A 2 × 2 3D Printed Micro-lens Array for THz Applications

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***Abstract*—This paper presented a 2 × 2 3D printed micro-lens array, which is used for THz focal plane array imaging applications. Firstly, the quasi-optical receiver unit is designed, which consists of a planar antenna chip and lens based on 3D printing technology. Then, a prototype of 2×2 lens array are designed and optimized with the coupling effect taken into account. The radiation pattern are calculated and the mirco-lens array are fabricated. All the measurements are in progress.**

I. INTRODUCTION

TERAHERTZ imaging systems are preferred in several applications, such as biomedical science, security inspection, etc. The focal plane array (FPA) imaging is one of the most popular method [1], which need less mechanical scanning. As the key part of FPA, the THz array receiver is a big challenge, which needs compact structure for high resolution and low noise for high sensitivity. Traditional receivers based on waveguide technology are bulky and expensive. Therefore, quasi-optical array receiver is a good substitute due to its simple structure and good consistency by monolithic technology.

To optimize the radiation pattern of the array receiver antenna and increase its directivity, there are two options: a single large lens with antennas array or a micro-lens for each antenna. The case of a single large lens increases larger dielectric loss and makes beam deteriorated in positions away from the lens axis, thus limits the size of array. It is preferable to adopt micro-lens array to obtain a better directivity with a reflector antenna or objective lens. Pre-existing design use optical photolithography [2] or micro-machine [3] technology to achieve the required precision. However, they are still costly and difficult to produce complex geometrical parts.

To solve the problems above, we studied a novel low cost approach to realize the micro-lens based on 3D printing. As an emerging technology, 3D printing could machine arbitrary shape and made the process more flexible. The materials used usually are photosensitive resin, nylon, ABS plastic, etc. By measuring their transmittance using THz time-domain spectroscopy (THz-TDS) technique, we could select particular material produce large scale lens array. In this paper, a low dielectric constant ($\varepsilon = 3.5$) polymer material was chosen. Firstly, the lens unit is designed and optimized. Then, a prototype of 2 × 2 array is studied, which take the coupling between two adjacent units into account. The optimized micro-lens prototype are fabricated for subsequent tests.

II. UNIT DESIGN

The quasi-optical receiver mainly consists of a lens with antenna array chip on the back, as shown in Fig. 1. The antenna on the array chip is a compact structure, with the nonlinear devices directly planted at the feed port of the planar antenna. The THz radiation is focused and concentrated to antenna chip in the middle of back. Due to the integrated nonlinear device, it could realize direct detect or heterodyne receive with LO feed.

In this contribution, we use the antenna chip reported in previous work [4], which is a planar antenna integrated with Schottky diode, as the primary feed. The antenna is a self-complementary log-periodic antenna designed to cover 340 GHz band. The Schottky diode shown in GaAs antenna chip, have a anode diameter of 1 um, measured average series resistance of 5 Ω and zero-bisa capacitance of 10 fF. The cutoff frequency of the Schottky diode is evaluated to be 2.6 THz.

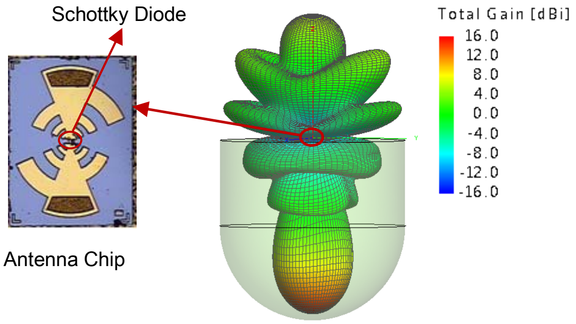

Fig. 1. The quasi-optical receiver unit and antenna chip are shown.

A single micro hyper-hemispherical lens ($D = 3\lambda_0$) is designed to verify the scheme. The micro hyper-hemispherical lens [5] unit is designed and optimized by MLFMA algorithm, of which the key parameters of the diameter and the extension length is determined to be 2.65 mm and 1.2 mm respectively. Fig.1 shows its radiation pattern. The single lens could achieve a gain of 18.8 dB with a -3 dB beam width of 15 deg is obtained, which shows the feasibility of the method.

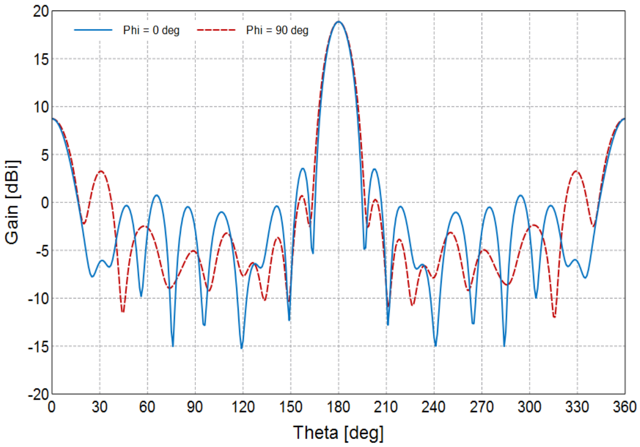

Fig. 2. Calculated radiation pattern of the micro-lens unit. The quasi-optical receiver mode and antenna chip are also shown.

III. ARRAY DESIGN

On the basis of receiver unit, we extend the above design to two-dimensional structure. The micro-lens is arranged to be tangent. Therefore, the 2 × 2 lens array is composed of a cube and four hemisphere structure. The cube size is 6 mm × 6 mm × 1.2 mm, with additional area for securing. The model could be built in SolidWorks, and be input a 3D printer directly for printing. Fig. 3 gives the lens array model and a prototype produced by FARSOON printer.

Influence by the reshaping extension should be take into account. Fig. 3 depicts the calculated near field distribution at the designed 2 × 2 lens array antenna aperture. The energy propagate coincides with single lens. Mutual coupling between elements are below -40 dB, which indicates it has comparatively high channel isolation.

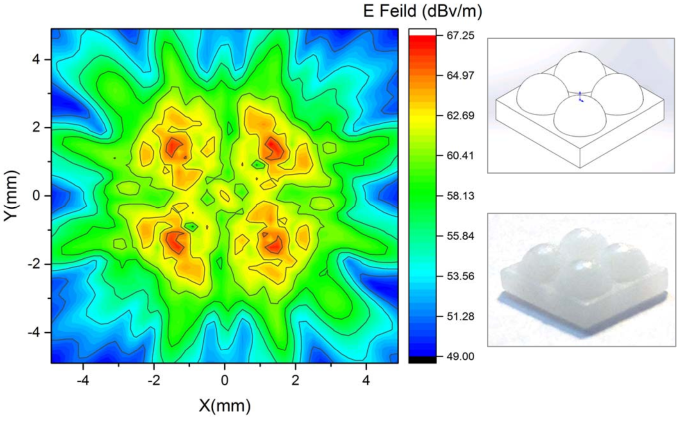

Fig. 3. Near field distribution of the 2 × 2 lens array at 340 GHz. Thumbnails of the array model and photograph is attached.

Calculated radiation pattern of the array is shown in Fig. 4. The maximum gain is 15.7 dB with side and back lobe edged up slightly. Corresponding unit antenna aperture efficiency is 42%. The main lobe of elements deviates from optic axis less than 2 deg under the influence of dielectric of adjacent units. It is expected to be eliminated when the array extended to larger scale, when symmetrical structure counteract the effect.

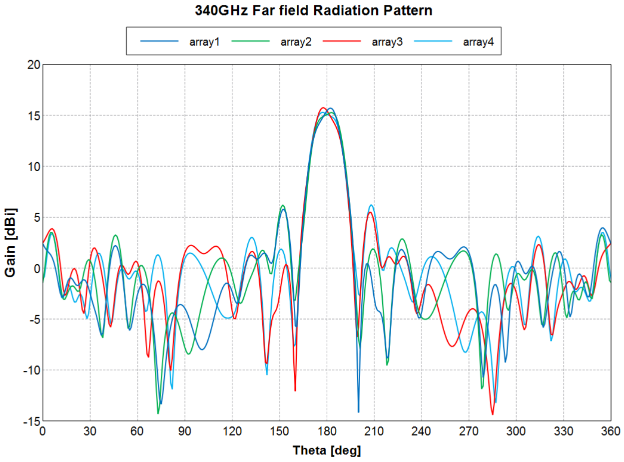

Fig. 4. Calculated radiation pattern of the designed 2 × 2 lens antenna array for FPA aplication at 340 GHz.

Antenna chip for lens array can be designed and fabricated as a whole to ensure positioning accuracy, and reduce the complexity. As THz radiation received, the down-converted signal is extracted by a readout circuit in each channel. The receiver works in the square law detection mode under small signal injection. From the recorded output power, we could deduced the response of the antenna in various angles, thus measure the directivity for every unit.

IV. SUMMARY

We demonstrated the concept of 3D printed dielectric micro-lens, and adopted this lens antenna for a 2 × 2 340 GHz receivers array. The design is easily to extend large scale to achieve more pixels, and is available for FPA imaging with a objective lens. Measurement of the lens array is preparing now.

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