Performance of the 4.7-THz Local Oscillator with Quantum Cascade Laser on Board of SOFIA

H. Richter[1], M. Greiner-Bär[1], M. Wienold[2], L. Schrottke[2], K. Biermann[2], H. T. Grahn[2], and H.-W. Hübers[1,3]
[1]Institute of Optical Sensor Systems, German Aerospace Center (DLR), Rutherfordstr. 2, 12489 Berlin, Germany
[2]Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany
[3]Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

***Abstract*— The design and the performance of a 4.7-THz local oscillator (LO) for the GREAT (German REceiver for Astronomy at Terahertz frequencies) heterodyne spectrometer on SOFIA, the Stratospheric Observatory for Infrared Astronomy, are presented. The LO is based on a quantum-cascade laser, which is mounted in a compact mechanical cryocooler. It delivers up to 150 µW output power into a nearly Gaussian shaped beam around the frequency of the fine structure line of neutral atomic oxygen, OI, at 4.7448 THz.**

I. INTRODUCTION

HIGH resolution heterodyne spectroscopy is widely used in astronomy and planetary research. A key component of any heterodyne receiver is the local oscillator (LO). THz quantum-cascade lasers (QCLs) are a promising alternative to multiplier-based sources especially at frequencies above 3 THz. They can provide high output powers up to several mW, continuous-wave (cw) operation up to 129 K, small intrinsic line widths of about 90 Hz, and frequency tunability of several GHz. In a few laboratory experiments, some basic demonstrations regarding the feasibility of a QCL-based LO such as pumping of a mixer, noise temperature measurements frequency and phase locking as well as heterodyne spectroscopy have been demonstrated. However, there existed until now no single LO system, which fulfills all requirements, and, consequently, no such LO has ever been implemented in a real mission. In this contribution, we report on the design and performance of a 4.7-THz LO, which is based on a QCL. The LO has been implemented into the GREAT spectrometer on SOFIA and was successfully operated during six observation flights in May 2014 and January 2015.

II. RESULTS

The LO combines a QCL with a compact, low-input-power Stirling cooler. The 4.7-THz QCL is based on a hybrid design and has been developed for continuous-wave operation, high output powers, and low electrical pump powers [1]. Efficient carrier injection is achieved by resonant longitudinal optical phonon scattering. This design allows for an operating voltage 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 [2]. The QCL has a lateral distributed feedback grating, which is optimized for 4.745 THz. This yields single mode emission over most of the driving current of the laser. Outcoupling is done through one of the end facets of the single-plasmon waveguide. The beam of the QCL is formed with a dedicated lens and a spatial filter into an almost Gaussian profile. The M^2 value which can be achieved with this method is approximately 1.2 [3]. The absolute frequency of the LO has been determined by measuring the absorption spectrum of CH_3OH and comparing this with data from the literature. The emission frequency of the LO covers the range from +2 to -4 GHz around the fine structure line of neutral atomic oxygen, OI, at 4.7448 THz.

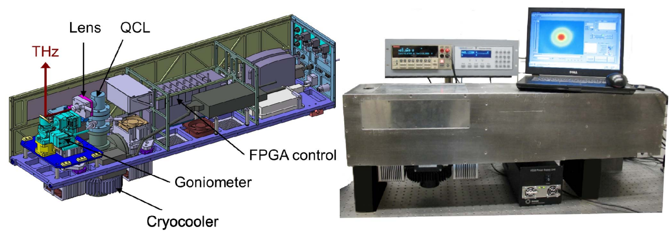

Fig. 1: Schematic of the LO (left) and photograph of the assembled LO (right) with power supply for the cryocooler, current supply, and temperature controller. The beam profile of the LO is shown on the laptop display.

III. SUMMARY

The design of a 4.7-THz QCL-based LO for the GREAT heterodyne spectrometer on SOFIA will be presented. All requirements such as output power, beam profile, accuracy of the absolute frequency, and frequency tunability are fulfilled. After passing extensive laboratory tests, the LO was operated during six flights of SOFIA in May 2014 and January 2015. All of these flights have been successfully completed, which demonstrates the capability of a QCL as LO. Finally, the in-flight performance of the LO will be presented.

REFERENCES

[1]. L. Schrottke, M. Wienold, R. Sharma, X. Lü, K. Biermann, R. Hey, A. Tahraoui, H. Richter, H.-W. Hübers, and H. T. Grahn, “Quantum-cascade lasers as local oscillators for heterodyne spectrometers in the spectral range around 4.745 THz,” Semicond. Sci. Technol. Vol. 28, 03511 (2013).
[2]. H. Richter, M. Greiner-Bär, S. G. Pavlov, A. D. Semenov, M. Wienold, L. Schrottke, M. Giehler, R. Hey, H. T. Grahn, and H.-W. Hübers, “A compact, continuous-wave terahertz source based on a quantum-cascade laser and a miniature cryocooler,” Opt. Express vol. 18, pp. 10177-10187 (2010).
[3]. H. Richter, A. D. Semenov, S. G. Pavlov, L. Mahler, A. Tredicucci, H. E. Beere, D. A. Ritchie, K. S. 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. vol. 93, 141108 (2010).