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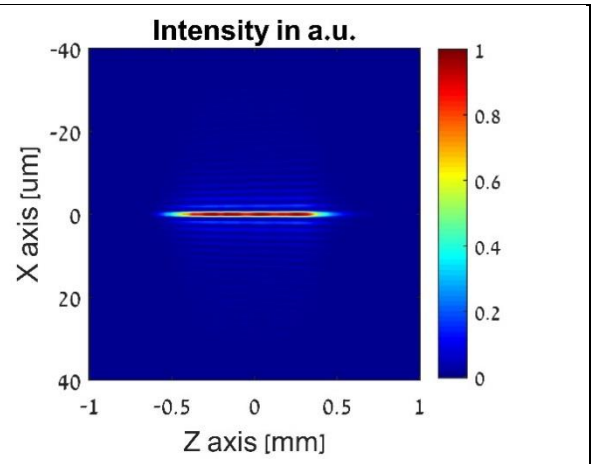
# Alignment manual for DeepCleave module

HOLO/OR 2020


3D layout




Intensity distribution

## 1. General installation recommendations

The DeepCleave module consists of radially symmetric optical elements.

The module has standard external SM1 thread on the entrance side to simplify integration.

The initial installation of the module is similar to that of High NA laser objectives and has the typical sensitivity to tilts and shifts. In addition, the DeepCleave requires adjustment of collimation and beam size adjustment to nominal value.

It's recommended to confirm collimation quality and incident beam diameter before installing the module in the system.

Recommended install configuration:

1. To install, screw the DeepCleave module to a mount with X, Y translation and tip-tilt control.
2. Make sure a variable beam expander is used before the DeepCleave module to adjust beam size to requirements
3. Align the DeepCleave module as below

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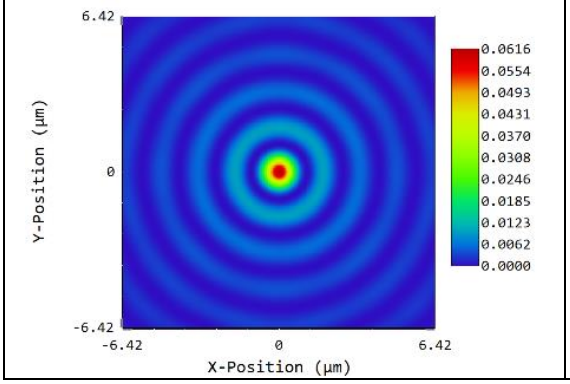
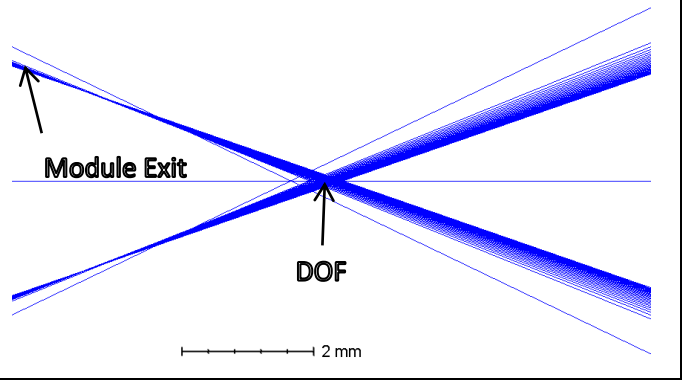
## 2. Recommended alignment procedure using screen or beam profiling camera.

The output intensity from the module has a ring shape of about 6 mm diameter and quickly converges. After some millimeters close to the working distance, it becomes to Bessel like beam. This is the working range with extended depth of focus DOF. After DOF region the ring starts diverging.

Decenter (shift misalignment) relative to input beam causes the ring intensity to be unequal along the perimeter, while the center of the ring remains constant when moving a screen along the optical axis.

The module is the most sensitive to tilt alignment. Tilt misalignment appears as a deformed ring with non-even intensity along ring perimeter. Unlike shift misalignment, when a screen is moved along the optical axis, the ring center doesn't maintain its position. Tilt tolerance tilts the original optical axis by about same angle.

| Huygens PSF close to DOF center | Rays diagram in ZX plane |
|---|---|
|  |  |



Recommended alignment procedure:

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)

1. Measure input beam profile with large aperture camera/profiler. Make sure (by using a variable beam expander) that input beam diameter is as close as possible to 6mm (diameter measured at $exp^{-2}$ of peak power). For elliptical beams, try to make deviations from 6mm symmetrical – i.e. if the beam is measured as 6X6.5 mm in both axes, adjust it to be 6.2X5.8mm.
2. 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 center of the ring stays in the same place
3. If the DeepCleave module is mounted vertically (as in Glass Cutting application), place the camera on the work surface and move the DeepCleave module distance to the camera so it is >9mm. Now change the distance while observing the camera image.
4. Make sure the ring is centered in the camera image and is not cut. If the image is cut, reduce the Module-camera distance until the full ring fits inside the image (as long as distance is still >9mm).

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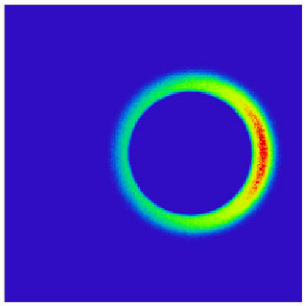
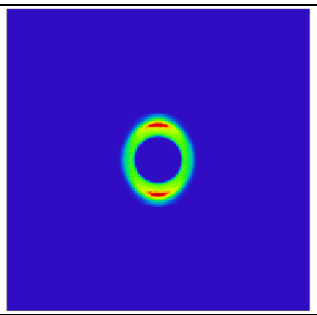
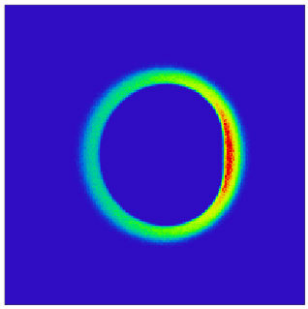
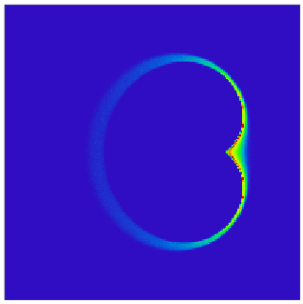
5. If the ring image in the camera drifts to the side while changing the module-camera distance, adjust the tip and tilt of DeepCleave module to eliminate this drift. Repeat the movement-adjustment cycle until drift is minimal.
6. Adjust x, y position to achieve the best symmetrical profile (for some elliptical beams this will be not perfectly symmetrical, see below).
7. DeepCleave module is now aligned to work plane.

## 3. Typical effects of misalignment

| **Shift 1 mm**: asymmetric intensity distribution along the ring. Image shift equal to misalignment shift (1 mm in example). | Effect of **elliptical beam** with ellipticity 1:2 |
|---|---|
|  |  |

| **Tilt 0.5 deg**.: ellipticity and asymmetry in intensity | **Tilt 1 deg**.: "peach" shape with asymmetry in intensity |
|---|---|
|  |  |

## 4. DOF region alignment

**With camera detector**

Central lobe of Bessel like beam is < 2 um. To get good measurement results a sensor with pixel size < 2 um is required. We don't recommend using a reimaging of the DOF region, due to high NA of the system and therefore expected aberrations in re-imaging.

If there is a possibility to place camera detector close enough to make direct measurement of the DOF region, 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.

**By process**

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

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