is of interest for frequency alignment and frequency stabilization of QCLs employed in heterodyne spectrometers [1]. By replacing the microscope optics by a fiber coupling scheme, very compact configurations become feasible, which are straightforward to implement in instrumentation hardware. Since no dedicated QCL development is required, light-induced frequency tuning can be readily applied to a large class of devices.

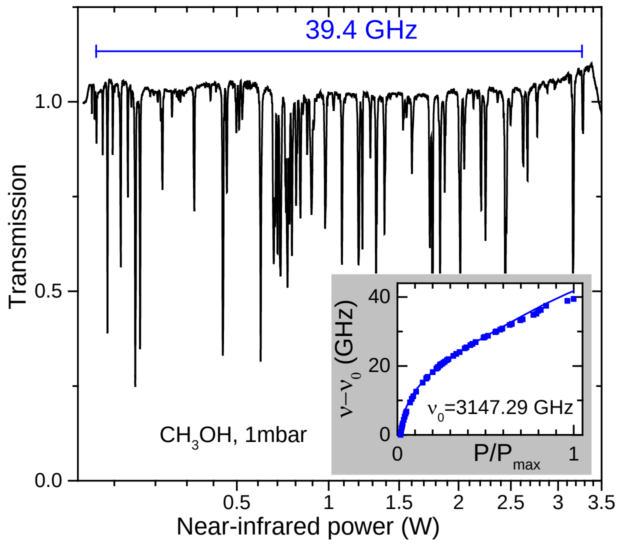

Fig. 1. Transmission through a methanol gas cell for near-infrared excitation with a high-power diode laser. Inset: Frequency shift according to the JPL molecular catalog. The solid line represents a square root fit to the data.

[1] German Aerospace Center (DLR), Institute of Optical Sensor Systems, Rutherfordstr. 2, 12489 Berlin, Germany

[2] Humboldt-Universität zu Berlin, Department of Physics, Newtonstr. 15, 12489 Berlin, Germany

[3] Paul-Drude-Institut für Festkörperelektronik, Leibnitz-Institut im Forschungsverbund Berlin e. V., Hausvogteiplatz 5 – 7, 10117 Berlin, Germany.

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