

Hybrid diffractive optics offer an elegant solution

Thanks to a set of unique properties, diffractive optical elements have the potential to transform light into almost any desired distribution. **Joshika Akhli** gives the low-down on the technology that can benefit laser marking, material processing, heat treatment, sensing, non-contact testing and optical metrology, to name just a few applications.

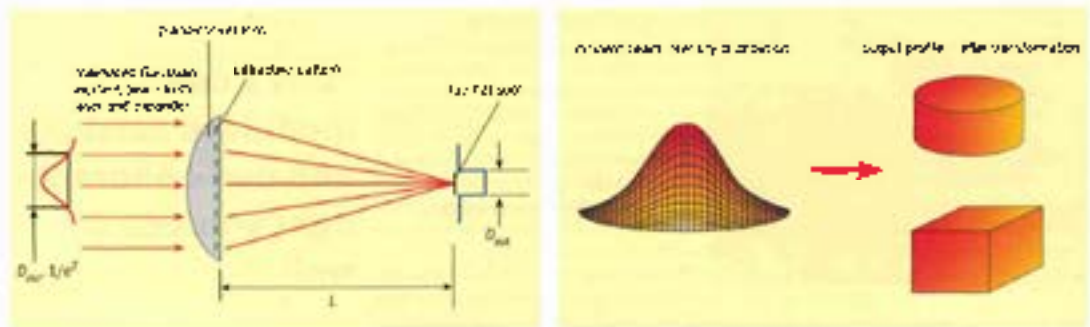


Fig. 1 Top-hat beam shapers can deliver outstanding results, transforming a near-Gaussian incident laser beam into a uniform-intensity spot.

Diffractive optical elements (DOEs) are a form of waveguide that directs all of the energy of a wavefront into a target area, but with the added advantage of beam manipulation features, such as beam homogenisers, flat lenses, beam splitters, of Fourier focal lenses, beam splitters and coupling ring structures, can be used to guide light into a most any desired distribution. Furthermore, the top-hat effect of top-hat beam shapers in laser systems, DOEs can be used to modulate partially coherent light that is not as well

Linear benefits

DOEs have the inherent ability to transform the original beam into a variety of shapes, distributions and numbered spots without unduly affecting the output intensity of the light. One of the greatest advantages is that a single optical element can often replace multiple optical systems to transform the beam profile to the desired shape and intensity distribution.

Key benefits of modern design and process control is to allow DOEs to be manufactured to a high level of accuracy and cost-effectiveness. Using holographic techniques, numerous diffractive gratings can be etched into the optical element to create a single optical device.

Hybrid DOEs can distribute the energy

between the centre and the periphery of a laser beam, making them ideal for beam shaping (Figure 1). Beam homogenisers are one of the primary profiles of an incident beam and can apply to systems such as laser alignment and fibre optic systems, where hot spots within the beam are unacceptable.

Traditionally, beam homogenisers have been restricted to operation within the focal plane of a lens, so operators can have a minimum working distance. Separated outside these conditions, angles will peak, an appearance of the distribution. However, there is a new device on the market that is less sensitive to position, called a DOE performance grating.

Beam shapers create specific energy distribution patterns in the flat surfaces. The basic principle is to phase-encode the intensity distribution profiles of the incident beam into an amplitude of distribution of a specific target shape, and at a specified distance. In principle, any transverse spot shape can be obtained, although the most useful geometries are top-hat with a set of rectangular and square. Adding lenses to the DOE creates a flat-to-flat device that can change the scale of the distribution, taking it to any final application.

One great advantage of the so-called diffractive top-hat beam shapers over other conventional Gaussian systems is that their design

is a trade-off between efficiency and spot homogeneity. By diffractively redistributing the beam energy, other techniques can simply block a significant portion of the energy.

Users should remember that to achieve good working results, the incident beam must have a well-defined Gaussian profile and be centred on the element. Beam spots, sizes and spatial filters can be used to equalise the output beam.

Important role

Top-hat intensity distributions suit applications where an even distribution of energy at the spot is essential, particularly in processes that have an exposure level and damage threshold for a given power density. Examples include surface micromachining and high-power laser treatments that require precise and uniform exposures.

As a result, DOEs are proving to be an essential component in industrial sectors such as laser ablation, welding and drilling, medical and aesthetic lasers, and laser displays. The uniform intensity spot, steep transition region and sharp profile offer unmatched manufacturing accuracy.

However, beam shaping is not limited to simply top-hat or Gaussian profiles. Custom optical elements can be manufactured to give various spot shapes and intensity distributions.

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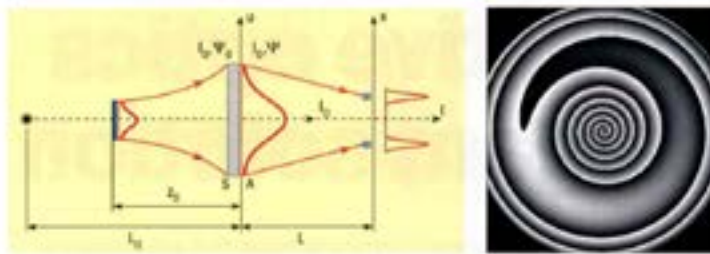


Fig. 2. Schematic view of a line comb setup (left) and the corresponding output pattern (right)

laser is white light and it is produced by a combination of various processes. Focused spots, whereas a diffraction grating effectively disperses the light, focus the light into a single plane. This is the basic operating principle of a diffractive micro-lens pattern on its planar surface. The DOE directs laser light towards the line comb or straight, circular, polygonal or irregular or at a single focal spot. Thus a line comb or array is achieved from the collimated laser beam and a line scanning system.

The micro-lens or line element provides novel spot patterns for laser marking, drilling and the welding of steels and metals as well as high-power lasers. Applications also

exist in photolithography and mask making, the optical heads of scanning laser systems, optical fibre data processing and laser surgery.

Splitting and multiplication

Recent advances in diffractive optics theory and technology have made beam splitting, multiplication and characterisation of optical resonators. Applications range from spot array generation and fibre optic coupling through to laser beam treatment of material surfaces and microlithography. Other promising applications for this technique include multiple and multifocal imaging, laser beam materials handling and simultaneous micro-slicing.

Diffractive beam splitters have been widely used for laser applications as they can be high

throughput and accurate positioning with cost saving any working material material (figure 4, p.57). By introducing diffraction gratings into these systems several parallel beams can be achieved since, consistently, light is directed to the same distance between the spots, regardless of the need for a focusing or a defocusing, improving performance.

Multiple spot (including double spot) DOEs provide a line or an array of diffraction spots located in the focal plane of a lens. Beams arranged in one or two different directions (2D) beam splitters offer advantages including uniformity in power between the spots. 2D beam splitters are available in 1, 2 and 3, 2 splitters and significantly more than other designs. The position and intensity of each beam type is fully controlled.

“DOEs can modulate partially and non-coherent light sources as well.”

Beam sampling

Another DOE, closely related to the beam splitter is the beam sampler, which enables cost-effective measurement of high-power laser beams to be made. The device produces two exact replicas, one of the input beam with only a small fraction of the total power, while the main part of the master beam is directed in the opposite direction. This allows the sample beam to be measured and analysed while the main beam remains unaffected and operational. Beam samplers can be produced to suit custom angles, spot lengths and various power fractions of the main beam.

Diffractive beam samplers are being used all those of various optical systems and more because they offer a less non-invasive analytical solution. For example, they are replacing thermopile measurements for CO₂ lasers. Such thermopiles are very delicate devices and the system, in the products are produced. Also, the diffractive beam samplers are a good means of independent and sensitive diagnostics can be taken while the laser is operating online.

Diffractive beam samplers are being used to measure high-power (10, 50, 100 W) and other laser systems in various processing methods applications used in laser industrial systems.

A single DOE can be used for focusing, collimating and high performance of a complex multiple optical elements based systems. The

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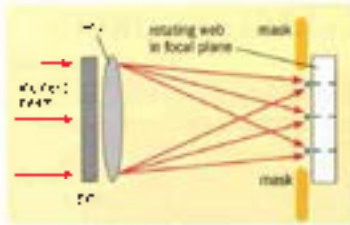


Fig. 3: The beam splitter DOE accepts a collimated beam and produces a number of beams with the same characteristics as the incident beam except for angle of propagation and power. By placing a focusing lens close to the element, all beams can be focused into a spot. A mask is recommended for blocking higher order diffraction fringes.

A flat or curved pattern on the planar side of the hologram diffracts incident light into a number of orders, depending on angle and wavelength, and a dramatic increase in power density over the optical length (OL).

Diffraction orders for a lens focus the incoming light onto a focal plane. Commonly, both a pass-through optic includes axis sharp focusing control of the focal spot shape. It is used into the diffraction order of the beam to target a spot of a desired diameter and to create multiple spot beams.

Combining two beams

Many medical and scientific laser systems use a red He-Ne (633 nm) laser or laser diode to combine with a Ti:Sa to generate an 800 nm pulsed beam. An element that can combine the He-Ne laser beam onto the output of the Ti:Sa beam can be used. A common method is often use lens doublets and other thin glass such as porous antireflective coatings with a large optical and relatively inexpensive to work with.

Although not ideal, this problem can be solved by a diffractive element called a wave-length beam combiner. This is a one second lens with a thin coated Ti:Sa on top of a porous antireflective coating. The thin pattern can be designed to control just one wavelength. When placed in the path of the 800 nm output from laser beams the 633 nm superimposes the wavelengths at the same angles, with the difference of 180°.

The advantages of a diffractive beam combiner for a medical laser system is that it is a thin, flat, and light weight. Also, the wave-length can be designed to control a wide range of wavelengths. A diffractive beam combiner is a superior alternative to a wave-length beam combiner in a medical laser system.

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