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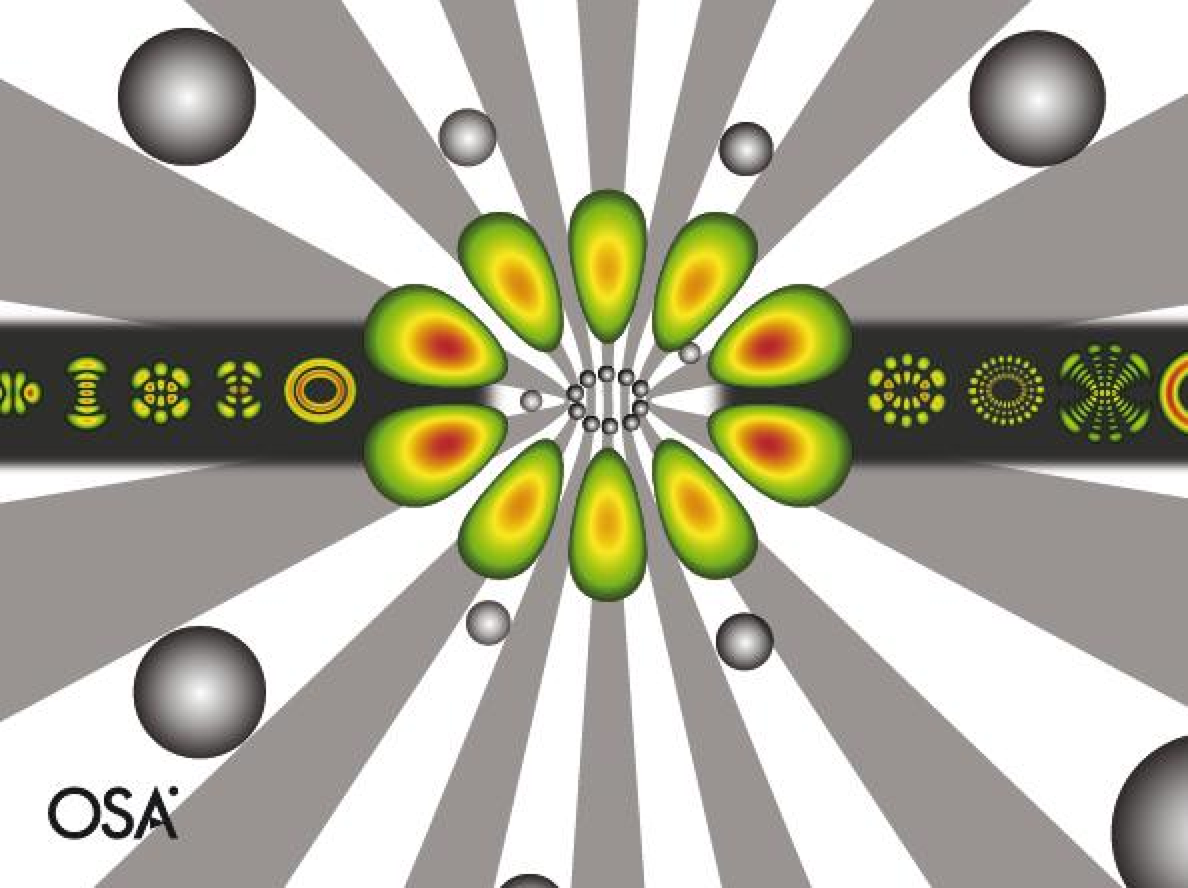

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Tailored Light Fields: A Novel Approach for Creating Complex Optical Traps

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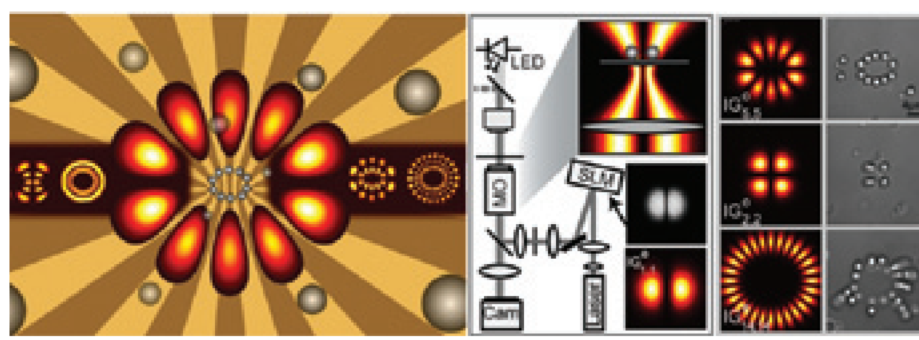
Any application of laser radiation demands a beam shape with specific intensity or phase distributions, propagation properties and polarization states. Thus, beam shaping has been a field of interest since the invention of the laser. Besides mechanical, acousto-optic and electro-optic modulation techniques, holographic modulation is now very important in beam shaping because it enables nearly limitless beam shapes in multiple working planes. In applications such as laser resonators, optical fibers or nonlinear photonics, particular Helmholtz equation solutions attract interest because they offer stable propagation properties in addition to different transversal field distributions.[1]

In the field of optical micromanipulation, tailored light modes meet the strong demand for extended optical potential landscapes with a high degree of order that can be transferred to micro- and nanostructures. Recently, we demonstrated that elliptical light fields are a valuable approach for organizing formidable, photonically induced extended three-dimensional structures. Elliptical light fields offer a wider range of beam shapes and include radial and Cartesian geometries.[1, 2]

Mathieu beams—non-diffracting light fields with elliptic symmetry—are of particular interest for multidimensional micromanipulation. They are characterized by their seemingly divergence-free propagation and self-reconstruction, which allows for generating extensive three-dimensional structures. We recently demonstrated the arrangement of elongated and spherical microparticles in three dimensions by non-diffracting Mathieu beams.[1] The direct visualization of the three-dimensional particle arrangement could be realized by implementing tailored light fields in a stereoscopic microscope.

(a) (b) (c)



(a) Ince-Gaussian (IG) beams provide an unmatched diversity of transverse field distributions for optical micromanipulation. Part (b) shows a holographic optical tweezers setup where IG beams are modulated with a phase-only hologram displayed on a spatial light modulator and focused into the sample chamber with a microscope objective (MO, NA=1.3). Part (c) shows a selection of 1.5 μm silica sphere particle arrangements organized with IG-modes.

These structures indicate promising applications, especially in the manipulation of functionalized or geometrically complex materials.

In contrast to non-diffracting light fields, Ince-Gaussian (IG) beams are self-similar light fields that show divergence while their transverse amplitude and phase distribution remain preserved in the far field (except for a scaling factor). The well-known self-similar Hermite-Gaussian (HG) and Laguerre-Gaussian (LG) beams are of unequaled importance in the history of optical micromanipulation.[3] Their popularity is based on their availability and, even more important, their unrivaled property diversity. Self-similar beams are transverse eigenmodes of typical laser resonators that are generated with high efficiency. IG beams merge valuable properties of HG and LG beams. They provide a more general solution to the paraxial wave equation. Thus they offer more diversity in transversal intensity patterns and versatility in the range of possible optical landscapes and accessible degrees of organization.[2] Moreover, IG beam helical modes allow optical orbital angular momentum to be carried and transferred to microscopic objects.

Tailored light fields form an important complement to iteratively calculated field distributions because of their holistic approach. This includes a diversity of transverse modes linked with distinct longitudinal propagation properties, making them highly desirable for many applications. ◭

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