RELATIVELY INEXPENSIVE TERAHERTZ IMAGING

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ABSTRACT

The advantages of imaging at terahertz [THz] frequencies are well known for homeland security applications. It is possible to image through non-highly conducting media, and there is no known biological hazard. Thus, it is possible to image concealed weapons and explosives. There are also many biomedical applications of THz radiation.

One problem limiting widespread use is the expense of such equipment, much of which revolves around the detector.

One solution is the use of miniature neon indicator lamps as detectors. Such devices cost about 30 cents each, and certain models exhibit noise equivalent powers to terahertz radiation similar to those of Golay cells and bolometers [1]. These miniature lamps are biased to an abnormal glow discharge, and illumination with THz radiation increases the discharge current.[2] In practical use, the THz radiation is amplitude modulated, and the neon glow discharge detector [GDD] detects the THz modulation envelope. Internal signal amplification on the order of a million can arise through ionizing collisions of signal electrons with neutral gas atoms.

The low price of GDD lamps, the electronic ruggedness, and their THz sensitivity make them an attractive choice as detectors for novel focal plane array THz cameras.[3] Indeed, such devices are currently under development. Preliminary images using 4x4 GDD arrays at 100 GHz have already been obtained. VLSI boards for a small array are being built for imaging at 300 GHz, and further development to 64X64 arrays is being planned. Image processing to improve THz image quality is also planned.

Index Terms— terahertz, imaging, plasma, homeland security, terror

1. INRODUCTION

Imaging systems in the electromagnetic spectrum between 100 GHz and 10 THz are required for applications in medicine, communications, homeland security, and space technology. This is because there is no known ionization hazard for biological tissue, and particulate scattering of terahertz (THz) radiation is low compared to that of infrared and optical rays. The lack of inexpensive room temperature detectors and FPAsin this spectral region makes it difficult to develop detection and imaging systems.

A candidate for being the FPA pixel is miniature neon indicator lamp N523 of International light technology (Peabody, MA) which was tested experimentally and found to be a very good THz detector [1]. There are two configurations to realize an FPA with such lamps. The first is where the THz radiation is incident to the side of the lamp, and the second is where the radiation is incident head-on. Those two configurations are given in Fig 1. The detection mechanism of the GDD in the THz regime was found to be enhanced cascade ionization [2]. The Noise Equivalent Power (NEP) for the side configuration (see Fig. 1 (a)) was measured in [1]. An improved NEP of 6×10^{-9} $W/\sqrt{Hz}$ was measured in head on configuration (see Fig. 1 (b)) [3].

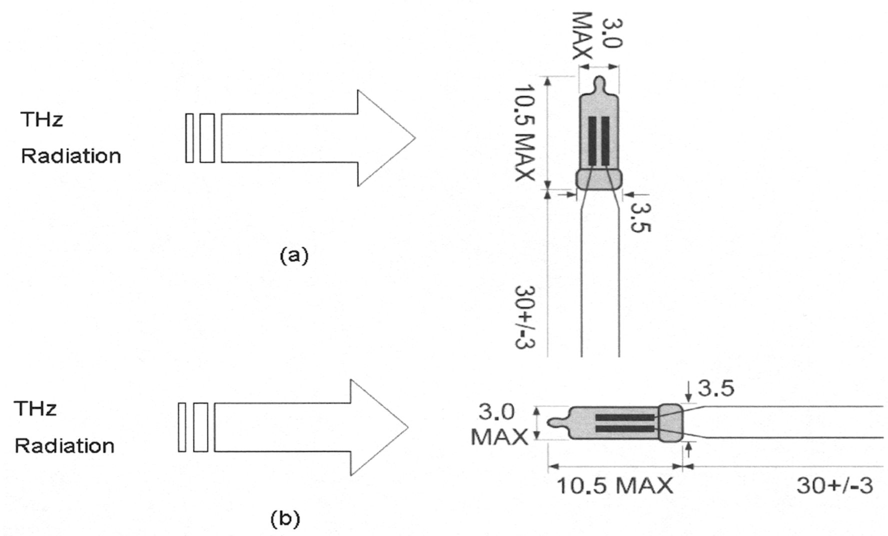

Figure 1: Two configurations of GDD operation (a) side radiation (b) head-on radiation. Dimensions of GDD lamp N523 are in mm

The responsivity curve of a GDD N523 lamp pixel in head on configuration was measured in four different DC bias current cases: 3mA, 4 mA, 6 mA, and 9 mA. Curves of GDD response at these bias currents are given in Fig 2 [3].

All measurements were made under the following electronic conditions: modulation frequency 1 kHz, amplifier bandwidth 100 – 100 KHz, external amplifier gain 30 dB. Except for 9 mA DC bias where amplifier saturation effects set in, response is seen to be linear.

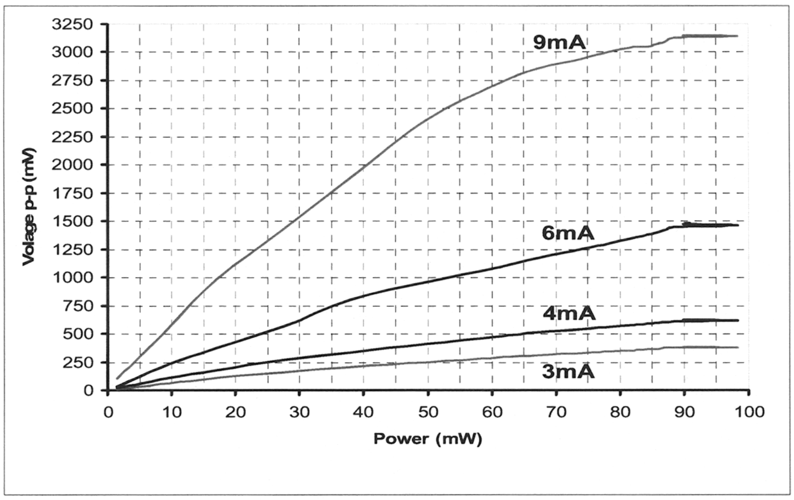

Figure 2: Response of GDD N532 pixel operating in head on configuration at 3mA, 4mA, 6mA, 9mA dc bias currents.

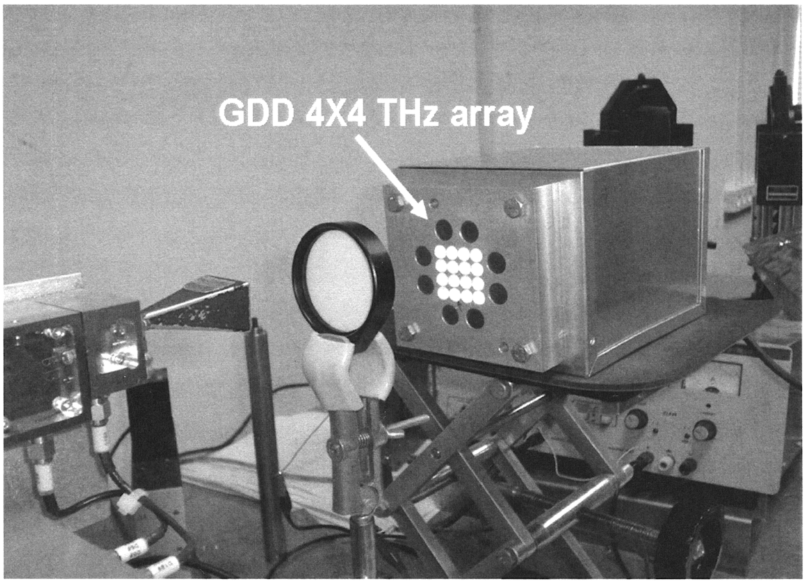

Figure 3: A Photo of the 4X4 THz FPA.

For relatively long range imaging the effective pixel size is determined by:

$$r = \frac{\lambda}{D} \cdot f \qquad (1)$$

where r is the diffraction limited pixel radius (which may be larger than the actual GDD radius), D is optics diameter, λ is THz radiation wavelength, and f is the focal length of the quasi-optical system. Using the head on configuration (see Fig. 1) in the FPA determines the diameter of the pixel in the array. Field of view (FOV) of the FPA in a given direction is given by Nd/f, or

$$FOV = \frac{N\lambda}{D} \qquad (2)$$

where N is the number of pixels in the FPA in the given direction. The resolution of the FPA can be improved by minimizing *FOV* and pixel diameter.

A complete design considerations and construction of the FPA based on GDD 4X4 THz array is given in [3]. Fig. 3 shows a Photo of such FPA. The size of each pixel in the FPA is 8 mm diameter with 1 mm gap of dead space between the pixels.

2. EXPERIMENTAL SE-UP

A THz imaging using the GDD 4X4 array was carried out. Using this set up we image a 10 mm wide aluminum strip. A detailed photo of the imaging experimental set up is given in Fig. 4. The THz source is a 100 GHz source based on GaAs X8 frequency multipliers of Virginia Diodes, Inc. (Charlottesville, VA, USA) [4]. The radiation was focused onto the aluminum strip through a polyethylene lens. The reflected radiation from the aluminum strip was collected by second polyethylene lens and focused on the THz 4X4 FPA. An absorbing material was used to avoid back reflections from the environment.

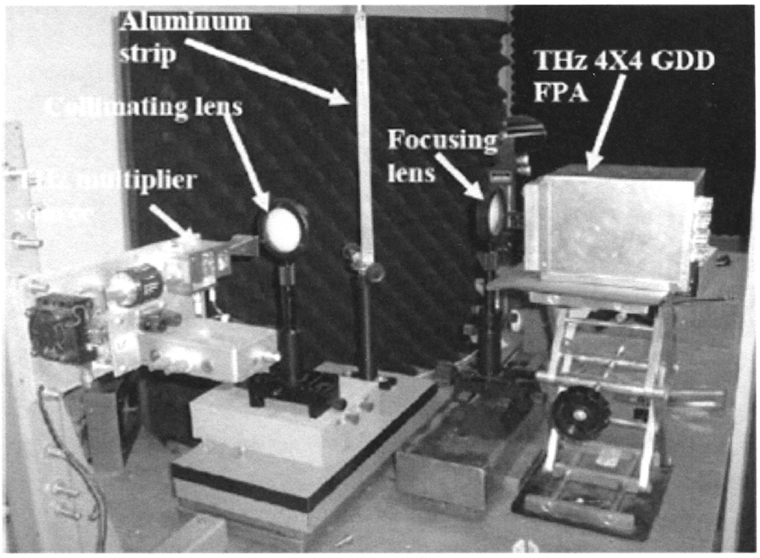

Figure 4: THz imaging experimental set-up of 10 mm width aluminum strip.

3. RESULTS

An image of the reflected beam from the aluminum strip as obtained by the THz 4X4 FPA is given in Fig. 5. The image was processed by MATLAB code. The focused 100 GHz beam can be seen clearly in the photo of Fig. 5. The size of the spot is about 6 mm diameter which is above the diffraction limit of the system and the FPA. The MATLAB code smooth part of the diffraction effects.

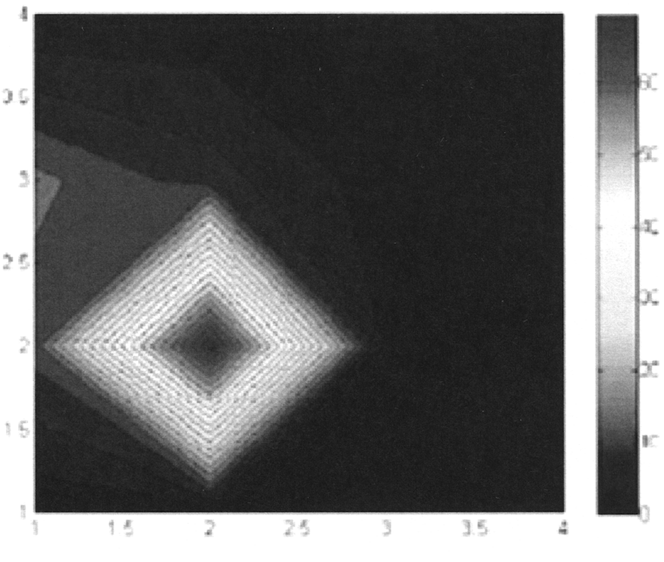

Figure 5: THz image of aluminum strip obtained with 4X4 GDD FPA.

4. ACKNOWLEGEMENT

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5. REFERENCES

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