

A 2.5-THz heterodyne spectrometer front-end integrated in a pulse-tube cooler

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Abstract—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 will be operated on board of SOFIA. For SOFIA, a heterodyne receiver which does not require cooling by liquid cryogenics will ease operation significantly, because the complexity and limitation of the operating time due to the use of cryo-liquids can be overcome.

As part of a study for a second generation heterodyne receiver on board of SOFIA we are developing a 2.5-THz front-end 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. The QCL is mounted on the first stage of the PTC and operates at a temperature of approximately 50 K while the HEB is mounted on the second stage of the PTC (temperature ~5 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. The intermediate frequency bandwidth of the front end is 2-4 GHz. This band is down-converted to 0.3-1.5 GHz and analyzed with a digital fast Fourier transform spectrometer. We will present the design of the front-end, present the results of an end-to-end test, and discuss the prospects for an application on board of SOFIA.