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

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Abstract

We report on molecular spectroscopy with a terahertz quantum-cascade laser (QCL). The frequency of the QCL is tuned by illuminating its facet using a near-infrared laser. A tuning range of 3.35 GHz is achieved for continuous-wave operation.

1. 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. For high-resolution spectroscopy, it is essential to tune the laser over a specific frequency range. Typically, 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 its facet illumination.

2. Results and Discussion

The employed QCL emits a single mode at 3.3 THz with up to 3 mW of output power operated in continuous-wave (cw) mode 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 molecular species. Temperature and current tuning coefficients of −220 MHz/K and +19 MHz/mA, respectively, were determined. For the frequency tuning experiment, a special cold finger was prepared to obtain access to both facets of the QCL. A near-infrared diode laser was used to illuminate one of the facets. 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. For illumination, we employed a home-made confocal microscope setup with a camera as illustrated in Fig. 1 (a). The laser spot was adjusted to the facet by an XYZ translation stage. A constant current of 360 mA was applied to the QCL, and the diode laser was tuned from below threshold up to the maximum operating current (400 mA). The emission from the other facet of the QCL was collimated by a TPX lens and measured with a Ge:Ga photo-conductive detector after passing through a 60-cm-long gas cell.

The maximal cw output power of the diode laser after the microscope objective lens amounts to around 100 mW. Absorption spectra are obtained by measuring the Ge:Ga detector signal as a function of the diode laser current. Figure 1(b) shows a typical absorption spectrum of methanol as acquired within 80 ms. The average current tuning coefficient for diode laser tuning was determined to be +17.6 MHz/mA.

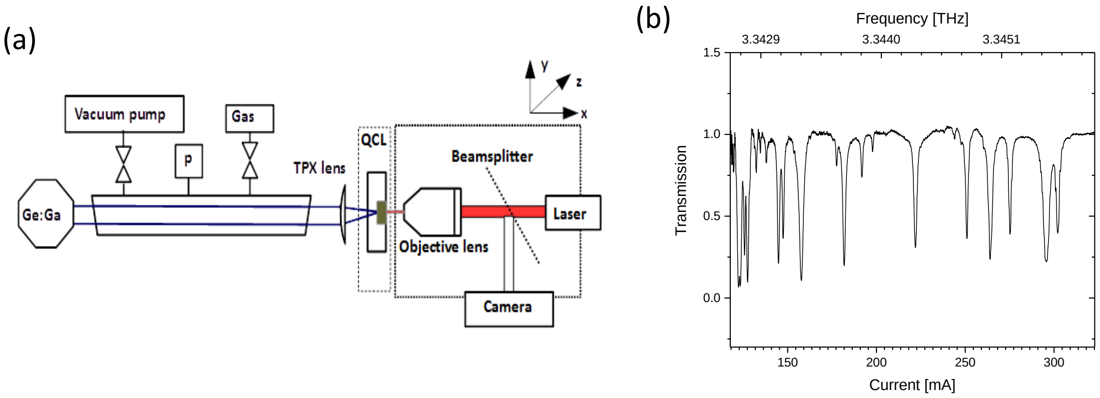

Fig. 1: (a) Schematic setup for the facet illumination of a QCL with a diode laser. (b) Transmission signal (methanol) as a function of the diode laser current.

Note that for temperature tuning the absorption lines are shifting toward lower frequencies, while for diode laser tuning the lines are shifting toward higher frequencies. From this observation, it is clear that the observed blueshift is not driven by heating, but rather due to a different mechanism which changes the refractive index close to the facet. The tuning range achieved by this method in the current configuration is already 3.35 GHz. In comparison, spectra are obtained on the same time scale as by ramping the QCL current, but the frequency range for diode-laser tuning is already larger by 0.73 GHz. A detailed study of this method and its further improvement is currently under investigation.

3. Conclusions

We have demonstrated molecular spectroscopy with a 3.3 THz QCL by tuning the frequency via facet illumination with a diode laser. A tuning range of 3.35 GHz was obtained with only 100 mW of injected optical power, which enabled the acquisition of highly resolved molecular spectra on a millisecond time scale.

References

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