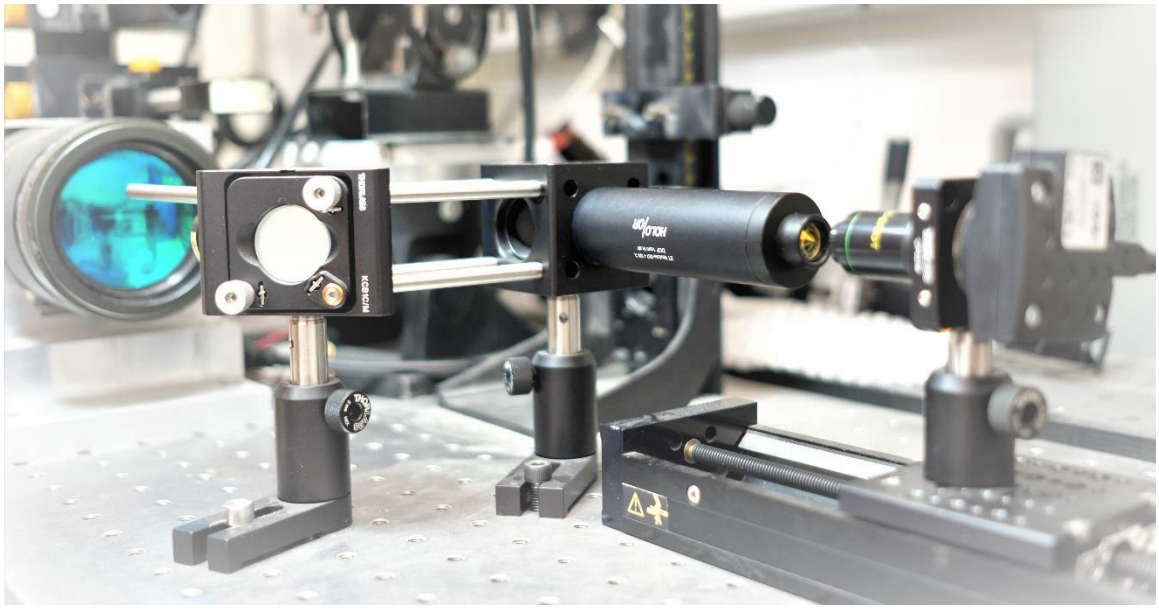
2021



DeepCleave Extended DOF Focus Optics

INSTALLATION MANUAL

HOLO/OR

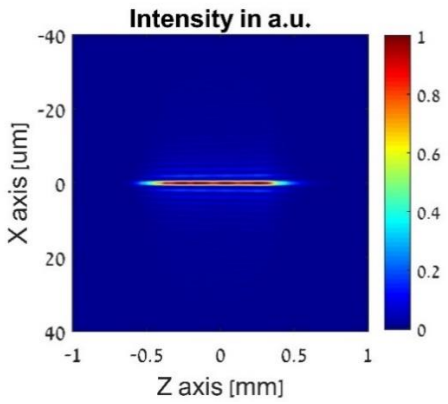
1. Introduction to DeepCleave

1.1. General characteristics of DeepCleave module

1.1.1. DeepCleave is a complete optical solution for laser glass cutting, providing a tight focus with constant peak power over an increased Depth of Focus (DOF).

1.1.2. DeepCleave module consists of radially symmetric optical elements. The module has a standard external SM1 thread on the entrance side to simplify integration.

1.1.3. Each DeepCleave module is shipped out of our factory with full optical characteristics and individual testing report.

Intensity Distribution	3D Layout
	

1.2. How to see DeepCleave performance advantage over an existing solution?

1.2.1. Most current glass cutting systems use an Axicon optical element, or a Diffractive Axicon to obtain the elongated DOF intensity distribution.

1.2.2. DeepCleave module's main advantage over an Axicon, is by generating constant peak power along the entire DOF with no decaying energy tail like the case with Axicon.

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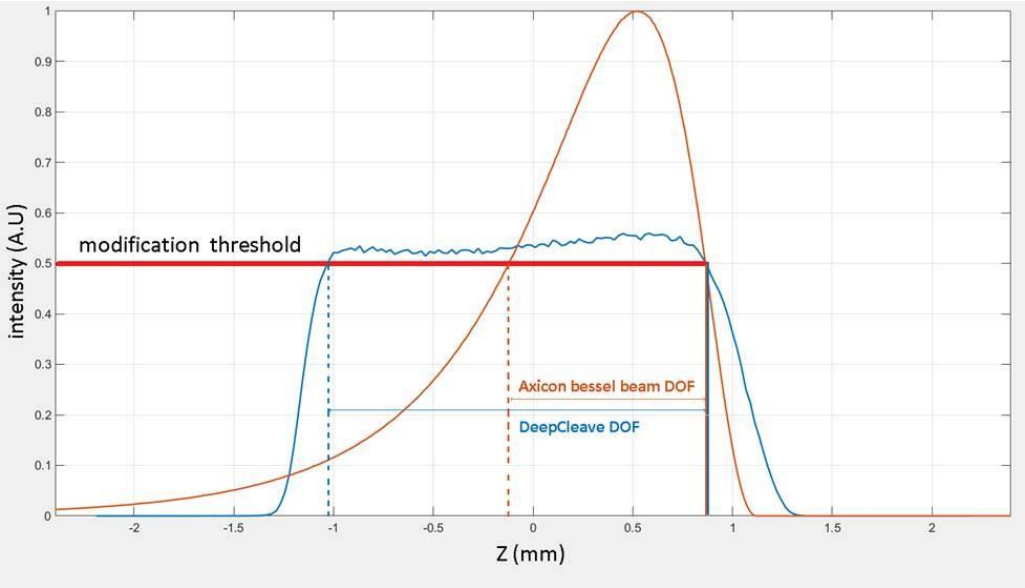

1.2.3. As such, DeepCleave enables higher processing throughput which can be seen in one of the following methods:

- Either altering the work sample thickness (try to cut thicker glass), and witness how during the same time and using the same laser energy as with a standard Axicon thicker glass can be cut, or
- Try to cut a similar thickness work sample using a different setup than that used with the Axicon, with lower pulse energy or faster axis travel, and witness how the sample is processed at a faster rate or with less power.

2. Installation recommendations

2.1. General introduction to DeepCleave module

2.1.1. The initial installation of the module is similar to that of High NA laser objectives and has similar typical sensitivities to tilts and shifts. Additionally, DeepCleave requires adjustment of collimation and of beam size to nominal values.

2.1.2. **It is recommended to confirm the collimation quality and the incident beam diameter before installing the module in the system.**

2.2. Recommended installation configuration:

2.2.1. To install, screw The SM1 port of DeepCleave module to a mount with X, Y translation and tip-tilt control.

2.2.2. Make sure a variable beam expander is used before DeepCleave module to adjust beam size to requirements

2.2.3. Align DeepCleave module according to the below described procedure.

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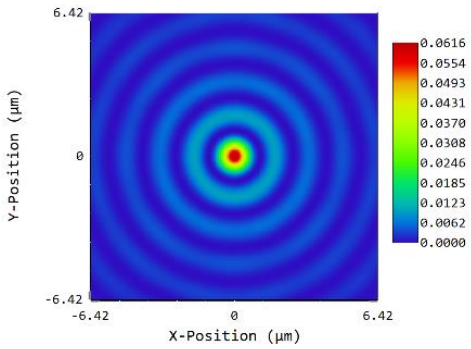
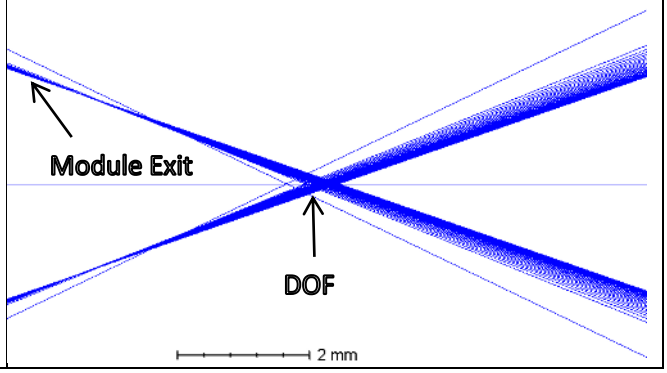
2.3. Recommended alignment procedure using screen or beam profiling camera

2.3.1. DeepCleave module output intensity profile has a ring shape of about 6 mm diameter which quickly converges. After some distance along the optical axis (millimeters), when coming close to the work distance, the profile becomes a Bessel-like beam. **This is the working range with the extended DOF**. After the DOF region, the ring start diverging. See image below:

Huygens PSF close to DOF center	Rays diagram in ZX plane
	

2.3.2. Required equipment:

- beam profiler/ camera with at least 7X7mm active area
- SM1 mount with x, y+ tip-tilt adjustment
- Method for moving camera vs Module (rail/ z-axis stage)

2.3.3. Measure the input beam profile with a large aperture camera/profiler. Make sure (by using a variable beam expander) that the **input beam diameter is as close as possible to 6mm** (beam diameter is measured at exp-2 of peak power). For elliptical beams, try to make symmetrical deviations around 6mm – i.e., if the beam is measured as 6X6.5 mm in both axes, adjust it to be 6.2X5.8mm.

2.3.4. Measure the output beam profile in the "Analysis Ring Region" as in the drawing above. Move the camera along the axis and see if the ring center ring maintains its position.

2.3.5. If DeepCleave is mounted vertically, as it is typically installed in glass cutting applications, place the camera on the work surface and move DeepCleave distance to the camera so it is > 9mm. Now change the distance while observing the camera image.

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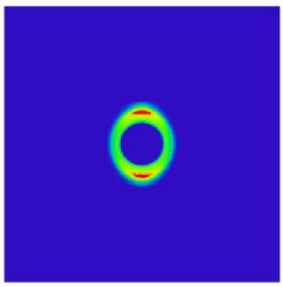
2.3.6. Make sure the ring is centered in the camera image and that it is not cut or trimmed. Also make sure it remains centered when moving the camera or screen along the optical axis.

2.3.7. Adjust x, y position to achieve best symmetrical profile. For some elliptical beams the optimum may not be perfectly symmetrical, see example for the effect of an elliptical beam with ellipticity 1:2:



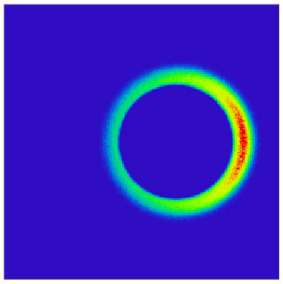
2.3.8. DeepCleave module should now be aligned to the work plane.

2.4. Troubleshooting misalignment issues

2.4.1. During the alignment process, you may encounter some of the following typical misalignment effects described below.

2.4.2. **Case 1. Shift misalignment or Decentering effect:**

- Decentering DeepCleave module relative to the input beam (shift misalignment) will cause the ring intensity to be unequal along the perimeter, however the center of the ring will remain constant when moving a screen along the optical axis. The Image shift is equal to misalignment shift.
- **Example -** asymmetric intensity distribution along the ring caused by 1 mm shift misalignment:



2.4.3. **Case 2. Tilt misalignment:**

- DeepCleave is rather sensitive to tilt misalignment, and if installed with a strong misalignment, the output profile may appear as a deformed ring with a non-even intensity along the ring perimeter. The deformation from the original optical axis will be with roughly the same angle as the tilt.

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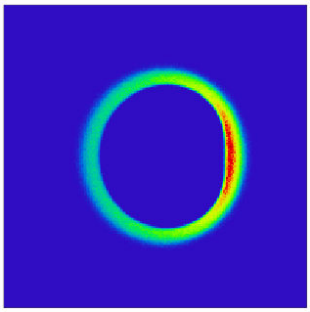
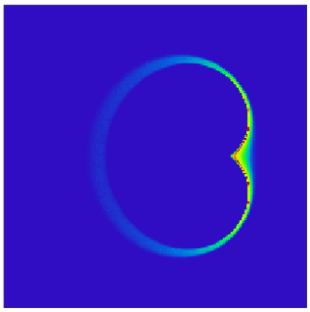
- To be sure that you are dealing with a tilt misalignment case, move the screen back and forth along the optical axis. Unlike the case with the shift misalignment, it this case the ring center will not maintain its position.
- If the ring image in the camera "drifts" to the side while changing the module-camera distance, adjust the tip and tilt of the DeepCleave module to eliminate this drift. Repeat the movement-adjustment cycle until drift is minimal.
- **Examples –**

Example 1 - ellipticity and an asymmetricity of intensity caused by tilt misalignment of 0.5 deg:	**Example 2 -** "peach" shape with asymmetric intensity caused by tilt misalignment of 1 deg:
	

2.4.4. **Case 3. Module-camera distance out of tolerance:**

- DeepCleave has a specific optimal work distance. If the image is cut or trimmed, reduce the module-camera distance until the full ring fits inside the image (as long as the distance remains > 9mm).

2.5. DOF region alignment

2.5.1. DeepCleave optimal performance is achieved when the central lobe of the Bessel-like beam is tightly focused < 2 um.

2.5.2. To get good measurement results, a sensor with pixel size < 2 um is required. Holo/Or does not recommend using a re-imaging of the DOF region, due to the high NA of the system, and therefore expected aberrations in re-imaging.

2.5.3. If there is a possibility to place a camera detector close enough in order to perform direct measurement of the DOF region this should be the preferred measurement method. The camera/DeepCleave can be placed on a motorized stage. The analysis can be done by scanning the camera along the optical axis and measuring the central spot size.

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2.5.4. Another measurement method, mostly adopted in the industry, is tuning during the material processing and post analysis with a microscope. In general, non-uniformity in the Z axis can be adjusted by small changes in the input beam diameter and divergence.

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