Frontend for a 2.5-THz heterodyne spectrometer without liquid cryogen

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Abstract— **As part of a study for a second generation heterodyne spectrometer on SOFIA we are developing a 2.5-THz frontend which is implemented in a pulse-tube cooler . It consists of a quantum-cascade laser as local oscillator and a phonon-cooled NbN hot electron bolometric mixer. Frequency stabilization to below 300 kHz full width at half maximum is achieved by locking to a molecular absorption line. We will present the design and performance of the frontend and discuss the prospects for an application on board of SOFIA.**

I. TRODUCTION AND BACKGROUND

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. Examples are the OH rotational transitions at 2.5 THz, the HD rotational transition at 2.7 THz, and the OI fine structure line at 4.7 THz. These lines are, for example, major targets to be observed with GREAT, the German Receiver for Astronomy at Terahertz Frequencies, which was operated for the first time on board of SOFIA, the Stratospheric Observatory for Infrared Astronomy, in April 2011. For SOFIA, a heterodyne receiver which does not require cooling by liquid cryogens will ease operation significantly, because the complexity and limitation of the operating time due to the use of cryo-liquids can be overcome. Another advantage fof such a frontend is, that largeformat mixer arrays are easily accommodated because of the high cooling capacity of a mechanical cooler as compared to cooling by liquid helium.

II. RESULTS

As part of a study for a second generation heterodyne receiver on SOFIA we are developing a 2.5-THz frontend which is implemented in a pulse-tube cooler (PTC). It consists of a quantum-cascade laser (QCL) as local oscillator and a phonon-cooled NbN hot electron bolometric mixer [1]. The QCL is mounted on the first stage of the PTC and operates at a temperature of about 50 K while the HEB is mounted on the second stage of the PTC (temperature ~5 K). A detailed study of the QCL beam quality yielded a beam propagation factor M^2 of 1.1-1.2. The double sideband noise temperature at 2.5 THz of the system is 2000 K and when corrected for optical losses in the signal path it is ~800 K.Frequency stabilization to below 300 kHz full width at half maximum is achieved by locking to a molecular absorption line [2]. While the gas absorption cell is outside the PTC the Ge:Ga detector, which is necessary for the locking scheme, is mounted on the second cold stage as well. We will present the design and performance of the frontend and discuss the prospects for an application on board of SOFIA.

REFERENCES

[1] H. Richter, A. D. Semenov, S. Pavlov, L. Mahler, A. Tredicucci, K. Il'in, M. Siegel, and H.-W. Hübers, 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, Appl. Phys. Lett. **96**, 071112 (2010).