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Multi-feed multi-mode metasurface for independent orbital angular momentum communication in dual polarization

Key words: Orbital angular momentum (OAM); Geometric phase; Multi-feed metasurface; Spin-decoupled metasurface; Vortex beam communication

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Motivation

The motivations of this paper are to address the limitations of existing metasurfaces in controlling circularly polarized (CP) wavefronts and orbital angular momentum (OAM) modes. The limitations include:

1. Lack of independent control: Most metasurfaces can control only one CP state or OAM mode at a time, limiting their ability to generate beams with dynamically switchable CP states and OAM combinations.

2. Static mode combination: Passive metasurfaces that generate multi-mode vortex beams often have a fixed combination of OAM modes, which restricts their practical applications in multi-mode multiplexing.

Motivation

3. Complexity and loading: Metasurfaces loaded with active components can achieve electronically controlled OAM modes, but this adds complexity to the design, especially for multi-bit-coding elements.

4. Uncontrollable energy distribution: Existing multi-feed metasurfaces that control OAM modes often lack control over the energy distribution between different OAM modes.

These limitations motivate the development of a multi-feed spin-decoupled metasurface allowing for dynamic switching, energy-controllable OAM beams, polarization-controllable beams, and low cross-polarization.

Main idea

The main ideas that deal with the above-mentioned limitations in this paper are:

1. spin-decoupled metasurface that can independently control different CP waves by combining the geometric phase and propagation phase;

2. multi-feed design in the metasurface to independently control multiple OAM modes;

3. integrating an amplitude term to balance the energy distribution in different OAM modes; and

4. investigating the robustness of the proposed elements to ensure practical application and minimize phase errors.

Method

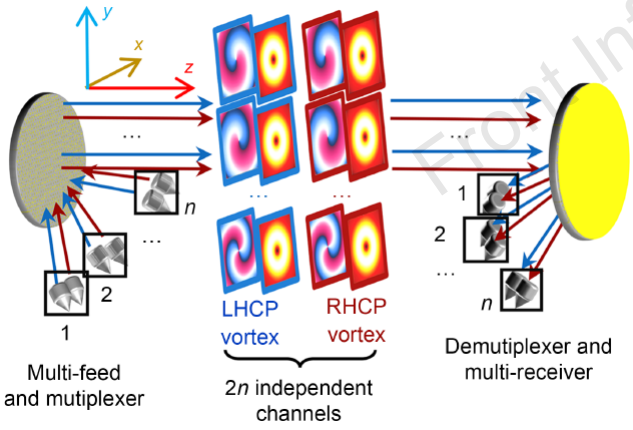
1. Theoretical analysis and simulation: The simulation results are compared with theoretical predictions to validate the performance of the metasurfaces.

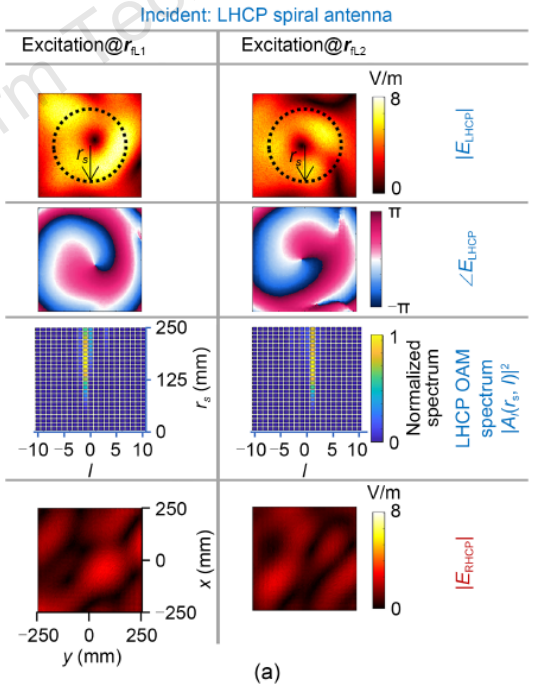
2. Experimental verification: The fabricated metasurfaces are tested for generating and controlling OAM modes, as well as for achieving independent control of spin states and OAM states in a four-channel system.

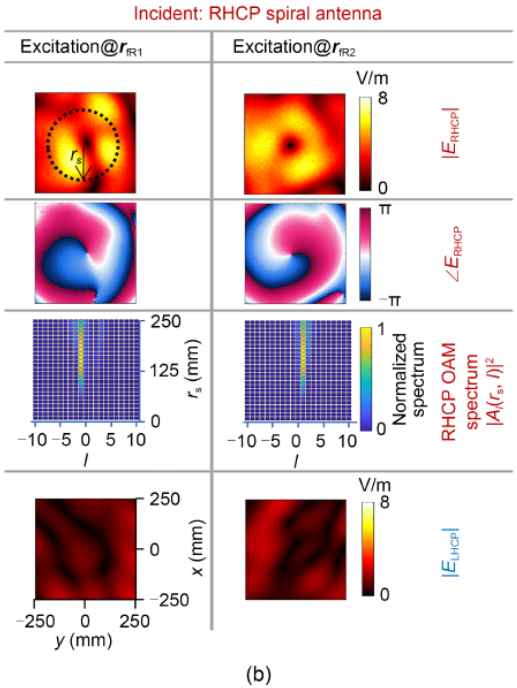
3. Communication system implementation: Demonstrating the application of the metasurfaces in a communication system demultiplexing four SAM-OAM modes with low crosstalk.

Major results

1. By exciting different antennas, the metasurface can dynamically switch between different OAM modes and polarizations, allowing for the generation of high-purity and low cross-polarization OAM beams.

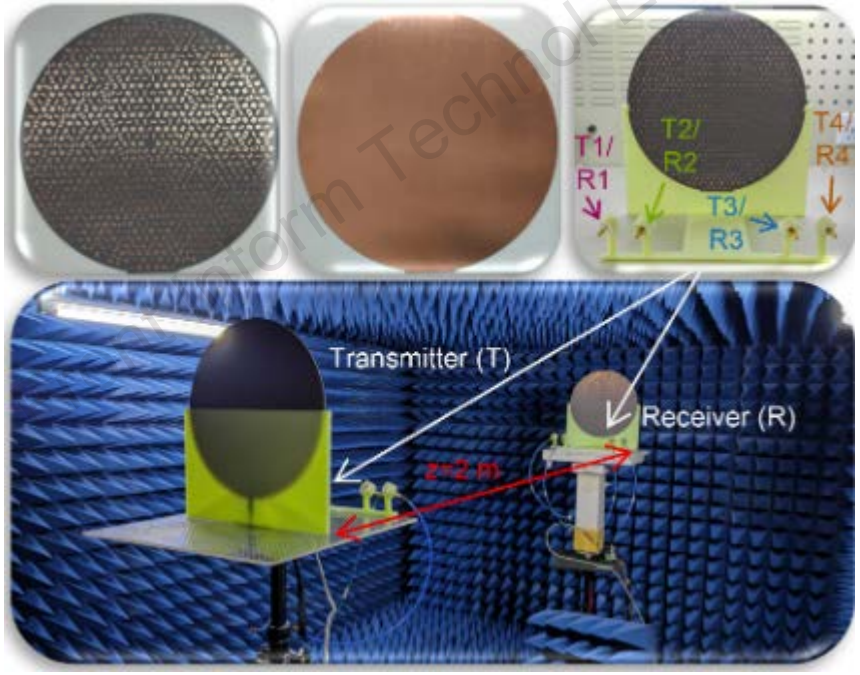






Major results

2. Showing the application of the metasurfaces in a four-channel communication system.



Conclusions

1. In this research, the multi-feed design in the metasurface overcomes the limitation of static OAM combinations in conventional metasurfaces and enables multi-mode multiplexing in wireless communications.

2. The amplitude term to balance the energy distribution in different OAM modes. This allows for controllable energy distribution between OAM modes, which is significant for multi-channel communication.

3. Our experiment verifies the independent control of spin states and OAM states in a four-channel system with controllable channel powers and low crosstalk.

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