Conformable metasurface patches for mm-waves holographic application

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Abstract

We present our work on the design, fabrication and characterisation of conformable metasurface patches in the mm-wave range for holographic applications.

1. Introduction

Metasurfaces Flexible metasurfaces merge the versatility of rigid metasurfaces with the practical advantages offered by a supple and conformable physical platform. In particular, they can be transferred onto virtually every target material or object, they can be mechanically tuned (statically or dynamically) after fabrication and they can exploit the mature manufacturing technology typical of printed electronics to scale up their area and manufacturing volume. These advantages are perhaps best exemplified by our recent demonstration that holographic metasurfaces can be placed on curved targets and, most importantly, that the designed holographic image depends on the specific shape of the target. [1, 2] Here we demonstrate that the flexible hologrphic metasurfaces (FHMS) can be scaled to the GHz range, for antennas and radar applications [3].

2. Results and Discussions

To design our metasurface we use the Gerchberg-Saxton iterative phase reconstruction algorithm (GSA). The inputs for the GSA are the required image and the source intensity. The output of the GSA, after many iterations, is a phase distribution which we encode into the metasurface. This is achieved by texturing at subwavelength scale the surface of the metasurface, defining suitably designed meta-atoms. Each meta-atom enforces a unique de-phasing to reflected radiation, between 0 and 360 degrees. In a recent paper [4] we demonstrated a modified GSA with the ability to tailor the holographic image to the shape of the FHMS, conformally coating a given target. The approach used a popular three layers geometry to create boradband and efficient reflection holograms. Here we show that the scheme can be adapted to the mm-wave range, choosing suitable substrates and c-ring meta-atoms designs. The fabrication procedure started depositing a sacrificial lift-off layer and a 5 μm thick polymeric substrate (SU8 in this case) on a rigid carrier (e.g. glass), followed by the deposition of 200 nm of gold via e-beam evaporation. The meta-atoms were then defined with an electron beam lithography step and trasnferred onto the gold layer with a dry etch process. The sacrificial lift-off layer was then dissolved to leave a free-floating membrane, which was placed on a 400 μm thick polymeric membrane, with a reflective backplane made of gold.

To characterise the FHMs we built a dedicated setup operating at 94 GHz. A mm-wave Gunn oscillator source is coupled to free space with a corrugated feedhorn and the beam is collimated with a suitable lens and directed at normal incidence towards the sample, via a polarising beam splitter (with the electric field parallel to the optical table). The FHMS is designed to create an image in reflection for the orthogonal polarisation. The reflection goes through the beam splitter, and is detected with a single mode waveguide X-Y scanning probe which is coupled to a heterodyne receiver. The intermediate frequency (IF) signal from the receiver is measured with a spectrum analyser. A laptop controls a beam scanner that records the power as a function of spatial position to map the output beam from the FHMS.

To demonstrate the successful realisation of a conformable holographic patch, we designed a FHMS for non-flat surfaces. Without loss in generality, we used on a non-flat cylindric design, using as the holographic image a focused spot displaced respect to the direction of geometric reflection. Fig. 1 shows a photograph of the FHMS patched applied to the target object and the raster scan image of the reflected beam, acquired at 10 cm distance from the metasurfaces, for the bare aluminum cylinder and for the patched case, both for the co- and cross-polarization cases.

In this communication we will discuss critically the limits and opportunities of the presented technology, placing particular emphasys on the novelty offered by an advanced design that allow to create different images for different curvatures and on the manufacturing of large scale holographic metasurfaces.

3. Conclusions

FHMS are a robust and credible platform to translate the metasurface technology out of the lab and deploy it in realistic environments. The ability to design at will the scattering of an object in the mm-wave range opens intriguing scenarios for antennas and radar applications. FHMS are conformable and tunable and can be used for novel de-

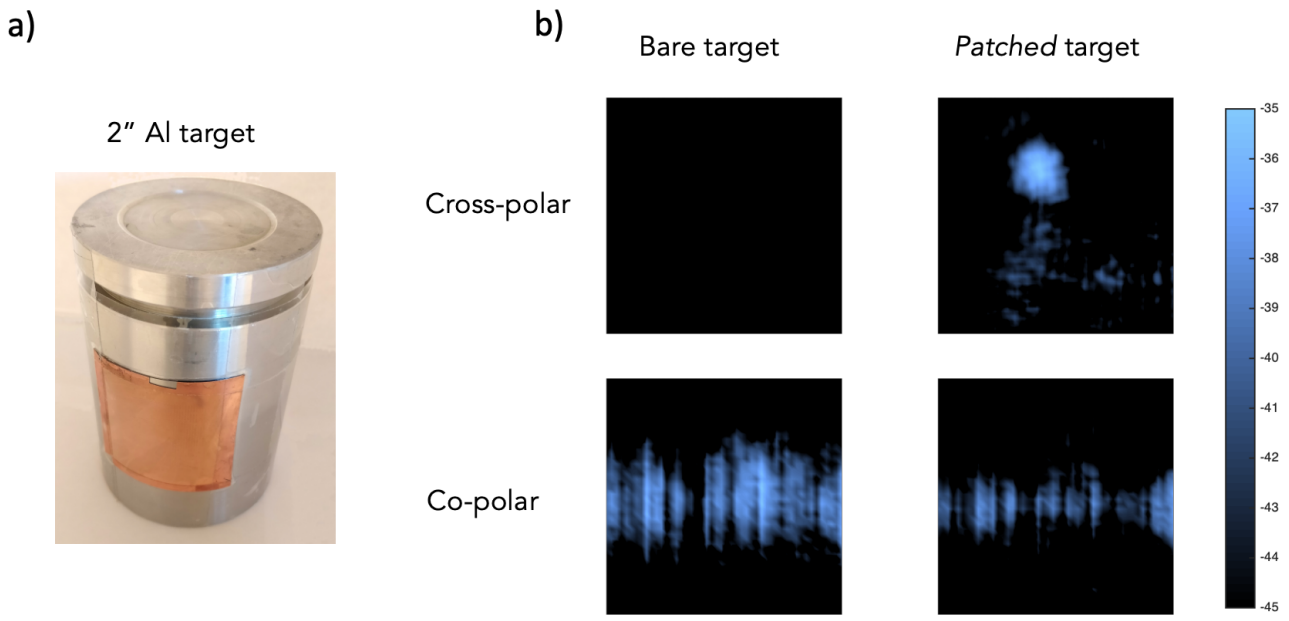

Figure 1: Figure 1. a) Photograph of a flexible holographic patch applied to an aluminum target. b) co- and cross-polar raster scan of the reflected beam for bare and patched cylinder.

signs or to retrofit existing devices with complex shapes and topologies.

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