Kaleidoscope mirror symmetry inspires new design for optical tools, technologies

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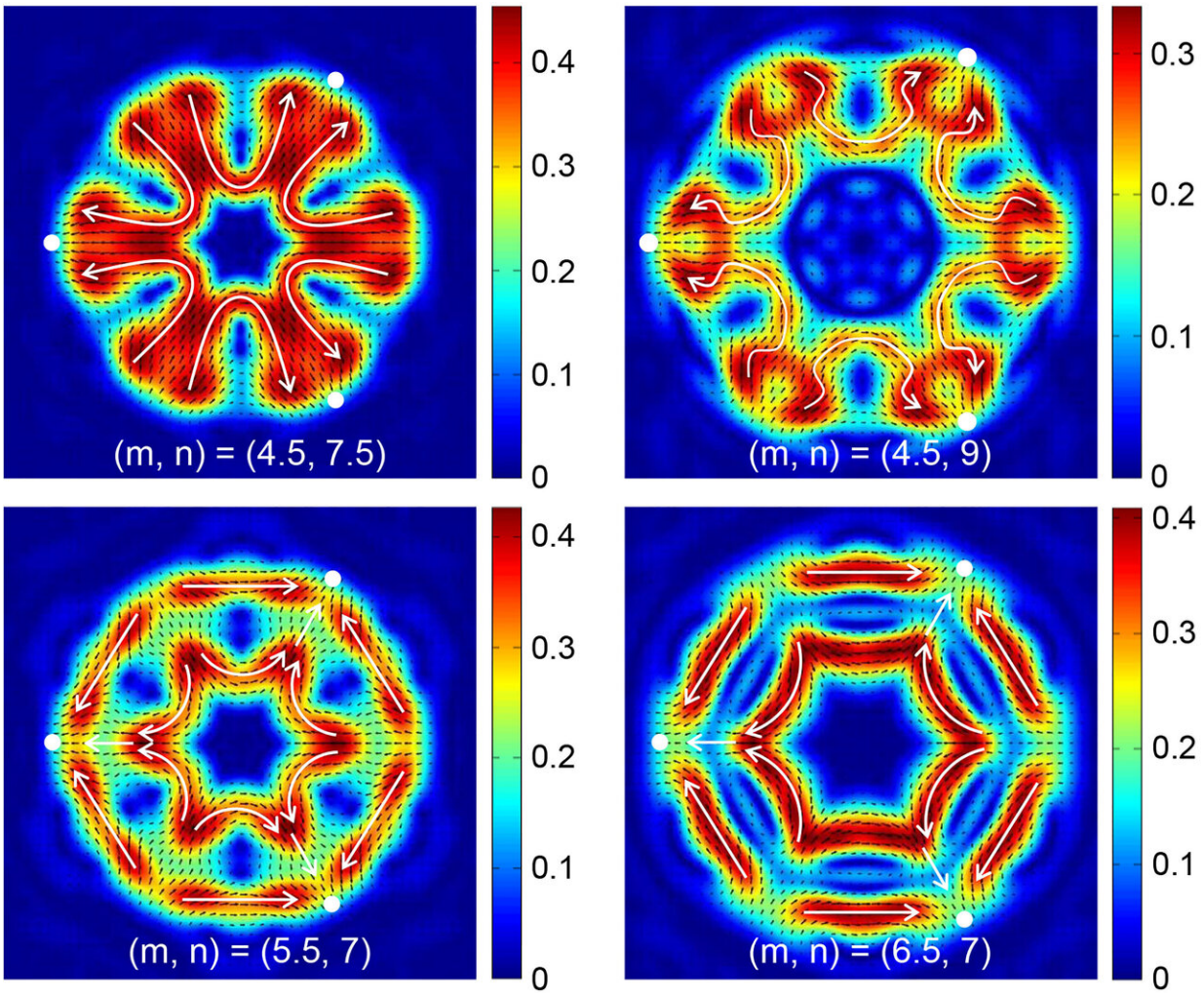

Transverse components of the normalized Poynting vectors in the focal plane of the tightly focused kaleidoscope-structured vector optical fields. The direction of the transverse energy flow is shown by the white and black arrows. The transverse energy flow shows six uniform tentacles (top left) and patterns like six

spanners (top right), which are useful to trap and transport the particles. Credit: Yue Pan/Qufu Normal University

In a kaleidoscope, mirrors are placed at angles to create a visual illusion of multiple, symmetric images from one original object. The number of symmetric axes in the kaleidoscope depends on the number of mirrors and angles inside.

Drawing inspiration from this multiple-axis symmetry, researchers have discovered a new method for creating mirror-symmetric axes in the polarizations of light, which allows for complex manipulations that are useful in optical tools and technologies.

For example, optical machining, photodetectors, optical cages and microscopy are all tools that rely on vector optical fields of varying degrees of complexity. Many of them use mirror symmetry in their polarization states and focal manipulation.

In the paper, published in *APL Photonics*, the researchers start with a cylindrical vector optical field and introduce a kaleidoscope structure to the polarization states by assigning a parameter for mirror-symmetric axes. That new parameter, which offers an additional degree of freedom, is scheduled into the transmission function on a holographic grating in a spatial light modulator to generate new vector optical fields.

"Mirror symmetry already exists in vector optical fields," author Yue Pan said. "However, no research has systematically studied the arbitrary symmetry properties of the original vector optical fields and spin angular momentum and energy flow in the focal plane. We first propose the kaleidoscope-structured vector optical fields with arbitrary symmetry, and gain spin angular momentum and energy flow with good properties

and applications."

By implementing multiple mirror symmetry axes into the design, they were able to create tightly focused fields in various useful shapes, including a subwavelength flattop sharp line that can be used in optical storage and lithography, and various cross, gear and hexagon shapes with tentacles and spanners that are useful for optical trapping. They were also able to introduce the elliptical polarization into the design of the new vector fields, which Pan said could help to further control the design and generation of kaleidoscope-structured vector optical fields.

Author Hui-Tian Wang, leader of the group, said they plan to study a theory that can accurately predict and manipulate the symmetry properties of tightly focused optical fields, propose new kinds of vector optical fields with novel orbital angular momentum, and further study the spin-orbital angular momentum conversion and coupling.

More information: "Spin angular momentum density and transverse energy flow of tightly focused kaleidoscope-structured vector optical fields," *APL Photonics*, DOI: 10.1063/1.5117269

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