DIFFRACTIVE OPTICAL ELEMENTS

HOLOEYE

Pioneers in Photonic Technology

HOLOEYE'S DOEs

Off-the-shelf DOEs:

► *Mounted versions* are well suitable for lab-bench proof-of-concept experiments.

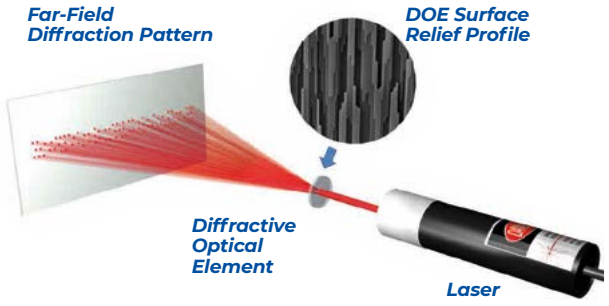
► *Unmounted versions* are easy to integrate into laser modules already containing mounts.

Customized DOEs:

For any requirements beyond our off-the-shelf product range, we offer development of customized DOEs designed to meet customer specifications.

Laser integration:

Renowned laser module manufacturers provide integration of both our standard and customized diffractive optical elements (DOEs) into their products.



Operation Principle of DOEs:

DOEs utilize a microstructure surface relief profile for their optical function. Light transmitted by a DOE can be reshaped to almost any desired distribution, just by diffraction and the subsequent propagation. The DOE only encodes the shape of the desired intensity pattern but maintains other properties of the incident light source (e.g. polarization).

Thanks to their design versatility, DOEs can have optical functions that are otherwise unattainable or only with complicated optical systems. DOEs can serve as beam-splitters, pattern generators, kinoforms, beam-shapers, diffusors, lenses, and gratings. Frequently, they can even integrate two or more of those optical functions.

Lust but not least, compared to refractive optical elements, DOEs are typically much thinner and lighter, making them an attractive replacement in various applications.

Essential Specification Parameters

Light Source:

► Type (cw laser, pulsed laser, edge emitter/ VCSEL laser diodes, LED, other)
► Wavelength (center, bandwidth, tolerance, shift)
► Polarization
► Power/Energy (average and/or peak)
► Beam profile (diameter, divergence, M^2 beam quality parameter)

Optical Function:

► Desired light field distribution (shape, uniformity, contrast, ...)
► Target surface/object (inclination, shape, ...) and sensor (CCD/CMOS/human eye/...)
► Field of view and working distance, or diffraction angles

Application:

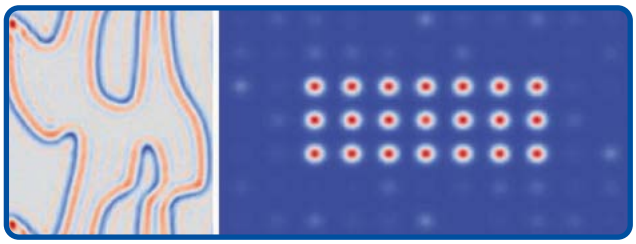
► Element form factor (size, shape)
► Element material (glass/polymer/...)
► Environmental conditions (temperature, humidity, exposure to UV radiation, ...)
► Eye Safety requirements
► AR coating requirements
► Laser-induced damage threshold (LIDT) requirements
► Packaging requirements
► Storage conditions

The required annual production volume and a price target are helpful in order to balance technical and economical requirements.

Design & Simulation

HOLOEYE utilizes its steadily growing experience in the design and simulation of diffractive optical elements to offer its customers a competitive solution. Using in-house developed as well as commercially available state-of-the-art software tools and algorithms, appropriate simulation methods (paraxial or rigorous electromagnetic) are used for computation of optimized DOE designs.

Fabrication constraints are considered right from the start, and a tolerance analysis is performed whenever necessary. Also, the alignment requirements of the DOE within the optical system are determined, so that the assembly procedure can be set up accordingly.



DEVELOPMENT OF CUSTOMIZED DOEs

Definition of specification in interaction with the customer

Design of microstructure and optical simulation

Direct fabrication of Diffractive Optical Elements

DOE Prototypes

Fabrication of mass production tools

Masks / reticles or molds for replication

Prototype fabrication and experimental verification

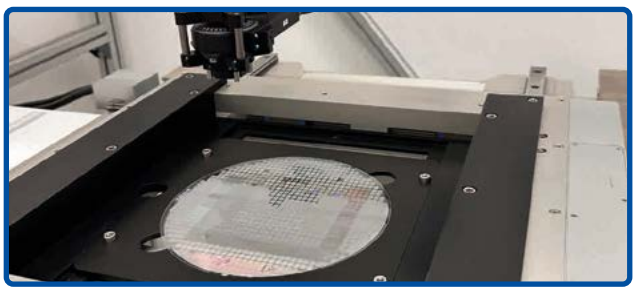
Volume production

Quality control / Optical performance tests

Quality Assurance & Implementation Support

After fabrication, HOLOEYE will validate the compliance of the DOEs with the specification, experimentally. For volume production of elements, optical key properties can be monitored using automated equipment.

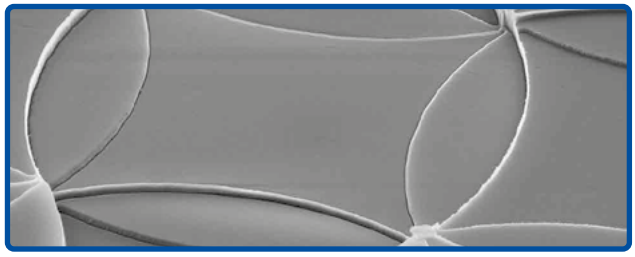
When an integrated solution like a DOE-based laser projection module is required in your application, HOLOEYE can be part of a joint development effort involving vendors for those products.



Mastering & Tooling

Direct write lithography processes are used to create either lithography masks or resist micro-relief profiles. Based on masks, micro-relief profiles are created by contact or projection lithography and subsequent etching processes like reactive ion etching to transfer the etch mask into the substrate.

The obtained micro-relief profiles serve as fused silica DOEs or templates for UV-curing-based replication processes. Alternatively, electroplating can be used to create inverted resist profiles which are usable for embossing and molding processes of polymer materials.



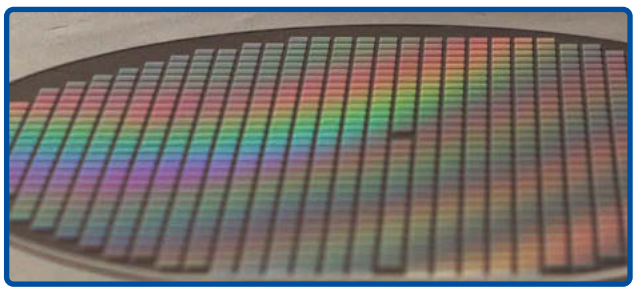
Volume Fabrication

HOLOEYE offers diffractive elements fabricated by one of the following options:

01. **Bulk polymer elements:** the substrate and a diffractive micro-relief surface are created by compression molding using materials like polycarbonate, PMMA, or Topas ®.
02. **Polymer-on-substrate:** the diffractive layer is created by UV curing on a polymer or glass substrate.
03. **Bulk-fused silica elements:** the diffractive micro-relief surface is created by reactive ion etching.

The sizes and shapes of the DOEs can be specified by the customer.

Fresnel-type surface reflections can be reduced by dielectric anti-reflective coatings, or by moth-eye micro-relief surface structures on the otherwise plain substrate surface.

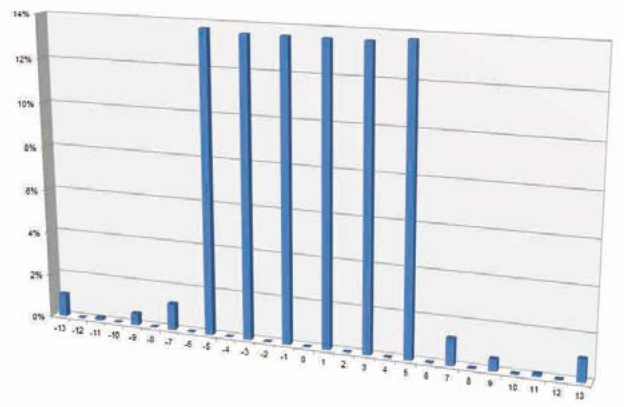


Diffractive Beam Splitter

A single incident laser beam is split into a 1-dimensional or 2-dimensional array of beams.

Typically diffractive beam splitters are used in combination with a focusing lens. If so, the output beam array becomes an array of focused spots at a certain distance behind the lens.

The arrangement of the spots is not limited to arrays in perpendicular x-y lattices. Also hexagonal or irregular lattices are possible. For more complex arrangement of spots, like for structured light pseudo-random spot patterns, the diffractive beam-splitters can also be referred to as ▶*Diffractive Pattern Generators*.



Applications:

▶ Multi-channel splitting for 1D or 2D sensors

▶ Process parallelization in material processing (laser dicing, laser scribing, ...)

▶ Multi-Focal Microscopy

▶ Coherent beam combination

▶ Camera calibration

Diffractive Pattern Generators

Complex patterns with a very high depth of field can be created.

The pattern comprises of many spots, which may overlap so that the element could be referred to as a ▶ *Diffractive Diffusor*, or still be visibly as individual spots, so that the element could be referred to as a ▶ *Diffractive Beam Splitter*.

Due to the high accuracy of the microstructures, the diffraction angles can be extremely precise, in particular when using a frequency stabilized laser source.

Applications:

▶ Structured light and pattern projection for 3D sensing applications: pseudo-random spot patterns, fringe patterns, De Brujn patterns

▶ Graphics, range and chart projection for alignment and measurements

▶ Laser aiming, barcode scanners, POI patterns

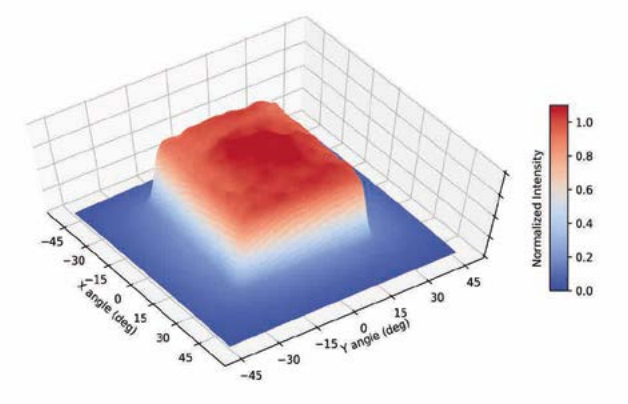
In most cases the incident laser beam is collimated or focused to a fixed distance behind the DOE. HOLOEYE also offers solutions for non-collimated or partially collimated light sources. This is achieved by combining pattern generation with focal power in the DOE microstructure.

Diffractive Diffusers

Flexible shaping or homogenization of the emitted angular power distribution of various light sources can be achieved.

Diffractive Diffusers can be best used with VCSEL arrays or laser light from multi-mode fibers because they consist of many individual incoherent laser emitters or modes. As a result, the angular far field diffracted light distribution is much less affected from interference-related intensity modulations, and more uniform light distributions are obtained.

With tailored diffractive diffusers, HOLOEYE is able to create various light distributions for the application wavelength. By suppressing the zero order diffraction to well below 1% compared to the incident light even for large diffraction angles, the desired profiles can be obtained in very good approximation.



Applications:

- Time-of-Flight 3D sensing
- Laser autofocus
- 2D sensing with flood illumination
- Illumination applications
- LIDAR

Diffractive Beam Shapers

An incident laser beam of ideally Gaussian intensity profile is transformed into a desired intensity profile at the target plane or workpiece.

In most cases, the target is a uniform ('flat-top') circular or rectangular beam profile. Other shapes and non-uniform profiles can be obtained as well.

For a custom development, precise information about the input beam intensity and phase profile is required. For beams with high beam quality of $M^2 < 1.3$, the phase profile is sufficiently described by the radius of curvature of its wavefront.

Applications:

- Laser material processing
- Lithography
- Biomedical devices

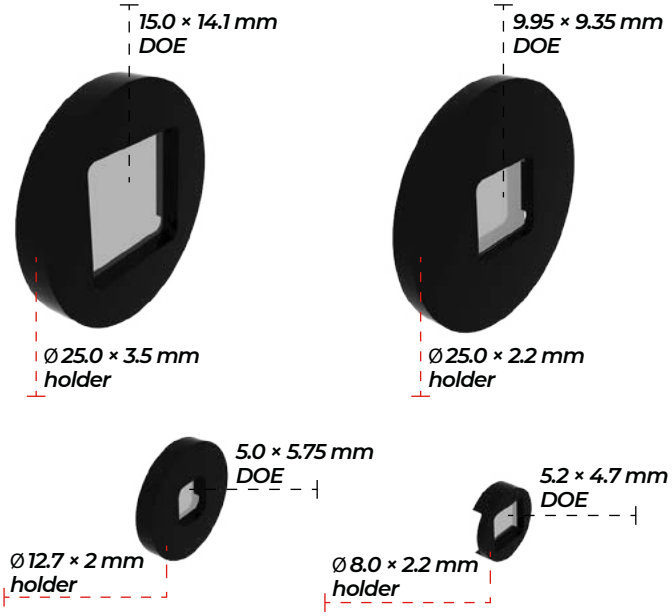
Furthermore, the focusing capabilities of HOLOEYE's DOEs are not restricted to fixed working distances. Our pattern generators can provide the necessary focal power to focus the laser onto steeply inclined target planes. Indeed, the optimal focus location for each diffraction direction can be adapted to nearly any surface.

Standard DOEs

HOLOEYE offers a steadily growing range of affordable off-the-shelf standard Diffractive Optical Elements made from polymer materials or glass materials.

The currently available DOEs are optimized for wavelengths between 420 nm and 1570 nm (dependent on pattern).

Off-the-shelf Glass DOEs



Our standard glass DOEs are made of fused silica glass by etching, or are replicated using acrylate on soda-lime glass substrates. In sample quantities, all size versions are available in circular holders for convenient use with standard optics mounts.

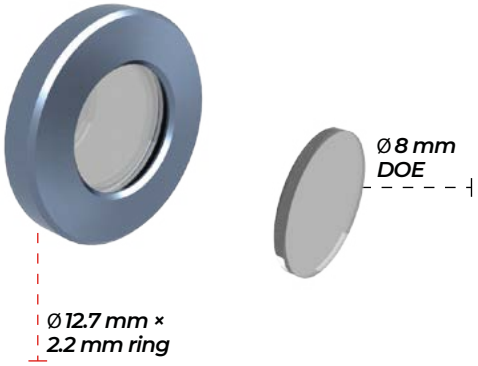
Advantages of Glass DOEs compared to Polymer-Based Diffractive Optical Elements:

- High Durability
- Enhanced Thermal Stability
- UV Resistance
- Increased Heat Resistance
- Higher Laser-Induced Damage Threshold (LIDT)
- Anti-Reflective (AR) Coatings
- Polarization Maintenance

Dependent on the type, the glass DOEs are available in the following versions:

- Fused Silica: 5.0 × 5.75 mm
- Fused Silica: 5.0 × 5.75 mm (multilevel)
- Fused Silica: 9.95 × 9.35 mm
- Fused Silica: 9.95 × 9.35 mm (multilevel)
- Fused Silica: 15.0 × 14.1 mm
- Fused Silica: 15.0 × 14.1 mm (multilevel)
- Acrylate-on-Soda-Lime glass: 5.2 × 4.7 mm

Off-the-shelf Polymer DOEs



Our standard polymer Diffractive Optical Elements are crafted through surface replication using materials such as polycarbonate (PC) or polymethyl methacrylate (PMMA).

These elements, with a standard diameter of 8 mm and a thickness between 0.6mm and 1.2mm, are designed to seamlessly integrate into various standard laser modules.

For use in the optics lab, the DOEs are also available mounted in a 12.7 mm x 2.2 mm stainless steel adapter ring.

Full list of standard DOEs:

CLICK OR SCAN

Explanation of DOE properties:

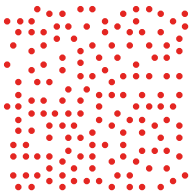
CLICK OR SCAN

Standard DOE Types

Dot Lines & Quasi-Continous Lines

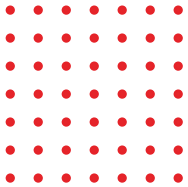
Beam Splitter, Dot Line Patterns and Quasi Continuous Lines.

Random Dot Patterns



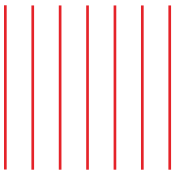
Pseudo-Random and Truely Random Dot Patterns (14552 Dots up to 101050 Dots).

Dot Matrix Patterns



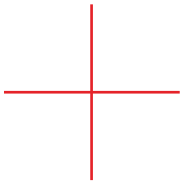
Dot Matrix Patterns from 2 x 2 Dots up to 101 x 101 Dots.

Multi Line Patterns



Line Patterns from 3 Lines up to 81 Parallel Lines.

Crosshair Patterns

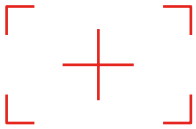


Crosshair Patterns from 5° up to 75° Pattern Angle.

Circles & Dot Circles

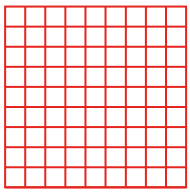
Solid Line Circles and Dot Circle Patterns (16, 36 and 72 Dots).

Viewfinder



Viewfinder Patterns (Circle & Square Patters).

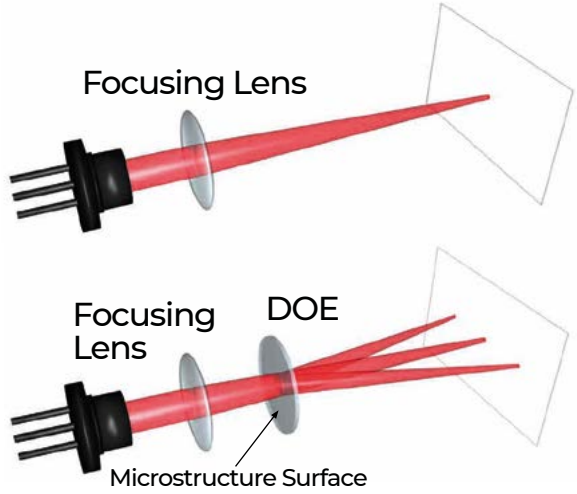
Special Patterns



Grids, Hexagons, Ring Patterns, Hexagonal Arrays and Square Patterns.

DOEs are best used with collimated or slightly convergent laser sources (see figure below). The microstructure surface should be oriented towards the laser.

Pattern size and angles, as well as the intensity in the undiffracted central spot, will vary most with the laser wavelength. This zero-order spot matches the size and shape of the incident laser beam that would be observed if the DOE were absent from the optical system, but its power is significantly reduced.



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