Measurements of Schottky-Diode Based THz Video Detectors

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Abstract: Schottky barrier diodes have several advantages when used as millimetre wave and terahertz video, or power detectors. These include their inherent small physical size, a broadband spectral response, a sub-nanosecond response time and room temperature operation. This paper describes the use of air-bridged GaAs Schottky diodes, fabricated at the STFC Rutherford Appleton Laboratory, as such rectifying detectors. Incoming radiation is coupled to the forward biased diodes via a hemispherical silicon lens and a broadband planar bow-tie antenna: the rectified signal then passes to a low noise amplifier. A compact, high speed, photonic system, based on 1.55 μm wavelength fibre-optic telecoms components and a waveguide photomixer, provides the test signal. The spectral dependence of responsivity and noise performance of the detectors will be reported.

Keywords: Schottky diodes, THz, Detector

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1. INTRODUCTION

Schottky diodes are widely used nonlinear elements for frequency conversion in the millimeter wave to terahertz part of the spectrum. They may also be used for direct detection of THz radiation [1]. Such Schottky detectors can operate at room temperature and have an extremely fast response time compared with other detectors, such as micro-bolometers [2] or Golay cell[3] detectors. There is a long heritage of using point contact Schottky devices with a long wire antenna for far infrared video detection [4]. More recently, planar devices have been introduced, either in zero-bias [5-7] or, as described here, forward biased forms [8].

2. DETECTOR STRUCTURE

We used an air-bridge GaAs Schottky diode as a rectifying device. Fig. 1 showed an electron micrograph of structures on the supporting GaAs wafer before cutting into chips with a dicing saw. The air-bridge could be seen, with Au contact pads on either side of the device. The Schottky contact /was at the left hand tip of the Au air-bridge. A diced device was inverted and soldered to a planar Au antenna, Fig. 2, which had been photolithographically defined on a quartz wafer. This antenna type does not have the broadband response of, say, the log spiral antenna [6], but has the advantage that its sensitivity to a single linear polarisation does not change with frequency.

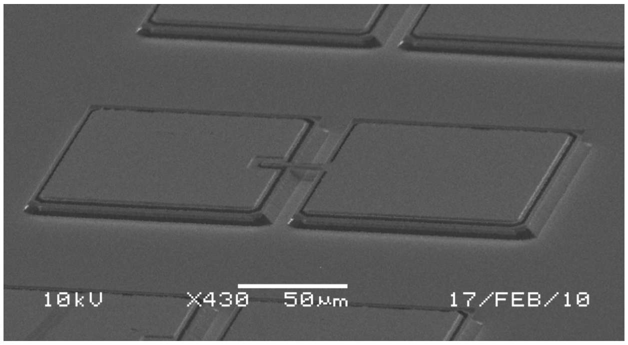

Fig. 1 Photograph of airbridged detector diodes.

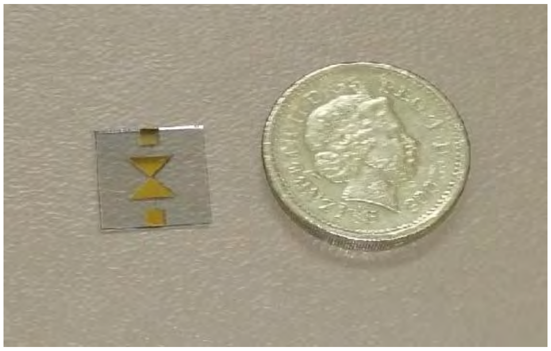

Fig. 2 Bow-tie antenna on quartz substrate.

To couple the antenna to incoming radiation propagating in free space, a high permittivity dielectric lens was placed in contact with the back of the quartz. We used an extended hemispherical lens, made of high resistivity silicon, in accordance with the findings published in Reference 9. A low noise op-amp circuit amplifies the detected signal and monitors the bias current drawn by the Schottky diode. The lens/antenna assembly is supported by a bracket attached to one end of the circuit board: Fig. 3. A cylindrical metal sleeve encloses the detector and preamplifier to provide electrical screening

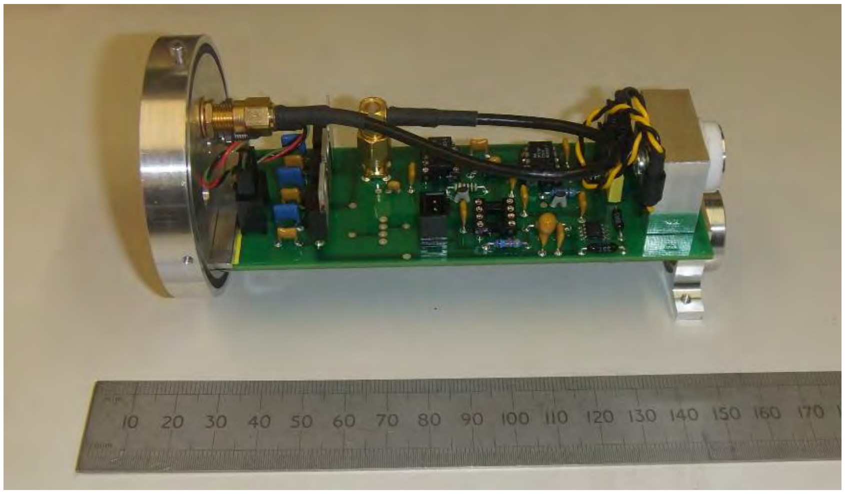

Fig. 3 Picture of detector with pre-amplifier circuitry. The silicon hyperhemispherical lens is mounted in the white cylinder on the extreme right. The cylindrical cover has been removed to shown the construction.

3. RESPONSIVITY MEASUREMENT SYSTEM

Photonic techniques were used to generate the amplitude modulated millimetre wave signal used to test the detector. In this process, the difference frequency of two 1.55 μm laser sources was generated in a photodiode based photomixer [10]. Light from two lasers is coupled into polarisation maintaining single mode telecoms fibre. The two outputs are combined into one fibre in a 3 dB fused coupler, and the combined beam passes through an amplitude modulator on its way to the waveguide photomixer. The output of the photomixer is converted into a free space mode via a feedhorn antenna, and this radiation in turn is focussed onto the silicon lens: Fig. 4.

The photomixing approach permits rapid and easy tuning of the millimetre wave frequency – by changing the temperature and/or the drive current of the diode laser – as well as allowing rapid amplitude modulation by using a fibre coupled $LiNbO_3$ analogue optical modulator with several GHz bandwidth. This offers near 100% modulation depth, and an ability to modulate at frequencies orders of magnitude above those achievable with mechanical choppers. An Erickson waveguide power meter was used to calibrate the output power of photomixer. To reduce the standing waves in the system, a moveable mount with position indicators is used to hold the detector when averaging the receiving signal.

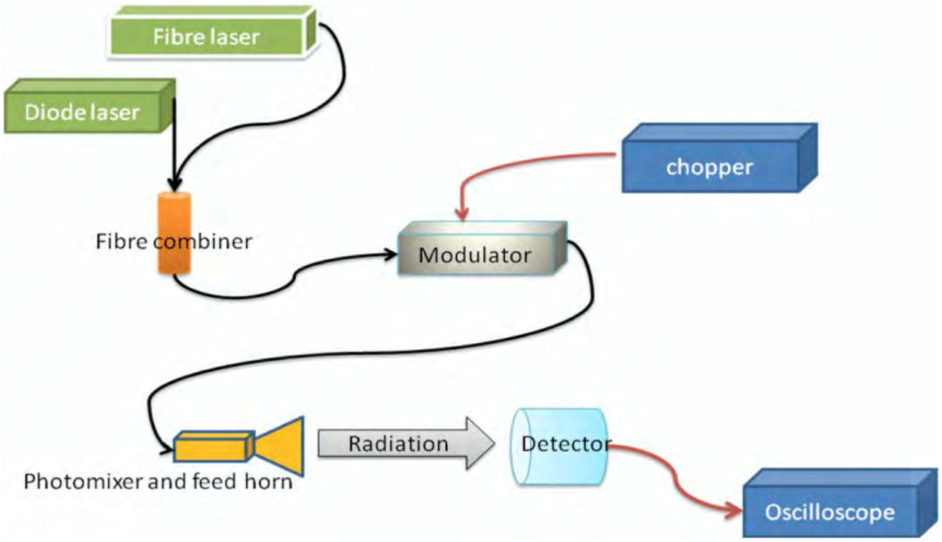

Fig. 4 Schematic of apparatus used for responsivity and frequency dependence measurements

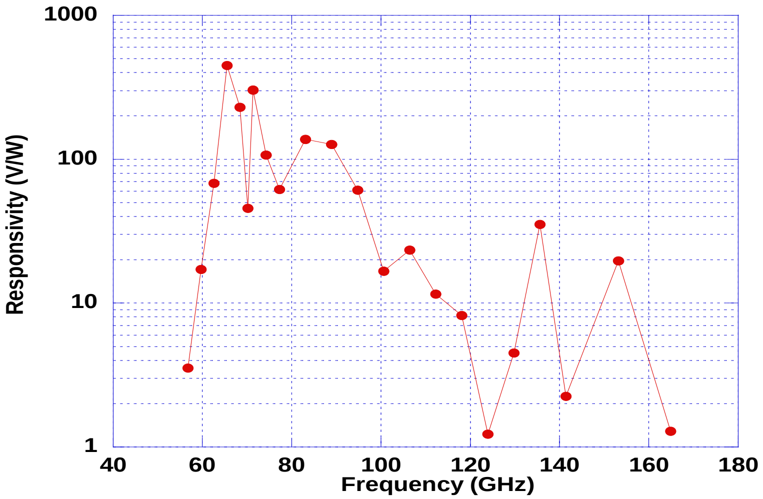

Fig. 5 Millimetre wave responsivity measurements

4. RESULTS

Fig. 5 displays the measured responsivity as a function of frequency. It shows that the sensitivity, in general, drops with increasing frequency. In the 75-110 *GHz* W-band, the decrease is from a few 100 *V/W* to circa 20 *V/W*. Within the 110 to 170 *GHz* D-band, the sensitivity is affected by standing waves, and varies between 1 and 30 *V/W*. The input noise for the detector is about 20 $nV/\sqrt{Hz}$ at a 1 *kHz* modulation frequency, corresponding to a noise-equivalent-power below 1 $nW/\sqrt{Hz}$ over most of the W-band, and to a NEP below 100 $pW/\sqrt{Hz}$ at the lowest frequencies. Studies are continuing to investigate the effects of varying bias current on sensitivity and NEP.

5. CONCLUSION

Measurements of the responsivity and noise properties of biased GaAs Schottky detector have been performed. It exhibits a typical responsivity of 100 *V/W* with NEP below 1 $nW/\sqrt{Hz}$ in W band. The factors governing the response are still under investigation in an effort to optimise the performance.

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[3] See, for example, http://www.tydex.ru/products/thz_optics/golay_cell/

[4] CD detector series from Farran Technology, www.Farran.com

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