Laser induced damage threshold of an Ibsen transmission pulse compression grating
FSTG-PCG-1250-1064
Introduction

The threshold fluence for laser induced damage on a transmission grating was determined. The grating of interest is a transmission grating designed for pulse compression operating at a center wavelength of 1064 nm with a grating resolution of 1250 l/mm made out of UV grade fused silica from Ibsen Photonics (FSTG-PCG-1250-1064). Measurements were conducted using the output of an amplified Ti:Sapphire laser system delivering pulses at 40 fs at a repetition rate of 3 kHz centered at 785 nm. The damage was then determined with a phase contrast microscope.

Procedure to determine the damage threshold

Figure 1 shows the beam profile at the equivalent grating plane. The effective area assuming a gaussian beam waist is $2.245 \times 10^4 \, \mu m^2$.

![Figure 1: Beam profile at the grating plane.](image)

The grating was exposed to different pulse fluences varying from 0.28 J/cm$^2$ to 1.22 J/cm$^2$. For that the pulses from a Ti:Sapphire laser system were sent through a half-wave plate mounted on a rotation mount followed by a polarising beam splitter to adjust the different energies. The beam was then focused with a lens (f=1m) and send onto the grating (Fig. 2). The grating was mounted on a x-y translation stage which was moved in a raster pattern for the different energies. Two measurement runs were performed applying the following fluences: 1.0572 J/cm$^2$, 1.2176 J/cm$^2$, 1.1433 J/cm$^2$, 0.9800 J/cm$^2$, 0.8018 J/cm$^2$, 0.6682 J/cm$^2$, 0.4826 J/cm$^2$, 0.3861 J/cm$^2$, 0.2851 J/cm$^2$ for...
the first run and 1.1879 J/cm², 1.1879 J/cm², 1.1136 J/cm², 1.0394 J/cm², 0.9800 J/cm², 0.8909 J/cm², 0.7424 J/cm², 0.5791 J/cm² for the second run. The exposure time for every tested spot was 5 s. A reflection of the spectrum and the 1st order of the grating were monitored by a spectrometer (HR 4000, Ocean Optics).

Figure 2: Experimental setup for testing the damage threshold of the grating. The percentages indicate the amount of energy in the diffracted and reflected beams compared to the incident beam.

In a second step the easily visible damages were identified with a microscope having a magnification of 10. To determine the physical damage for the different fluence levels around the damage threshold, a phase contrast measurement (magnification 40) was performed.
<table>
<thead>
<tr>
<th>Fluence</th>
<th>Microscope</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.22 J/cm²</td>
<td><img src="image1.png" alt="Image" /></td>
<td>Backscatter, white spot visible by eye and SPM. Magnification 40x.</td>
</tr>
<tr>
<td>1.19 J/cm²</td>
<td><img src="image2.png" alt="Image" /></td>
<td>Backscatter, white spot visible by eye and SPM. Magnification 10x.</td>
</tr>
<tr>
<td>1.19 J/cm²</td>
<td><img src="image3.png" alt="Image" /></td>
<td>Backscatter, white spot visible by eye. Magnification 10x.</td>
</tr>
<tr>
<td>1.14 J/cm²</td>
<td><img src="image4.png" alt="Image" /></td>
<td>No spectral broadening. Magnification 40x.</td>
</tr>
<tr>
<td>1.11 J/cm²</td>
<td><img src="image5.png" alt="Image" /></td>
<td>Backscatter, white spot visible by eye and SPM. Magnification 40x.</td>
</tr>
<tr>
<td>1.04 J/cm²</td>
<td><img src="image6.png" alt="Image" /></td>
<td>No spectral broadening. Magnification 40x.</td>
</tr>
</tbody>
</table>

**Figure 3:** The table shows different kinds of damages for different fluences. The pictures with a magnification of 40 were captured with a phase contrast microscope.
Results and discussion

The goal of this test was to determine at which fluences physical damage on a transmission pulse compression grating appears. Self-phase modulation (SPM) was already detected at much lower intensities, but was not part of this investigation. For more information regarding nonlinear effects in Ibsen transmission gratings see [1].

For all tested fluences no damage to the actual grating lines could be identified. The damage always occurred on the UV-grade fused silica side which agrees with the self-collapse distance estimated with a simple approximation [3]. The latter lies between 1.1 mm and 2.2 mm for input intensities of 30.4 TW/cm$^2$ to 7.1 TW/cm$^2$ respectively. In Figure 3 you can see the microscope images of the fused silica side of the grating showing damage for fluences above 0.98 J/cm$^2$ or 23 TW/cm$^2$.

The lowest fluence for which laser induced damage on the grating was observed is 1.04 J/cm$^2$, corresponding to a peak intensity of 24.4 TW/cm$^2$, which is consistent with the measurements on dielectrics taken by Lenzner [2]. For fluences between 1.04 J/cm$^2$ and 1.14 J/cm$^2$, the damage mostly appeared as a small approximately 4 micron diameter spot under the phase contrast microscope, but could not be detected using the normal microscope with a magnification of 10. Above 1.14 J/cm$^2$, the damage appeared as a collection of spots with an overall diameter of approximately 100 micron.

References

