Nondiffracting Light On-Demand

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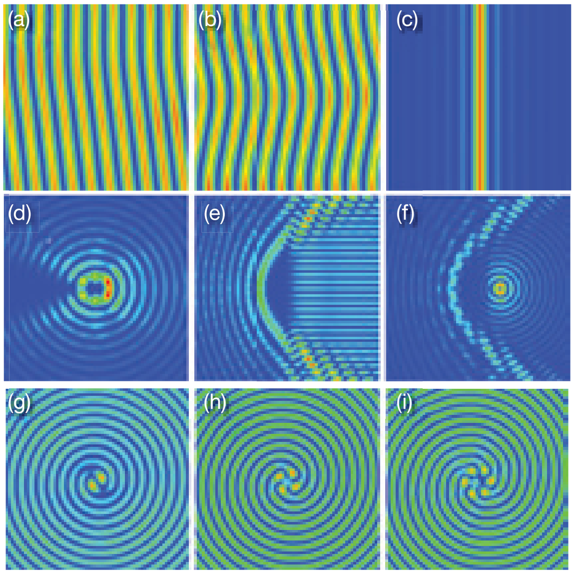
Suppressing the diffraction of light beams is a holy grail in optics. Nondiffracting light patterns are widely used in many applications where invariance of the beam is desired, including trapping of micro-objects and optical tweezing,[1] as well as in quantum[2] and nonlinear optics.[3] The patterns used to date correspond only to the known sets of simple nondiffracting beams that are exact solutions of Helmholtz equation governing propagation of light in uniform linear media. They include periodic, Bessel, Mathieu and parabolic beams.[4]

However, each of these beams has a particular topology, thereby affording specific applications. Thus, a task of paramount importance is the formation of quasi-nondiffracting beams with arbitrarily complex shapes and topologies, so that they meet with the requirements of each particular application.

This year we put forward a new strategy that allows the formation of complex light patterns that diffract extremely slowly—thus, they may be considered nondiffracting over huge distances which are dictated by the width of the beam angular spectrum.[5] The amplitude of any truly nondiffracting beam propagating along a straight trajectory can be expressed in terms of convolution of its angular spectrum defined on an infinitely narrow ring in the frequency space with an exponential kernel function.[5] A broadening of the angular spectrum allows for the generation of beams with arbitrarily complex transverse shapes that remain quasi-nondiffracting as long as the width of their angular spectrum remains sufficiently small. This technique affords the possibility to distort otherwise rigorous nondiffracting beams in a controllable manner, rendering them quasi-nondiffracting.

In particular, one can generate quasi-one-dimensional beams with stripes experiencing an abrupt bending in a desired part of the space (a), deformed patterns featuring stripes that may periodically curve in the transverse plane (b), or specific beams featuring several pronounced stripes (c). The angular spectrum engineering also allows us to obtain patterns featuring practically any combinations of known harmonic, Bessel, Mathieu or parabolic beams occupying different arbitrary domains in the transverse plane that propagate undistorted over considerable distances.



Intensity distributions in quasi-nondiffracting beams constructed via angular spectrum engineering. Top row shows bent (a), curved (b), and stripe-like (c) beams. Middle row shows truncated Mathieu (d), parabolic-cosine (e), and parabolic-Bessel (f) beams. Bottom row (g)-(i) shows specific spiraling patterns.

The figure above shows examples of truncated Mathieu beams (d), combinations of parabolic and cosine beams (e), and parabolic and Bessel beams (f). Importantly, the engineering of the angular spectrum is a powerful tool that can be used to generate beams that in principle have no analogs among known nondiffracting beams. The illuminating examples in the form of quasi-nondiffracting spiraling patterns are shown in panels (g)-(i).

In summary, the concept allows generating "on-demand" beams that are nondiffracting for all practical purposes. Such beam0s are expected to find important applications in several branches of science that currently use nondiffracting light beams for the manipulation of matter or light itself. ◭

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