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Chromatic Transmitarray for 3D Terahertz Imaging

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The terahertz frequency range spanning from 0.1 to 10 THz has been foreseen for diverse applications, such as ultrafast-data-rate wireless communications and non-destructive imaging [1]. Beamforming techniques, which aim at creating desired beam patterns in the near- or far-field region, play an essential role in bringing these applications to fruition. To this end, transmitarrays, which are commonly formed by arranging subwavelength metallic or dielectric radiating elements as a planar and periodic array, offer an effective route to tailoring the magnitude, phase, and polarization of terahertz waves [2].

Conventional transmitarray-based lenses focus a collimated incident beam into a point at a single frequency. As such, employing them to acquire the 3D profile of an object with a large depth of field requires tedious 3D mechanical scans, which are highly inefficient for practical scenarios. Alternatively, various designs obtaining tunable focal lengths have been proposed for confocal imaging. However, they either employ phase-change material [3] that is capable of focusing terahertz waves at only discretised distances or involve stretchable substrate [4] that requires applying different levels of strain to gradually adjust the focal length.

Here, we propose a broadband transmitarray exhibiting frequency-dependent focal lengths towards terahertz confocal imaging. More specifically, Fig. 1(a) illustrates the manufactured structure employing split-ring resonators of variable sizes that are sandwiched by two orthogonal wire grids [5]. The transmitarray concurrently focuses terahertz waves of different frequencies at distinct focal lengths, as revealed in Fig. 1(b). The measured focal spot continuously migrates with a total distance of 21.9 mm from 220 to 330 GHz. This unique feature makes it distinct from the existing designs and ideal for extracting the 3D profile of a multi-layer structure by simply implementing 2D raster scans.

To demonstrate its functionality of acquiring 3D image of an object, a 3D-printed Siemens star in Fig. 1(c) consisting of 14 spokes with heights ranging from 1 to 14 mm is raster scanned under the illumination of focused beams. Figure 1(d) indicates that the 3D profile of the Siemens star can be reconstructed by stacking multiple images taken at different frequencies. Potential applications of the proposed transmitarray include in-situ detection of defects in materials and concealed objects identification in security screening.

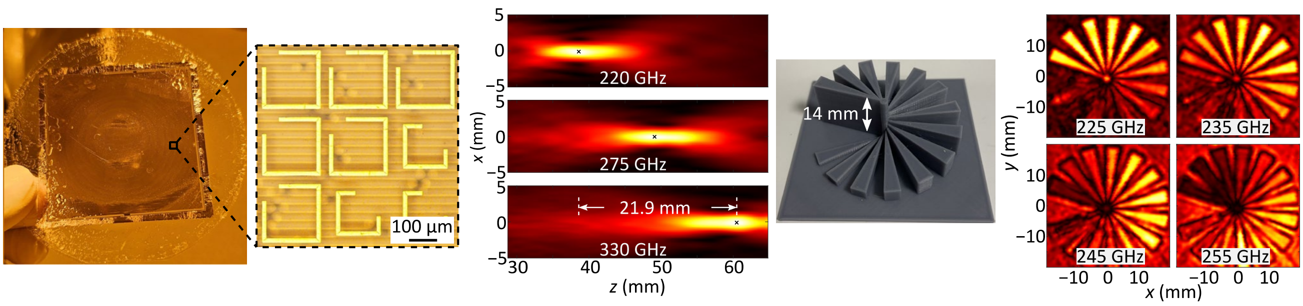

Figure 1. Broadband focusing transmitarray and its demonstration for terahertz confocal imaging. (a) Fabricated free-standing prototype, where an inset shows the magnified view of the middle metallic layer. (b) Measured focused beams at 220, 275, and 330 GHz in the *xz*-plane, where black crosses mark the positions of focal spots. (c) 3D-printed Siemens star for terahertz imaging and (d) its reflections at different frequencies.

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