A compact, continuous-wave radiation source for local oscillator applications based on a THz quantum-cascade laser

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Abstract

Heterodyne spectroscopy of molecular rotational lines and atomic fine-structure lines is a powerful tool in astronomy and planetary research. It allows for studying the chemical composition, the evolution, and the dynamical behaviour of many astronomical objects. As a consequence, current and future airborne as well as spaceborne observatories such as SOFIA, Herschel or Millimetron are equipped with heterodyne spectrometers.

A major challenge for heterodyne receivers operating above approximately 2 THz is the local oscillator, which should be a compact source requiring little electrical input power. THz quantum-cascade lasers (QCLs) have the potential to comply with these requirements. However, until now, THz QCLs operate at rather low temperatures so that cooling by liquid helium or using large cryo-coolers becomes necessary. While these cooling approaches might be acceptable for laboratory experiments, they either result in too many restrictions on airborne or spaceborne heterodyne receivers or are completely unacceptable.

We report on the development of a compact, easy-to-use source, which combines a QCL operating at 3.1 THz with a compact, low-input-power Stirling cooler. The QCL, which is based on a two-miniband design, has been developed for high output powers and low electrical pump powers [1]. Efficient carrier injection is achieved by resonant longitudinal-optical phonon scattering. At the same time, the operating voltage can be kept below 6 V. The amount of generated heat complies with the cooling capacity of the Stirling cooler of 7 W at 65 K with 240 W of electrical input power. Special care has been taken to achieve a good thermal coupling between the QCL and the cold finger of the cryostat. The whole system weighs less than 15 kg including cooler, power supplies etc. The output power is well above 1 mW at 3.1 THz. With an appropriate optical beam shaping, the emission profile of the laser becomes a fundamental Gaussian one. In addition to the performance of the QCL in the Stirling cooler, we will present results of the application of this source to high-resolution molecular spectroscopy.

References

[1] M. Wienold, L. Schrottke, M. Giehler, R. Hey, W. Anders, and H. T. Grahn, Electron. Lett. 45, 1030–1031 (2009).