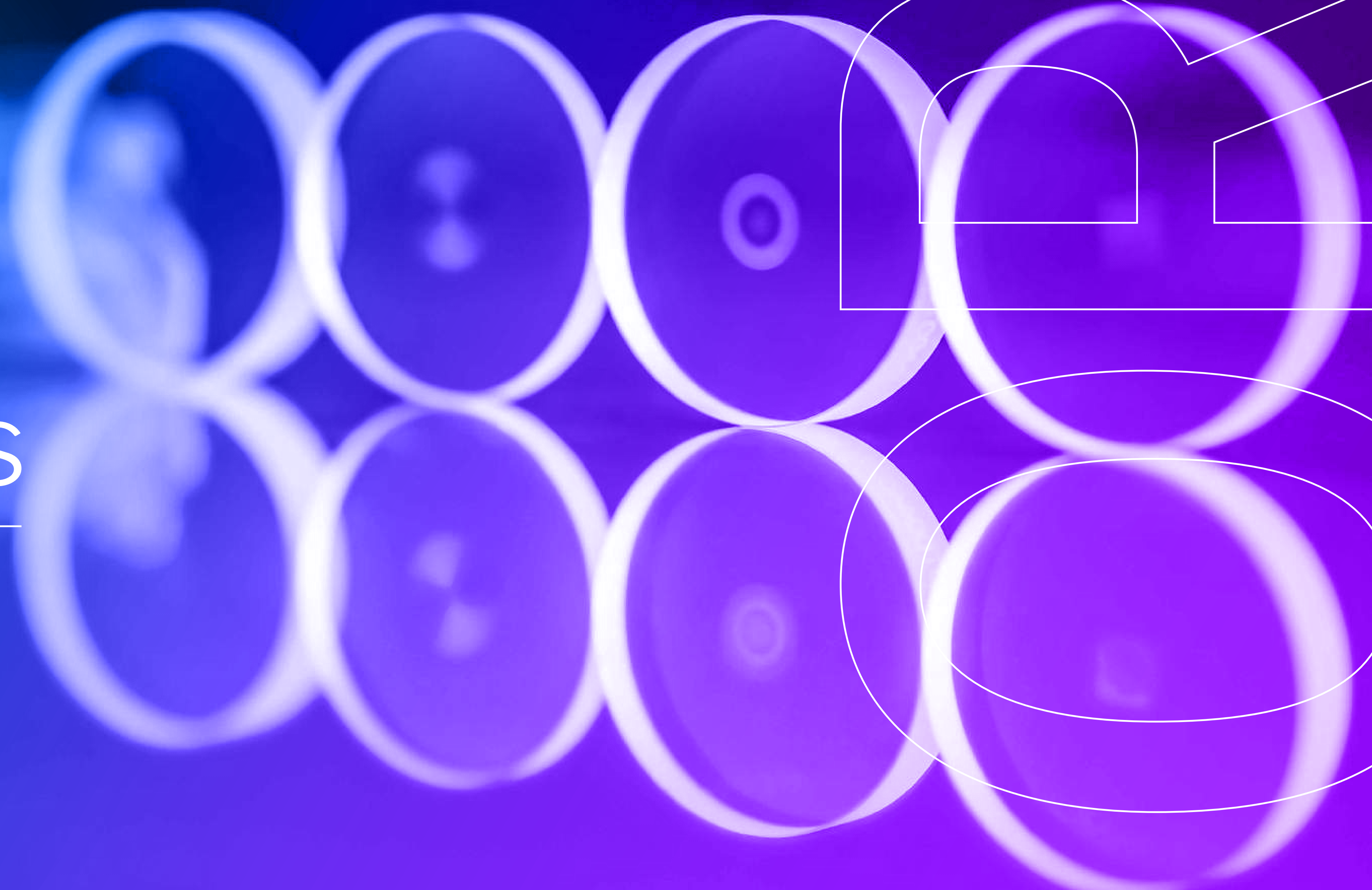
ORISANDO

OPTICS FOR YOUR BEAM CONTROL

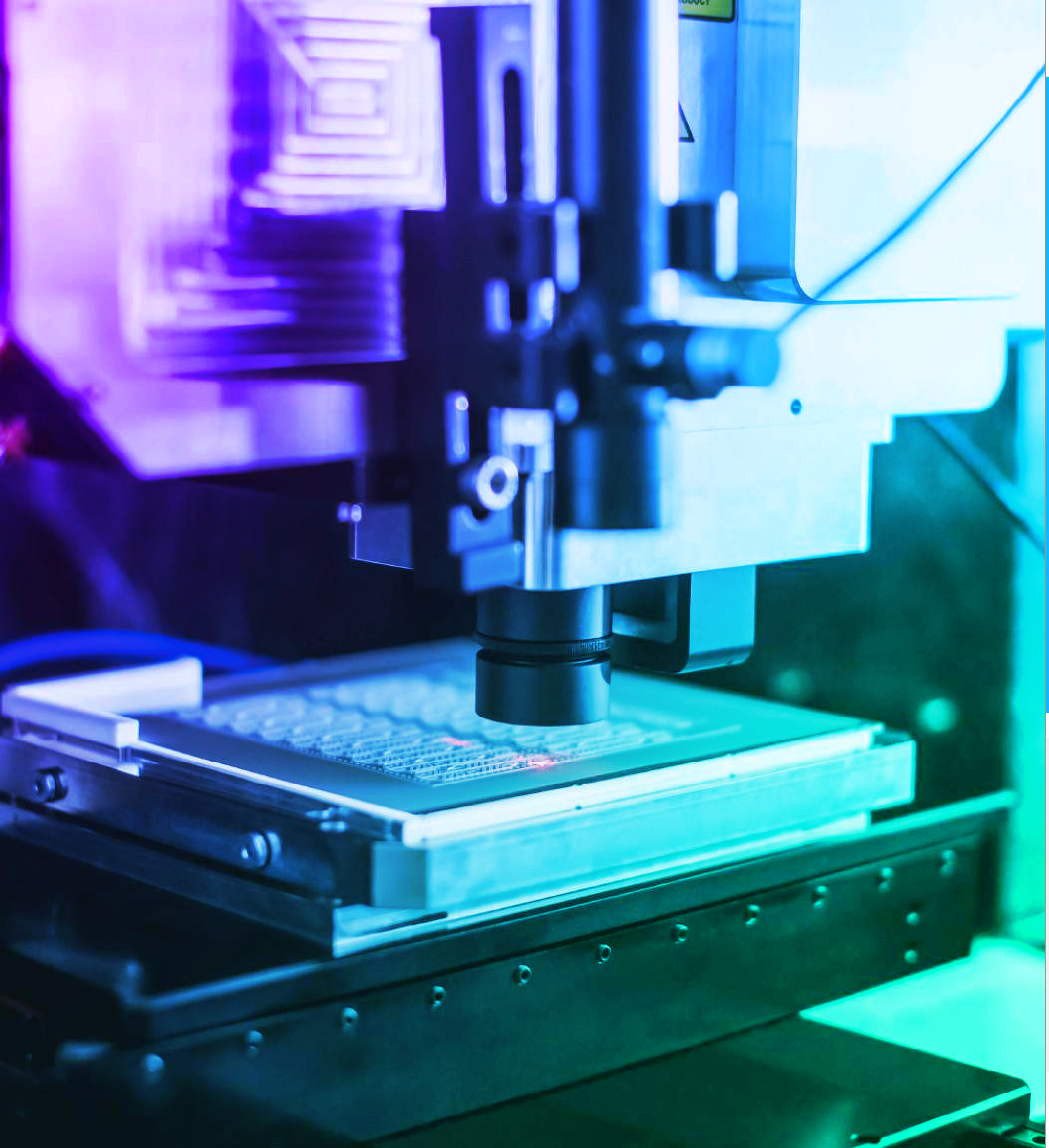
Space-Variant Retarders

www.orisando.com



Mokslininku st. 6A, Vilnius LT-08412, Lithuania.
Phone: +370 5 215 7551
E-mail: sales@orisando.com
www.orisando.com

Content



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ORISANDO is a new brand of Space Variant Retarders (SVR) developed by **WOP | Workshop of Photonics.**

WOP is a femtosecond laser micromachining solutions provider for industry & science customers around the globe.

With over 20 years of experience, WOP delivers fully integrated services from feasibility and prototyping to actual solutions – micromachining services and tailor-made laser workstations.

WOP introduced its special optics—space-variant retarders (SVR)—to the market in 2012, and they quickly became one of the company's key activities. Subsequently, WOP decided to establish a new brand for its SVR products, resulting in ORISANDO.

More about WOP: www.wophotonics.com

WOP
WORKSHOP OF PHOTONICS

ORISANDO

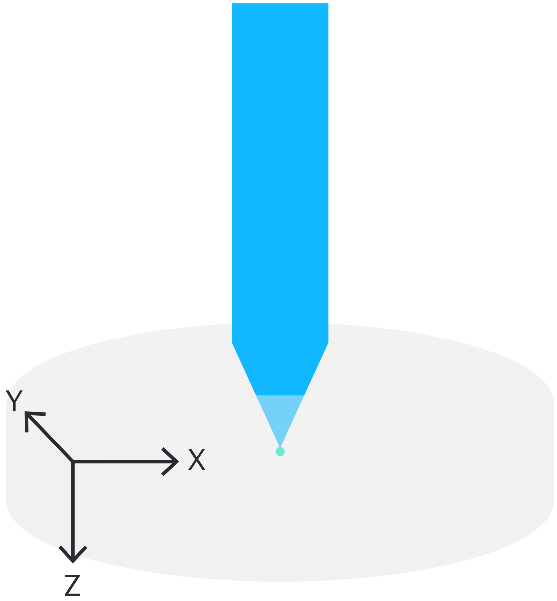
ORISANDO has a dual meaning: "ORI" signifies originality and a unique way of production. "SANDŌ," a Japanese term, refers to a visiting path, which in our context symbolizes the path of the light beam. Additionally, "SAND" represents the optical elements, crafted from fused silica glass made from quartz sand.

The brand name is framed by two "O"s, representing optical elements. Finally, the logo features a stylized path of the light leading to the ending "O."

Patented technology

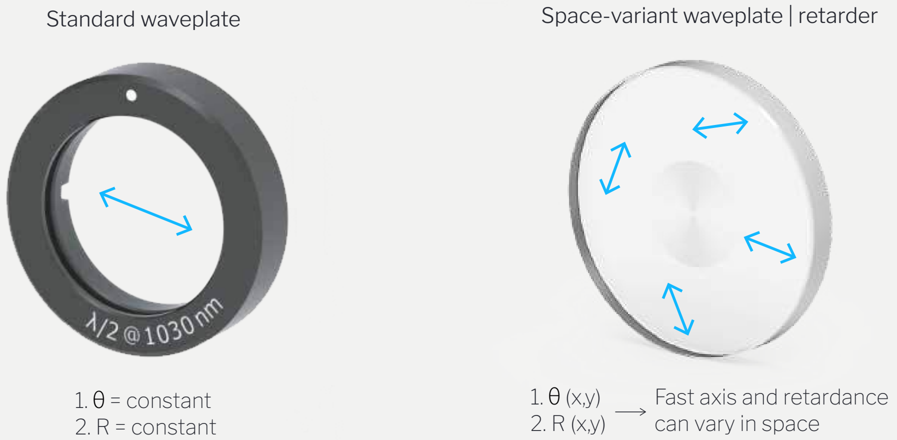
ORISANDO Space-Variant Retarders (SVR) are designed and manufactured using patented direct laser writing technology. This advanced technique enables the formation of self-organized periodic nanostructures, so-called nanogratings, within the bulk of fused silica glass.

The inscription of these self-organized nanogratings inside the glass sets a new standard for precision and performance.



Exceptional accuracy

These nano gratings exhibit tailored birefringent properties that can be precisely controlled during fabrication, offering five degrees of freedom: spatial positioning, retardance, and the orientation of the birefringence axis. As a result, we produce a range of flat optical elements capable of manipulating light's polarization, phase, or amplitude with exceptional accuracy.



Differences between standard waveplate and space-variant retarders (SVR)

Ideal for high LIDT applications and high-power lasers

Due to their high laser damage threshold, these components are perfectly suited for demanding applications involving high-power lasers in precision materials processing.

Furthermore, their unique properties make them valuable tools in imaging, spectroscopy, optical communications, and more.

S-Waveplate

Converts linear polarization to radial or azimuthal polarization

Why choose an S-waveplate?

- Best choice for converting:
  - linear polarization to radial or azimuthal polarization;
  - circular polarization to an optical vortex.
- 94% transmission @1030 nm, without AR coating (99% with AR).
- Stand-alone – no additional optical elements needed.
- Suitable for high LIDT applications and high-power lasers.
- Reliable and resistant surface – the structure is inside the bulk.

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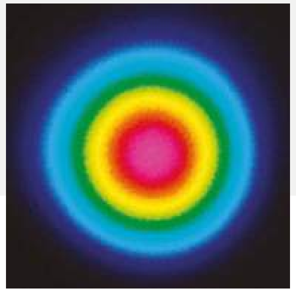
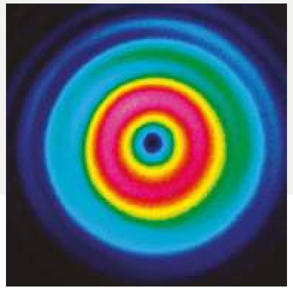
S-waveplate

This comprises a space-variant retarder that converts linear polarization to radial or azimuthal polarization and circular polarization to an optical vortex. The fabrication of s-waveplates is based on the inscription of self-organized nanograting's inside fused silica glass using a femtosecond laser.

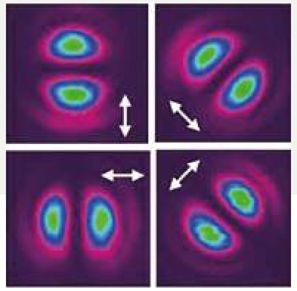


Linear polarization

S-waveplate



Radial/azimuthal polarization

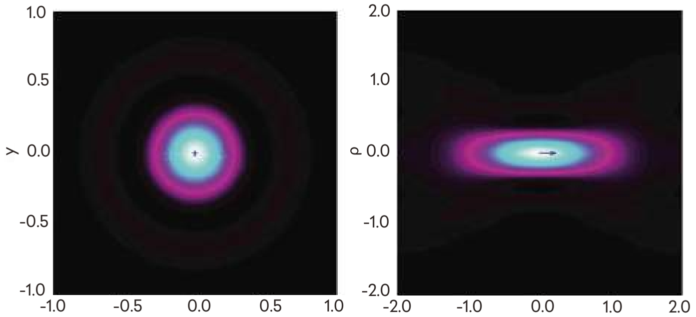


After linear polarizer

Beams with radial or azimuthal polarization attract significant interest due to having unique optical properties associated with their inherent symmetry. Such beams enable resolution below the diffraction limit and interact without the undesirable anisotropy produced by linearly polarized light.[1]

S-waveplates can be beneficial for polarizartion-sensitive applications. For example, a radially polarized beam is more efficient at drilling and cutting high-aspect-ratio features in metals. Vector beams are also applicable in optical tweezers, laser micromachining, STED microscopy, and two-photon-excitation fluorescence microscopy.

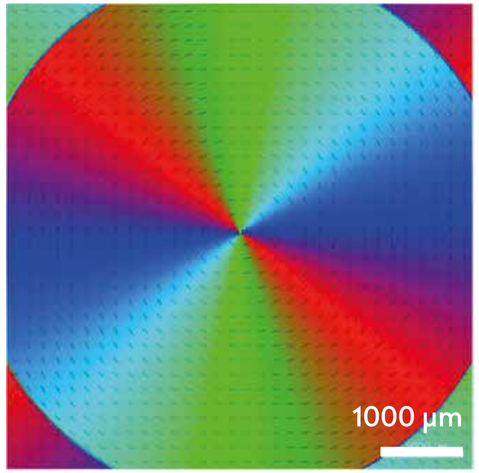
Application example:

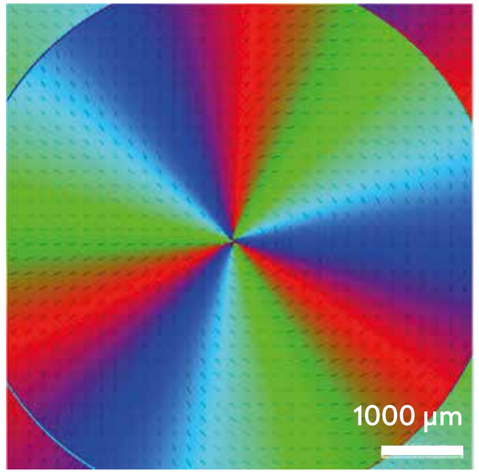


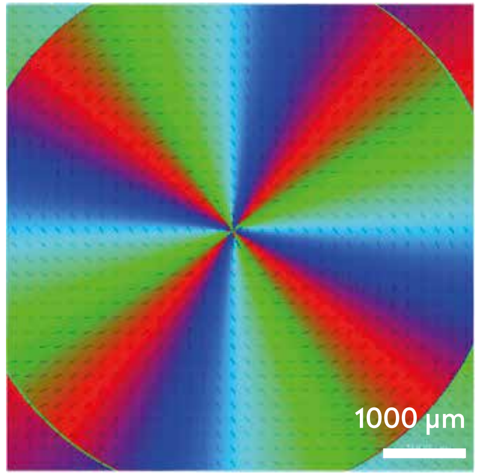
Normalized intensity of the longitudinal (z-) component of a high-NA (1.32) radially polarized beam at focus and through focus. Intensities of 0 and 1 correspond to black and white, respectively. The units of x, y, ρ, and z are in wavelengths.[2]

[1] Radially polarized optical vortex converter created by femtosecond laser nanostructuring of glass Martynas Beresna, Mindaugas Gecevicius, Peter G. Kazansky, and Titas Gertus.

[2] Focusing of high numerical aperture cylindrical-vector beams KS Youngworth, TG Brown - Optics Express, 2000





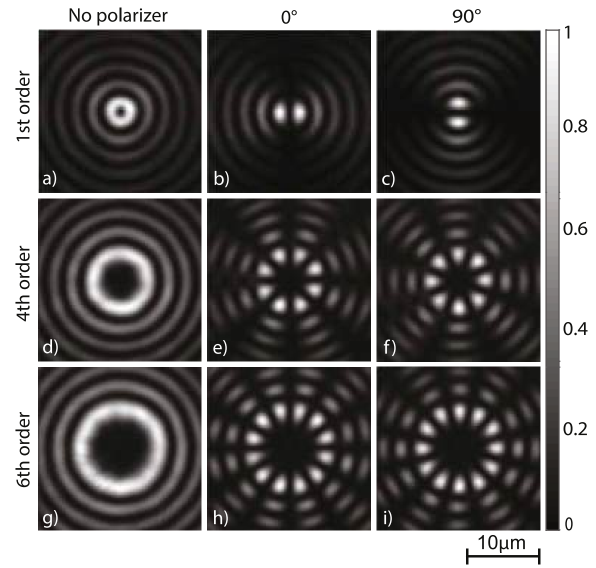


Higher-order S-waveplate

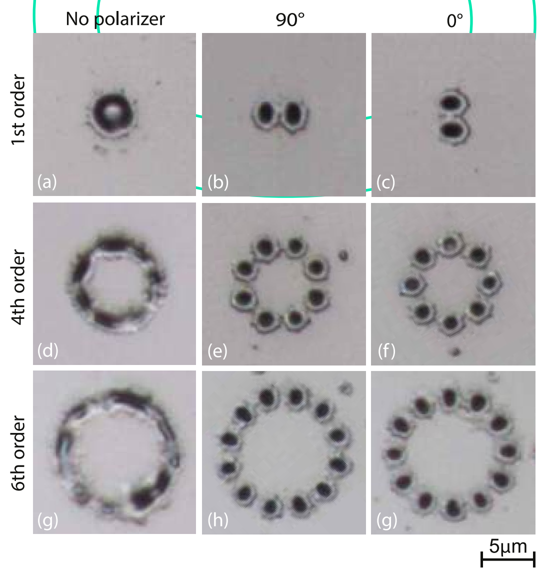
Higher-order S-waveplate converts linear polarization to higher-order polarization patterns.

Examples of fast axis patterns for 2nd (upper), 3rd (center) and 4th (bottom) order S-Waveplates (measured with Hinds Instruments Exicor MicroImager).

Combining HOS with an axicon enables vector Bessel beams (VBBs) to be obtained that can be used for the efficient drilling of transparent materials.



Beam spatial intensity profiles of the 1st, 4th and 6th order vector Bessel-Gauss beams (a, d, g) and their single polarization component spatial intensity distribution when polarizer was rotated at two different angles. When the polarizer was parallel to incoming polarization (0 deg) beam intensity profiles are depicted in second column and when polarizer was perpendicular (90 deg) beams are depicted in third column.[3]



Transparent material modification on the D263t glass sample surface with higher order VBB's and their transverse polarization components. 1st, 4th and 6th order VBB damages are depicted in a, d, and g respectively. The single polarization component of the appropriate VBB are depicted in second and third column.[3]

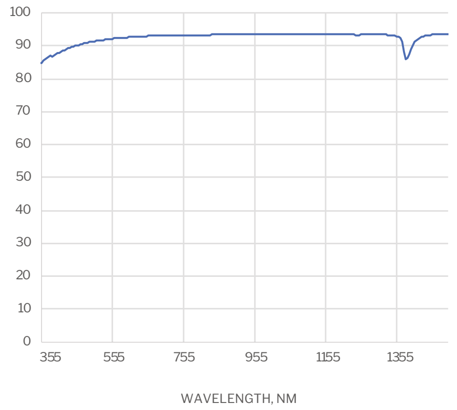
[3] Justas Baltrukonis, Orestas Ulcinas, Pavel Gotovski, Sergej Orlov, Vytautas Jukna, "Realization of higher order vector Bessel beams for transparent material processing applications," Proc. SPIE 11268, Laser-based Micro- and Nanoprocessing XIV, 112681D (2 March 2020); doi: 10.1117/12.2545093

Technical features

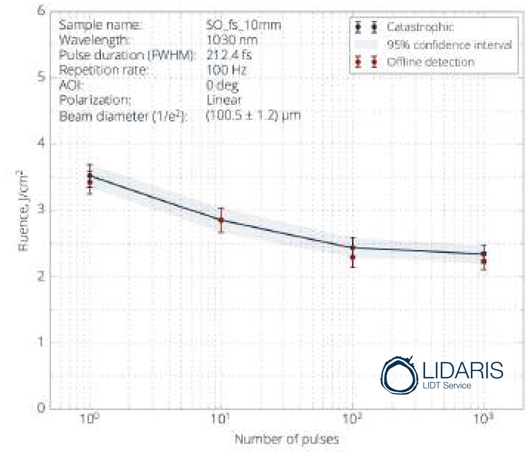
- LIDT | High damage threshold:
  63,4 J/cm2 @ 1064 nm, 10 ns
  2,2 J/cm2 @ 1030 nm, 212 fs
- High transmission (no AR coating):
  94% @ 1030 nm, 92% @ 515 nm,
  85% @ 343 nm of most SS lasers
- Large aperture possible - up to 15 mm

Application examples

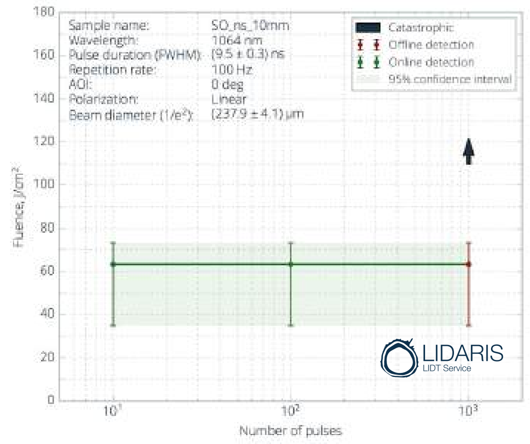
- STED microscopy
- Micromachining
- Micro drilling high-aspect-ratio channels
- Generate any cylindrical vector vortex
- Multiple particle trapping
- Micro-mill is driven by optical tweezers
- Use as an intracavity polarization-controlling element in cladding-pumped ytterbium-doped fiber laser for radially polarized output beam generation



Transmission of uncoated s-waveplate



LIDT at femtosecond regime



LIDT at nanosecond regime

Flat Axicon

Transforms Gaussian beam into a Bessel-Gauss beam

Why it is better than ordinary axicon?

- Positive and negative Bessel-Gauss zones - 3 in 1 usage possibilities.
- Suitable for high LIDT applications and high-power lasers.
- Flat optics - saves space, easy to handle.
- Reliable and resistant surface - the structure is inside the bulk.

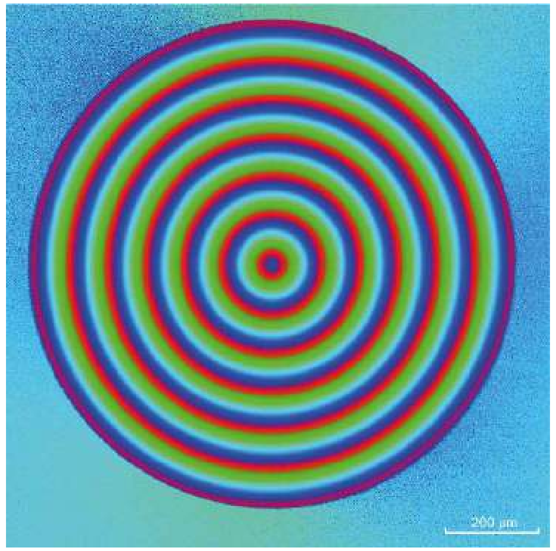
Description

Circular grating (a.k.a flat axicon) is a space-variant retarder that transforms Gaussian beam into a Bessel-Gauss beam.

The product is leading for its high damage threshold, comparing to alternative devices. It has laser irradiation resistance similar to uncoated fused silica substrates.

The structure of the element is unique due to formation birefringent nanograting's inside a bulk of fused silica glass, sensitive to the incident polarization.

Circular grating can generate both - positive and negative Bessel-Gauss zones, separately with LHCP and RHCP polarizations. Also, positive and negative zones simultaneously with linear polarization. The working regime depends only on incident polarization.



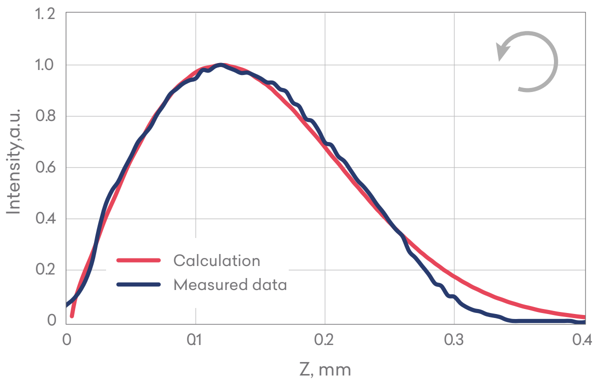
Fast axis distribution across the element (measured with HINDS MicroImager)

Applications:

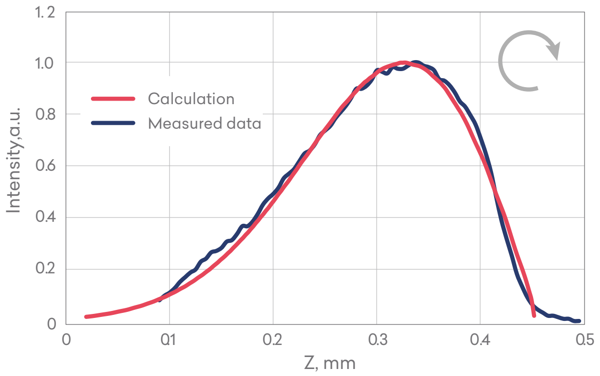
- Micromachining
- Ultra-high aspect ratio micro holes drilling
- High 90% efficiency Bragg gratings
- Cutting of transparent materials

Technical features:

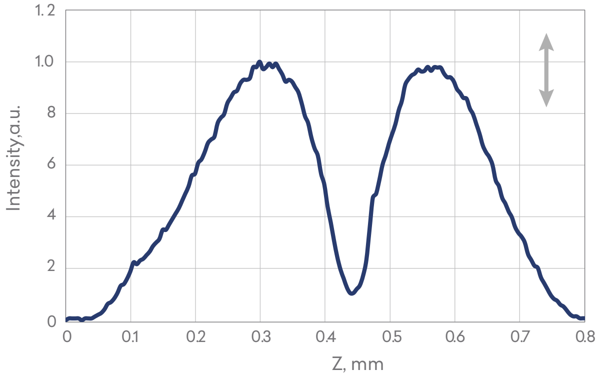
- Material: UVFS, IRFS
- Wavelength range: 330nm to 2000 nm
- Min Apex angle: 176-179.9° @1030 nm
- Diffraction efficiency: up to 95%
- Clear aperture size: up to 15 mm
- Coating (optional): AR/AR coating
- Uncertainty of diameter of cone tip - ~20 µm
- LIDT | High damage threshold:
  63 J/cm2 @1064 mn, 10ns;
  2 J/cm2 @1030 nm, 212fs
- Transmission (no AR coating):
  85% @343 nm,
  92% @515 nm, 94% @1030 n



Positive Bessel-Gauss zone
Incident light polarization > left-hand circular – emulating convex axicon.



Negative Bessel-Gauss zone
Incident light polarization > right-hand circular – emulating concave axicon.



Positive & Negative Bessel-Gauss zones
Incident light polarization > emulating both axicons simultaneously.

Flat Top Converter

Transforms Gaussian beam into a flat-top shaped beam

Why choose flat-top?

- 100% suitable for your application – designed according to your laser beam specifications.
- Suitable for high-LIDT applications and high-power lasers.
- Wavelength range from 300 nm to 2 μm.
- Conversion efficiency up to 70% (wavelength dependent).
- Large aperture (up to 15 mm; standard is 6 mm).

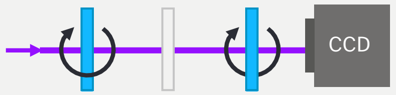
Gauss to top-hat converter

Space variant waveplate for flat-top conversion is beam shaping optics.

A combination of a space-variant waveplate and a polarizer acts as a space-variant transmission filter that converts the Gaussian beam spot profile to a flat-top beam with equal energy distribution.

$$\theta(r) = \text{asin}\left(0.65 \cdot e^{\left(\frac{r}{2\ 21}\right)^2 - \left(\frac{r}{1\ 8876}\right)^{14}}\right) \cdot 180/\pi$$

$$R = \text{const}$$



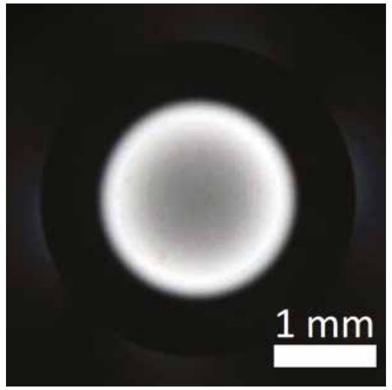
It is a space-variant phase retardation plate inscribed inside a bulk of fused silica glass by femtosecond laser pulses.

A well-known fact is that flat-top intensity distributions have noticeable advantages in micromachining in terms of efficiency and quality compared to Gaussian beam profiles.[1]

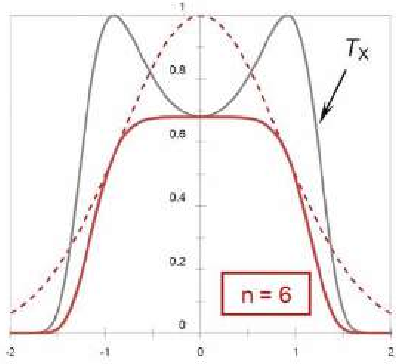
A converter enables on-the-fly adjustment of the beam shape from flat-top to a shape with a dip in the middle.

The converter paired with a polarizer filters out the input beam to generate a beam with Super-Gaussian intensity distribution. The Super-Gausian intensity profile can be adjusted for the best performance according to specific needs.

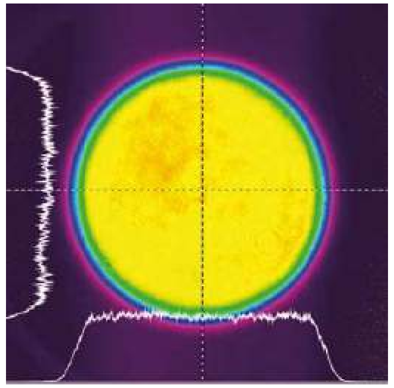
The converter is compatible with high-power ultrashort lasers.



Converter photo in cross polarized light (CA = 4 mm, λ = 1064



Slow axis distribution

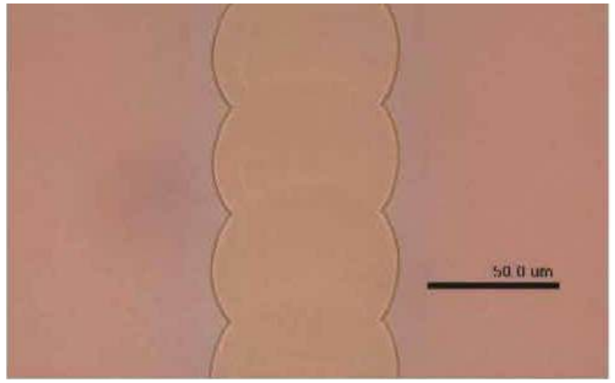


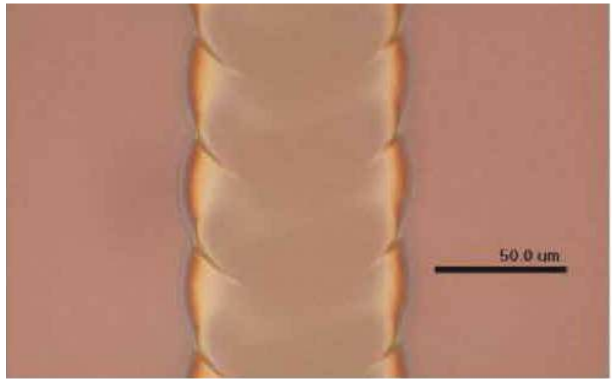
Measured Flat-top intensity distribution after converter

[1] Homburg, O., & Mitra, T. (2012). Gaussian-to-top-hat beam shaping: an overview of parameters, methods, and applications. Laser Resonators, Microresonators, and Beam Control XIV. doi:10.1117/12.907914

Technical features:

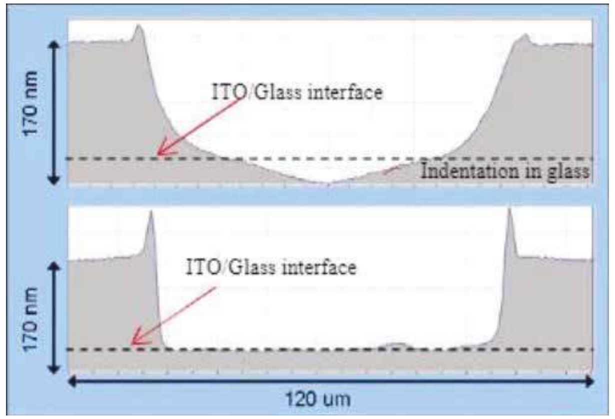
- Material: UVFS, IRFS
- Wavelength range: 330 – 2000 nm
- Efficiency: depends on Super-Gauss order N
- Clear aperture size: up to 15 mm
- Coating (optional): AR/AR coating
- LIDT | High damage threshold:
  63 J/cm^2 @ 1064 mn, 10 ns;
  2 J/cm^2 @ 1030 nm, 212 fs
- Transmission (no AR coating):
  85% @ 343 nm, 92% @ 515 nm,
  94% @ 1030 n





Application examples

- Micromachining applications
- Laser pump shaping



High power, nanosecond pulse Q switch laser technology with Flattop beam shaping technique for efficient industrial laser processing

Depolarization Compensator

Compensates depolarization in the gain medium

Advantages vs. alternatives

- No absorption.
- Very low scattering.
- Custom and continuous point-by-point patterns.
- Maximum power extraction possibility without additional beam quality degradation.
- Flexibility to compensate different amounts of depolarization by stacking more than one element.
- Saves space, is easy to handle.
- Significantly lower price.

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Depolarization in the gain medium

Thermal effects in a high-power laser's gain medium create predictable axially symmetric temperature gradients.

Temperature gradients generate mechanical stresses in pumped crystal, which lead to induced birefringence.

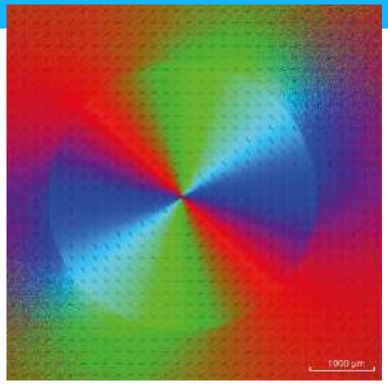
Generated optical anisotropy causes significant power losses if a laser system contains polarization-sensitive elements (e. g. Brewster plates, Faraday rotators).[1]

ORISANDO by WOP solution – depolarization compensator

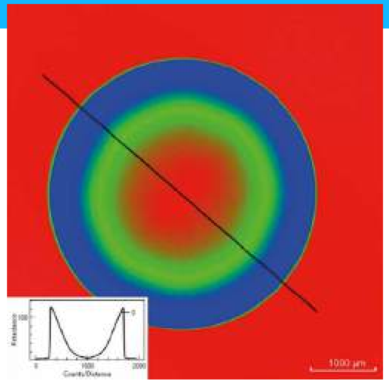
WOP has developed and validated a solution for solving the depolarization issue: an optical element compensating the distortion of original polarization in the gain medium.

This spatially variable waveplate (SVWP) is fabricated based on the level of depolarization, its origin, and the parameters of the amplified laser beam.

Thanks to the unique characteristics of precisely inscribed point-by-point nano-gratings, our depolarization compensator is flexible and versatile, allowing extensive customization to meet customer needs.



Two-dimensional distribution map of orientation of fast and slow axes.



Retardance profile.

[1] Veselis, L., Burokas, R., Ulčinas, O., Gertus, T., Michailovas, K., & Michailovas, A. (2021). Depolarization compensation with a spatially variable wave plate in a 116 W, 441 fs, 1 MHz Yb: YAG double-pass laser amplifier. Applied Optics, 60(24), 7164-7171.

Advantages

Our method offers significant advantages over other methods, such as the use of an intracavity quarter-wave plate, an intracavity Faraday rotator, a classical depolarization compensation setup with two identically pumped and relay-imaged gain media, and varying crystal cut directions.[1]

The reasons are: [1]

- The substrate of spatially variable wave plate (SVWP) is fused silica, providing low bulk absorption of laser radiation and featuring a significantly lower nonlinear refractive index, as compared to a Faraday rotator, thus minimizing thermal effects and nonlinear interaction in high-intensity lasers.
- The SVWP element is compact (6 mm in thickness, usually 25.4 mm in diameter), whereas Faraday rotator material is usually at least 20 mm in length;
- There is the possibility to compensate for depolarization in the highly pumped gain medium, which is not the case using a simple approach with a quarter-wave plate;
- It is not overly sensitive to alignment and specific configuration;
- It is very practical, as the induced/compensated depolarization level can be tuned by either changing the incident laser beam size or stacking a few SVWPs in the same optical layout.

Depolarization compensator

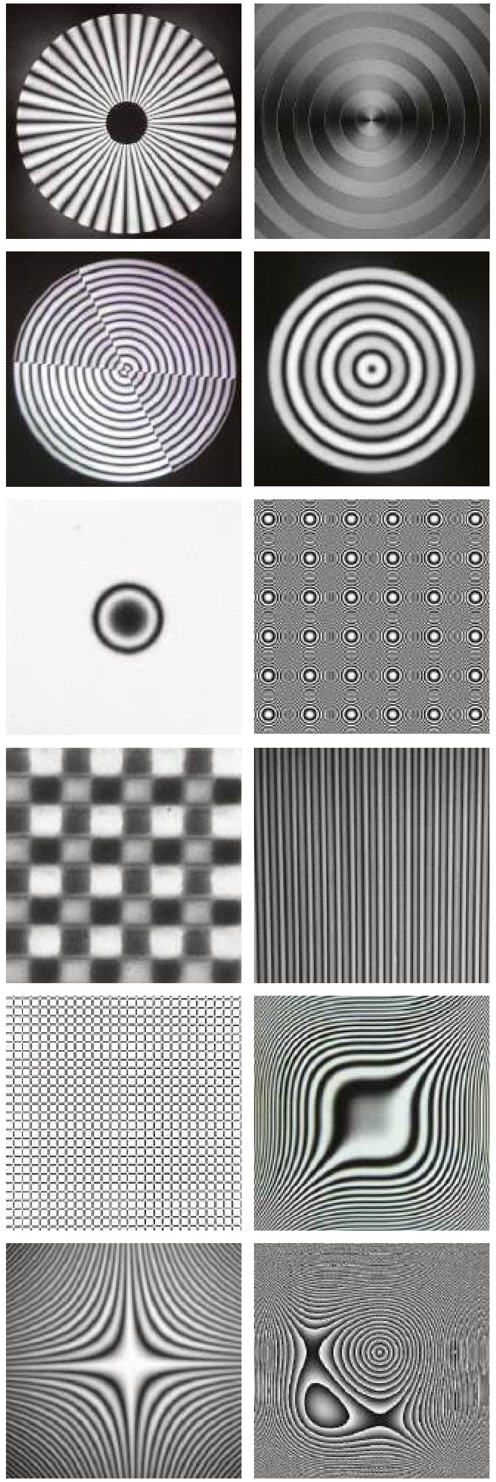
Custom Space Variant Retarders

Adapted to the specific end-user needs

Features

- Wavelength range from 200 nm to 3500 nm.
- Aperture size from 1 mm to 15 mm.
- High damage threshold: 63,4 J/cm^2 @1064 nm, 10 ns and 2,2 J/cm^2 @1030 nm, 212 fs.
- 94% transmission @1030 nm, without AR coating (99% with AR).
- Suitable for high LIDT applications and high-power lasers.
- Reliable and resistant surface – the structure is inside the bulk.
- Custom fast axis and retardance patterns.

- We can fabricate various SVRs for tailored polarization conversion and beam shaping.
- Rapid prototyping enables the adaptation of every element to the specific end-user needs - fast axis and retardance distribution, clear aperture, substrate shape, and thickness - without high additional development costs.



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