Frequency stabilization of a THz quantum-cascade laser to a molecular absorption line

H. Richter [1)], S. G. Pavlov [1)], A. D. Semenov [1)], L. Mahler [2)],
A. Tredicucci [2)], H. E. Beere [3)], D. A. Ritchie [3)], and H.-W. Hübers [1), 4)]

[1)] Institute of Planetary Research, German Aerospace Center (DLR),
Rutherfordstr. 2, 12489 Berlin, Germany

[2)] NEST CNR-INFM and Scuola Normale Superiore,
Piazza dei Cavalieri 7, 56126 Pisa, Italy

[3)] Cavendish Laboratory, University of Cambridge, Madingley Road,
Cambridge CB3 0HE, United Kingdom

[4)] Institut für Optik und Atomare Physik, Technische Universität Berlin,
Hardenbergstraße 36, 10623 Berlin, Germany

Abstract

The terahertz (THz) portion of the electromagnetic spectrum bears an amazing scientific potential in astronomy. High resolution spectroscopy in particular heterodyne spectroscopy of molecular rotational lines and fine structure lines of atoms or ions is a powerful tool, which allows obtaining valuable information about the observed object such as temperature and dynamical processes as well as density and distribution of particular species. One example is the OI fine structure line at 4.7 THz. This is a main target to be observed with GREAT, the German Receiver for Astronomy at Terahertz Frequencies, which will be operated on board of SOFIA. A major challenge for a heterodyne receivers operating at this frequency is the local oscillator (LO). THz quantum-cascade lasers (QCLs) have the potential to replace the presently used gas laser LO. A major issue is the frequency stabilization of the QCL, because its free-running linewidth is several MHz.

We report on the frequency stabilization of a THz QCL to the absorption line of methanol gas at a frequency of 2.55 THz. The QCL is mounted on the first stage of a pulse tube cooler and operates at a temperature of about 50 K. The stabilization method is based on frequency modulation of the laser emission across the absorption line. The resulting derivative-like signal is used as error signal for a control loop which keeps the laser frequency at maximum absorption. The unstabilized laser has frequency fluctuations of 15 MHz which are reduced to 300 kHz (full width at half maximum) with the control loop in action. The line shape of the locked signal is Gaussian. The achieved linewidth is already sufficient for many applications. For example the frequency resolution of a typical heterodyne receiver with an acousto-optical backend spectrometer is 1.5 MHz. With a 300 kHz linewidth of the LO this increases marginally to 1.53 MHz. In addition, the stabilization scheme is robust and versatile, because it requires only an additional detector and a small gas absorption cell, while being applicable even at the highest THz frequencies due to the rich absorption spectra of molecules such as CH_3OH or H_2O.

References

[1] H. Richter, A. D. Semenov, S. Pavlov, L. Mahler, A. Tredicucci, H. E. Beere, D. A. Ritchie, K. Il'in, M. Siegel, and H.-W. Hübers, "Terahertz heterodyne receiver with quantum cascade laser and hot electron bolometer mixer in a pulse tube cooler", Appl. Phys. Lett. 93, 141108 (2008).

[2] H. Richter, S. G. Pavlov, A. D. Semenov, L. Mahler, A. Tredicucci, H. E. Beere, D. A. Ritchie, and H.-W. Hübers "Sub-megahertz frequency stabilization of a terahertz quantum cascade laser to a molecular absorption line", submitted to Appl. Phys. Lett.