

Mechanically-Controlled Miniaturized-Element Frequency Selective Surfaces for Multi-Mode Orbital Angular Moment Generation

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This work introduces a novel system for generating multiple orbital angular momentum (OAM) modes at 225 GHz using two mechanically tunable, reflectionless plates. Each plate, with a diameter of 10 cm and thickness of 0.6 mm, employs miniaturized-element frequency selective surfaces (MEFSS) to achieve precise phase modulation for OAM mode generation. By discretizing each plate into angular slices with unique phase responses, different OAM modes are generated by mechanically rotating one plate relative to the other. This allows new alignments between slices to produce combined phase profiles tailored to specific OAM modes, as shown in Fig. 1.

The system operates with minimal sensitivity to the separation distance between plates due to their reflectionless design, simplifying implementation. The key innovation lies in achieving multi-mode flexibility, overcoming the limitations of traditional fixed-mode methods such as stepped dielectric structures and metasurfaces. The plates can generate distinct modes (e.g., $l_1 = 1$ and $l_2 = 2$) through precise angular configurations and demonstrate robust performance even in the presence of slight misalignments.

Fabrication involved high-precision etching of fused silica wafers, metallization with a 300 nm copper layer for efficient phase manipulation, and the application of a 500 nm parylene-C layer for bonding. The wafers were aligned and bonded using an EVG 620 aligner and EVG 510 bonder, ensuring pattern accuracy and minimal residual stress. Electromagnetic simulations confirmed that the combined phase profiles generate distinct OAM modes, with simulations and measurements validating near-perfect orthogonality of the modes.

This work demonstrates a versatile, compact, and efficient platform for OAM mode generation, with potential applications in near-field communication, high-resolution imaging, and radar systems. The methodology can be further generalized by adding additional plates to support more modes, extending its utility for dynamic and high-capacity communication systems.

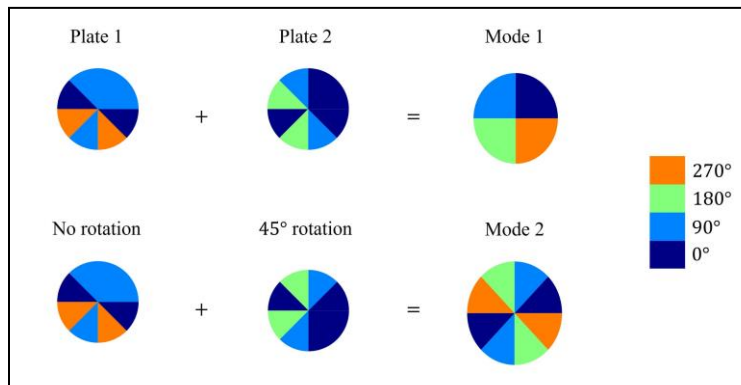


Figure 1. Required phase front of each plate to achieve both OAM modes.