Frequency tuning of terahertz quantum-cascade lasers by spatially controlled optical excitation

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***Abstract*: We demonstrate the feasibility of wideband frequency tuning of terahertz quantum-cascade lasers by spatially well-controlled near-infrared optical excitation. We observe a single-mode continuous-wave frequency coverage of up to 40 GHz for a 3.1 THz laser. This represents a tenfold improvement of the tuning range for the same device as compared to tuning by current. This method is applicable to a wide variety of existing terahertz quantum-cascade lasers.**

INTRODUCTION

Terahertz (THz) spectroscopy is an exciting field for astronomy and planetary research since many molecular rotational transitions fall into this spectral range. Quantum-cascade lasers (QCLs) are excellent candidates for local oscillators used in heterodyne detection and for diverse spectroscopic applications with high emission powers. However, they require at the same time a fast continuous tunability over a broad frequency range. Frequency tuning is typically realized either by ramping 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. A promising technique for the frequency tuning of THz QCLs is the illumination of the rear facet with a near-infrared (NIR) diode laser [1], which has been introduced recently. Here, we demonstrate a spatially well controlled optical excitation method for high-resolution molecular spectroscopy.

I. EXPERIMENTAL SETUP AND RESULTS

The schematic configuration for the measurement is shown in Fig. 1. It consists of two parts: frequency tuning by NIR optical excitation and molecular spectroscopy with an absorption cell and a detector. For frequency tuning, one facet of the QCL is illuminated with focused light from an NIR diode laser. We have used a confocal microscope setup based on a x-y-z translation stage to align and focus the NIR laser. For molecular spectroscopy, the THz emission from the opposite facet of the QCL is collected by a THz lens and directed to a Ge:Ga photoconductive detector through a 60-cm-long absorption cell. The largest tuning range of nearly 40 GHz as shown in Fig. 2(a) was achieved by exciting the substrate underneath the QCL active region with a high-power multimode laser emitting at 808 nm.

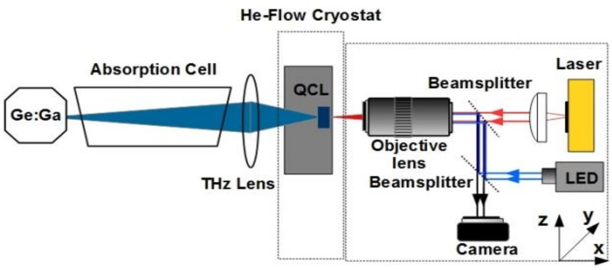

Fig. 1. Schematic setup for the facet illumination of a QCL with an NIR diode laser.

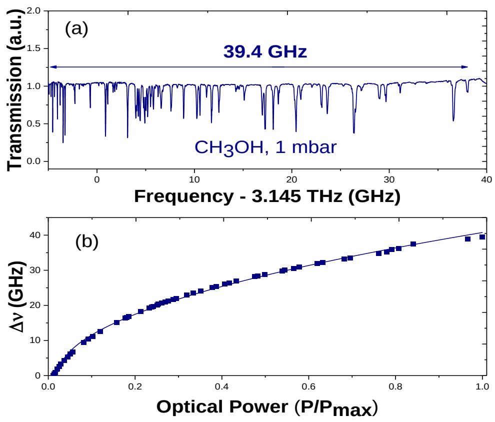

Fig. 2. (a) Measured transmission spectra through a methanol gas cell for near-infrared excitation with a high-power NIR diode laser. (b) QCL frequency shift as a function of the normalized optical power

A detailed analysis of the tuning behavior [2] showed that the frequency shift is due to the generation of an electron-hole plasma, which changes the refractive index close to the facet. The observed frequency shift follows a square root power dependence as shown in Fig. 2(b). In combination with a fast detector, this method is intrinsically fast, enabling the acquisition of highly resolved molecular spectra on a millisecond time scale.

REFERENCES

[1] M. Hempel, B. Röben, L. Schrottke, H.-W. Hübers, and H. T. Grahn, “Fast continuous tuning of terahertz quantum-cascade lasers by rear-facet illumination”, *Appl. Phys. Lett.* **108**, 191106 (2016).

[2] T. Alam, M. Wienold, X. Lü, K. Biermann, L. Schrottke, H. T. Grahn, and H. W. Hübers, “Wideband highresolution terahertz spectroscopy by light-induced frequency tuning of quantum cascade lasers,” *Opt. Express* **27**, in press (2019).