All in Fiber Systems for Material Processing

U. Dürr / Rofin-Lasag

SWISS TRADITION FOR WORLDWIDE PRECISION
All In Fiber Systems
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All in Fiber Systems for (industrial/medical) Material Processing

SM Fiberlaser
Control Laser Control Process
User Panel
Interface Industrie 4.0

Beam handling: Temporal/spatial shape Modes Polarization

Processing Optics, Beam distribution

Sensor Data Acquisition & Processing

Integration of components: plug & play or splice & play
Fiber laser + Transport Fiber + beam Control

cw / cw-modulated / qcw / pulse shape / pulsed (not UFL)
SM because of mode stability and beam quality

Advantages:
SM high power / average power / stable wavelength flexibility

Fundamental Problems:
Backreflection / fiber damage
Raman (power loss / damage fiber laser)
Linewidth (limits in efficiency of nl effects)
Coupling losses (heat damage)
Connecting High Performance Fiber Laser & Amplifier Components

7 x 200W + 915 Pumps

200W 200W
200W 200W 200W
200W 200W

7:1 TFB + HR FBG (99%)
HP Fiber Splices
Cladding Mode Stripper

35m 20/400 YDF

1 kW Signal Power

End Cap
OC FBG (10%)
Intracavity Tap Monitor
OSA
Photo Detector
Fiberlaser + Transport Fiber + beam Control

cw/cw-modulated / qcw /pulse shape /pulsed (not UFL)
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Advantages:
SM high power /average power/stable
wavelength flexibility
Experiment 1: Raman shifter

- Slope efficiency: 6%
- Max. output power: 35mW
- FWHM: 10nm

Diagram:
- FBG HR at 1100nm
- Pump/signal combiner
- Heating of fiber to 70°C for ASE suppression
- 1100nm signal generation
- 1100nm amplification
- 6/125 DC PM Yb-doped fiber

Graphs:
- Raman around 1154nm vs 1100nm pump [W]
- Intensity [dB] vs wavelength [nm]
  - 1100nm pump power: 1.25W
  - Raman output power: 31mW
Fiberlaser + Transport Fiber + beam Control

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Fundamental Problems:
Backreflection / fiber damage
Raman (power loss/ damage fiber laser)
Linewidth (limits in efficiency of nl effects)
Coupling losses (heat damage)
Optoskand fundamental fiber technology

- **Mode stripper** – Surface treatment that remove all cladding modes.
- **Quartz block** – Bonded fused silica end cap. Decrease surface power density.
- **AR-coating** – Remove Fresnel losses.
Fiberlaser (SM) + Transport Fiber

cw / cw-modulated / qcw / pulse shape / pulsed (not UKP)

SM because of mode stability and beam quality

Fundamental Problems:
Influence of optical components and application on Fiberlaser

Backreflection / fiber damage / Laser damage

Thermal cutting of Sapphire
LMA Double Clad Fibers

<table>
<thead>
<tr>
<th></th>
<th>Singlemode “SM”</th>
<th>Multimode “MM”</th>
<th>Large Mode Area “LMA”</th>
</tr>
</thead>
<tbody>
<tr>
<td># Signals</td>
<td>1</td>
<td>~ 1000</td>
<td>2 to 5</td>
</tr>
<tr>
<td>Core Size (microns)</td>
<td>3 – 10</td>
<td>50 – 150</td>
<td>15 - 50</td>
</tr>
<tr>
<td>NA</td>
<td>0.12 – 0.20</td>
<td>0.20 – 0.35</td>
<td>0.05 – 0.10</td>
</tr>
</tbody>
</table>

- Large, Low NA Cores offer large mode areas
- LMA fibers, while few moded, can be used for single fundamental mode operation.
Beam Control / manipulation by fibers or pigtailed components

cw/cw-modulated / qcw / pulse shape / pulsed SM

Fibers or pigtailed optical components with low losses and high damage threshold?

Advantages:
No free optics/adjustment/contamination

Examples for existing fibers with beam shaping capabilities:
- GRIN (Refractive index)
- Square Shape (cross section)
- Structured fiber
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Processing head

- Focusing optics/autofocus

- Spatial beam distribution (time share (scan)/energy share (DOE))

- Process measurements (on/offline) (backreflection (absorption/depth etc/ Temperature/imaging)

- Workpiece surface measurements (autofocus/Structure/roughness etc)

Low power Medical Laser system with fiber probes or laser endoscopes already all in fiber systems
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Sensor data acquisition & processing

Intelligent plug or fiberoptic signal capture and separation and processing in module

Or intelligent integration
Example: all in fiber OCT in combination with fs laser for cornea treatment
QD fiber – Sensor principle

Photodiodes

Light guide

Glas cylinder with or without AR-coating

Beam in forward direction

Mode stripper

Back reflected light (process-light)

Temperature sensor

ΔT sensor

Humidity sensor

H

T

\( T_{\text{out}} - T_{\text{in}} \)

1000 W and 1 l/min

\[ \Rightarrow \Delta T = 14 \, ^{\circ}\text{C} \]
All in Fiber Systems

Sensor data acquisition & processing

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All in Fiber Systems

Summary

All in fiber systems for medical applications (low power) already available

All in fiber systems for (high power) material processing need improvement on component level to
- Manage thermal and nonlinear effects of the components
- Manage interaction of components
- Integrate new multiplexing methods (see IT fiber technology)
- Splice and play on proper fiber package (customized application system)
Vielen Dank für Ihre Aufmerksamkeit
Thank you for your attention
Optoskand fundamental fiber technology

- **Mode stripper** – Surface treatment that remove all cladding modes.
- **Quartz block** – Bonded fused silica end cap. Decrease surface power density.
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Polarization Maintaining Fibers

- **PM-RGB Fibers (400 – 850 nm)**
  - Ge Doped and Pure Silica Core
  - Hytrel and Nylon Buffers

- **PM Telcom Fibers (980 – 1550 nm)**
  - Gratings, Couplers, Fiber Pigtails
  - 250 or 400 μm Acrylate Coating

Temperature Cycling Results
QD fiber – Sensor communication

- Integrated sensor board for each QD connector.
- Switch off the fiber interlock in case of reaching the threshold level.
- Analogue values available through CANopen.
Photosensitive Fibers

- Photosensitive Glass
  - Ge/B or Ge/F co-doped
- CMS or CMO designs
- FBGs for kW Class Lasers