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Moiré metasurfaces: low-cost solution for dynamic beamforming

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Dynamic beamforming is a critical technique in many applications such as radar detection, holographic imaging, and reconfigurable intelligent surfaces (RIS). Current approaches for achieving dynamic beamforming rely on the excessive use of active components (e.g., pin-diodes, varactor diodes), which inevitably cause serious cost issues in large-scale commercial deployments, especially at millimeter-wave and sub-terahertz frequencies, at which such active components become extremely expensive or even commercially unavailable.

In recent years, there has been a renewed interest in the rich physics that emerges in the moiré unit cells formed by two mutually twisted two-dimensional (2D) materials. Here, we report an entirely new mechanism for reaching dynamic beamforming through two closely stacked metasurfaces (Figure 1). More specifically, we can control the beam direction continuously in the reflection space by simply making in-plane twisting of two metasurfaces. Intriguingly, by designing different pattern styles for each metasurface, we can have a wide variety of choice on the number and direction of the beams, and their trajectories with the mutual rotation. In this work, we design and experimentally demonstrate two different moiré metasurfaces, the chessboard-type and triangular-type, which produce four-beam and six-beam radiations, respectively. Remarkably, the beam efficiency achieved by our moiré metasurfaces is even greater than the conventional metasurface designed with super unit cell configuration. Note that the design of moiré metasurfaces is fundamentally different from all previously reported moiré metasurfaces, in which the separation between the two metasurfaces is designed large enough to ensure linear combination of the functionality of each individual layer.

In additional to the low-cost benefit, the presented moiré metasurface with fully passive design have many other outstanding features, such as zero-static power consumption, zero receiver noise, high-power handling capacity, showing great potential for RIS and electronic warfare applications. By considering multi-layer stacking configuration, future moiré metasurface are expected to have larger flexibility on the beam trajectories.

Our work opens up new routes for synthesizing far-field scattering through the tight stacking of ultrathin metallic patterns with different plane symmetry groups, which is not only of fundamental importance but also shows great potential in many engineering applications. We therefore believe that our work will generate a broad impact in the communities of electromagnetism, antenna design, and wireless communications.

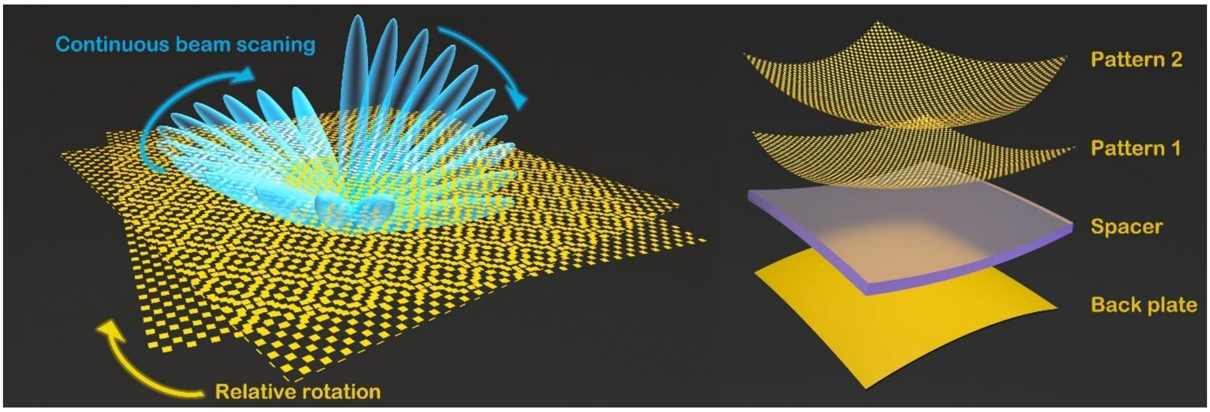

Figure 1 Schematic illustration and composition of a moiré metasurface.