Compact and efficient 4.7-THz local oscillator with a GaAs/AlAs quantum-cascade laser

H.-W. Hübers[1,2*], T. Hagelschuer[1], H. Richter[1], M. Wienold[1], L. Schrottke[3], X. Lü[3], B. Röben[3], K. Biermann[3], and H. T. Grahn[3]

[1]*German Aerospace Center (DLR), Institute of Optical Sensor Systems, Rutherfordstr. 2, 12489 Berlin, Germany*
[2]*Humboldt-Universität zu Berlin, Department of Physics, Newtonstr. 15, 12489 Berlin, Germany*
[3]*Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institut im Forschungsverbund Berlin e. V., Hausvogteiplatz 5–7, 10117 Berlin, Germany*
[*]Contact: heinz-wilhelm.huebers@dlr.de

Abstract— A major challenge for heterodyne receivers operating above approximately 3 THz is the local oscillator (LO), which has to be a compact source requiring high output power and low electrical input power. The atomic oxygen fine structure transition at 4.7 THz is of particular interest for astronomy as well as for atmospheric research. Since almost four years, a 4.7-THz LO, which is based on a quantum-cascade laser (QCL), is in operation on SOFIA, the Stratospheric Observatory for Infrared Astronomy. It is part of the heterodyne receivers GREAT and upGREAT (German REceiver for Astronomy at Terahertz frequencies) [1]. While the laser itself is only a few mm long, the mechanical cryocooler, which is necessary for operation of the QCL, determines the mass and power budget of the LO. The LO of GREAT/upGREAT has a mass of about 40 kg and a power consumption of about 400 W. For application in a space mission, an LO with the same performance has to be significantly more compact and less power consuming than for airborne instruments. We will report on the development of a compact, easy-to-use source, which employs a QCL operating in a very compact, low-input-power linear Stirling cooler. The QCL, which is based on a hybrid design using the GaAs/AlAs material system [2], has been developed for high output power and low electrical pump power. Efficient carrier injection is achieved by resonant longitudinal-optical phonon scattering. The QCL operates on a single mode at 4.75 THz exhibiting more than three times higher wall plug efficiency than GaAs/$Al_{0.25}Ga_{0.75}As$ QCLs with an almost identical design. At the same time, the threshold current density is significantly reduced. The cryocooler with the QCL weighs less than 4 kg. The QCL provides up to 7.5 mW output power at an operating temperature of 42 K in an almost Gaussian-shaped beam profile. The results indicate that a compact LO based on a GaAs/AlAs QCL is feasible for spaceborne applications.

[1] H. Richter, M. Wienold, L. Schrottke, K. Biermann, H. T. Grahn, and H.-W. Hübers, 4.7-THz local oscillator for the GREAT heterodyne spectrometer on SOFIA, IEEE Trans. Terahertz Sci. Technol. **5**, 539 (2015).
[2] L. Schrottke, X. Lü, G. Rozas, K. Biermann, and H. T. Grahn, Terahertz GaAs/AlAs quantum-cascade lasers, Appl. Phys. Lett. **108**, 102102 (2016).