Towards celestial sources above 1 THz with a heterodyne receiver based on a hot-electron bolometer mixer

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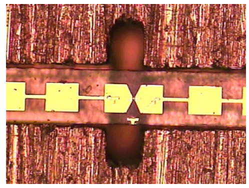
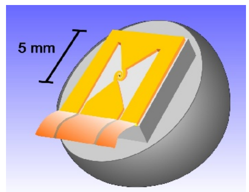
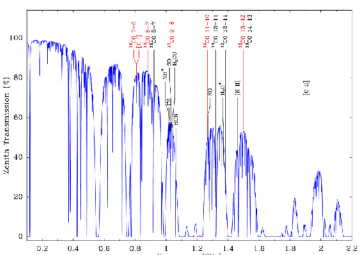
HOT-ELECTRON BOLOMETER (HEB) MIXER



Electromagnetic radiation absorbed by the film drives the superconducting film out of thermal equilibrium. Nonequilibrium ("hot") electrons are scattered by thermal vibrations of the lattice, which leads to the rise of the lattice (phonon) temperature. The lattice in its turn passes it on to the substrate. Besides interacting with the film phonons, the nonequilibrium electrons may diffuse out of the film into the contacts. Which of the two processes will dominate depends only on the device geometry.



TERAHERTZ RADIATION IN SPACE λ = 30 μm – 1 mm, ν = 300 GHz – 10 THz



plot taken from Dan Marrone et al., Observations in the 1.3 and 1.5 THz Atmospheric Windows with the Receiver Lab Telescope, in the Proc. 16th Int. Symp. on Space Terahertz Technology, Goteborg, Sweden, May 2005.

The terahertz region of the electromagnetic spectrum is emerging as an important field for observational astronomy. Certain processes in the life cycle of the interstellar medium and galaxies have signature emission or absorption lines at terahertz frequencies. Hence, observations performed in the terahertz region may provide a deeper understanding of the phenomena which take place inside giant interstellar molecular clouds and star formation regions, as well as information about various processes occurring in the Milky Way and in other galaxies.

Observations in the terahertz region are quite challenging, primarily due to strong attenuation of electromagnetic radiation of this frequency range by the earth's atmosphere, which is why telescopes have to be located at high altitudes or launched on board air- or spacecrafts.

THE RECEIVER LAB TELESCOPE

The **R**eceiver **L**ab **T**elescope (RLT) is the first ground-based radio telescope designed for operation at frequencies above 1 THz. It began observations from **an altitude of 5525 meters** (18,125 feet) on Cerro Sairecabur in northern Chile.

- main reflector diameter 80 cm
- frequency range 0.8 – 1.3 THz

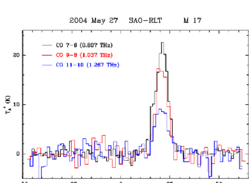
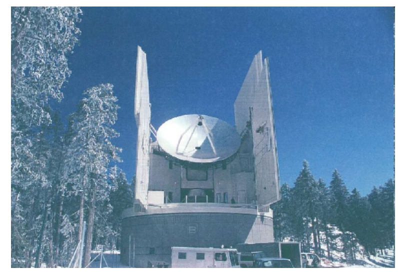


Fig. 2. CO emission detected in M17 from the RLT on 2004 May 27. At the time of this measurement, the ^{12}CO $J = 11 \rightarrow 10$ line was the highest frequency line ever detected from the ground.

plot taken from Dan Marrone et al., Observations in the 1.3 and 1.5 THz Atmospheric Windows with the Receiver Lab Telescope, in the Proc. 16th Int. Symp. on Space Terahertz Technology, Goteborg, Sweden, May 2005.

FIRST GROUND-BASED OBSERVATION WITH HEB MIXERS BEYOND 1 THz

Submillimeter Telescope Observatory, the University of Arizona
– elevation 3186 m, main reflector 10 m, frequency range 150 GHz – 1 THz



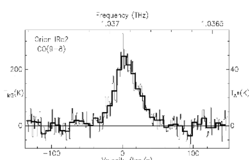
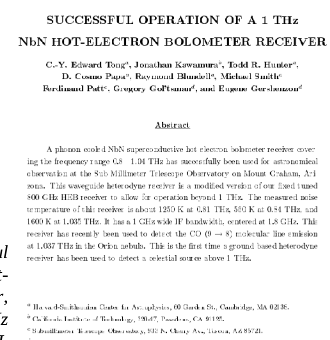


Fig. 5 Spectrum recorded by the HEB receiver at an LO frequency of 1.0352 THz from the Orion nebula. The resolution of the IF spectrometer was 4 MHz. The solid line shows a smoothed spectrum at a resolution of 25 MHz. The temperature scale of the spectrum is calibrated by taking into account the receiver noise temperature, estimated atmospheric opacity and estimated efficiency of telescope.

C.E. Tong et al., Successful operation of a 1 THz NbN Hot-Electron Bolometer receiver, in the Proc. 11th Space THz Symposium, Ann Arbor, MI, pp. 49-59 (May 2000).



SUCCESSFUL OPERATION OF A 1 THz NbN HOT-ELECTRON BOLOMETER RECEIVER

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Abstract

A phonon cooled NbN superconductive hot electron bolometer receiver covering the frequency range 0.8 – 1.04 THz has successfully been used for astronomical observation at the Sub Millimeter Telescope Observatory on Mount Graham, Arizona. This waveguide heterodyne receiver is a modified version of our fixed tuned 800 GHz HEB receiver to allow for operation beyond 1 THz. The measured noise temperature of this receiver is about 1250 K at 0.81 THz, 580 K at 0.84 THz, and 1600 K at 1.035 THz. It has a 1 GHz wide IF bandwidth, centered at 1.8 GHz. This receiver has recently been used to detect the CO (9 → 8) molecular line emission at 1.037 THz in the Orion nebula. This is the first time a ground based heterodyne receiver has been used to detect a celestial source above 1 THz.

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HOT-ELECTRON BOLOMETER MIXERS ON BOARD HERSCHEL

The European Space Agency's **Herschel Space Observatory** (formerly called Far Infrared and Sub-millimetre Telescope or FIRST) has the largest single mirror ever built for a space telescope. At 3.5-metres in diameter the mirror will collect long-wavelength radiation from some of the coldest and most distant objects in the Universe. In addition, Herschel will be the only space observatory to cover a spectral range from the far infrared to sub-millimetre.

Heterodyne Instrument for the Far Infrared (HIFI):

- HEB mixers for 1410 – 1910 GHz
- IF bandwidth 4 GHz

http://sci.esa.int/science-e/www/area/index.cfm?fareaid=16

MILLIMETRON – THE 12 m CRYOGENIC TELESCOPE FOR SINGLE DISH AND INTERFEROMETRY

The goal of the project is to construct a space observatory operating in the millimeter, sub-millimeter and infrared using 12-m cryogenic telescope in a single-dish mode and as an interferometer with the space-ground and space-space baselines (the later after the launch of the second identical space telescope). The observatory will allow conducting astronomical observations with super high sensitivity (down to nanoJansky level) in a single dish mode, and observations with high angular resolution in the interferometer mode.

- main reflector diameter 12 m, cooled to 4.2 K
- HEB mixers for 1 – 6 THz

http://www.asc.rssi.ru/millimetron/eng/millim_eng.htm