Molecular spectroscopy by illumination-induced frequency tuning of a terahertz quantum-cascade laser

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Summary

We report on molecular spectroscopy with a terahertz quantum-cascade laser (QCL). The frequency of the QCL is tuned by illuminating its rear facet using a near-infrared laser. A tuning range of 220 MHz is achieved for continuous-wave operation.

Introduction

Terahertz (THz) spectroscopy plays an important role in astronomy and planetary research since many absorption and emission lines of interest fall into this spectral range. In high-resolution spectroscopy, it is essential to tune the laser over a specific frequency range. Conventionally, THz quantum-cascade lasers (QCLs) are tuned either by ramping up the driving current or varying the heat sink temperature. The drawbacks of these techniques are the limited tuning range and the rather slow speed for temperature tuning. In order to overcome these limitations, several techniques have been demonstrated during the last few years. Among them are the use of external optical cavities [1], mechanical tuning of cavities [2], and electrical frequency tuning [3]. A promising technique for the frequency tuning of THz QCLs is the illumination of the rear facet with a near-infrared diode laser [4], which has been introduced recently. Here, we report on molecular spectroscopy using a THz QCL tuned by rear-facet illumination.

Results and Discussion

The employed QCL emits a single, continuous-wave (cw) mode at 4.7 THz with up to 1 mW of output power when operated in a mechanical cryocooler at 40 K. In a first step, the current and temperature tuning coefficients as well as the frequency range were determined. For this calibration, a current ramp was applied, and the transmission signal through a gas cell was measured. Due to its rich absorption spectrum, methanol was used as an exemplary molecule. Frequency tuning coefficients of −82 MHz/K and −40 MHz/mA were determined. For the frequency tuning experiment, a near-infrared diode laser was used to illuminate the rear facet of the QCL through an optical fiber. The diode laser emits at 807 nm with a lasing threshold current of 107 mA. It is coupled to a polarization-maintaining fiber (PM780-HP) with 4.5 µm core size. The maximal cw output power is 250 mW at 378 mA.

The diode laser is driven by a cw current source (ILX LDX-3232). The fiber is cleaved and aligned to illuminate the back facet as shown in Fig. 1(a). The radiation of the QCL is collimated by an off-axis mirror and measured with a Ge:Ga photo-conductive detector after passing through a 60-cm-long gas cell.

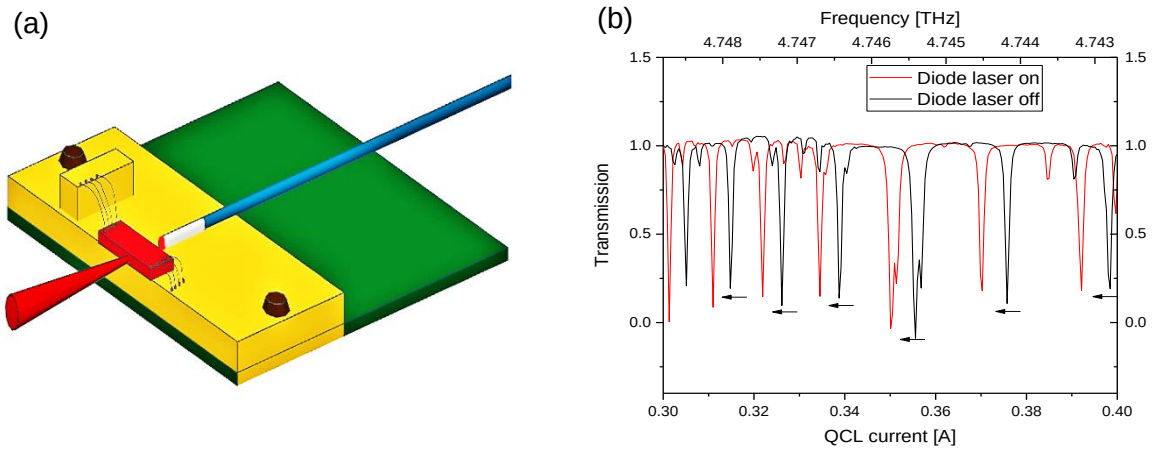

Fig. 1: (a) Schematic setup for the back-facet illumination of a QCL with a diode laser through a fiber. (b) Frequency shift of the methanol (CH_3OH) absorption lines induced by optical excitation with the diode laser.

For the tuning experiment, the spectra are determined by measuring the Ge:Ga detector signal as a function of the QCL current for both, the diode laser switched off and the diode laser current set to 378 mA. Figure 1(b) shows a shift of the absorption lines toward higher frequencies when the diode laser is on. The observed blue shift is driven by non-equilibrium carrier generation and heating which changes the refractive index close to the facet [4]. The tuning range achieved by this method in the current configuration is around 220 MHz. An increase of the tuning range by using a diode laser with a higher power and a detailed study of the applicability of this method to high-resolution molecular spectroscopy are currently investigated.

Conclusions

We have demonstrated frequency tuning of a 4.7 THz QCL by a fiber-coupled illumination scheme applied to molecular spectroscopy. As an exemplary molecule, methanol was used. In order to increase the tuning range, a diode laser with a higher output power needs to be employed.

References

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