Low-loss Type II waveguide writing in fused silica with single picosecond laser pulses

Haibin Zhang, Shane M. Eaton, Abbas Hosseini, Peter R. Herman

Dept. of Electrical and Computer Engineering
Institute for Optical Sciences
University of Toronto

http://photonics.light.utoronto.ca/laserphotonics/
Introduction (1)

Nonlinear absorption & waveguide writing

- Focusing lens
- Nonlinear absorption
- Glass

- Side writing
- Axial writing
Introduction (2)

Pulse Overlap and Pulse Duration

Low Reprate
~1-kHz

High Reprate
>200-kHz

1. Usually favor high-overlapping method (tens to thousands of pulses overlap in the focal volume).
2. Pulse duration is preferably selected to be <200 fs
Introduction (2)

Pulse Overlap and Pulse Duration

Our results: Type II (Non overlap)

Type I (High overlap)
Experiments(1)

Laser Writing Arrangement

Spectra-Physics Spitfire Pro system
Delivers: 40-fs, 2mJ/pulse, 1kHz

Wide parameter space
- 50 fs ~ 5 ps
- 0.1 ~ 10 μJ / pulse
- 0.1 ~ 10 mm/s (volume separated by 0.1μm to 10μm)

Spitfire
NA 0.25
Spotsize: 1.2μm
Experiments(2)
Type II waveguide writing scheme

At high scan speed of ~1mm/s

- Ellipsoids separates into isolated interaction volumes
- Separation $d$ depend on the rep rate and scan speed
- When ellipsoids barely overlap, the waveguide is written point-by-point $\Rightarrow$ Type II
Experiments(3)
Mode and Loss characterization

6.9 x 8.7 \( \mu m^2 \)  Distance (cm)
Results: Effect of scan speed

Waveguide written in Fused Silica with 1-ps, 0.6-μJ/pulse

<table>
<thead>
<tr>
<th>High overlapping</th>
<th>Partial overlapping</th>
<th>No overlapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6 mm/s</td>
<td>0.7 mm/s</td>
<td>0.8 mm/s</td>
</tr>
<tr>
<td>0.9 mm/s</td>
<td>1.0 mm/s</td>
<td>1.25 mm/s</td>
</tr>
<tr>
<td>1.5 mm/s</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overhead

- Mode size increases as the scan speed increase
- Lowest loss about 0.2dB/cm, refractive index is inferred to be about 5x10^-4

Facet

633nm mode

- Mode size increases as the scan speed increase
- Lowest loss about 0.2dB/cm, refractive index is inferred to be about 5x10^-4
Pulse duration effect

Waveguide written in fused silica with 1-mm/s, ~0.6-μJ/pulse

- Single mode waveguiding is observed over 1.5-ps span.
- Little variation in the waveguide appearance, mode diameters. ⇒ suggest weak dependence of Δn on pulse duration in this span.
Pulse duration effect

Waveguide written in fused silica with 0.9 and 1-mm/s, ~0.6-μJ/pulse

![Graph showing loss vs. pulse duration for 0.9 mm/s and 1.0 mm/s]
Conclusion

1. Type II (point-by-point) waveguides were written in Fused Silica glass.

2. A wide 1.5-ps processing window is explored, with lowest loss waveguide at 1-ps.

3. Guiding at 633nm (red) is demonstrated, and the modes and losses were characterized.
Acknowledgement
the end