Si metalens for quasi-optical THz HEB mixer arrays

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***Abstract*—We present the development of a Si metalens for large THz hot electron bolometer (HEB) mixer arrays. The metalens of 1×1 cm² is based on a metasurface consisting of 100 μm long rectangular Si pillars with variable area, arranged in a 50×50 μm² periodic pattern. As proof of the concept, we designed a metalens with a focal distance of 1 cm. A prototype of the metalens has been fabricated on a Si wafer using a deep reactive ion etching process. The metalens was optically characterized at 2.1 THz and was demonstrated successfully by focusing a collimated beam at its designed focal distance.**

***Keywords*—Metalens, metasurface, THz, HEB mixer array**

I. Introduction

HEB mixer arrays have already been used for THz observatories, such as SOFIA and GUSTO, due to the fast-scanning speed, which is roughly scaled to the number of pixels. GUSTO has arrays of 8 pixels using lens-antenna quasi-optical HEB mixers [1]. Using individual elliptical lenses, as for the GUSTO arrays, will be extremely challenging to extend to future arrays of ≥100 pixels. Here we present a metalens concept, that can lead to an flat lens array on a Si wafer, which can be integrated with an HEB array on another Si wafer to form a large HEB array of ≥100 pixels.

II. Results

Fig. 1a shows a photograph of a fabricated metalens on a 525 μm thick Si wafer. The metalens is designed to have a focal distance ~1 cm as a proof of the concept and is composed of meta-atoms of rectangular pillars, with a periodicity of 50 μm. The lateral dimension of each Si pillar varies from 4 to 40 μm to cover the full phase shift from zero to 2π, which is the relative phase change of the transmitted light with respect to the original light. A similar approach was reported [2][3]. A 2D finite element simulation is used to estimate the focusing effect of the designed metalens shown in Fig. 1c. A laser writer was used for the lithography in the fabrication, while 100 iterations of a Bosch process were performed in an ICP-RIE system to etch and to form Si pillars of 100 μm in depth, shown in Fig. 1b. With an incident Gaussian beam of ~ 1 cm in diameter at 2.1 THz normal to the metalens, the focal distance is expected to be ~ 1cm, as illustrated by the red region of high intensity in Fig. 1c. To optically characterize the metalens, we used the 2.1 THz radiation from a QCL operated in a Stirling cooler. The QCL beam was collimated using an off-axis parabola. The collimated beam measured in front of the metalens and focused beam at the designed focal point are shown in Fig. 2**a** and **b**, respectively, confirming the focusing effect.

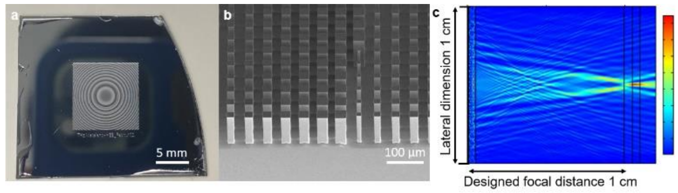

Fig. 1. a) Photograph of the metalens. **b)** 45° tilted view of the Si nanopillars after cleaving the middle of the sample from **a)**. **c)** Finite element simulation of the focusing effect of the metalens shown in **a).**

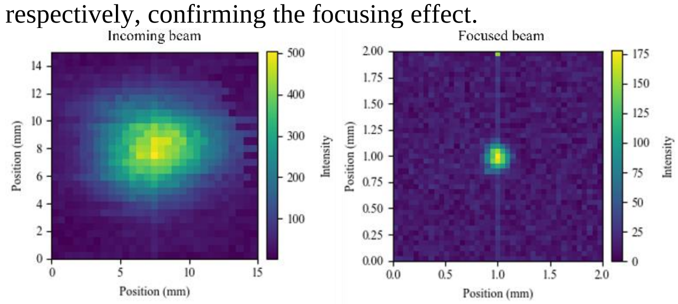

Fig. 2. a) Collimated incident beam measured in front of the metalens and **b)** beam measured at the designed focal point of the metalens.

III. Conclusion

We successfully designed, fabricated, and demonstrated a flat lens at 2.1 THz using a meta-surface, aiming for large HEB arrays. Currently, we are working on a new design of metalens at 2.5 THz, which can combine with a twin-slot antenna HEB to demonstrate the lens-antenna system.

References

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