Generation of Broadband Orbital Angular Momentum in Millimeter Wave Domain

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Electromagnetic beams carrying orbital angular momentum (OAM) have attracted great attentions owing to their interesting unconventional properties and exciting potential applications. An OAM beam is characterized with a helical wavefront that is described by an azimuthal phase dependence $e^{j\alpha\varphi}$, where α is called OAM mode number and φ is transverse azimuthal angle. Theoretical study and exploration of diversified applications of OAM beams have been extensively reported first in the optical regime and subsequently in low frequency domain like millimeter wave and RF band. Among various novel applications of OAM beams, the capability of offering a brand new mechanism of data multiplexing for communications is probably the most intriguing one and has fueled widespread interests. Other promising applications of OAM beams include holographic imaging and detection of defects.

Some methods have been proposed to generate OAM beams in the microwave and millimeter wave range. The first way is using properly engineered structures like spiral phase plates or flat phase plate. The second technique makes use of circular waveguides. The third method is based on metasurface. The fourth one takes advantage of a phased array antenna. But most of the reported OAM beam launchers are designed purely for specified single frequency, which hampers some potential applications of OAM. For example, OAM beams bearing a broad bandwidth are desirable in communication applications aiming to increase the capacity and spectral efficiency via OAM multiplexing. Similarly, broadband OAM beams can improve the resolution in related imaging applications.

In this work, generation of broadband millimeter wave OAM operating from 55 to 65 GHz is proposed. The OAM generator is made of metasurface backed by a ground plane and thus works in reflective mode. Differing from metasurfaces based on metal elements that are unfavorable for achieving broadband feature, dielectric elements with high refractive index located on substrate with low refractive index are adopted in this design, shown in Fig. 1. By tuning dimensions of the dielectric elements, phase variation from 0 to 2π can be obtained between incident and reflected wave. To realize the azimuthal phase change of an OAM beam with $\alpha = 1$, the metasurface plate is divided into eight sections having different element dimensions and phase variations that can lead to 45° phase difference between each two adjacent sections. Further proper adjustment of the dimensions of the dielectric elements can render the phase difference between each two adjacent sections maintain largely around 45° in a broad bandwidth from 55 to 65 GHz, offering the ability of producing broadband millimeter wave OAM. In addition, the designed broadband OAM generator can also convert the polarization of the incident wave, which is beneficial for practical applications of such reflective type structure.

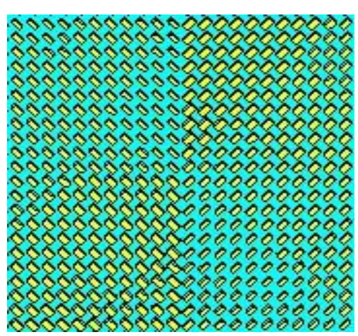

Fig. 1. Geometry of the broadband OAM generator.