Frequency Instabilities of Terahertz Quantum-Cascade Lasers Induced by Optical Feedback

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Heterodyne spectroscopy is a unique tool for applications in remote sensing, in particular in astronomy and planetary research. Its major strength is the high spectral resolving power up to $\nu/\Delta\nu = 10^7$. This allows to resolve the line shape of many atomic and molecular emission or absorption lines. A key component which determines to a large extent the frequency resolution of such a spectrometer is the local oscillator (LO). Since 2014, a THz quantum-cascade laser is operated as the LO in the German Receiver for Astronomy at Terahertz Frequencies (GREAT) on board of SOFIA, the Stratospheric Observatory for Infrared Astronomy. This LO is based on a 4.7 THz QCL in a compact mechanical cryocooler [1,2].

For laser diodes, it is well-known that optical feedback into the laser cavity will shift the lasing frequency as well as change its output power. In the case of a QCL, such an effect may deteriorate its performance when used as an LO. The influence of optical feedback on the emission frequency of QCLs is investigated. The emission frequency is measured with high spectral resolution (< 1 MHz) and a time resolution down to 1 ms by mixing the output from two QCLs with almost the same frequency in a Schottky diode and analyzing the difference frequency. QCLs operating at 3.4 and 4.7 THz with different designs of the active medium are investigated, and the data are analyzed using the theory originally developed for laser diodes. A shift of the QCL frequency as well as mode hopping is observed, both depending on the operation parameters of the QCLs. A quantitative analysis shows that a fraction of only 3×10^{-5} of the output power of the QCL is sufficient to change its emission frequency by 70 MHz. The induced variation occurs on a time scale of less than 1 ms. The results emphasize the importance of reducing optical feedback for high-resolution spectroscopy with THz QCLs.

References

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