Advanced seeders for fiber lasers
- IFLA

23 June. 2014
Seeders - introduction

In MOPA* pulsed fiber lasers, seeders largely impact major characteristics of the laser system:

- Optical spectrum
- Peak power
- Noise
- Pulse shape
- Pulse frequency
- Extinction ratio
- Flexibility

Today we will present several advanced seeder techniques

* MOPA - Master Oscillator Power Amplifier

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Some common seeder design schemes in MOPA lasers

• Mode locked or Q-switched

• Directly modulated laser diodes:
  – Programmable pulse-width in the nano-second range
  – Pulse width in the picoseconds range
  – Flexible pulse shaping in the nano-second range

• Flexible pulse shaping in the pico-second to nano-second range deploying optical modulators

This talk is focused primarily on directly modulated laser diode methods
Seeders with programmable pulse-width in the nano-second range

Key elements:
• Pulser in the nano-second range
• Laser driver
• Laser diode module
• Temperature controller
1ns and 20ns waveforms

- Directly modulated LD, 1064 FBG
- Peak current 1.5A
- Note the non-linearity of the optical waveform
Picoseconds seeders – LD current modulation

Picosecond seeder design considerations:
• The pulser part produces sub-nanosecond pulses
• Driver must have shorter response time
• Laser bias current shall be calibrated carefully per laser diode
• Laser diode must have the characteristics to match the user's requirements

Test results
• Peak power levels of up to more than 1W can be achieved when the laser diode is operated in gain-switching mode
• With typical laser diodes pulses in the range of 30ps to 200ps can be generated
• The modulation may have substantial impact on the optical spectrum – especially in laser diodes with FBG
Picoseconds seeders
Impact of modulation on optical spectrum of an FBG stabilized laser diode

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Picoseconds seeders

- Gain Switching in a DFB laser diode
- Eagleyard 1064nm
- Peak power ~ 500mW

Pulse width = 31ps

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Seeders with flexible pulse shaping in the nanosecond range – Current modulation

- Programmable waveforms through SW or fixed waveforms
- Any waveform in nano-second resolution
- Peak current levels of up to a few Amps

Programmable waveform generator

Temperature / wavelength control

Laser diode module

Linear high-speed current driver

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Seeders with flexible pulse shaping in the nanosecond range

- A pulse shape with ramps to demonstrate linearity
- Exponential pulse shape – a common technique to suppress pulse saturation in fiber amplifiers

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Seeders with flexible pulse shaping in the nanosecond range

Train of 2 ns pulses

5 growing pulses

Peak current 0.5 A / Peak power ~ 250 mW
Seeders with flexible pulse shaping in the nanosecond range

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A MOPA system with flexible pulse shaping in the nanosecond range

Two amplification stages to produce 220µJ pulses, 1064nm

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Specified input electrical pulse-shapes

Optical output pulse-shape from the MOPA versus \( W \), the pulse duration, with constant \( E_{\text{out}} = 220\mu\text{J} \)

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Courtesy of Dr. Alain Jolly, Alphanov, France

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A MOPA system with flexible pulse shaping in the nanosecond range

Two amplification stages, 1064nm

Peak power of > 10KW can be achieved with the ability to further increase peak power increase in pulse energy

Laser output at various pump currents (I) along with the accompanying peak power (Pp), for a 50ns long seeder pulse

PW ~ 55ns

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Seeders with programmable waveforms in the pico-second to nano-second range

- Seeders with temporal pulse shaping in the pico-second range must deploy optical modulation
- Mach-Zehnder interferometer modulator of Electro-Absorption modulator

Major advantages:
- Capability to shape the pulses in resolution down to ~100ps
- Excellent control on optical spectrum

Disadvantages:
- Extinction ratio limited to ~ 25dB
- Low power (10’s of mW)
- Costly
- Large footprint
- Availability of modulators is limited to 1064nm and 1550nm
A 3-stage **hybrid** MOPA system with flexible pulse shaping in the Picosecond range

The first amplifier is a Yb-YAG thin-disk regenerative amplifier with $\sim 10^6$ gain followed by a Yb-YAG thin-disk multi-pass amplifier providing a gain of $\sim 100$. The seed pulse has been shaped to achieve an approximately flat-top temporal pulse out of the second amplifier.

Temporally-shaped seed source
1 nJ pulses at 10 kHz & 1030 nm

Regenerative amplifier
1 mJ, Gain x 1,000,000

Multi-pass amplifier
100 mJ, Gain x 100

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Courtesy of Dr. Paul Mason, Dr. Thomas Butcher and Dr. Waseem Shaikh / DiPOLE team at the **STFC Rutherford Appleton Laboratory**, Central Laser Facility, UK

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Seeders with directly modulated laser diodes offer a cost-effective solution to most fiber laser applications.

<table>
<thead>
<tr>
<th></th>
<th>Type 1</th>
<th>Type 2</th>
<th>Type 3</th>
<th>Type 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology</strong></td>
<td>- Electronic pulser</td>
<td>- Electronic pulser</td>
<td>- Arbitrary waveform generator</td>
<td>- A CW laser diode</td>
</tr>
<tr>
<td></td>
<td>- Current driver</td>
<td>- Gain-switching using direct modulation and careful biasing</td>
<td>- Linear driver</td>
<td>- Electronic pulser</td>
</tr>
<tr>
<td></td>
<td>- Direct modulation of a laser diode</td>
<td></td>
<td>- Direct modulation of a laser diode</td>
<td>- Voltage driver</td>
</tr>
<tr>
<td><strong>Peak power</strong></td>
<td>Up to ~1W</td>
<td>Up to ~1W</td>
<td>Up to ~1W</td>
<td>Up to ~100mW</td>
</tr>
<tr>
<td><strong>Laser diode type</strong></td>
<td>Any high-speed</td>
<td>Selected high-speed</td>
<td>Linear and high-speed</td>
<td>Only selected wavelength, PM</td>
</tr>
<tr>
<td><strong>Waveform flexibility</strong></td>
<td>Pulse width</td>
<td>minor</td>
<td>Any, down to 1ns</td>
<td>Any</td>
</tr>
<tr>
<td><strong>Spectrum control</strong></td>
<td>Depends on LD</td>
<td>Depends on LD + broadening</td>
<td>Less than 0.1nm with DFB</td>
<td>Best</td>
</tr>
<tr>
<td><strong>Ext. ratio</strong></td>
<td>Excellent (40 dB)</td>
<td>Excellent (40 dB)</td>
<td>Good (30 dB)</td>
<td>Mid (25dB)</td>
</tr>
<tr>
<td><strong>size</strong></td>
<td>small</td>
<td>small</td>
<td>bigger</td>
<td>Biggest</td>
</tr>
<tr>
<td><strong>cost</strong></td>
<td>low</td>
<td>mid</td>
<td>higher</td>
<td>Highest</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Low cost nano-second pulses</td>
<td>Low cost pico-second pulses</td>
<td>Handle gain sat Flexible processes</td>
<td>High energy, high peak power systems</td>
</tr>
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</table>
Thank you

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