Photometry of THz Radiation using Golay Cell Detector

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Abstract

The measurement of THz radiation in the continuum presents new technical challenges concerning materials, frequency filters and detection devices. We present the first results of a radiometric system using Golay cell as a detector, for the whole > 15 THz range, and at discrete frequencies centered at 2, 10 and 30 THz. The system was designed to measure solar THz radiation. It is capable to detect small solar bursts, with a large dynamic range to be able to detect larger events.

1. Introduction

Photometry and imaging in the terahertz range (frequency interval between 0.1 and 30 THz) require technologies for a new generation of devices, designed to operate in many applications including civil, military, medical, and scientific areas. Remote sensing at terahertz frequencies is able to search for hidden objects, see through materials, determine compositions, and other applications. A new multidisciplinary science is been developed to combine sensors, detectors, and filters, to work in this range of frequency. During the past years, we carried up several tests addressed to THz materials, filters, and detectors.

The Solar Submillimeter-wave Telescope (SST) located at Argentina Andes [1], operating at 0.2 and 0.4 terahertz, has discovered a new solar burst spectral component during flares, exhibiting fluxes increasing for smaller wavelengths, separated from the well known microwave component [2]. Solar activity observations in the terahertz range will lead us to better understand the emission mechanisms by high energy particle acceleration processes. Continuum spectral photometry is essential to diagnose the emission component found at THz frequencies. This component might be the evidence of synchrotron emission from high energy electrons peaking somewhere in the far infrared range. THz photometry can only be done outside the terrestrial atmosphere, which is opaque at that range [3].

We developed a terahertz photometry test assembly to characterize the system response at THz frequency ranges $\lambda > 20$ µm (f < 15 THz), 2 THz, 10 THz, and 30 THz, using an opto-acoustic detector (Golay cell). The setup is composed by two distinct parts: that blackbody radiation source and the radiometer prototype system, shown in Fig. 1. The left part of the assembly simulates the solar disk. The first prototype experiments were done at El Leoncito Observatory, San Juan, Argentina as part of a collaboration research conducted by Brazil groups: Mackenzie Presbyterian University, Semiconductors Component Center, Unicamp, and "Bernard Lyot" Solar Observatory.

This was the result of several developments carried out to characterize THz filters, materials, and detectors [4, 5]. They were intended to design a THz photometer to operate outside the terrestrial atmosphere (Solar-T Experiment). The Tydex Golay cell detector has been selected as the most sensitive in comparison to others that were tested (pyroelectric and micorbolometer [4, 5]). This photometry has been also used in the 30 THz mid-IR (i.e.,

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the 10 μm band), to operate in the ground. The suppression of the visible and near infrared is obtained by a rough surface reflector [6] and a low-pass membrane filter [4]. The band-pass is obtained with a resonant metal mesh filter [7]. This system was coupled to 75 mm aperture telescope to obtain maximum detectability of temperature variation due to flare excess emissions. The whole project included its planning, construction, integration, and testing.

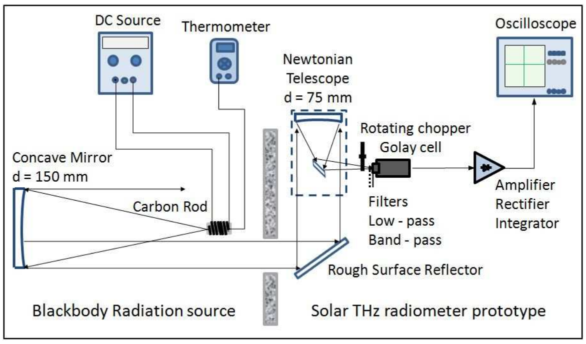

Fig. 1 – THz photometry tests assembly. In the left side, the blackbody source simulates the solar disk. At the right side, after reflection in the rough mirror, the radiation is concentrated by a telescope. The Golay cell detector is preceded by a membrane low-pass filter, a metal mesh THz band-pass filter, and a chopper.

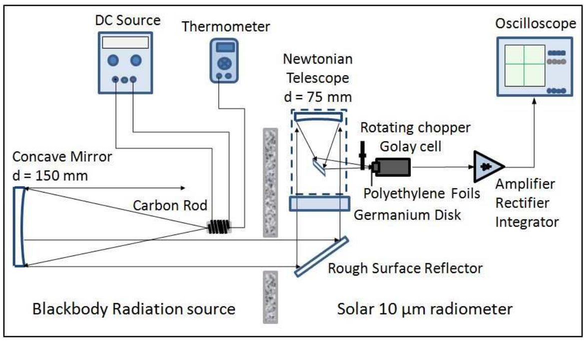

Fig. 2 – Test assembly for 30 THz band. The system is similar to that one shown in Fig. 1, where the band-pass filter is accomplished by the rough flat mirror low-pass, and by a Germanium disk, 20 mm thick. The Golay cell was preceded by a set of polyethylene foils attenuator, added to measure the direct solar radiation without saturation.

2. Experimental Arrangement

The test assemblies are shown in Figs. 1 and 2. The blackbody source, at the left, uses a small carbon rod heated by a nickel-chrome resistance with temperature measured by a coupled thermopair. The carbon rod is placed at the focus of a concave mirror with 150 mm diameter and 60 cm focal length. A plane parallel beam radiates from the mirror, and the carbon rod size simulates the actual solar disk as observed from the photometer aperture.

The assembled radiometer system is shown at Fig. 3, corresponding to Fig. 2 diagram for 30 THz. The incoming radiation is reflected by the rough surface flat mirror at 45°, which diffuses a substantial fraction of the visible and near infrared by a factor of 3. A 75 millimeter aperture telescope is placed at a distance from which the apparent diameter of the carbon rod hot source is comparable to the solar diameter (i.e., 0.5 degrees). The Golay cell is placed at the Newtonian telescope focus. For the 30 THz band, a 20 mm thick Germanium disk is placed in front of the telescope. For tests at lower bands (Fig. 1), the low-pass filter consisted in a TydexBlack membrane, and the band-pass filter in resonant metal mashes fabricated to be tuned at 2 and 10 THz.

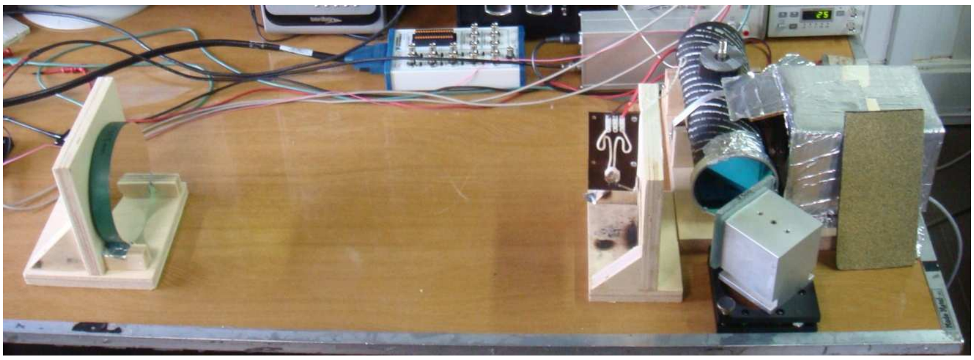

Fig. 3 – The 30 THz test setup assembly, corresponding to the diagram shown in Fig. 2, at El Leoncito Observatory.

Fig. 4 – The 30 THz (10 µm) band radiometer assembly receives solar radiation from the coelostat external to the building (see Fig. 5).

Fig. 5 – The 30 cm Jensch-Zeiss coelostat operates outside the building where the 30 THz (10 µm) solar radiation was measured.

3. Measurements

In Fig. 6 (a) we show the temperature response of the system in the 30 THz band (see Figs. 2, 3, and 4). The chopper frequency was of 25 Hz. To prevent saturation in direct solar measurement, we have added 8 polyethylene foils (0.45 mm total thickness) as an attenuator. The temperature scale is approximate. It has been calibrated by extrapolating the plot shown in Fig. 6 (a) to the output obtained with direct observation of solar disk (see Fig. 4 and 5), assumed to be of about 5000 K [8, 9].

The system temperature responses at lower THz frequencies are shown in Fig. 6 (b, c, and d). They were obtained with the setup shown in Fig. 1. The temperature scale is approximate, adopting the same calibration obtained at 30 THz direct solar observation. Fig. 6 (b) shows the response for radiation at wavelengths > 20 µm, using a TydexBlack membrane low-pass filter in front of the Golay cell. Figs. 6 (c) and (d) show the response for 2 and 10 THz discrete frequencies, by adding the respective resonant band-pass filter to the TydexBlack membrane. The stability or "noise", of these measurements was of about 0.5 K r.m.s., with a 200 ms integration time.

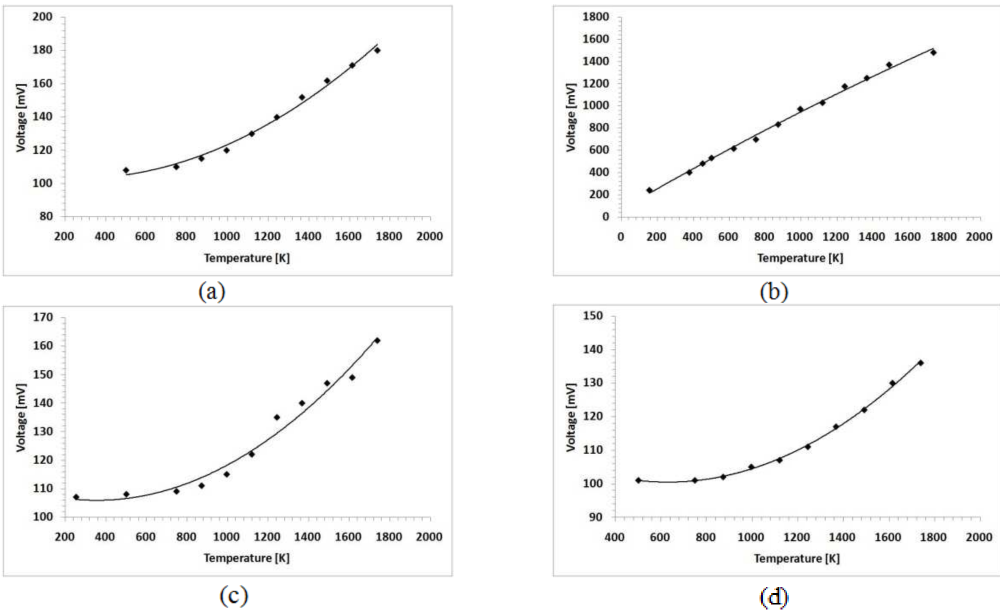

Fig. 6 – The radiometer system response to Sun-size blackbody temperature radiation: (a) at 30 THz with Germanium disk and polyethylene foils attenuator (b) at f < 15 THz, using TydexBlack low-pass filter; (c) at 2 THz, adding a resonant metal mesh band-pass filter; and (d) at 10 THz, adding a resonant metal mesh band-pass filter.

4. Concluding Remarks

The sensitivity of the experiment to detect solar flare fluxes can be expressed using the Rayleigh-Jeans approximation to the Plank formula:

$$\Delta S = 2\ k\ \Delta T / A_e \quad [W/m\ Hz]$$

Where k is the Boltzmann constant, ΔT is the minimum detectable temperature difference, and A_e is the effective aperture area. For 75 millimeter diameter mirror, with 50 % efficiency, a minimum detectable temperature of 0.5 K difference gives $\Delta S \sim 60 \times 10^{-22}\ Wm^{-2}Hz^{-1}$ (or 60 SFU), that corresponds to the flux for a small solar burst. With adequate adjustments of the output amplifier, the dynamic range may be extended by few orders of magnitude to be able to detect stronger flares.

5. Acknowledgments

This research received partial support from Brazilian agencies FAPESP, CNPq, CNPq/INCT-NAMITEC, Mackpesquisa, and Argentina agency CONICET.

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