

Lingjun YANG, Sheng SUN, Wei E.I. SHA, Long LI, Jun HU, 2023. Multi-feed multi-mode metasurface for independent orbital angular momentum communication in dual polarization. *Frontiers of Information Technology & Electronic Engineering*, 24(12):1776-1790. <https://doi.org/10.1631/FITEE.200471>

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

Corresponding author: Sheng SUN

E-mail: sunsheng@ieee.org

 ORCID: <https://orcid.org/0000-0003-2684-9662>

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:

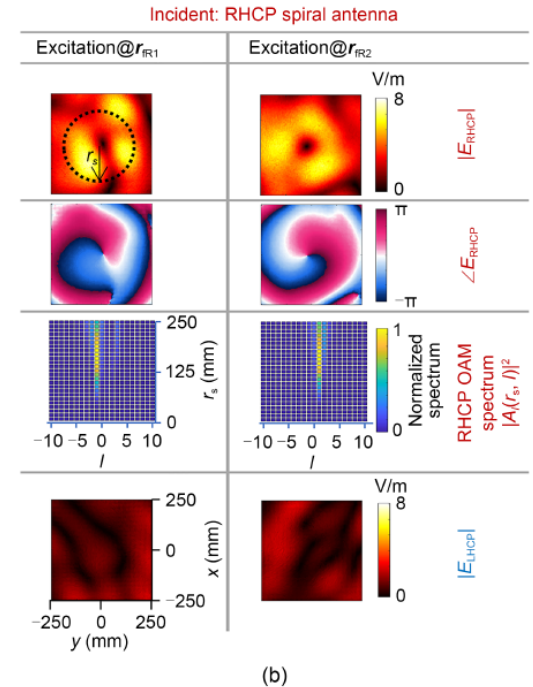
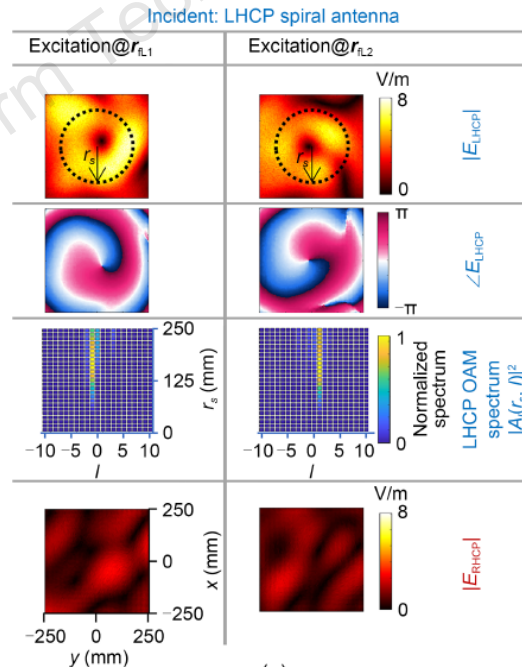
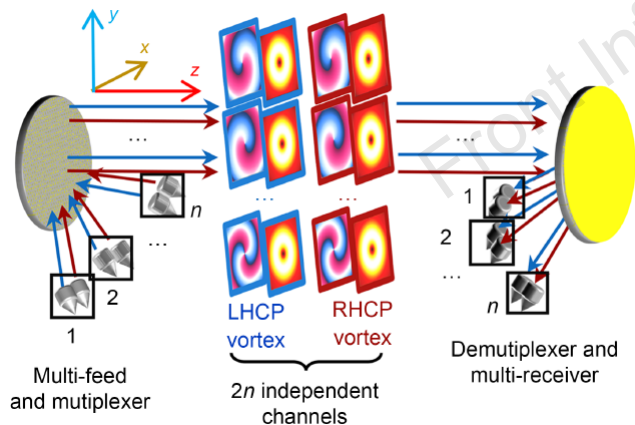
1. spin-decoupled metasurface that can independently control different CP waves by combining the geometric phase and propagation phase;
2. multi-feed design in the metasurface to independently control multiple OAM modes;
3. integrating an amplitude term to balance the energy distribution in different 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.

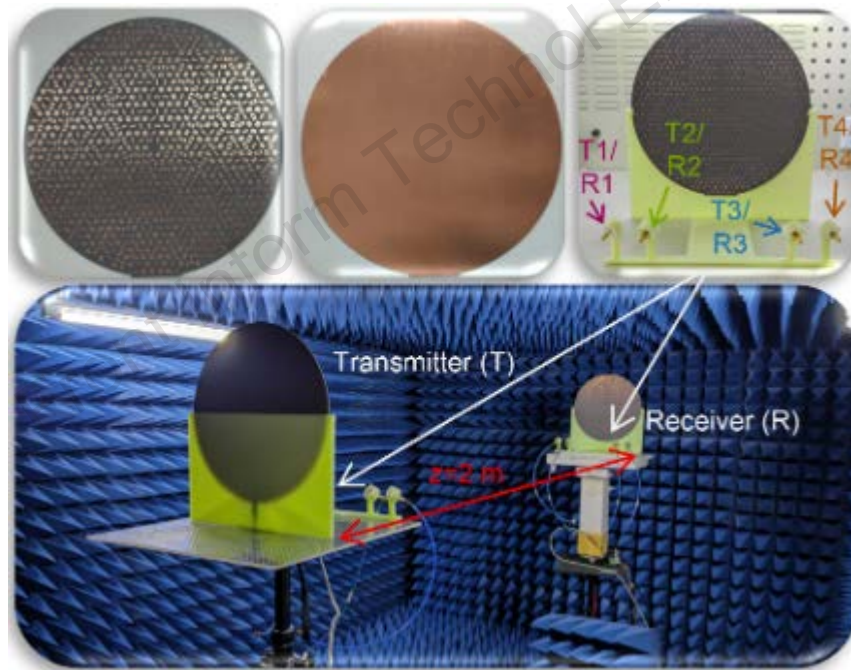
Major results

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.



Lingjun YANG (Student Member, IEEE) was born in Guilin, Guangxi, China. He received the BE degree in electrical engineering from Xidian University, Xi'an, China, in 2017. He is currently pursuing the PhD degree in electromagnetic field and radio technology from the University of Electronic Science and Technology of China, Chengdu, China. His current research interests include electromagnetic vortex beam with orbital angular momentum, equivalent circuits, spiral antennas, and metasurfaces.



Sheng SUN (Senior Member, IEEE) received the BE degree in information engineering from Xi'an Jiaotong University, Xi'an, China, in 2001, and the PhD degree in electrical and electronic engineering from Nanyang Technological University (NTU), Singapore, in 2006. From 2005 to 2006, he was with the Institute of Microelectronics, Singapore. From 2006 to 2008, he was a post-doctoral research fellow with NTU. From 2008 to 2010, he was a Humboldt research fellow with the Institute of Microwave Techniques, University of Ulm, Ulm, Germany. From 2010 to 2015, he was a research assistant professor with the University of Hong Kong, Hong Kong. Since 2015, he has been a full professor with the University of Electronic Science and Technology of China, Chengdu, China.



Wei E.I. SHA (Senior Member, IEEE) received the BS and PhD degrees in Electronic Engineering at Anhui University, Hefei, China, in 2003 and 2008, respectively. From July 2008 to July 2017, he was a post-doctoral research fellow and then a research assistant professor in the Department of Electrical and Electronic Engineering at the University of Hong Kong, Hong Kong. From Mar. 2018 to Mar. 2019, he worked at University College London as a Marie-Curie individual fellow. From Oct. 2017, he joined the College of Information Science & Electronic Engineering at Zhejiang University, Hangzhou, China, where he is currently a tenure-tracked assistant professor.



Long LI (Senior Member, IEEE) received the BE and PhD degrees in electromagnetic fields and microwave technology from Xidian University, Xi'an, China, in 1998 and 2005, respectively. He joined the Wireless Communications Research Center, City University of Hong Kong, Hong Kong, as a senior research associate, in 2006. He joined the Pennsylvania State University, State College, PA, USA, as a senior visiting scholar, in 2014. He is currently a professor with the School of Electronic Engineering, Xidian University, where he is the director of the Key Laboratory of High-Speed Circuit Design and EMC, Ministry of Education, and the dean of the Hai-Tang No. 9 Academy.



Jun HU (Senior Member, IEEE) received the BS, MS, and PhD degrees in electromagnetic field and microwave technique from the University of Electronic Science and Technology of China (UESTC), Chengdu, China, in 1995, 1998, and 2000, respectively. In 2001, he was with the Center of Wireless Communication, City University of Hong Kong, Hong Kong, as a research assistant. From Mar. to Aug. 2010, he was a visiting scholar with the ElectroScience Laboratory, Department of ECE, the Ohio State University, Columbus, OH, USA. He was a visiting professor with the City University of Hong Kong from Feb. to Mar. 2011. He is currently a full professor with the School of Electronic Science and Engineering, UESTC. Since Sept. 2017, he has been the vice president of UESTC. He has authored or coauthored over 300 technical papers. His current research interests include integral equation methods in computational electromagnetics, electromagnetic scattering, and radiation.