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Fully reflective bessel beam generation with constant energy distribution over the propagation axis for complex glass cutting

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Abstract

Glass cutting with femtosecond lasers is spreading led by the touch panel displays development. Bessel beams are very efficient and precise way to process glass thanks to their extended depth of focus 100 times longer than a standard Gaussian beam and their central beam which can be smaller than the diffraction limit. High quality glass cutting with a reflective axicon has already been demonstrated with no oscillations leading to cleaner cuts and faster processes. The beam is able to propagate through a galvo-scanner and a F-theta lens. The reflective design is compatible with extreme high peak and average power. Here we describe the generation of a complex Bessel beam profile flatter over the propagation axis based on a reflective design. The tail of this profile is five times sharper compared to standard Bessel beams paving the way to complex glass cutting such as multi-layer glasses.

Keywords: Glass processing ; Ultra-Short Pulse laser ; femtosecond ; beam shaping ; Bessel beam

1. Introduction

Laser material processing with Ultra-Short Pulse (USP) lasers has developed over the last decades thanks to the unique quality of the resulting process. Indeed, femto-second lasers processes are athermal, meaning that with the optimal process parameters there is no heat affected zone. Among the developing processes is glass cutting, lead by the touch panel displays market. Cutting glass with

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standard USP lasers is spread among most glass manufacturers. For some years improved glass cutting performance has been demonstrated using Bessel beams generated by axicons, Bhuyan et al. 2010.

The generation of Bessel beams is highly improved when using reflective axicons as the generated beam quality is improved with no oscillations over the propagation, J. Del Hoyo et. Al., 2019. Moreover, a reflective design leads to a more stable Bessel beams and the possibility to process larger area through a galvo-scanner, A. Billaud et al, 2020.

The aim of this study is to improve further the generation of Bessel beams with a specific profile over the propagation axis. The intensity is more constant of the depth of focus of the beam, and decreases along a shorter transition length. This is performed using a reflective technology to preserve the advantages demonstrated previously.

2. Bessel beams

Bessel beams are generated using axicons. Standard axicon are glass transparent optics, plano on the entrance side and conical on the other side. The output beam is therefore with a conical phase, generating a specific beam as it is interfering with itself along the propagation axis. The generated beam will have a high intensity leading to the capability to perform processing. It will have very specific properties: its width might be extremely small, below the diffraction limit, and the length extremely long, aspect ratio 100 times longer than standard gaussian beams might be generated.

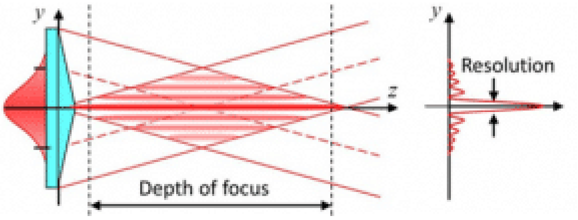

Fig. 1. Principle of Bessel beams generation

The generation of Bessel beams based on reflective technology is similar, with a conical phase beam interfering with itself. The optics is an off-axis optics to ease the integration.

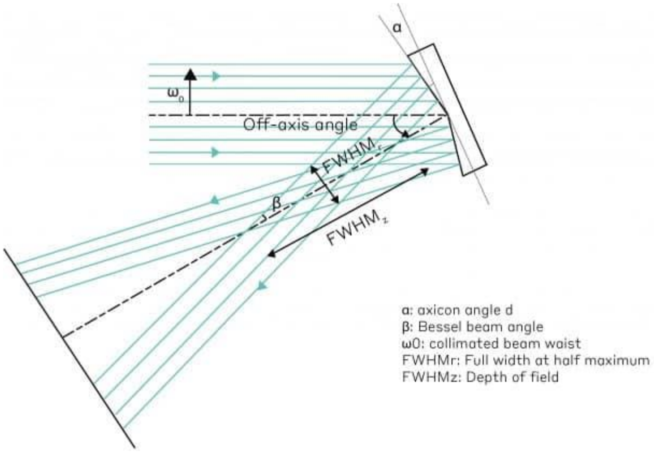

Fig. 2. Bessel beam generation with a reflective optics

The improved Bessel beam with a homogenous intensity profile over the axis is generated with a similar principle, and integrated within a module in order to ease even more its integration, the output beam and input beam being collinear.

3. Optical Set-up

The optical set-up includes:

- A 1030 nm diode laser source from Q-photonics collimated with a 8 mm EFL lens from Kirchoff-Schafter
- A beam expander in order to tune the waist dimension entering the module
- 2 mirrors to align the tilt and shift of the beam before the module
- The shaping module
- A Dataray camera (5.5 µm pixels) on a rail to measure the intensity profile along the axis

Fig. 3. Optical set-up to characterize the Bessel beam

4. Optical performance

The Full Width Half Maximum (FWHM) transverse to the propagation is 25 µm, and the FWHM along the propagation is 300 mm.

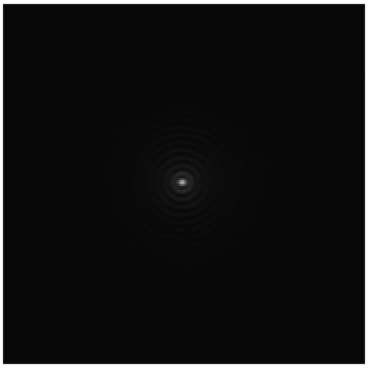

Fig. 4. Improved Bessel beam transverse intensity profile

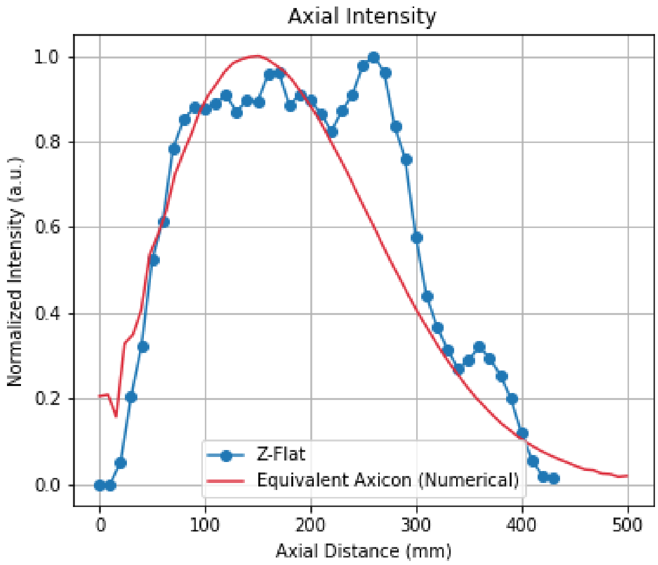

Fig. 5. Intensity profile along the optical axis compared to a standard Bessel beam of similar FWHM long the propagation

5. Conclusion

The generated Bessel beam is indeed having a 3 times shorter transition length: the transition from the maximum intensity to 50 % of the maximum is within 40 mm compared to 120 mm for a standard Bessel beam. Within the range of intensities above 50 % of the maximum intensity, the intensity is on average higher, leading to a more homogeneous profile: 85 % of the maximum versus 80 % of the maximum intensity. The standard deviation of the intensity within the range of intensity superior to 50 % is reduced from 15 % to 10 % of the maximum. At last, the intensity is superior to 80 % of its maximum over 210 mm, compared to 135 mm for a standard Bessel beam, the waisted energy is therefore highly reduced.

This more homogenous beam generated will lead to improved performance of glass processing which will be demonstrated in future.

References

Antonin Billaud et al., 2020, High quality Bessel beam generation through reflective axicon for femtosecond laser glass microprocessing at *"Photonics West"*

Jesús Del Hoyo et al. , 2019, High aspect ratio nanochannel drilling in glass by femtosecond laser pulse of high cone angle, high quality Bessel-Gauss beam at *"Photonics West"*

MK Bhuyan et al. 2010, High aspect ratio nanochannel machining using single shot femtosecond Bessel beams in *"Applied Physics Letters"*