Progress towards a 2.5-THz Solid State Heterodyne Receiver with Quantum Cascade Laser and Hot Electron Bolometric Mixer

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Abstract— **We report on progress towards a solid state 2.5-THz heterodyne receiver. The front-end of the receiver is integrated in a pulse tube cooler. 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 about 45 K while the HEB is mounted on the second stage of the PTC (temperature ~5 K). Design and performance of the receiver will be reported.**

I. Introduction And Background

The terahertz (THz) portion of the electromagnetic spectrum bears an amazing scientific potential in astronomy and planetary research. 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 dynamic processes as well as density and distribution of particular species. Two examples are the HD rotational transition at 2.7 THz, and the OI fine structure line at 4.7 THz.

We will report on progress towards a liquid cryogen-free, solid state heterodyne receiver for operation at 2.5 THz. The front-end of the receiver is integrated in a pulse tube cooler (PTC). It consists of a quantum cascade laser (QCL) as local oscillator (LO)[1] and a phonon-cooled NbN hot electron bolometric (HEB) mixer[2]. The QCL is mounted on the first stage of the PTC and operates at a temperature of about 45 K while the HEB is mounted on the second stage of the PTC (temperature ~5 K) (Fig. 1). A TPX lens is used to focus the emission from the QCL onto the HEB mixer. A 6 µm thick Mylar beamsplitter is used to superimpose the signal radiation and the radiation from the QCL. The QCL has a Fabry-Perot resonator and a surface-plasmon type waveguide. The active medium is a GaAs/AlGaAs superlattice with 110 repeat units. The design follows the so-called bound-to-continuum approach. The resonator is a mesa-etched, 240 µm wide ridge with a length of 2.5 mm defined by cleaving. The HEB is a 2 µm wide, 0.2 µm long, and ~5.5 nm thin NbN strip on a high resistivity (> 5 kΩ) silicon substrate located in the center of a planar antenna. It is glued onto the flat side of an extended hemispherical 12 mm-diameter silicon lens.

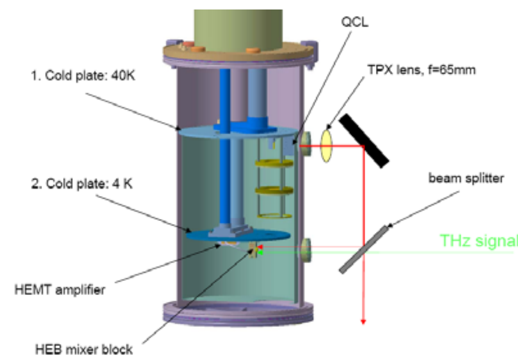

Fig. 1: Setup of the front-end of the heterodyne receiver in a PTC.

II. Results

The QCL has a maximum output power of a few mW and operates up to 58 K in cw mode. Its intrinsic emission linewidth as measured by mixing with the emission from an optically pumped THz gas laser is less than 20 KHz. At the position of the HEB the beam profile is close to Gaussian (inset in Fig. 2) allowing for an efficient coupling of the LO radiation into the mixer. With this setup the HEB mixer was pumped into the normal state (Fig. 2). The double sideband noise temperature measured with this set-up was 2000 K. When corrected for optical losses in the setup it is about 800 K. These experiments demonstrate that a solid state THz heterodyne receiver in a PTC is feasible.

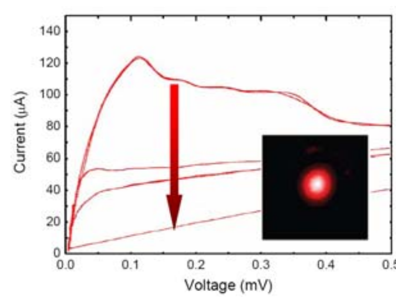

Fig. 2: Pumped IV-curves of an HEB mixer. The arrow indicates increasing pump power. The inset shows the beamprofile measured at the position of the HEB mixer. The area shown is 10x10mm^2.

References

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