Design and fabrication of metasurface collimating lens at 300-GHz-band

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With the advancements in various semiconductor technologies that operate at millimeter-wave bands (30 ~ 500 GHz), numerous applications in radar, sensing, and imaging were developed. The development of radars in bands between 24 and 79 GHz was demonstrated in automotive applications [1]. These types of devices can perform low-resolution mapping and detection in relatively uncluttered scenes but do not allow for object recognition. Contrarily, the use of higher frequencies, e.g. 300 GHz, can notably improve the resolution of sensors for short-range applications, allowing also for object recognition [2].

Like in wireless communication, various beamforming techniques were developed in radar and sensing to allow for the formation of beam radiation patterns, beam scanning, or spectral selectivity, among which metasurface devices have been intensively studied as an enabling technology for millimeter-wave radar and sensing. While phase gradient metasurface designs allow to achieve beamforming of the incident beam, the output power is often lower than the input antenna signal. To increase the output power that is necessary for radar and sensing applications, the side lobe power need to be guided towards the main lobe direction. Subsequently, multiple types of lenses and collimators were developed at lower frequencies.

In this work, we have designed and fabricated a set of collimating lenses that can precisely focus the incident beam into the desired direction at the 300 GHz. Fig.1(a) shows a continuous 2π phase controllable multilayer metamaterial cell used in this work. The small cell size of 0.25 mm ($\lambda/4$ @300 GHz) allowed for a higher transmission efficiency design of a multi-bit metasurface lens, due to a smaller step size (higher quantization). The change of the phase was achieved by the variation of the radius, *r*, of the metamaterial cell in the range of 0.07 mm to 0.12 mm. Cells were organized into a 3-bit (8-phase step) lens pattern that was designed based on the calculated phase profile of the lens for given focal points f_1 and f_2 on both sides of the lens. In the schematic in Fig. 1(b), cells of different sizes are organized into radial patterns with a transmission phase step of $\Delta\varphi = 45°$ between each zone. The inset shows an image of a fabricated device. Fig. 1(c) shows the simulation and experimental results of near-***E***-field obtained for the collimating lens in this work, at 300-GHz-band. A highly collimated beam was obtained in both simulation and experiment, validating the design, and accuracy of fabrication. To the extent of our knowledge, this is the first experimental work showing collimating lenses at 300-GHz-band for sensing and radar applications.

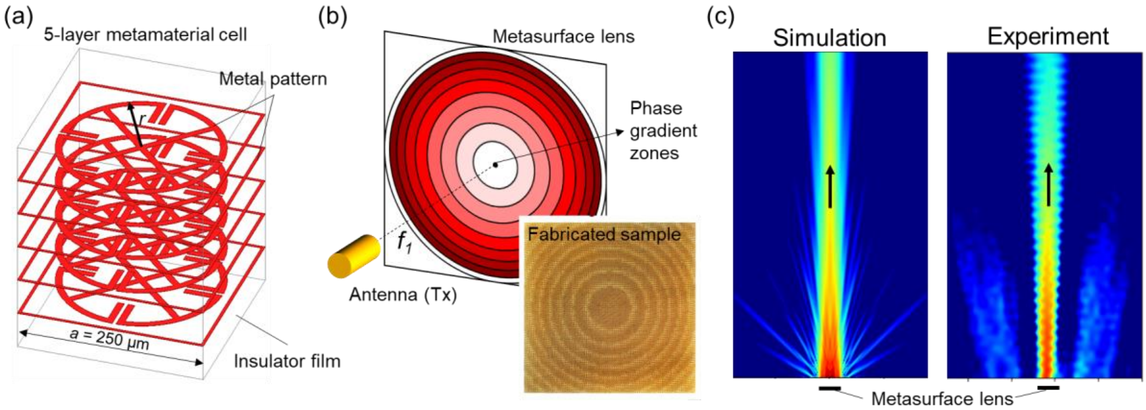

Fig. 1. (a) Schematic of multilayer metamaterial cell. (b) Schematic of multibit collimating lens patterns and fabricated device. (c) Simulation and experimental results of the near-***E***-field distribution.

Reference

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[2] L. Daniel, *et al.*, Sub-THz Radar Imagery for Automotive Application, in Proceedings of the 19th European Radar Conference, 2019.