Tunable optical metasurfaces for continuous beam steering and dynamic focusing

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Optical metasurfaces are ultrathin layers of nanostructures that enable a high level of control over the propagation of light. Dynamically tuning of various functionalities of metasurfaces is highly desirable for many applications. I will introduce recent results from my research group in the University of Southampton, UK on tunable optical metasurfaces. The tuning is achieved by using coherent control [1], which employs two coherent, counter-propagating light beams to illuminate a metasurface or a thin metamaterial. The coherent interference of these two incident beams creates an electromagnetic field that depends on the location and the relative phase and intensity of the incident waves. As a metasurface is sensitive to the local electromagnetic field, the coherent control can highlight and suppress different resonances in the metasurface. This control scheme can be used on freestanding thin films, as well as on metasurfaces and metamaterials fabricated on a thick substrate [2].

We have recently demonstrated via numerical simulation a coherently controlled, beam-steering metasurface (Fig. 1). The metasurface consists an array of silicon nanopillars on top of a glass substrate. The optical response of individual pillars can be tuned by controlling the relative phase and strength of two incident light beams. The collective response of all the pillars results in a tunable phase gradient across the metasurface, which dictates the direction of the output laser beam. Within the calculated range, the direction is tuned within a range of approximately 10 degrees. Rearranging the nanopillars on the interface produces a metasurface with a tunable focal length.

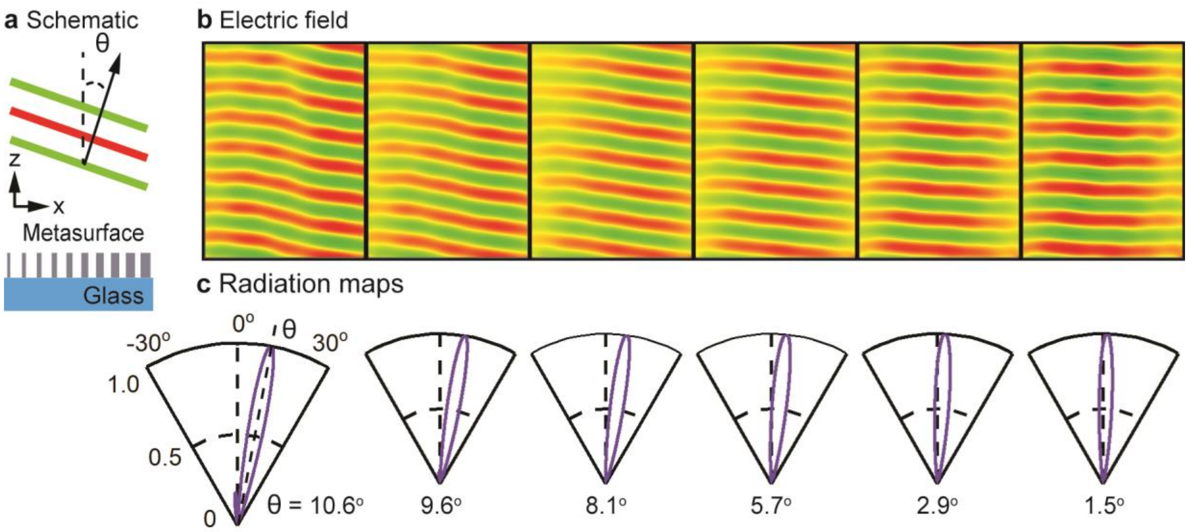

Fig. 1 Beam steering characteristics of a metasurface. (a) Device schematic with the steering angle specified. (b) The output electric field under six different illumination conditions, where the relative phase or strength of the two incident light waves (not depicted) vary with the illumination condition. All the maps are normalized against the same value and are at the same color scale. (c) Corresponding radiation patterns, with each map normalized against its respective maximum.

Reference

1. X. Fang, K. F. MacDonald & N. I. Zheludev. *Chapter 7 Controlling Light with Light via Interference on Photonic Metamaterialsin*, in Quantum Photonics: Pioneering Advances and Emerging Applications, R. Boyd, S. Lukishova, and V. Zadkov ed. (Springer, 2019).
2. F. He, K. F. MacDonald & X. Fang. Coherent illumination spectroscopy of nanostructures and thin films on thick substrates. *Optics Express* **26**, 12415 (2018).