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Flexible Metasurface with Reconfigurable Intrinsic Chirality from Zero to Near-unity

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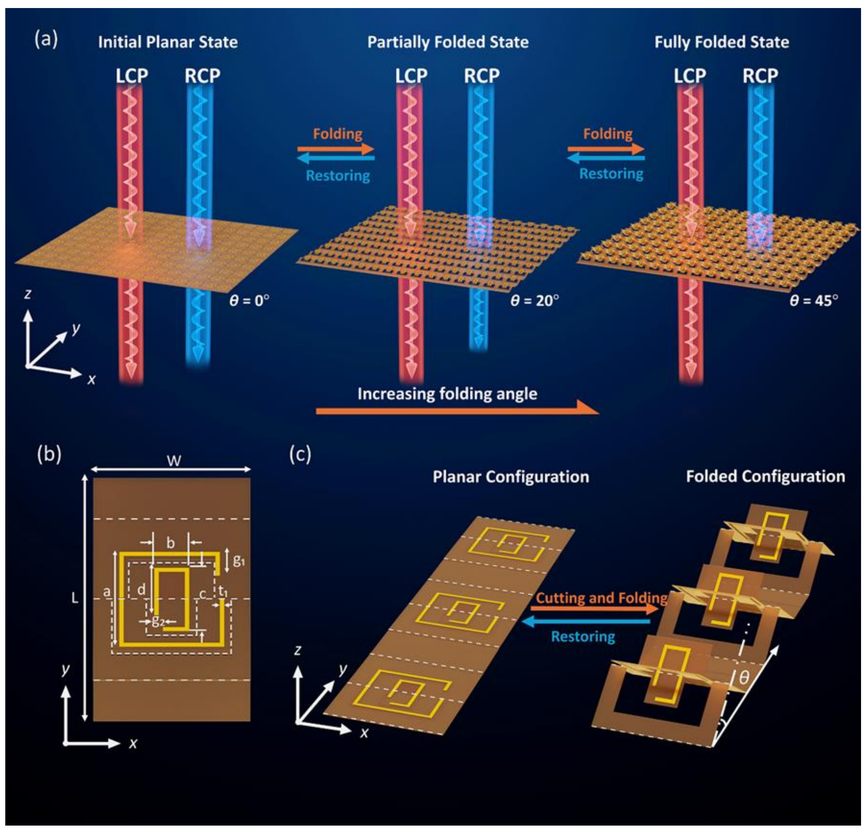
Introduction

◆ Chiral responses in electromagnetic metasurfaces are generally classified into extrinsic chirality, produced by asymmetric interactions with the incident wave, and intrinsic chirality, originating from 3D symmetry breaking of the unit cell [1-2]. However, most metasurfaces can only control one type at a time. To overcome this limitation, we propose a kirigami-based flexible metasurface capable of dynamically and continuously tuning chirality. The flat, unfolded structure shows only extrinsic chirality under oblique incidence. When kirigami cuts and folds are introduced, the metasurface transforms into a 3D chiral geometry, enabling tunable intrinsic chirality together with asymmetric extrinsic chirality. Increasing the folding angle continuously enhances the chiral response, yielding strong and adjustable circular dichroism across the X-band.

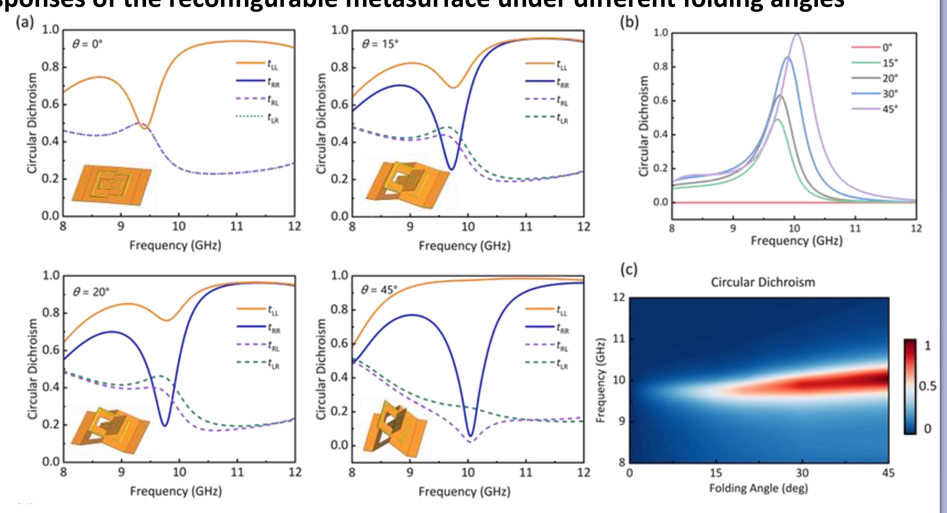


Simulation

◆ **Transmission and chiral responses of the reconfigurable metasurface under different folding angles**

To verify this mechanism, we use the commercial finite element software COMSOL Multiphysics to simulate the circular polarization transmissions of the metasurfaces with different folding angles.

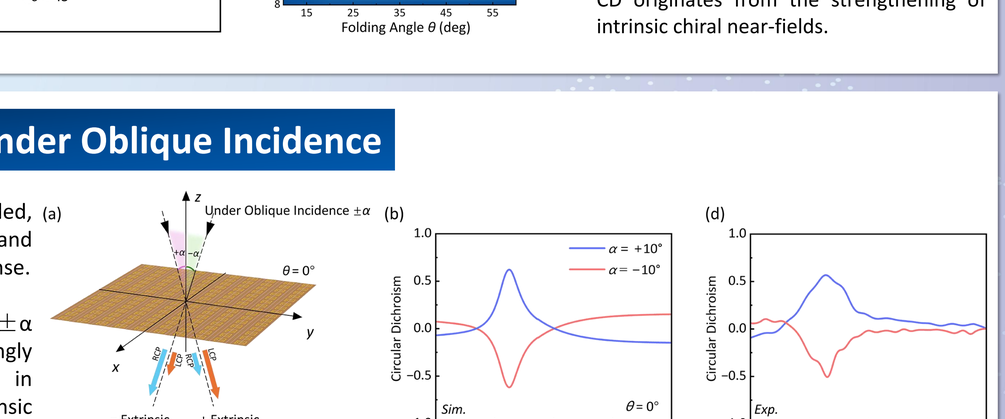
As the folding angle θ increases, a growing difference emerges between t*LL* and t*RR*. At θ=45° , tLL approaches near 1 while tRR drops close to zero, demonstrating a high-efficiency circular polarization-selective transmission and implying a significant CD.



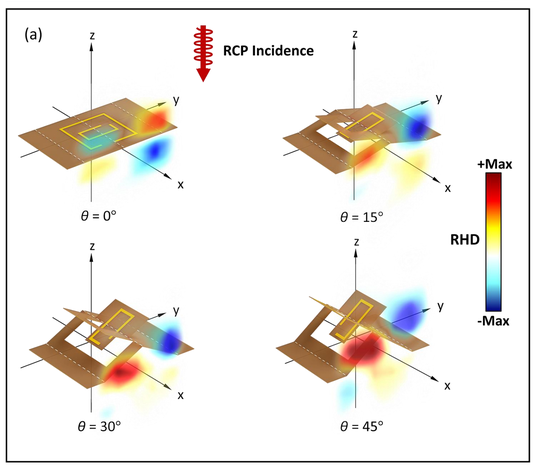
Multipole Analysis

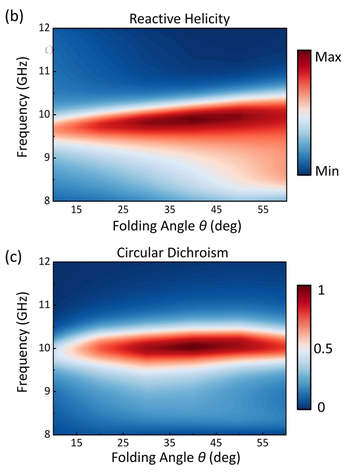
◆ The calculated scattering cross sections of ED, MD, and TD components [3] under LCP and RCP incidences.

◆ Compared to the LCP case, the RCP incidence induces significantly stronger ED and TD, indicating a polarization-sensitive multipole response.



RHD Distribution





We introduce the Reactive helicity density (RHD) [4] as an evaluation metric, which plays a significant role in characterizing the generation of chiral radiation.

$$\chi_r = \frac{c}{\omega}\mathrm{Re}\left(\mathbf{B}^* \cdot \mathbf{D}\right),$$

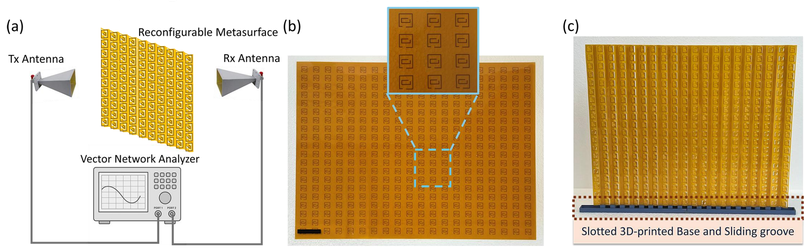
which quantifies the strength and handedness of the local chiral near-fields.

As folding angle increasesthe regions of opposite helicity become increasingly unbalanced, forming strong localized chiral near-fields.
The RHD with CD spectra, and both exhibit a similar increasing trend as the folding angle rises, confirming that the enhanced CD originates from the strengthening of intrinsic chiral near-fields.

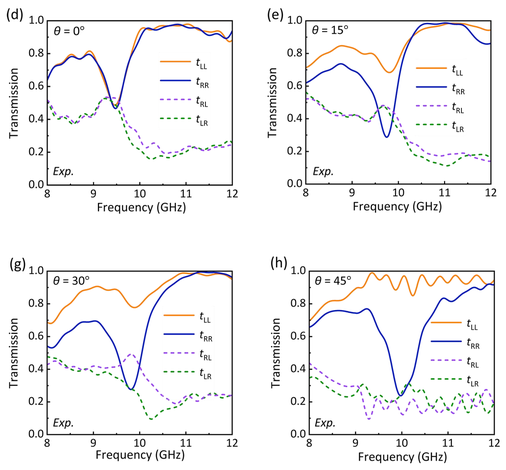
Experimental Results

◆ **Measurement**

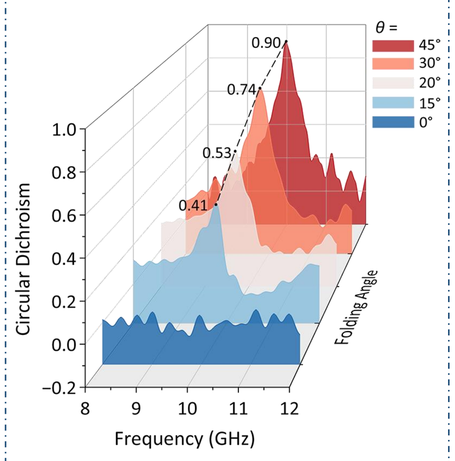
Schematic of the experimental setup using two linear-polarized horn antennas for transmission measurement, along with a vector network analyzer.



◆ The experimentally measured transmission coefficient spectra of circular polarization components at folding angles of 0° , 15° , 25° , 30° , and 45° , respectively.



◆ The measured CD spectra calculated from (d)-(h) with peak value reaching 0.90 near 10 GHz.



Asymmetric CD under Oblique Incidence

Once the structure is folded, intrinsic chirality appears and couples with the extrinsic response.

This coupling breaks the ±α symmetry, resulting in strongly asymmetric CD spectra both in simulation and experiment, intrinsic and extrinsic chiralities do not simply add — they interfere nonlinearly, creating a hybrid effect that allows rapid and wide-range control of circular dichroism.

This hybrid mechanism is what enables our metasurface to achieve nearly unity CD with only small changes in folding angle or illumination direction.

Reference

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