Optical Scanning Techniques for Characterization of Terahertz Photoconductive Antenna Arrays

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Abstract—**Optical scanning methods for characterizing radiation properties of THz photoconductive antenna arrays are proposed, and as an example, a fourteen element equally spaced array structure made on low temperature grown GaAs (LT-GaAs) is characterized using the proposed methods.**

I. Introduction

UNLIKE antenna properties at microwave and millimeter wave frequencies, the properties of antennas in the terahertz (THz) frequency range have not been fully investigated due to the lack of electronic instruments operating at THz frequencies. Terahertz signal generation using biased photoconductive antennas excited by laser sources is a low efficiency generation mechanism. Maximum radiated THz power is constrained by the size and thermal limitations of the photoconductive antenna elements. Array structures have been proposed and developed to increase the radiated THz power [1], [2]. In an efficient array structure, each array element can be operated at the optimum bias field and optical intensity, and a large number of elements can be properly positioned to give the required radiation pattern and maximum far field signal.

In optoelectronic THz sources and detectors [3], the THz signals are generated and detected by means of laser excitation. To characterize single element or arrays of these devices in terms of their radiation properties and antenna efficiencies, selective optical excitation techniques are needed in order to control the laser excitation of the antenna elements.

In this work, we propose optical scanning techniques for study and characterization of the radiation properties of photoconductive THz antenna arrays, and demonstrate the proposed approach for a fourteen-element THz array source.

II. Results

A 300μm × 300μm × 1.3μm LT-GaAs array structure [2] with fourteen equally spaced elements each with 11μm × 300μm active area was used in these experiments (Fig. 1). The array was fabricated on a semi-insulating GaAs substrate and then was transferred to a 500μm thick sapphire substrate. The array is illuminated through the sapphire substrate with 800nm light from a femtosecond mode-locked Ti:sapphire oscillator. The laser pulse was compressed with a pair of external dispersion compensation prisms, giving pulse duration of ~25 fs.

Using a knife edge mounted on a precise translation stage it is possible to sequentially activate a subset of the array elements. To ensure uniform excitation intensity (~50 W/cm^2 with chopper open), the optical beam diameter is much larger than the array dimensions. The peak THz electric field, detected by electro-optic sampling in a 1 mm thick ZnTe crystal, and dc photocurrent (average with chopper rotating) are shown in Fig. 2 for the knife edge parallel to the array electrodes, as a function of knife edge position. The number of steps in the peak THz electric field and dc photocurrent corresponds to the number of array elements. The small peaks in the detected signal can be attributed to diffraction from the knife edge.

The radiated THz electric fields from one element, 7 elements, and 14 elements, are shown in Fig. 3. The shape and the phase delay of the THz electric field waveforms are unaffected by the knife edge position, as shown in Fig. 3. However, if a metallic knife edge is too close to the array, the knife may affect the radiation properties. The spectrum of the radiated THz field from the entire array is shown in Fig. 4.

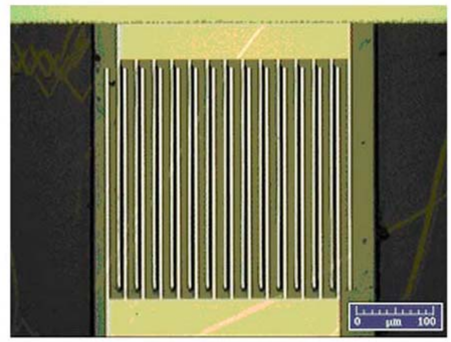

Fig. 1 Photograph of the 14-element THz photoconductive array antenna

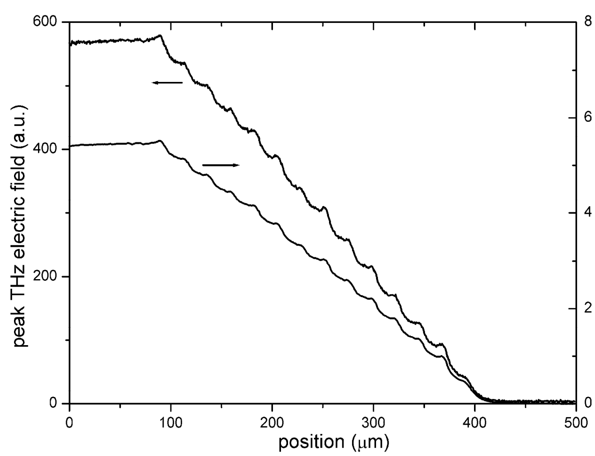

Fig.2 Peak THz electric field and dc photocurrent as a function of knife edge position

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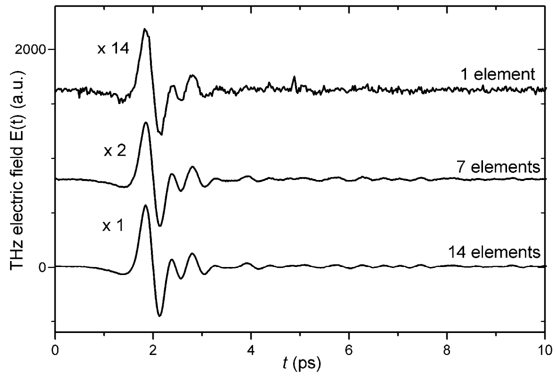

Fig. 3 THz electric field for three different numbers of active elements.

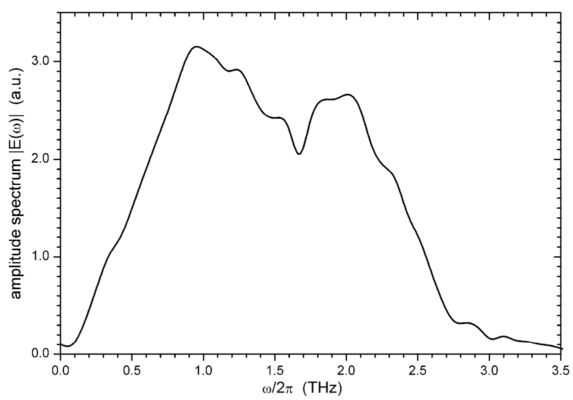

Fig. 4 Spectrum of the detected THz field from the entire array. Scan was done under dry nitrogen purge condition.

In order to excite individual elements of the array, a cylindrical lens (f = 15 mm) was used to create a line focus (linear power density ~0.3 W/cm with chopper open) at the array and parallel to the electrodes. The array is scanned in a direction perpendicular to the directions of the pump light propagation and the line focus orientation. The peak THz electric field, the dc photocurrent, and the transmitted infrared light through the device as a function of array position are shown in Fig. 5. The spatial resolution is limited by the width of the focal line (~8 μm). The photocurrent and THz signal are not uniform across the array, which can be due to the non-uniformity of the LT-GaAs material. The THz electric field and dc photocurrent are correlated, as expected.

Figure 6 shows the super-linear dependence of both the THz peak electric field and the dc photocurrent on the applied bias for a single element excited with the cylindrical lens. Also shown is the peak THz electric field of the entire array excited with uniform intensity 50 W/cm^2. The super-linear behavior is attributed to the increase in carrier lifetime in LT-GaAs with increasing bias electric field [4]. The active area excitation power for the single element is 9 mW and for the entire array is 23 mW. According to Fig. 6, the peak field from the single element is about 25% of the peak field from the entire array. The apparent onset of saturation in the radiated THz signal from the single element may be attributed to screening effects at high laser pulse fluences.

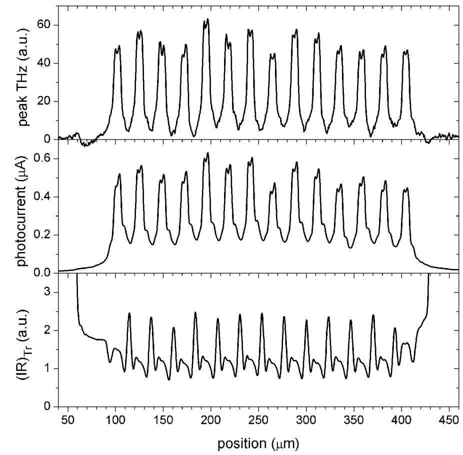

Fig.5 Peak THz electric field, dc photocurrent, and transmitted 800 nm infrared light through the device as a function of array position.

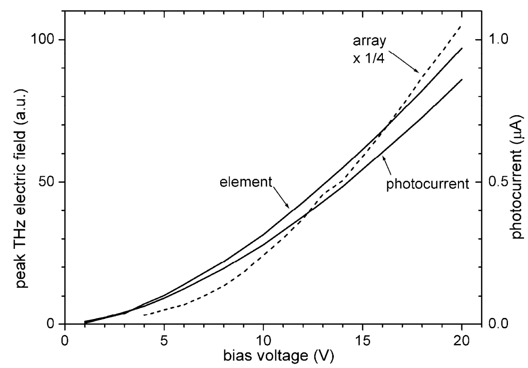

Fig. 6 Peak THz electric field for a single element, entire array, and dc photocurrent for a single element versus dc bias voltage.

III. CONCLUSION

The proposed optical scanning techniques are promising for characterization of radiation properties of THz photoconductive antennas.

IV. ACKNOWLEDGMENT

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