MOVING LASER: A Simple Technique to Remove Thermal Distortions in Pulsed Solid State Lasers

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Motivation

Average power of solid-state lasers limited by thermal effects.

Yb and Nd-doped glasses have numerous attractive properties for CPA, however glass has poor thermal conductivity.

Need to remove thermal effects

1. Thermal distortions
   a. Thermal lensing
   b. Thermal birefringence
   c. Higher-order aberrations

2. Thermal fracture
Three Steps for the Removal of Thermal Distortions

1. Uniform Pumping
   Pumping of the laser medium results in a uniform inversion distribution transverse to the lasing beam path.

2. Lase before Thermal Diffusion
   Pumping and lasing must occur during the time period when the resulting uniform temperature profile exists (< 1 ms).

3. Move out heated material, Move in cooled material
   Heated region must be moved away from the lasing path to be cooled and a cooled region moved into the lasing path before the next pump pulse arrives.
Distinctions From Other Moving Lasers

- Laser operation occurs during transient uniform temperature increase
- Effectively single-shot thermal effects
- Laser operation occurs with a steady-state temperature distribution
- Different techniques used to remove thermal effects:
  - zig-zag slab
  - thin disks
Other Geometries for Moving Gain Media

Linearly Translating Slab

Rotating Cassette of Rods

Rotating Disk
Interferometer Setup to Measure the Transient Temperature Profile

- AOM - acousto-optic modulator chops He-Ne to 10 μs pulses synchronized to the 10 Hz of the alexandrite laser
- HR1 - high reflector at 760 nm, transmissive at 632 nm
- HR2 - high reflector at 632 nm
- BS - 50:50 beamsplitters at 632 nm
Pump Beam Spatial Profile Incident on Nd:glass Hollow Cylinder
Interferograms Imaged from the Face of the Hollow Cylinder

Hollow cylinder is stationary and pumped for 3 s at 10 Hz

Curved fringes indicates heat diffusion in outgoing media

Circle indicates pumped region of 2.4 mm diameter. Half-wave increase within circle indicates nearly uniform temperature rise.

Straight fringes indicates cooled incoming media

Hollow cylinder is rotating upwards at a speed of 0.2 rev/sec
## Moving Gain Medium Respective Sizes for a 1 kW laser (1 J at 1 kHz)

<table>
<thead>
<tr>
<th>Material</th>
<th>Saturation Fluence (J/cm²)</th>
<th>Thermal cond. (W/m/K)</th>
<th>Beam radius (cm)</th>
<th>Thermal decay const (sec)</th>
<th>Cylinder radius (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nd:silicate</td>
<td>7.8</td>
<td>1.1</td>
<td>0.14</td>
<td>1.3</td>
<td>59</td>
</tr>
<tr>
<td>Nd:YAG</td>
<td>0.7</td>
<td>14</td>
<td>0.48</td>
<td>1.8</td>
<td>270</td>
</tr>
<tr>
<td>Ti:sapphire</td>
<td>0.62</td>
<td>52</td>
<td>0.51</td>
<td>0.33</td>
<td>54</td>
</tr>
<tr>
<td>Yb:YAG</td>
<td>9.6</td>
<td>7.3</td>
<td>0.13</td>
<td>0.25</td>
<td>10</td>
</tr>
<tr>
<td>Yb:phosphate</td>
<td>50</td>
<td>0.85</td>
<td>0.056</td>
<td>0.30</td>
<td>5.4</td>
</tr>
</tbody>
</table>

\[ r_c \propto \frac{r_p^3 R}{k} \]