Laser development: Taking physics to industry

4th Biennial Conference

Presented by Dr Daniel Esser

2012-08-09
Presentation Outline

• Modern laser development
  • Diode-end-pumped solid-state lasers
  • Fibre-laser-pumped solid-state lasers

• Applications & Specifications

• Few examples
  • Pumping another laser
  • Directed infrared countermeasures
  • 3D printing
  • Gated imaging

• Concept Laser Products

• Advanced Photonics Manufacturing Facility
Lasers

Gas lasers

Liquid (dye) lasers

Solid-state lasers
Solid-state Lasers

Gas lasers

Liquid (dye) lasers

Solid-state lasers

Semiconductor (diode)

Fibre
Diode-pumped Solid-state Lasers

Gas lasers

Liquid (Dye) lasers

Solid-state lasers

Semiconductor (diode)

Fibre
Diode-pumped Solid-state Lasers

Gas lasers

Liquid (Dye) lasers

Solid-state lasers

Fibre
Fibre-laser-pumped Solid-state Lasers

- Gas lasers
- Liquid (Dye) lasers
- Solid-state lasers

Fibre
Unique laser properties lead to unique applications

**Light Amplification by Stimulated Emission of Radiation (LASER)**

The laser slogan: *One colour, One direction, Too the point!*

**Monochromatic**  
One colour or wavelength

**Directional**  
Laser beam does not expand as ‘quickly’ as other light beams

**Coherent**  
All waves are generated in phase with each other → small focus  
Generated at the same time → short laser pulse
Laser application – laser is part of system

System

Determine laser light characteristics
- Mode (Continuous / single shot)
- Power / Energy
- Beam Quality
- Wavelength(s)

Determine system properties
- Efficiency
- Power supply
- Laser type / technology
- Size & weight

Laser

Distance

Atmosphere

Divergence

Object / Target

www.csir.co.za
Laser application: to pump another laser

Diode Laser

Mode: Continuous
Power: very high
Beam Quality: very bad
Wavelength: TBD
Efficiency: 50%
Power supply: DC
Technology: Semiconductor
Size & weight: small
Laser application: to pump another laser

- Mode: Continuous
- Power: very high
- Beam Quality: very bad
- Wavelength: TBD
- Efficiency: 50%
- Power supply: DC
- Technology: Semiconductor
- Size & weight: small

Mode: Continuous
Power: high
Beam Quality: very good
Wavelength: choice
Efficiency: 10 - 40%
Cooling required
Technology: solid-state
Size & weight: compact
Laser application: to pump another laser

Diode Laser

Mode: Continuous or pulsed
Power: high
Beam Quality: very good
Wavelength: choice
Efficiency: 10 - 40%
Cooling required
Technology: solid-state
Size & weight: compact

Mode: Continuous
Power: very high
Beam Quality: very bad
Wavelength: TBD
Efficiency: 50%
Power supply: DC
Technology: Semiconductor
Size & weight: small
Laser application: to pump another laser

**Diode Laser**

Mode: Continuous
Power: very high
Beam Quality: very bad
Wavelength: TBD
Efficiency: 50%
Power supply: DC
Technology: Semiconductor
Size & weight: small

Mode: Continuous
Power: high
Beam Quality: perfect
Wavelength: choice
Efficiency: 50-80%
Cooling required
Technology: fibre laser
Size & weight: compact
Laser application: to pump other lasers

World records
- Highest energy Ho:YLF ring oscillator-amplifier – 70 mJ
- Highest energy Ho:YLF slab amplifier – 330 mJ
- Highest power Tm:YLF slab laser – 225 W
- Highest energy HBr laser – 5 mJ per pulse
- First HBr amplifier – 10 mJ per pulse
- First HBr wavelength selection 3.8 – 4.4 µm
DIRCM: Directed Infra-Red Counter Measure

MAWS

Controller

Laser

Pointing system

Distance ~1-5 km

Divergence

Target

System & application determine specs
- Mode (Continuous / single shot)
- Power / Energy
- Beam Quality: Good
- Wavelengths: 2 µm; 3-5 µm
Demonstrated laser technologies for DIRCM

Jamming
- Low Average Power Laser

1st Generation:
Flight demonstration
- Solid-state technology
- 1 µm laser + converters
- Fieldable system
- Airborne jamming
- Jamming codes

Damaging/Hard-kill
- High Energy Laser

Lab demonstration
- Pulsed high-energy lasers
- 2 µm laser + converter
- Lab demonstrator
- Destroy detector material
- World leading

Dazzling
- High Average Power Laser

2nd Generation:
Current development
- Full multi-spectral system
- 2 µm lasers + converters
- Portable evaluation tool
- Demonstrate dazzling
- Route to industrialisation
Laser application: Additive Manufacturing (3D printing)

Mode: Continuous & modulation
Power: 5 000 W
Beam Quality: extremely good
Wavelength: 1 µm
E-to-O Efficiency: 28%
3-phase power & water cooling
Technology: Yb:fibre oscillator-amplifier
Size & weight: typical fridge-size

www.csir.co.za
Laser application: Laser range finding

System

Laser

Detector

±t

Low divergence

Target

Distance: ~10 km

Atmosphere

Determine laser light characteristics

- Mode: Pulsed
- Energy: 10-50 mJ
- Beam Quality: good
- Efficiency
- Power supply: batteries
- Laser type / technology: solid-state
- Wavelength(s): eye safe?
- Size & weight

www.csir.co.za
Laser application: Gated imaging

System

Camera

Laser

Atmosphere & camouflage

Distance: ~10 km

Determine laser light characteristics

- Mode: Pulsed
- Energy: 10-50 mJ
- Beam Quality: good
- Efficiency
- Triggering of camera & laser
Concept Laser Product: Multi-wavelength high-power laser

Applications: DIRCM evaluation tool; illumination; Gated imaging

Output power:
- 10 W at 2 µm
- 10 W at 3-5 µm
- 1 W at 8-12 µm

Pulse repetition Frequency: 10 – 50 kHz

Pulse duration: 20 to 100 ns
Concept Laser Product: DIRCM laser (Southern Star)

Application: Directed Infrared Countermeasures (DIRCM) on fixed & rotary wing platforms

Output power: 5 W at 2 µm
5 W at 3-5 µm

Pulse repetition Frequency: 10 – 50 kHz

Pulse duration: 10 to 100 ns
Concept Laser Product: High-energy laser (Nd:YLF)

Applications: Laser ranging; Frequency conversion to green; Industrial materials processing

Output power: 50 W at 1.053 µm
Output energy: 50 mJ per pulse
Pulse repetition Frequency: 1 – 10 kHz
Pulse duration: 25 to 75 ns
Concept Laser Product: Short-pulse laser (Nd:YVO 2 ns)

Application: Laser ranging; Laser mapping (3D image generation)

- Peak power: 5 kW at 1.064 µm
- Pulse repetition Frequency: 100 kHz – 150 kHz
- Pulse duration: 2 ns
CSIR entry to photonics industry – Advanced Photonics Manufacturing Facility

State of the art facility
Small-volume production of advanced laser products
Prototype development of photonic devices

<table>
<thead>
<tr>
<th>Environmental Test facility</th>
<th>Clean room (class 100) / laminar flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>High / low temp Vibration</td>
<td>Optical</td>
</tr>
<tr>
<td>Diagnostic equipment</td>
<td>Reception &amp; Dispatch</td>
</tr>
<tr>
<td></td>
<td>Advanced Photonics Manufacturing Facility</td>
</tr>
<tr>
<td></td>
<td>Mechanical</td>
</tr>
<tr>
<td></td>
<td>Change room</td>
</tr>
</tbody>
</table>

Services: air conditioning, compressed dry air, chilled water

Characterisation & Certification of Laser Products

- Pulse Repetition Frequency [Hz]
- Peak Power [W]
- Energy [J]
- Time [s]
- Pulse length [s]

\[ M^2 = \frac{D \Theta \pi}{4 \lambda} \]
Thank you