Gradient-index Beam Shaper

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Category
Engineering & Physical Sciences/Design Specifications
Engineering & Physical Sciences/Photonics
Software & IT/Algorithms

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Gradient-index Optics for Laser Beam Shaping

Custom-designed gradient refractive index (GRIN) optics is used to shape the intensity profile of a laser beam. Instead of using a single refractive surface to transform the beam, as in a custom aspheric lens or diffractive optic, in a GRIN element, the refractive index changes continuously throughout the device. The spatial variation in refractive index is designed to compensate for the effects of diffraction, and the gradual nature of the beam transformation ensures higher efficiency than is achieved with conventional optics. This technology enables arbitrary beam shaping operations, such as transforming a Gaussian beam to a flat-top, and coherent combination of an array of beams by complete aperture filling. Beam shapers for any specific application can be designed using a unique numerical algorithm, and designs can be made for on-chip waveguides or volume devices.

Gradient Refractive Index Offers Advantages Over Current Methods

In demanding applications, reducing the number of optics in a laser-based system and improving efficiency are essential. Conventional systems may require many optical elements to transform the spatial intensity profile of a laser beam. However, GRIN media, which can reshape intensity profiles arbitrarily within a single device, perform advanced spatial control functions within a single, compact optic with high accuracy and no inherent loss. In addition, GRIN elements are compact, rugged, and lightweight. Since their optical function is contained inside the medium, they require no internal alignment and their outer surface can be made into any shape for convenient packaging. GRIN media also offer thermal advantages, as heat is removed to the surrounding material, which can be cooled externally without affecting the optical region.

Improves Beam Combining

In the area of beam combining, GRIN optics offers a solution to conventional limitations in both free space and integrated devices. Arrays of laser beams generally do not have a perfect fill-factor since neighboring beams do not overlap, and each beam is brightest at its center. However, a GRIN element can transform the intensity of each beam, flattening brightness at the center, while ensuring phase agreement between neighboring beams. On-chip devices, such as branched waveguides, can perform efficient beam combining through evanescent coupling of neighboring beams. However, they are limited to small size scales, and therefore incapable of handling high optical power. Though different optical structures can improve this, the quantized steps in refractive index reduce the set of optical functions that can be achieved efficiently. By allowing the refractive index to vary smoothly, as in GRIN, arbitrary field transformations can be achieved both in on-chip platforms and in free space. A suitably designed GRIN element can convert an array of mutually coherent beams into a uniform field profile with no unwanted interference fringes.

Refractive Index can Vary Continuously with Position

This new technology offers the freedom to specify the refractive index continuously throughout space, enabling the creation of devices to suit a wide variety of specialized needs while maintaining high efficiency. Volumetric GRIN devices can be made for high-power or free-space applications, while planar GRIN devices can be implemented on-chip. By allowing the refractive index to vary continuously with position, specialized optical functions such as N-to-1 beam combining and spatial mode conversion can be achieved at performance levels beyond the essential lens/mirror/beam-splitter optics that comprise most systems.

BENEFITS AND FEATURES:

- Arbitrary spatial transformation of laser beams
- Smoothly varying refractive index profile compensates the effects of diffraction
- Perform sophisticated optical functions accurately and without loss
- Self-contained and requires no internal alignment
- Enables low system complexity compared to typical optics
- Good mechanical properties: durable, compact, lightweight

APPLICATIONS:

- Integrated photonic waveguide devices
- Beam shapers for industrial/surgical lasers and directed energy
- Optical couplers in telecommunications
- Beam reshapers/combiners for laser arrays (e.g. laser diode or fiber arrays)
- Optoelectronics

Phase of Development - Prototype developed

Researchers

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Publications

Gradient-index design for mode conversion of diffracting beams

Optics Express, Vol. 24, Issue 12, pp. 13480-13488 (2016)

Numerical design of gradient-index beam shapers

Laser Resonators, Microresonators, and Beam Control XIX 2017, Jan 1 2017

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