Oblate Optics Laser Optics Solutions: Applications Note

<info@oblateoptics.com>

Glass ablation with Oblate EDoF lenses

The Oblate lenses offer significant advantages in glass cutting applications. These lenses enhance the precision and efficiency of laser cutting systems by maintaining focus over a larger range of depths. This eliminates the need for frequent manual refocusing, thus increasing throughput and reducing operational complexity. Oblate EDoF lenses have been used with femtosecond laser pulses to mark glass slides. Preliminary results from the tests are shown below.

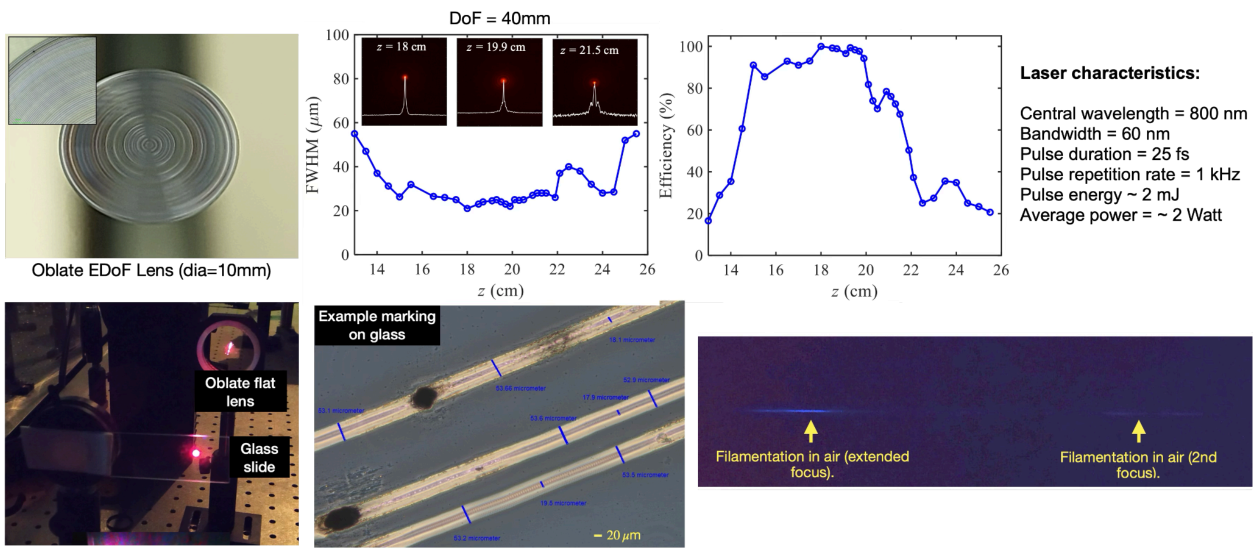

Fig. 1: *Preliminary results of processing glass using a fs laser focused by a single Oblate EDoF lens. No other optics required.*

1. Consistent Focus Over Varying Depths: Conventional lenses have limited depth-of-focus (DoF), necessitating frequent adjustments as the glass thickness or cutting depth changes. EDoF lenses maintain a consistent focus over a wide range, ensuring precise cuts without manual intervention.

2. Elimination of Refocusing: Frequent refocusing interrupts the cutting process and reduces efficiency. EDoF lenses eliminate this need as they maintain focus across varying geometries and positions. This results in increased throughput and reduced downtime in glass cutting operations.

3. Cost Reduction: Traditional f-theta lenses used for scanning large workspaces are expensive and still require refocusing for depth variations. EDoF lenses can replace these lenses, reducing both the complexity and cost of the laser systems. Pilot experiments showed that EDoF lenses provided uniform linewidths over an extended depth range compared to conventional f-theta lenses.

4. Damage Prevention: Conventional optics, such as axicons, can damage scan mirrors by focusing light too close. The Oblate EDOF flat lenses are designed to avoid this, protecting equipment and reducing maintenance costs. In addition, Oblate lenses can be made in a variety of materials with high laser damage threshold.

5. Versatile beam shaping: In addition to providing extended depth-of-focus, Oblate flat lenses can be customized to create high-contrast, shaped focal spots. This customization can significantly enhance the efficiency of glass cutting or marking applications.

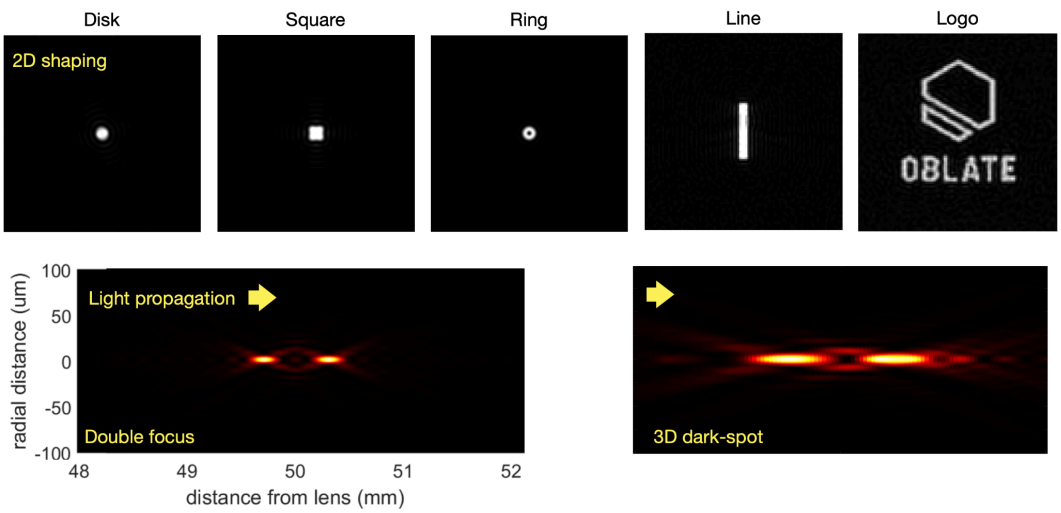

Fig. 2: *The Oblate flat lens can be custom designed to project various shaped focal spots in 2D (top row) or in 3D (bottom row). A double focus lens can be used in glass cutting.*

Laser marking with Oblate EDoF lenses

Oblate's extended-depth-of-focus (EDoF) metalenses can not only provide an unprecedented increase in depth-of-focus (DOF) of > 10 X, but also replace much more expensive f-theta lenses in laser processing tools.

Laser marking relies on precision optics to focus the beam onto the target surface. However, conventional optics have highly limited DOF ranges, necessitating frequent manual refocusing as target geometries and positions vary. Manual intervention can dramatically reduce throughput of a marking line. An EDoF lens can eliminate any manual intervention as the focus is maintained over a large range covering many different product shapes and sizes, and no refocusing is required. In figure 3, we show example marks on an acetyl-copolymer sheet using a 1064 nm laser, illustrating that the linewidth is maintained at ~0.2mm over a DOF = 50mm. A corresponding video illustration is available at this link.

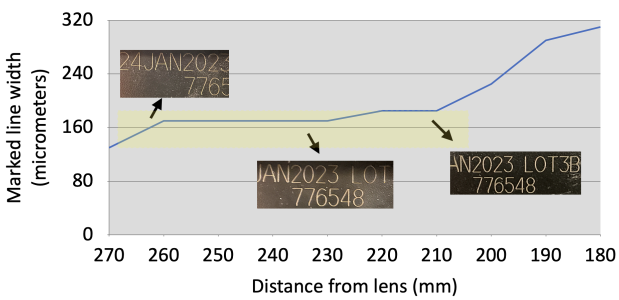

Fig. 3: *Exemplary linewidth vs working distance when using the Oblate EDoF lens to mark acetylcopolymer sheet using a IPG YLP-20W pulsed fiber laser (1064 nm) with nominal 20W power, pulse energies up to 1mJ and beam expanded to 3mm diameter.*

To enable scanning across flat workspaces, laser marking systems commonly incorporate large and expensive f-theta scan lenses. These bulky optics expand the scan field, but still require refocusing for depth variations. We can eliminate the f-theta lens, by placing the Oblate EDoF lens before the scan mirrors as indicated in the figure below. By carefully designing the working distance, we can completely prevent any damage to the scan mirrors as well.

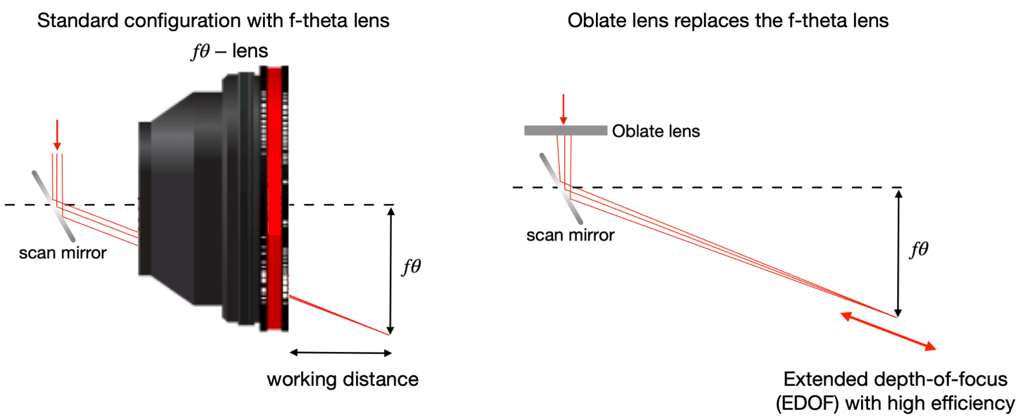

Fig. 4: *The Oblate EDoF lens can replace the conventional f-theta lens, while providing an extended DOF. Note that this simplifies the tool configuration and reduces costs.*

In pilot experiments, we confirmed that the marking performance of our EDoF lens is superior to that of a conventional f-theta lens (see Table 1 and Fig. 5). Conventional f-theta lenses are not only more expensive, but also restrict the obtainable mark field due to aberrations. In comparison, the Oblate EDoF lens can attain mark fields limited only by the clear aperture of the XY scanner, and are less expensive.

Table 1: *Comparison of laser marking with EDoF lens and a conventional f-theta lens.*

	Oblate EDoF lens	F-theta lens
Linewidth	192 μm	245 μm
Variation in linewidth	∓ 5 μm	∓ 10 μm
Field width	115 mm	120 mm
Working distance	210 mm	224 mm

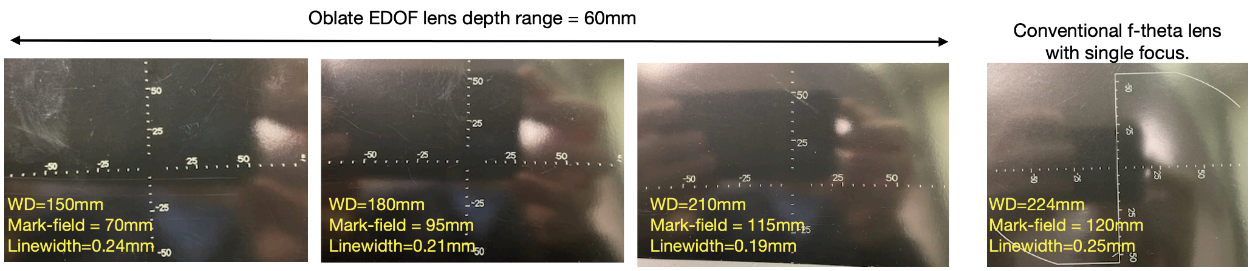

Fig. 5: *Exemplary marking on cardstock paper using the Oblate EDoF lens over a depth range of 60mm, while maintaining linewidth uniformity across the geometrical field size. In comparison, the conventional f-theta lens marks at a single plane. Marking performed with a 1064nm laser. WD = working distance.*

Additionally, the Oblate EDoF lenses can be designed for a variety of laser systems including UV, fiber-laser and CO_2 lasers; a range of incident powers for applications from microscopy to marking and laser welding; and a range of working distances, beam-diameters and target linewidths. Our EDoF lenses can also generate structured beams such as top-hats and doughnut-spots over an extended DOF. Since these lenses are manufactured using standard semiconductor processing methods, their pricing at volume can be extremely competitive.

Relevant technical publications (peer-reviewed):

- R. Menon and N. Brimhall, "Perspectives on imaging with diffractive flat optics," *ACS Photonics* 2023, 10, 4, 1046–1052.
- W. Jia, R. Menon and B. Sensale-Rodriguez, "Visible and near-infrared varifocal multi-level diffractive lenses with phase change material Sb2S3," *Opt. Exp.* 30(5) 6808-6817 (2022).
- A. Majumder, M. Meem, R. Stewart & R. Menon, "Broadband point-spread function engineering via a free-form diffractive microlens array," *Opt. Exp.* 30(2) 1967-1975 (2022).
- M. Meem, S. Banerji, A, Majumder, C. Pies, T. Oberbiermann, B. Sensale-Rodriguez & R. Menon, "Inverse-designed flat lens for imaging in the visible & near-infrared with diameter > 3mm and NA=0.3," *Appl. Phys. Lett.* 117(4) 041101 (2020).
- M. Meem, S. Banerji, A, Majumder, C. Pies, T. Oberbiermann, B. Sensale-Rodriguez & R. Menon, "Large-area, high-NA multi-level diffractive lens via inverse design," *Optica* 7(3) 252-253 (2020).
- S. Banerji, M. Meem, A, Majumder, B. Sensale-Rodriguez & R. Menon, "Diffractive flat lens enables Extreme Depth-of-focus Imaging," *Optica* 7(3) 214-2017 (2020).
- Anita Kumari, Vasu Dev, Tina M. Hayward, Rajesh Menon, Vishwa Pal; Generating optical vortex needle beams with a flat diffractive lens. *J. Appl. Phys.* 21 September 2024; 136 (11): 113105.
- T. M. Hayward, S. N. Qadri, F. Santiago, C. C. Cheung, M. Christophersen, N. Brimhall, and R. Menon," Imaging with an inverse-designed 50 mm-diameter f/1 MWIR flat lens with enhanced field-of-view & depth-of-focus," *Opt. Lett.* 49(18), 5015-5018 (2024).
- A. Hamza, T. N. Hayward, A. Majumdar, N. Brimhall, R. Menon & J. Ha, "High-resolution optical coherence tomography using a multi-level diffractive lens" *Opt. Exp.* 32(16) 27748-27755 (2024).