Lasers à fibres ns et ps de forte puissance

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EOLITE systems
Solid-State Laser Concepts

- Rod
- Disk
- Slab
- Fiber

-> thermal lensing and thermal stress-induced birefringence

-> reduced thermo-optical distortions
Fiber lasers: a revolution in laser technology

Fundamental breakthrough:
No thermal effect -> high average power with very good beam quality

Limitations of standard fibers
Limited absorption → long (100 ns) pulses
Non-linear effects → low peak power

Rod type photonic fibers: a new generation of fiber
High peak power, linearly polarized, high average power and perfect beam quality

The ultimate solution to get the best of rod and fibers
Rod type fiber

(Patented design)

Air clad
Pump clad area
Active core area

2 mm fused silica-rod (whole diameter hidden)

200 µm
80 µm

Very large mode area > 5000 µm²
Very large absorption 30 dB/m
No photodarkening
Rod type fiber Technology
Nanosecond lasers
Common characteristics

- Pulse duration down to 8 ns
- Beam Quality $M^2 < 1.2$
- Spectral width < 200 pm
Laser Configuration

Single stage oscillator

- Fiber length ≈ 50 cm
- Pump diode @ 976 nm
- AOM for Q-Switching
Infra-red: 1030 nm

- >100 W
- >2 mJ
- 8 ns
- 300 kW

Up to 140 W demonstrated for 200 W pumping
Amplifier set-up

- PUMP DIODE
- AOM Q-Switch
- Rod-Type Fiber
- SHG/THG

Diagram showing the setup with various components including a pump diode, AOM Q-Switch, and Rod-Type Fiber.
Amplifier results

- 240 W
- 5 mJ
- 10 ns
- 500 kW

BORHAS HE-IR150
1030nm

- Power
- Pulse width

Average Power (W)

Pulse Width (ns)

Repetition Rate (kHz)
GREEN  515 nm
GREEN 515 nm

Oscillator

- 53 W
- 10 ns
- Up to 400 kHz
BOREAS family at different pump powers

- G15
- G30
- G45

The graph shows the average power (W) plotted against the repetition rate (kHz), indicating electronic limitation at higher rates.
Beam shape @ 30W
Beam Quality
M2 measurement at full power
BOREAS HP G60

Up to 60 W
Up to 300 µJ
60% SHG

Bores HP-G60
515nm

Average Power (W)

Repetition Rate (kHz)

M² = 1.17
ULTIMATE BEAM POINTING STABILITY

BOREAS G30
\( \lambda = 515 \text{ nm} \)
Temperature fluctuation: \( \pm 1^\circ \text{C} \)

Short term 8h

Long term 300h

< 10 \( \mu \text{rad} \)
UV fiber laser
BOREAS HF 7UV

THG in LBO

- $M^2 < 1.3$
- Patented long lifetime crystal
High Power UV

Single Oscillator + THG
19 W

Amplifier + THG
40 W

Up to 300 kHz
Main difficulty for picosecond pulses is Self Phase Modulation

\[ \Phi_{NL} = \frac{2\pi}{\lambda} n_2 I_z = \frac{2\pi}{\lambda} n_2 \frac{P_c S}{z} \]

Needed for harmonic generation

Standard fibers give \( S = 50 \, \mu m^2 \)

Rod type fibers give \( S = 5000 \, \mu m^2 \) i.e. 100x standard fibers
Architecture

PicosecondSeeder

Rod type fiber

SHG / THG/FHG

Pump diode
HEGOA & SIROCCO set-up
The fiber laser design

The Modelocked fiber laser 1/1

Ring cavity design:

- SESAM with 9ps relaxation time and 40% modulation depth
- 5.9 - 80MHz ➔ all normal long ring laser cavity (1.2 - 35m)
- Output average power: ~3mW
- Central wavelength: 1030nm
The fiber laser design

The fiber pre-amplifier

Oscillator
Fiber Isolator
Pump/signal combiner
PM Ytterbium double clad doped fiber
12\(\mu\)m core diameter
NA 0.07
7dB/m cladding absorption
Polarization maintaining
Length : 1.5 meters

976nm / 10W Multimode Pump diode

Fiber pigtailed collimator output
SIROCCO
All fiber laser

Seeder: 83 MHz
30 ps
0.1 nm
5 W
SIROCCO results

1030 nm

40 % optical conversion
Up to 92 W output at 80 MHz

37 kW peak power
SIROCCO Beam profile @ 92W
Rod type fiber for narrow spectrum

0.1 nm linewidth for efficient conversion to the UV and DUV
High efficiency harmonic generation

69 W IR → 46W Green

67 % SHG efficiency
Harmonic Generation at 80 MHz

3w: 343 nm 15 W

4w: 257 nm 4W
Architecture low repetition rates

- Picosecond Seeder
- Rod type fiber
- isolator
- Pulse picker
- SHG / THG
- Modulator
- Pump diode
Low repetition rates results
Frequency doubling and tripling @ 6 MHz

Results obtained with the 50cm long 80µm core diameter fiber:

Max converted power: > 40 Watts at 515nm, up to 20W at 343nm.
Energy at 343nm : 3.4µJ per pulse.

Max efficiency: 70% for SHG, 35% at 343nm.
Low repetition rates

Record Third Harmonic Generation efficiency

>50% IR to UV efficiency
HEGOA10 UV

30 ps, 200 kHz – 5 MHz

Up to 16 W at 6 MHz
## EOLITE’s Roadmap

<table>
<thead>
<tr>
<th>Year</th>
<th>Nanosecond</th>
<th>Picosecond</th>
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</thead>
<tbody>
<tr>
<td>2008</td>
<td>240 W, 10 ns</td>
<td>50 W, 30 ps</td>
</tr>
<tr>
<td>2009</td>
<td>110 W, 10 ns</td>
<td>30 W</td>
</tr>
<tr>
<td>2010</td>
<td>20 W, 10 ns</td>
<td>15 W</td>
</tr>
<tr>
<td>2011</td>
<td>1 kW, 10 ns</td>
<td>200 W, 30 ps</td>
</tr>
<tr>
<td>2012</td>
<td>500 W, 10 ns</td>
<td>100 W</td>
</tr>
</tbody>
</table>
Conclusion

• Les fibres microstructurées rigides sont une solution efficace pour la production d’impulsions de très forte puissance moyenne

• Le gain d’une fibre rod type ouvre des voies nouvelles

• Lasers très performants mais structures très simples

• On est très loin d’avoir atteint les limites