Processing of transparent materials with a 2 µm ultra-short pulsed laser source

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Outline

1. InnoLas Photonics

2. 2 µm USP-Laser
   - Setup: CPA-system
   - Characterization

3. Setup for glass processing

4. Glass processing
   - Inside Glass Modification
   - Surface ablation
   - Selective laser etching

5. Silicon processing

6. Conclusion and Outlook
CONTACT

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PRODUCT OVERVIEW

Q-Switched DPSS Lasers

All-in-One Marker

Direct Diode Lasers

High Energy Lasers

Workshop "Laser Processing of glass materials"
**PRODUCT OVERVIEW**

**blizz**
High Power Q-Switched Lasers
- **30 W**
- **TEM**
- 48 VDC OEP Power Supply
- Water Cooling

**nano series**
Q-Switched Lasers
- **Up to 23 W**
- **TEM**
- 19" OEP Power Supply
- Water Cooling

**Nano Air**
Air cooled Q-Switched Lasers
- **Up to 16 W**
- **TEM**
- 24 VDC OEP Power Supply
- Air Cooling

**mosquitoo**
Miniature Q-Switched Lasers
- **Up to 6 W**
- **TEM**
- 24 VDC OEP Power Supply
- Contact Cooling

**Nano Direct Diode**
Turn-key Systems
- **Up to 100 W**
- 400 μm Fiber
- 13" OEP Unit

**SL 400 Micro Weld**
High Energy Lasers
- **Up to 8 J**
- 200 μm Fiber
- Vision System
- Single or Double Fiber Output

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2 μm USP laser setup

- Oscillator with 5 mW output power @ 30 MHz, 200 nm bandwidth @ 2000 nm
- Chirped pulse amplification: Stretcher and compressor with single Chirped Volume Bragg Grating (CVG)
- 2 preamp stages: core and cladding pumped Thulium doped fiber amplifier
- Pulse picker for reduction of repetition rate
- Thulium doped fiber main amplifier
Output power and pulse energies

- After Compression in Chirped Volume Bragg Grating: 1.6 W @ 2MHz
- Pulse energy up to 1.9 µJ with existing setup
Pulse duration

- Pulse duration:
  - From laser 3.5 ps
  - Onset of nonlinear effects for pulse energies > 2µJ: longer pulses

- Remaining fiber GVD can be compensated with additional compressor pulse duration of 500 fs can be reached

\[
\Delta \tau_{\text{sech}^2} = 480 \text{ fs}
\]
**Beam profile and focal spots**

**M²-Measurement**
- $M^2_{x/y} = 1.25/1.22$
- Beam quality limited by reflection in VBG

**Focusing with aspheres**
- Focal length 1.8 mm and 4 mm
Measurement of focal spot with knife edge-method:
- 5.4 µm 1/e²-Diameter
Setup

Fixed Optics
- 1.8 and 4 mm aspheric lens
- 2.5 mm beam diameter

XYZ-Stage moves sample
- DC-Motor stage with ball bearing in XYZ-directions
- Speed: 1 µm/s ... 6 mm/s

Laser Parameters
- Center wavelength 1950 nm, Repetition Rate: 300 kHz
- Pulse durations: approx. 3,5 ps
- Pulse energy: 0.9 µJ
Soda-lime glass: Inside glass modifications

- Laser: 300 kHz/.9µJ/3,5 ps
- Writing speed: 0.1 mm/s
- Focusing lens 4 mm
- Fluence: 2,5 J/cm²
- Smooth inside glass modifications
- Possible Application: Waveguide Structures inside glass
- Same modifications in fused silica, borosilicate, silicon
Soda-lime glass: Backside ablation

- Laser: 300 kHz/.9µJ/3.5 ps
- Writing speed: 0.1 mm/s
- Focusing lens 1.8 mm
- Fluence: 4 J/cm²
- Polarization parallel to the direction of movement
- Ablation at back surface
- Nanograting formation

Grating period ~2 µm
Selective Laser Etching of borosilicate glass

Inside Glass Modifications in Borofloat Glass

- Glass Material: Boroplate (GVB). floated borosilicate glass 3.3 (DIN ISO 3585)
- Etchability/ Selectivity of Etching of exposed vs. unexposed Structures

Courtesy of LightFab
Inside Modification of Silicon

- unpolished Si-wafer
- Writing speed: 0.1-1mm/s
- Focusing lens: 1.8mm
- IR Microscope
- Inside Modification (520µm sub surface)
- 1µm USP-Laser is absorbed at surface!

Fraunhofer EMFT: IR Microscope Picture
Laser Induced Modifications Inside Bulk Silicon
Conclusion and Outlook

Conclusion

• Ultra short laser pulses at 2 micron wavelength:
  – 1.6 W output power @2MHz
  – Compressible to 500 fs
  – $M^2 < 1.3$

• Glass Processing @ with 2 µm USP laser:
  – Index modification
  – Surface ablation

• Inside Silicon Modification

Outlook

• Additional Fiber Amplifier for Higher Output Energies: 5 - 10 µJ / 10 W

• Test of new applications: Writing of waveguides in glass for sensor and telecom applications

• Inside processing of semiconductor materials
Thanks to all partners

Thank you for your attention!