S-WAVEPLATE
LINEAR TO RADIAL/AZIMUTH POLARIZATION CONVERTER

Operation manual

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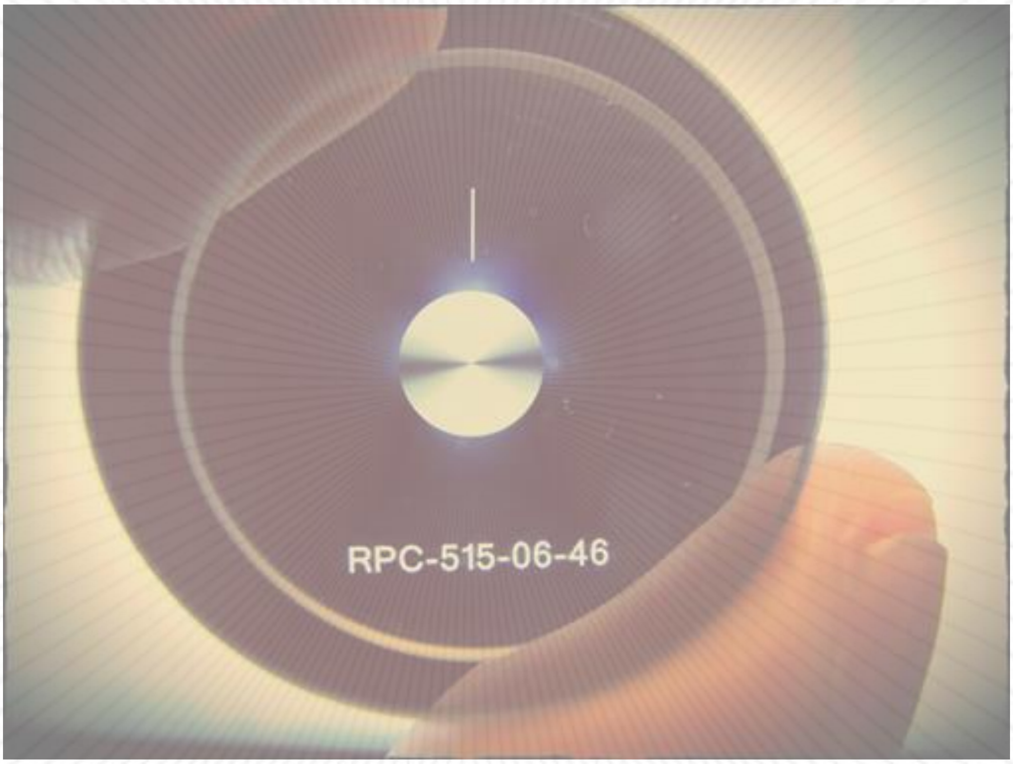

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INTRODUCTION

S-waveplate is a super-structured space variant polarization converter. It converts incident LINEAR to RADIAL or AZIMUTH polarization. S-waveplate can also generate optical vortex (OV) beams with circular polarization. Converter is unique for its high damage threshold - 100 times exceeding alternative LCD based devices.

Production of S-waveplate is based on unique laser nano-structuring technique developed by prof. Peter G. Kazansky group from Optoelectronics Research Centre at Southampton University[1]. Prototype S-waveplate production is published in Applied Physics Letters[2].

UNIVERSITY OF Southampton

S-waveplate Radial/Azimuth polarization converter RPC-488-06-56 fabricated in the bulk of 1” diameter 3 mm thickness UVFS substrate.

I. FEATURES

- Converts linear polarization to radial or azimuthal
- Can be used to create an optical vortex (OV) beam
- High damage threshold
- Nearly 100% efficiency in polarization conversion for dedicated wavelengths
- 30-90% transmission (wavelength dependent)
- Large aperture possible (up to 10 mm; standard is 6 mm)

II. BENEFITS

In Laser Micro Machining

- Allows focusing into smaller spot size (using NA > 0.9) [3]
- Ensures the same machining properties in all directions*
- Ensures the same cutting speed in all directions*
- Enable ring shaped intensity distribution in focus (at NA <0.8)
- Increases cutting speed

**if process is sensitive to incident polarization direction*

Optical Tweezers

- Increases trapping force
- Might trap particles with lower refractive index comparing to surroundings

III. SPECIFICATIONS

Standard S-waveplate polarization converter is fabricated in the volume of 1 inch, 3 mm thickness UVFS substrate (other size possible on demand). It comes in various clear aperture sizes (from 0,1 mm to 10 mm) and operates with dedicated wavelength (±10 nm) only. To increase transmission characteristics converter can be coated with antireflection coatings AR/AR on both sides.

Scattering and Absorption

S-waveplate transmission properties are caused by scattering and absorption losses inside the converter structure. Measured view of 515 nm converter scattering is displayed in the **Error! Reference source not found.**.

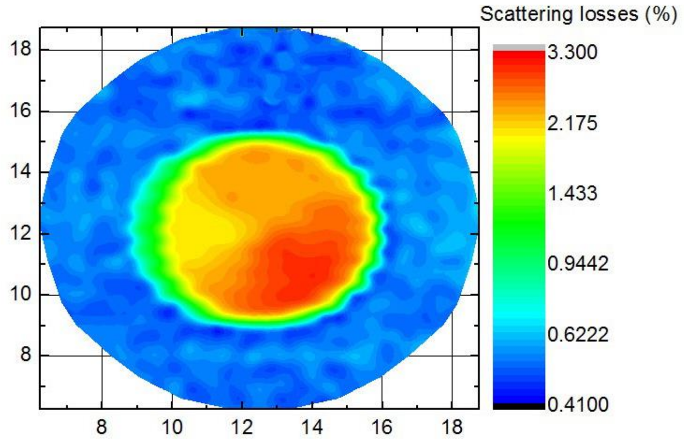


Figure 1 Scattering profile of the converter structure; center red-yellow area represents the converter aperture.

Damage threshold

S-waveplate laser induced damage threshold was performed according to S-on-1 test procedure: ISO 11254 – 2. At pulse duration τ = 3.5 ns, f = 10 Hz repetition rate damage threshold for different wavelengths is listed in **Table 1**.

Table 1 S-waveplate laser induced damage threshold results

λ = 1064 nm	λ = 532 nm
LIDT $_{1\text{-on-}1}$ = 26.25 ± 3.15 J/cm^2 LIDT $_{1000\text{-on-}1}$ = 22.80 ± 2.74 J/cm^2	LIDT $_{1\text{-on-}1}$ = 4.71 ± 0.56 J/cm^2 LIDT $_{1000\text{-on-}1}$ = 3.67 ± 0.44 J/cm^2

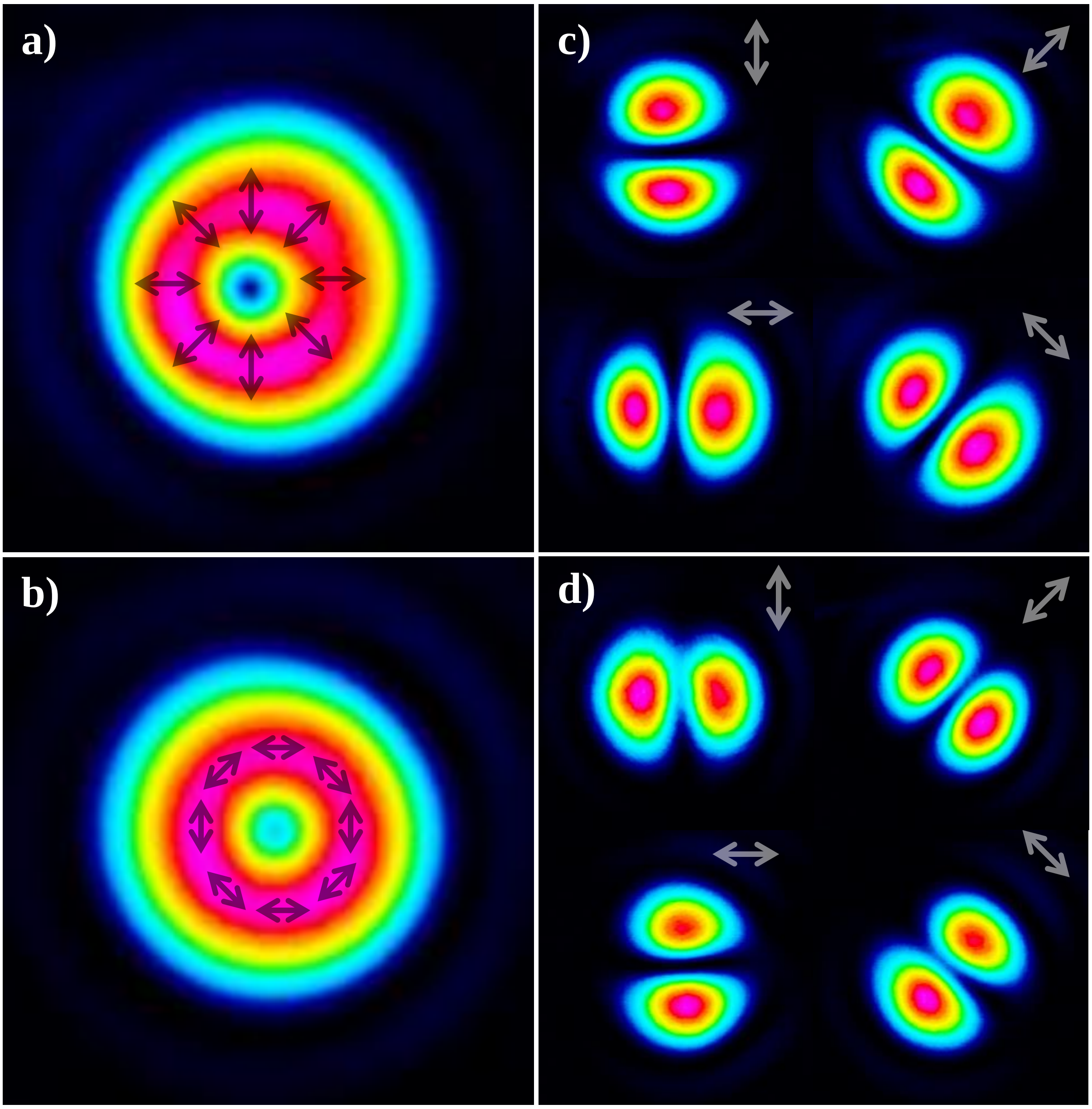


Figure 2 HeNe laser a) radial and b) azimuth polarization intensity distributions measured with WinCamD CCD camera. Measured intensity distributions c) radial and d) azimuth - linear polarizer (at different angles) was placed after converter. White arrow indicates polarizer orientation.

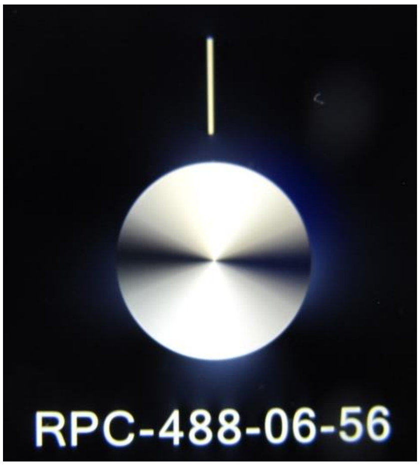
IV. METHOD OF USE

Radial/Azimuth polarization conversion using S-waveplate

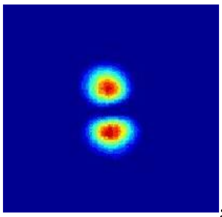
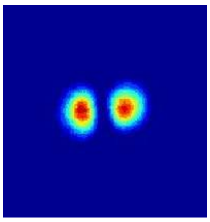
Following step-by-step procedure must be done in order to generate radial or azimuthal polarization beams:

a) Place the converter into linearly polarized laser beam.

b) Align the center of the converter with the optical axis of the incident laser beam. Make sure converter rotation along z axis is correct. Alignment mark is fabricated on converter. It should be aligned *parallel* to incident linear polarization orientation to get **radial** and *perpendicular* to get **azimuth** polarization.



c) Check the alignment with linear polarizer placed after converter. The dumbbell shape must be symmetric for all polarizer angles:

0 deg: , 90 deg: 

d) Polarization state of the output beam can be controlled by rotating the converter or the incident polarization (by rotating λ/2 waveplate placed before converter). If the dumbbell shape is aligned along linear polarizer transmission axis, the output polarization is radial. If the dumbbell shape is perpendicular to the polarizer transmission axis, the output polarization is azimuthal.

Optical vortex generation using S-waveplate

S-waveplate can also be used to generate optical vortex beam. Following step-by-step procedure must be done in order to generate optical vortex beam:

1. Place the converter into ***circularly*** polarized laser beam.
2. Align the center of the converter with the optical axis of the incident laser beam.

Note: The sign of the optical vortex charge „+“, „-“ on handedness of the incident circular polarization.

[1] Y. Shimotsuma, **P. G. Kazansky**, J. Qiu, K. Hirao, Self-Organized Nanogratings in Glass Irradiated by Ultrashort Light Pulses, Phys. Rev. Lett. 91, 247405 (2003).
[2] M. Beresna, M. Gecevičius, **P. G. Kazansky** and T. Gertus, Radially polarized optical vortex converter created by femtosecond laser nanostructuring of glass, Appl. Phys. Lett. 98, 201101 (2011).
3. R. Dorn, S. Quabis, and G. Leuchs, Phys. Rev. Lett. **91**, 233901 (2003).