THz Photoconductive Antenna Array Based Near Field Imaging

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***Abstract*—In this work, a 2 × 2 photoconductive antenna (PCA) array is used in a THz near field imaging setup as THz emitters while the sample is placed close to the antenna array (the antenna-sample distance is about 10 μm). A microlens array is used to couple and focus femto-second laser pulse onto each antenna. The response of a sample of gold pattern on quartz is measured. A FDTD model combined with HFSS simulation is used to predict the time domain current and near field scanning result. Good agreement between simulation and experiment is obtained.**

I. INTRODUCTION

Terahertz time-domain spectroscopy (THz-TDS) is a very useful tool in various applications such as material characterization and identification, biomedical imaging and nondestructive detection. In a typical far-field imaging setup, the sample is placed in the far-field region of the THz antenna, either in transmission or reflection configuration. However, the resolution of a far-field system is restricted by the diffraction limit. Near field imaging can be applied to improve the resolution which is independent of wavelength but mainly determined by the scanning probe configuration [1].

Most of the previously reported THz-TDS near-field imaging uses the detection mode [1], where the sample is placed very close to the THz detector. Emission mode is also reported in [2] where a single emitting antenna is used for near field scanning. In this work, we apply a PCA array structure (2 × 2 stripline antenna array) as the THz emitters. With this configuration, a number of useful techniques can be applied including Hadamard multiplexing method to improve the SNR [3] and compressive sensing method to decrease the number of measurements [4].

II. SCANNING RESULTS

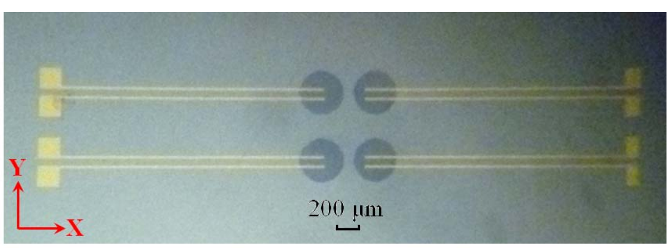

Fig. 1. Microscope image of the 2×2 PCA array (The stripline has 50 μm gap and 20 μm linewidth, the dark circles are SiO_2 passivation layers).

The PCA array is fabricated on an 800 nm laser-transparent sapphire substrate with 1μm-thick MBE-growth GaAs layer on top. The microscope image of the array is shown in Fig. 1. The antenna chip is later wire-bonded to a printed circuit board where the DC biases are connected and individually controlled by switches. We use backside laser illumination which ensures the sample to be within the sub-wavelength regime of the emitting antennas, about 10 μm in our experiment. The pump laser is split into four beams and each is focused onto one element of the PCA array using a microlens array with 500 μm pitch size. A single detector which is also a PCA is placed in the far-field region. A sample providing a dielectric-metal edge is fabricated with thin gold film partially covering a quartz substrate. The sample is mounted on a sample holder which is controlled by a 3D stage for later scanning.

Initial investigation of this near-field imaging system is carried out by scanning the gold film on quartz sample in the x-direction. Moreover, a time-domain simulation is performed by combing an in-house FDTD model with HFSS simulation. The received time domain signal at a fixed time delay (the first peak position of the signal when antenna is facing the quartz region) versus the scanning positions (with 20 μm step) using just a single antenna are plotted in Fig. 2 for both the simulation and experimental data and normalized to their peak values correspondingly. It can be observed that the spatial resolution defined by 10% to 90% edge response is about 360 μm corresponding to 0.142λ for the TDS peak frequency of 118 GHz. The results for the entire array will be presented in the conference.

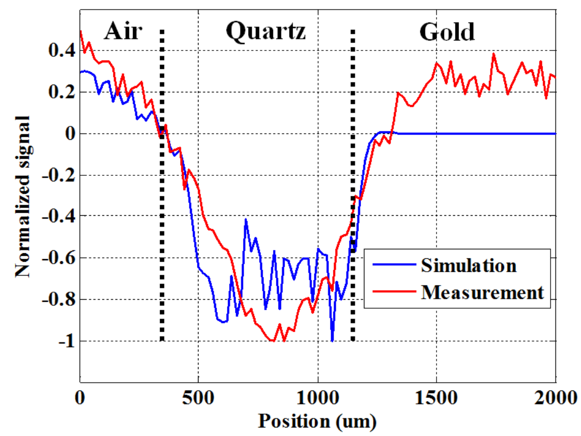

Fig. 2. Comparison of simulated and measured time domain signal at a fixed time delay versus different scanning positions.

III. SUMMARY

The near field imaging system incorporating a PCA array as THz emitters is designed and realized in this work. A resolution of 360 μm corresponding to 14% of wavelength is achieved. Further work utilizing Hadamard multiplexing method is being implemented to improve the system SNR.

REFERENCES

[1]. A Bitzer, A Ortner, and M Walther, "Terahertz near-field microscopy with subwavelength spatial resolution based on photoconductive antennas," *Applied Optics*, vol. 49, no. 19, pp. E1-E6, 2010.

[2]. I. Brener, S. Hunsche, Y. Cai, M. C. Nuss, J. Wynn, J. Lopata, and L. Pfeiffer, "Time resolved near field imaging and diffraction with sub-wavelength far-infrared dipole sources," *Ultrafast Phenomena XI, Springer Series in Chemical Physics*, vol. 63, pp. 171-173, 1998.

[3]. M. Harwit. Hadamard transform optics. *Elsevier*, 2012.

[4]. E. J. Candès, and M. B. Wakin. "An introduction to compressive sampling," *IEEE Signal Processing Magazine*, vol. 25, no. 2, pp. 21-30, 2008.