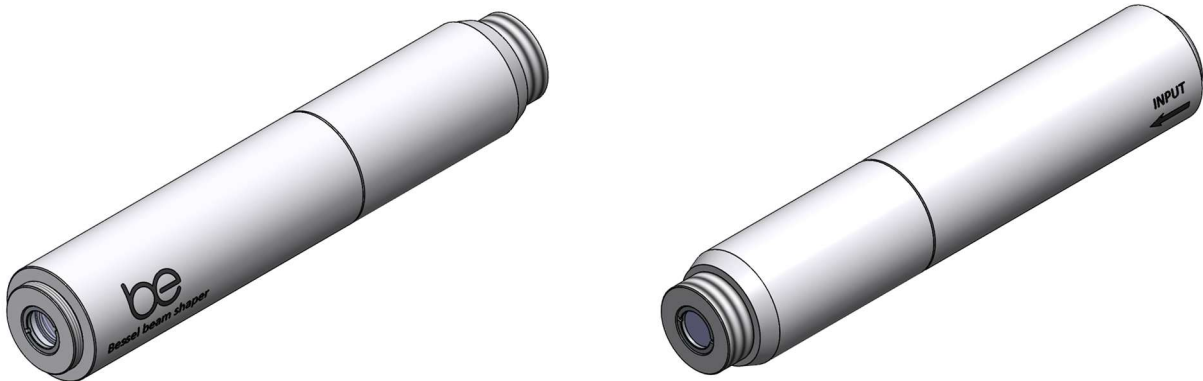




White paper Bessel Beam Shaper



1. Overview

Bessel Beam Shaper is an objective designed to conveniently transform Gaussian beam into ready-to-used Gauss-Bessel beam. It features several unique features that make it a dependable tool for glass drilling and cutting Bragg grating writing applications:

- High damage threshold - LIDT is only limited by coating
- Negative, Positive or double Bessel-Gauss zones are available at the output
- Easy alignment - mounts into standard cage system

Bessel Beam Shaper is available for 1-st, 2-nd & 3-rd harmonics of both Neodymium and Ytterbium laser lines.

The device is designed to comply with strict stability, robustness requirements that are inflicted by industrial laser applications, which makes it suitable for both – industrial and demanding scientific use.



2. Specifications

Bessel Beam Shaper

Wavelength: 1030 nm

Negative Bessel-Gauss zone (or positive/or both – depending on input polarization)

Max Input (Gauss) beam diameter at e^{-2} : \varnothing 6mm

Output Bessel-like beam diameter \varnothing 3.4 μ m (2 fig.)

Output Bessel-like beam length (1 fig):

~0.12 mm (FWHM) with input gaussian beam \varnothing 1 mm (at e^{-2})

~0.25 mm (FWHM) with input gaussian beam \varnothing 2 mm (at e^{-2})

~0.43 mm (FWHM) with input gaussian beam \varnothing 3 mm (at e^{-2})

~0.53 mm (FWHM) with input gaussian beam \varnothing 4 mm (at e^{-2})

~0.67 mm (FWHM) with input gaussian beam \varnothing 5 mm (at e^{-2})

~0.80 mm (FWHM) with input gaussian beam \varnothing 6 mm (at e^{-2})

Working distance (3 fig.):

~ 12 mm (negative Bessel-Gauss zone)

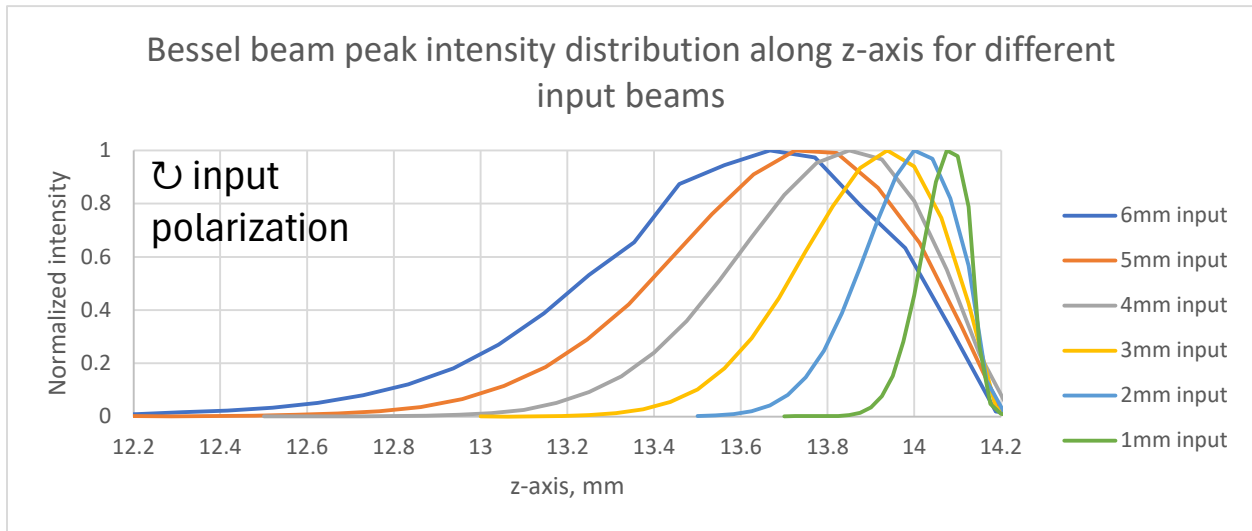
~ 14 mm (positive Bessel-Gauss zone)



3. Simulations

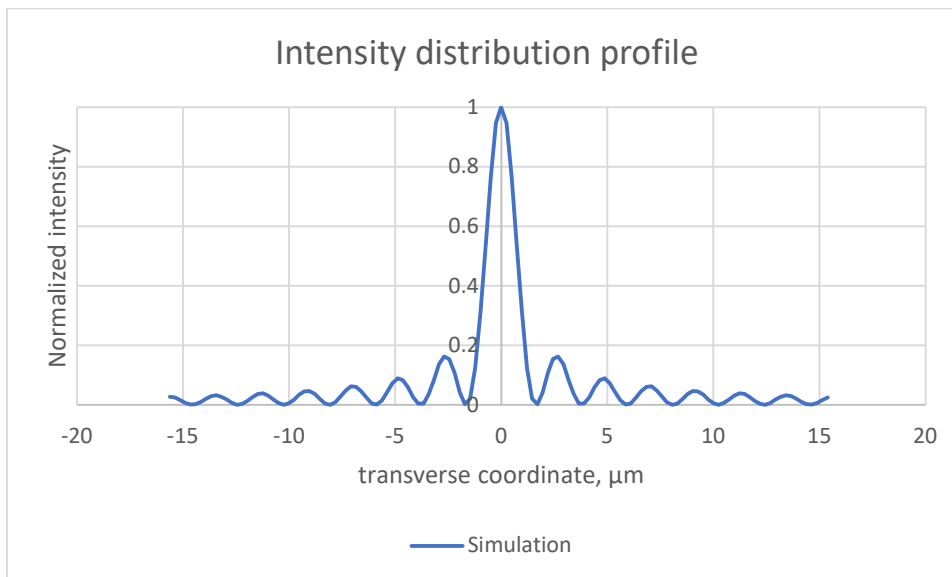
Longitudinal and lateral Bessel beam distribution

Bessel beam shaper generates ready to use Bessel beam, which properties depend on input beam size. The larger input beam size – the longer Bessel zone



1 fig. Bessel beam central intensity distribution (negative Bessel beam)

However, transverse Bessel beam intensity profile does not depend on input beam size and maintains its shape along whole Bessel beam propagation distance.



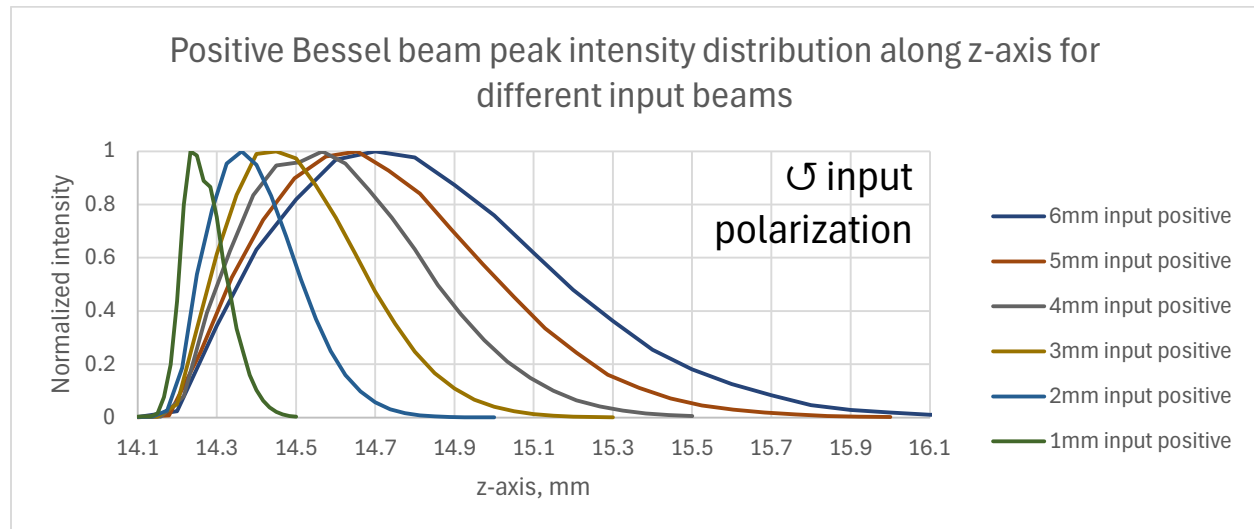
2 fig. Bessel beam lateral intensity distribution.



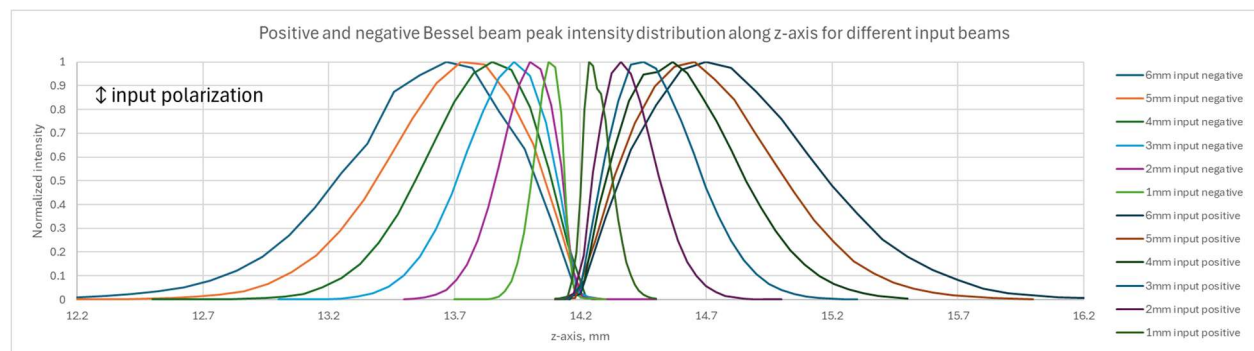
Positive and Negative Bessel beam zones

Beamera Bessel Beam shaper employs FLAT axicon, which is a fused silica window with nanograting structure embedded in the volume. Light passing it interacts with nanostructure and as a result after the element light propagates as it has passed axicon. The unique feature of nanostructure structure is that it is birefringent, therefore polarization dependent. As a result, flat axicon can act as:

- Convex axicon – if input beam has circular right-hand polarization. Therefore, positive Bessel Beam is generated – 1 fig.
- Concave axicon – if input beam has circular left-hand polarization, Therefore negative Bessel Beam is generated 3 fig.
- Both – convex and concave axicon at the same time – if input beam is linearly polarized. Therefore both – positive and negative Bessel beams are generated simultaneously effectively twice increasing Bessel zone (also referred as DOF – depth of focus) – 4 fig.



3 fig. Bessel beam central intensity distribution (negative Bessel beam)

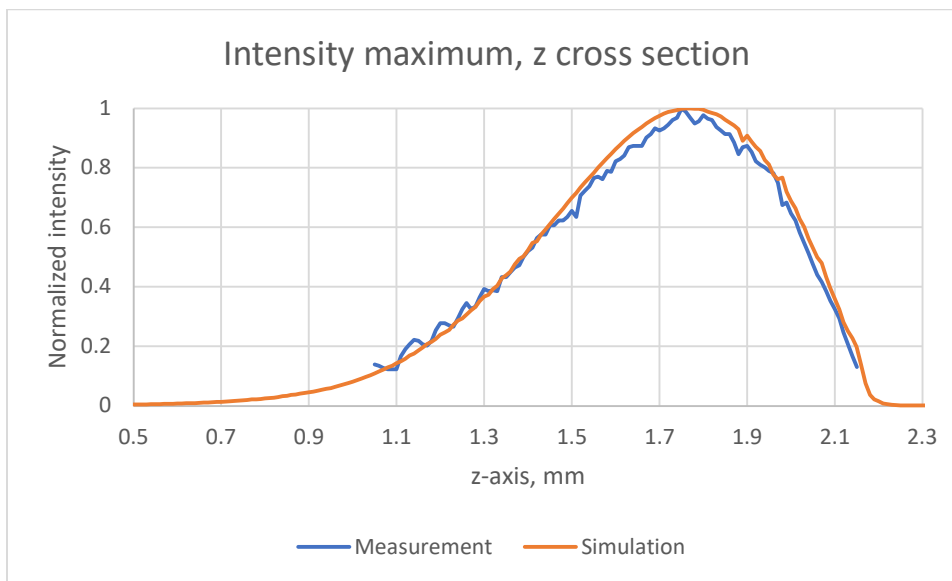


4 fig. Bessel beam central intensity distribution (positive and negative Bessel beams)

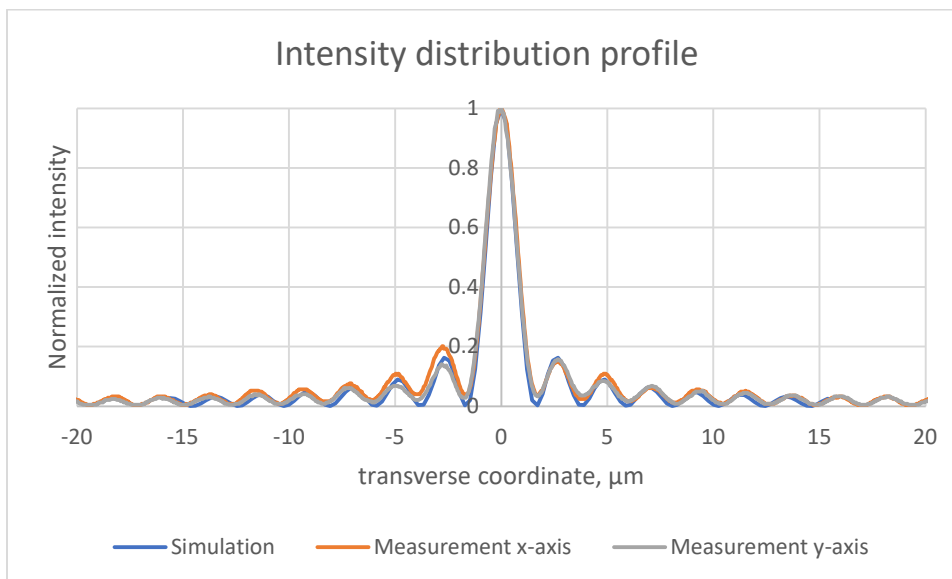


4. Measurements

Bessel Beam shaper performance is evaluated by comparing simulation results with measurements from lab environment, that is close to actual application. Bessel beam lateral intensity distribution profiles and peak intensity distribution along z-axis was measured. The results are presented in the pictures below.



5 fig. Bessel beam shaper peak intensity distribution along z (comparison simulation vs. measurement)



6 fig. Bessel beam shaper lateral intensity distribution comparison (simulation vs. measurement)



5. Conclusions

Bessel beam shaper operation is in agreement with simulations, therefore it can be concluded, that:

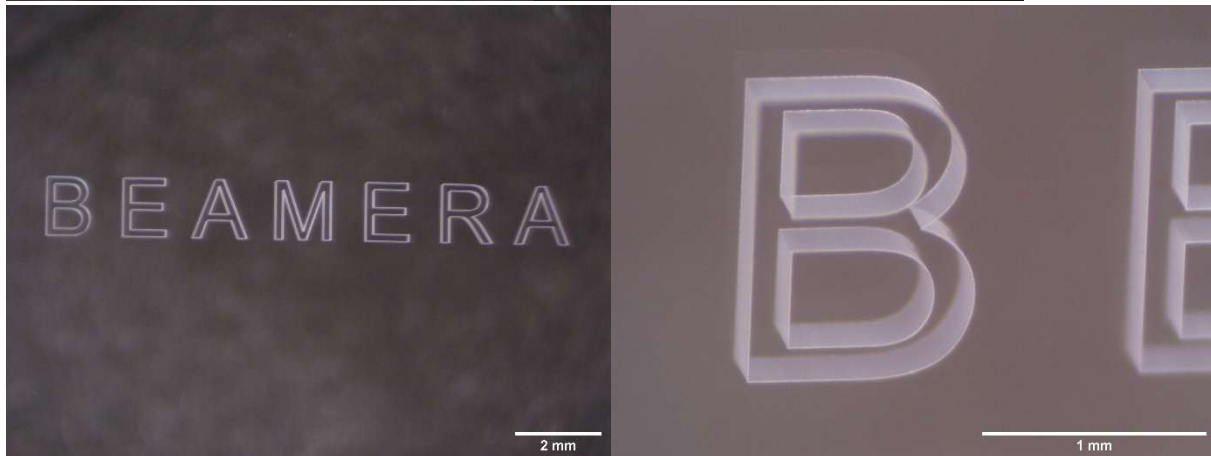
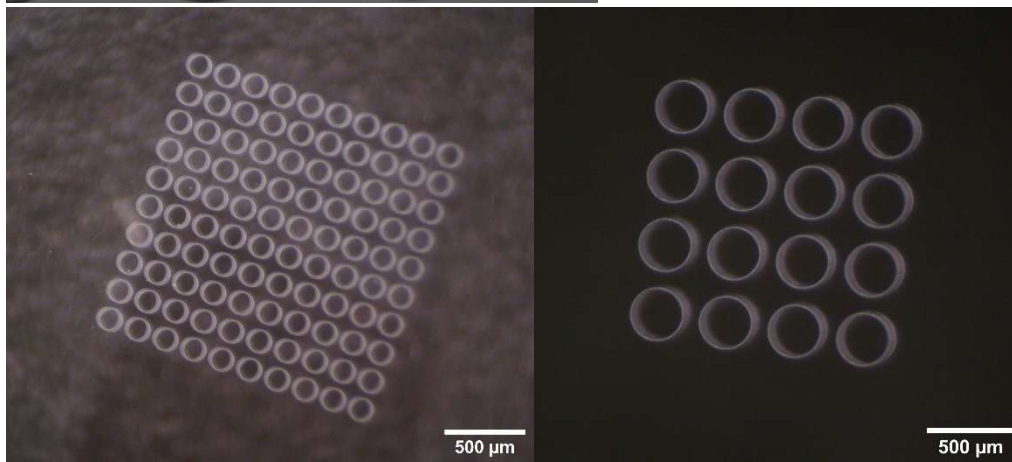
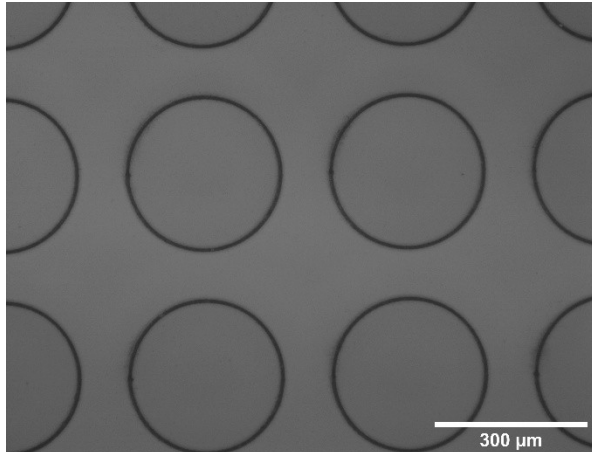
1. Theoretical model of optical system is accurate
2. Nanograting-based Flat axicon is superior alternative for refractive axicon:
 - a. It's angle can be accurately and repeatably manufactured
 - b. Little-to-non peak intensity fluctuations along z-axis suggest, that axicon does not have "round tip" problem, that is inherent for refractive axicon
 - i. This is major improvement compared to **convex** type axicons, that typically have 0.5m~3mm sized round apex.
 - ii. This is revolutionary improvement compared to **concave** type axicons, that typically have >1mm sized central pit of undefined shape



6. Application examples

Glass modifications inscribed inside the volume

Laser beam/pulse parameters unknown



7 fig. Glass modifications inscribed inside the volume, Laser beam/pulse parameters unknown

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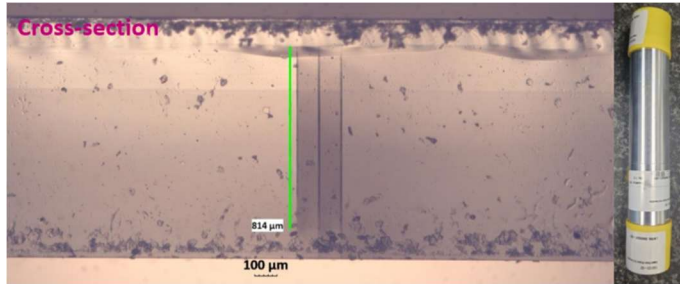
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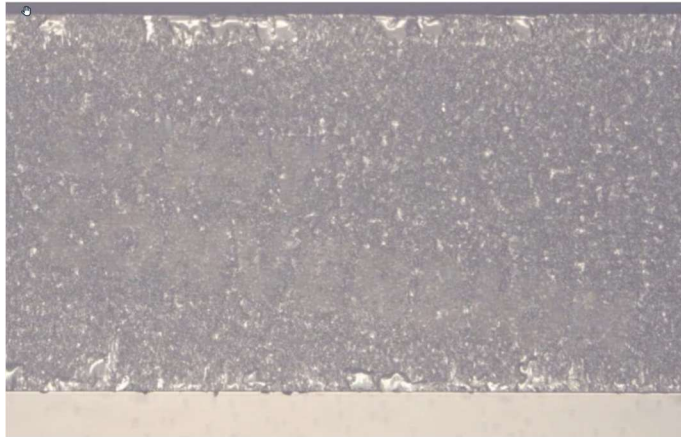
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08130, Vilnius, Lithuania
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Glass modifications inscribed inside the volume and cutting



8 fig. Laser modification length in glass using the Beamera Bessel beam shaper. Pulse energy: 130 μJ on the sample. Pulse duration \sim picoseconds



9 fig. Cross-section of glass samples processed using the Beamera Bessel Beam Shaper. Pulse energy: 130 μJ on the sample. Pulse duration \sim picoseconds



10 fig. Cross-section of glass samples processed using the Beamera Bessel Beam Shaper. Pulse energy: 130 μJ on the sample. Pulse duration \sim picoseconds

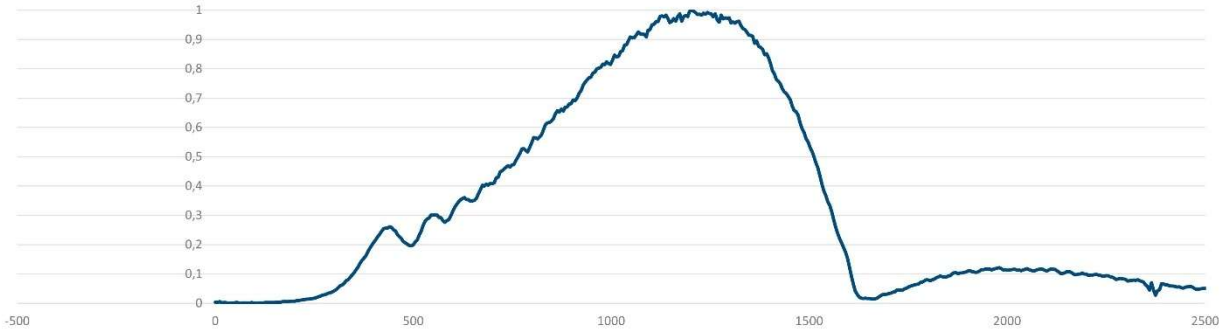
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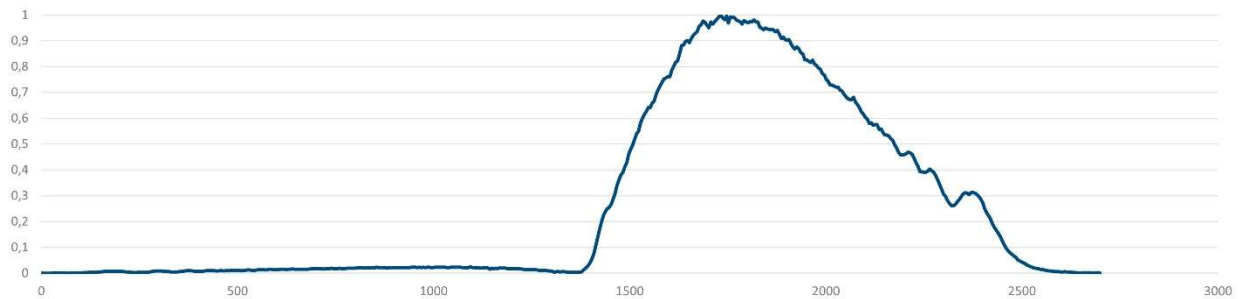
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Independent test of Bessel beam peak intensity profile along z-axis and practical result of switching between positive/negative/both Bessel beams



11 fig. Negative Bessel beam peak intensity distribution along z – \cup input beam polarization



12 fig. Positive Bessel beam shaper peak intensity distribution along z. – \cup input beam polarization



13 fig. Both – positive and negative Bessel beam shaper peak intensity distribution along z – \updownarrow input beam polarization

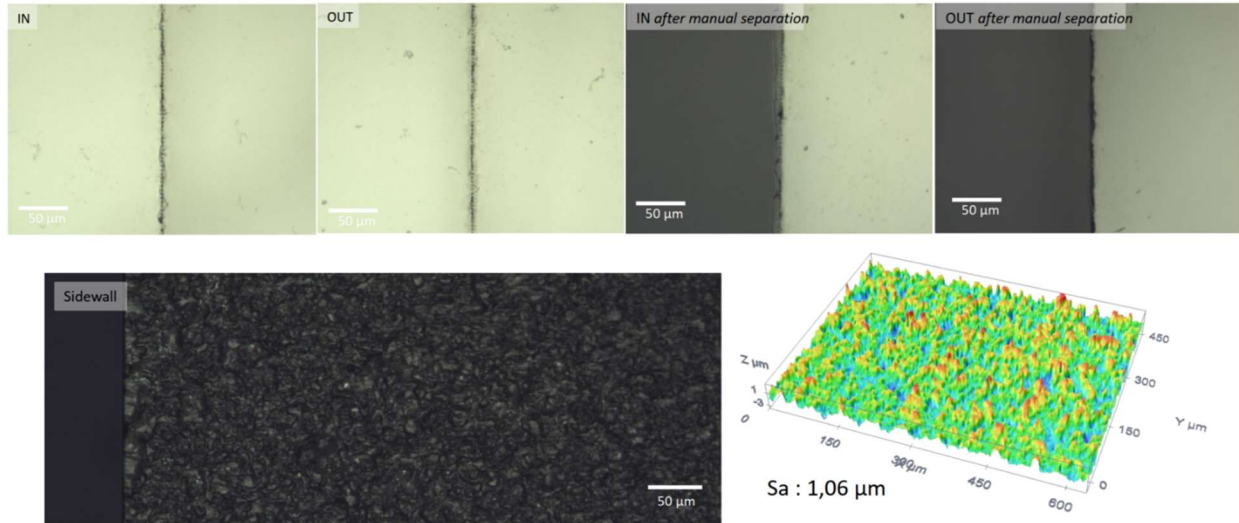


Glass cutting with Tangor 500 μ J; 2.5W; 5 kHz with the GHz burst mode.

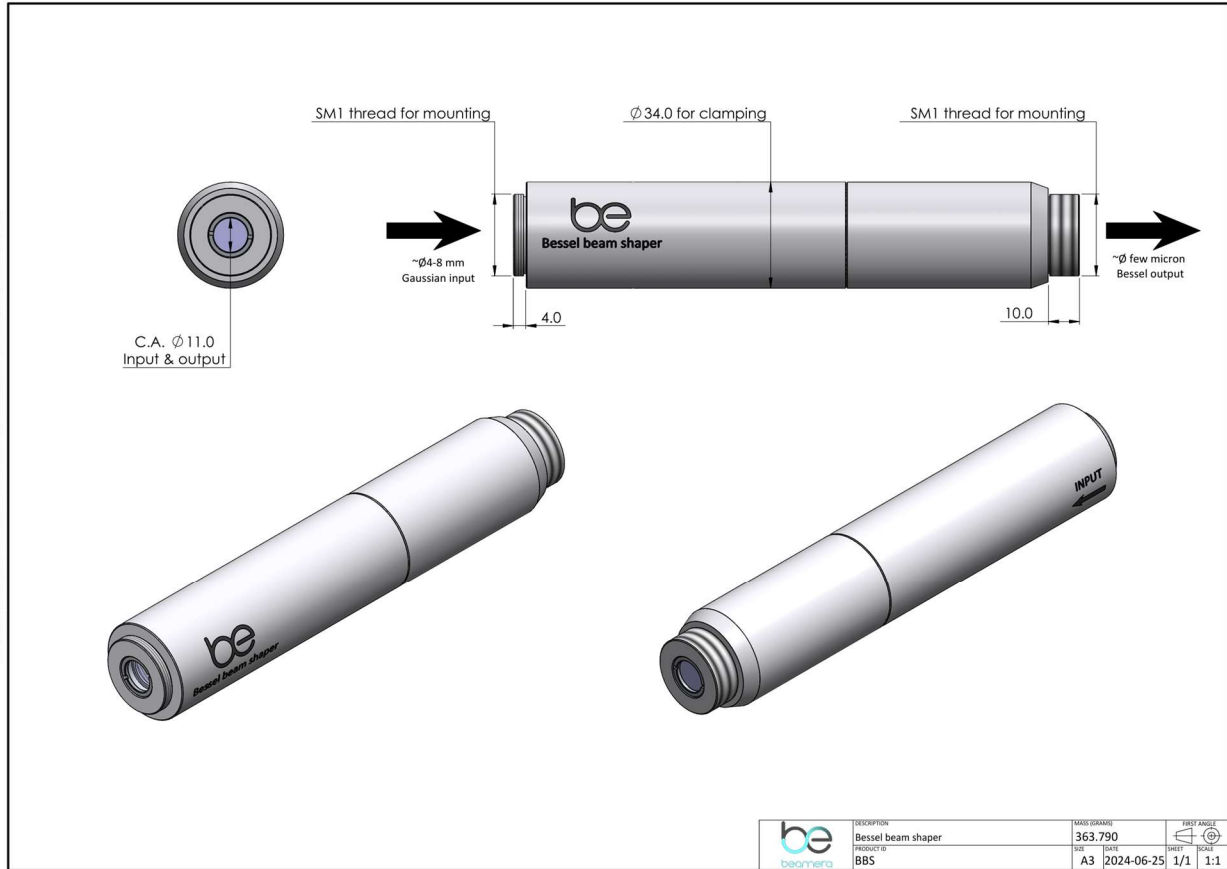
02 / Results

2.1 Glass Cutting *_ Non oriented linear polarization*

5 kHz _ 2,5W _ 500 μ J
GHz : 32 ppb @ 1,28 GHz
Sample : Glass 1 mm



14 fig. Pictures and cut surface roughness measurement of 1mm thick glass sample cut with 100W femtosecond laser in GHz burst mode.



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