Broadband Detector Measures IR, Millimeter & THz Waves

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Abstract— **We used a commercial neon lamp to detect THz waves (0.1, 0.2, 0.37 THz), IR (800 nm) and UV light (200 ~ 400 nm). The amplified responsivities at 0.1 THz, 0.2 THz, and 0.37 THz are 150 V/W, 57.5 V/W and 19.3 V/W, respectively.**

I. Introduction and Background

THE broadband electro-magnetic (EM) wave detector, based on a commercial neon lamp, is a gas discharge lamp containing primarily neon gas at low pressure. The advantages of such a detector include low cost (less than $1/each for a commercial neon lamp), wide dynamic range, broadband operation, electronic ruggedness, room temperature operation, and fast responsivity (microsecond rise time) [1].

The concept of an EM wave detector in the microwave range was investigated more than 50 years ago [2]. Its usage as a terahertz (THz) wave detector for 0.1 THz and 0.25 THz wave detection was first reported in 2007 [3]. There are no reports of this kind of EM wave detector being used at a higher frequency region such as infrared (IR) or X-ray. The detection mechanism in the microwave and THz regions is enhanced cascade ionization, which causes an increase in the discharge current [4]. The current change is derived from enhanced ionizing collisions of electrons with neutral atoms generated by the incident electromagnetic wave.

In this paper, we demonstrate that a commercial neon lamp can be used as an EM wave detector which has a broadband operation frequency region including THz waves, IR and UV light.

II. Experiments

In the experiment, electromagnetic wave was focused on the EM wave detector by a lens. A Gunn diode (40 mW at 0.2 THz), a backward wave oscillator (BWO) (6.3 mW at 0.1 THz and 29 mW at 0.37 THz), a femtosecond laser (350 mW at 800 nm), and a UV gun (90 mW at 200 ~ 400 nm) were used as THz wave, IR, and UV light source, respectively, to test the broadband operation of EM wave detector.

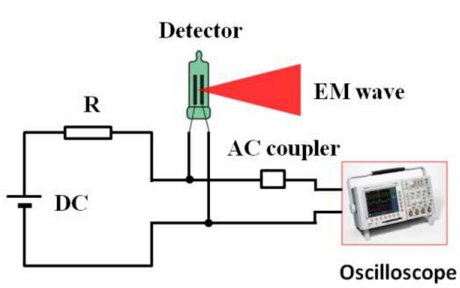

Fig. 1. Experiment setup to measure the EM waves by a broadband EM wave detector

Fig. 1 is the schematic diagram of experiment setup. The EM wave detector was biased by a DC power supply to break down the gas. The incident EM wave was modulated by a mechanical chopper and the measured signal caused by modulation can be separated from the DC bias by an AC coupler. The signal from the EM wave detector can be measured by an oscilloscope or a lock-in amplifier.

III. Experimental Results

The 0.2 THz signal measured directly from the EM wave detector by an oscilloscope is shown in **Fig. 2**. The higher signal is from the EM wave detector with a metallic reflector, which was made by sticking a metal tape on the backside of the glass wall. The metal reflector can increase the intensity of EM wave at the EM wave detector. The signal from the detector with a metallic reflector is 4 times higher than that from the detector without a metallic reflector at the same condition. The signal to noise ratio (SNR) of the signal from the EM wave detector with metallic reflector is about 100 with 64 times average. When the same signal is measured by a lock-in amplifier, the SNR of the signal is 750.

The 0.1 THz (6.3 mW) and 0.37 THz (29 mW) wave also were measured by the detector. The signals normalized by the THz source power at 0.1 THz, 0.2 THz, and 0.37 THz are shown in **Fig. 3**. The responsivity of the detector at 0.1 THz, 0.2 THz and 0.37 THz are 1.02 V/W, 0.3 V/W, and 0.138 V/W, respectively. When an amplifier with the gain of 150 was used to enhance the signal, the amplified responsivities are 150 V/W, 57.5 V/W and 19.3 V/W, respectively. The responsivity decreases with the increasing of frequency. One of the reasons is that the THz absorption of glass wall of EM wave detector increases with the increasing of frequency.

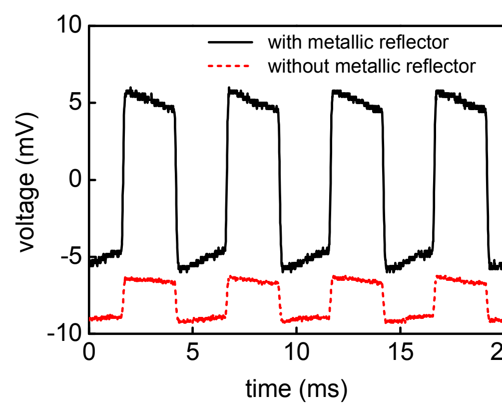

Fig. 2. Measured THz signal (40 mW at 0.2 THz) from the EM wave detector with a metallic reflector (solid line) and that without a metallic reflector (dash line) by an oscilloscope with 64 times average. The chopping frequency is 200 Hz.

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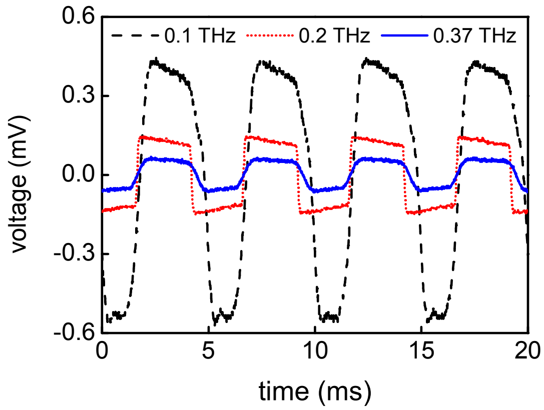

Fig. 3. THz signal (6.3 mW at 0.1 THz, 40 mW at 0.2 THz, and 29 mW at 0.37 THz) normalized by THz source power. The signals are from the EM wave detector with a metallic reflector tested by an oscilloscope with 64 times average. The chopping frequency is 200 Hz.

The EM wave detector has several zones between anode and cathode such as cathode glow space, anode glow space, Faraday space, and etc. However, the electrode gap of the EM detector is only 0.1 ~ 0.2 mm, and the focused beam diameters of 0.1 THz, 0.2 THz, and 0.37 THz wave are 3.5 mm, 2.5 mm, and 1.5 mm, respectively. Because the beam sizes are much larger than the electrode gap, the measured signal is the average effect of THz wave on these zones.

The IR signal is from a femtosecond laser (350 mW at 800 nm), and the beam of the laser can be focused into a less than 50 µm spot. When the IR light illuminates on the anode, the measured signal by an oscilloscope is shown in **Fig. 4 (a)**. The signal is weak, and the peak to peak voltage is just 3 mV. **Fig. 4 (b)** shows the IR signal from the Faraday space, the signal is strong at this region, and the peak to peak value is over 2 V. When the IR light illuminates the cathode, the signal is higher than that from anode, which is shown in **Fig.4 (c)**.

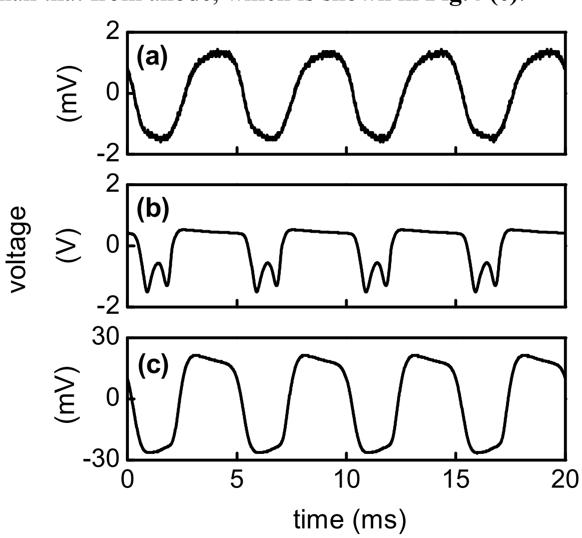

Fig. 4. Measured IR signal (350 mW at 800 nm) from **(a)** anode, **(b)** Faraday space, and **(c)** cathode of the EM wave detector by an oscilloscope with 64 times average. The chopping frequency is 200 Hz.

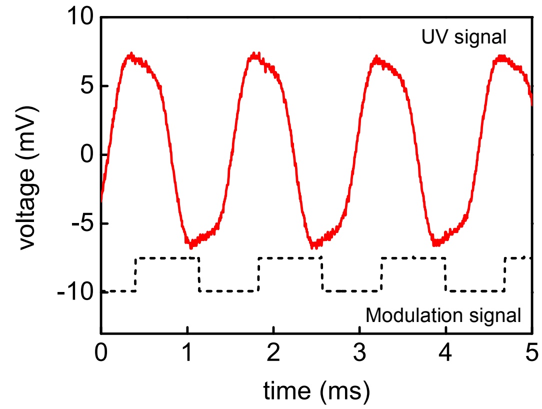

Fig. 5. Measured UV signal (90 mW at 200 ~ 400 nm) from the EM wave detector without a metal reflector by an oscilloscope with 64 times average. The chopping frequency is 700 Hz.

At the cathode, the electrons collide with neon atoms and ionize them. The incident EM wave enhanced the ionizing collisions. However, the electrons lost most of their energy because of collision when they move from cathode to anode. Around the anode, the ionization is very weak, so the effect of EM wave is also weak.

The EM wave detector can also measure UV light. In the experiment, the UV gun (ELC-410, Edmund Optics) has 200 ~ 400 nm wavelengths and 90 mW power. However, the light from UV gun is emanative and difficult to be focused. The detector was placed to the UV source, and the size of UV light is much larger than that of the detector. Less than 10% of the UV energy was measured by detector. If the UV beam can be focused to a small beam and illuminates detector, the waveform of the UV signal can be much better than that in **Fig. 5**.

IV. Conclusions

We used a commercial neon lamp to detect THz waves (0.1, 0.2, 0.37 THz), IR (800 nm) and UV light (200 ~ 400 nm). The amplified responsivities at 0.1 THz, 0.2 THz, and 0.37 THz are 150 V/W, 57.5 V/W and 19.3 V/W, respectively. Signal to noise ratio (SNR) of the detector for a THz wave (40 mW at 0.2 THz) is about 750 using a lock-in amplifier.

V. Acknowledgment

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