New Laser Glass from SCHOTT Meets Challenges of New Applications-

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Advanced Optics – SCHOTT North America
APOMA Tucson Meeting 2016
Agenda

Active Laser Glass from SCHOTT Meets Challenge of New Applications

- Brief History of Laser Glass
- Broadband Laser Glass
  - Short Pulse, High Peak Power Lasers
  - Tunable High Energy Laser
- High Energy and High Repetition Rate Eye Safe Laser Glass
  - Cosmetic, LIDAR, and LRF
Neodymium doped glasses have long been used as amplifier slabs in large solid state laser systems.

- Early lasers used silicate glasses from non-SCHOTT sources.
- Phosphate glasses became lead materials in the early 1980’s.
- Platinum particle free phosphate glass became available in 1986.
- The size of available high homogeneity slabs increased to meet the demands of various laser designs.

Examples of laser glass showing the progression of manufacturing technology as a function of time.
Laser Glass Utilized in Many Large Scale High Power Lasers

Novette, 1981-1983

NOVA 1984-1987

Beamlet 1991

NIF, 2001-2004

Laser MegaJoule, 2001-2004

Corporate Technical Achievement Awards
Choice Between Energy and Duration or Maybe Both?

- Glass laser fusion programs
- Petawatt Glass laser studies
- Multi beam
- Hybrid concepts
- Hybrid/OPCPA
- OPCPA
- Ti:Sapphire
- PFS

- In progress
- demonstrated
- Incomplete listing

Pulse energy [J] vs. Pulse duration [fs]
Gain narrowing in the glass amplifiers limits achievable pulse durations

\[ S_{amp}(\lambda) = S_{seed}(\lambda) \exp[n_g(\lambda)l] \]

Time-bandwidth limit for the achievable pulse durations

\[ \Delta \tau_{pulse} \geq \frac{0.44 \lambda_0^2}{c \Delta \lambda} \]
The hybrid design: OPCPA with mixed Nd:glass amplifiers to increase bandwidth
Can We Improve Performance with a Single Glass?
The BLG80: Utilizing Cooperative Emission from Nd and Yb

<table>
<thead>
<tr>
<th>Glass code</th>
<th>CDA-1</th>
<th>CDA-2</th>
<th>CDA-3</th>
<th>CDA-4</th>
<th>CDA-5</th>
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</thead>
<tbody>
<tr>
<td>Nd/Yb ratio</td>
<td>No Yb input</td>
<td>0.12</td>
<td>1</td>
<td>4</td>
<td>No Nd input</td>
</tr>
<tr>
<td>Lifetime, Nd$^{3+}$ (μsec)</td>
<td>365.3</td>
<td>423.3</td>
<td>686.8</td>
<td>1292.6</td>
<td>N/A</td>
</tr>
<tr>
<td>μNd-Yb transfer</td>
<td>N/A</td>
<td>0.45</td>
<td>0.86</td>
<td>1.00</td>
<td>N/A</td>
</tr>
</tbody>
</table>

![Fluorescence Signal vs Wavelength (nm)](image)
The BLG80: In Laser Performance Measurements

808nm, quasi-CW diode laser pump operated at 0.1Hz, performance efficiency measurements are completed below thermal lensing threshold.

Higher laser efficiency is obtained with an Yb sensitized glass when compared to the singly doped glass.
BLG80 For Most Powerful Lasers in the World

- 80 nm or more bandwidth in one glass with codoping
- Gain BW greater than the combined emission from the best current LG’s
- 50fs Exawatt laser operation with glass now feasible
- Flashlamp pumping for low-cost architectures
- Diode pumping also possible
Laser Glass is Excellent Material for Many Commercial Applications

- High optical homogeneity, isotropy of properties
- Large dimensions possible
- Finished/Coated with standard procedures used for optical glass
- Scalable, nearly any size possible, high volume possible
- Broad absorption bands for pumping of active ions
- Customized glass properties
- High amounts of doping ions possible
- Low non linear refractive index (→ self focusing)
BLG80: High Peak Power, Short Pulse Applications

Materials Machining and Manufacturing

Long Pulse

Femtosecond Pulse

Droplets

Minimal affected area for precise machining

Heat Affected Zone: cracks and melting
BLG80: High Peak Power, Short Pulse Applications

Ophtalmic Laser Systems

Short Pulse reduces collateral damage from heat to surrounding tissue
Pin point resolution as laser fluence is only above threshold within focal waist
BLG80: High Power Tunable Laser

Tattoo Removal

• 3 of every 10 Americans have at least one tattoo
• Of those, 7 out of 10 have more than one
• Metal nanoparticles in the ink create the color of the tattoo
• Tattoo removal is accomplished by light absorption ablating the metal particles
• The ablated metal particles are small enough for the human body to reabsorb and pass
• Each color has a unique absorption spectrum
• BLG-80 pumped by Alexandrite (755 nm) and coupled with SHG and THG gives broadly tunable high power laser system covering most required wavelengths
BLG80: Other Applications

R&D, Military, Communications

Co-doped Er/Yb Glass for Eye Safe Applications

- Retinal Transmission is near zero for wavelengths greater than 1.4 micron
- Atmosphere is transparent to same wavelengths
- Eye Safe Laser glass is currently utilized in several applications
  - Laser Range Finder
  - LIDAR
  - Cosmetic – Skin Resurfacing
  - Communication
- Poor Thermo-mechanical properties of earlier glass types
  - Restricted to Low Rep Rate
  - Restricted to longer pulse lengths in higher energy applications
  - Limited range
  - High Energy OR Rep Rate
Can we make a laser glass that is both high energy and high rep rate?
LG960: Seeking a stronger material for high gain applications

Based on state-of-the-art glass development principles several glasses were manufactured for optimization.

Best glasses for commercial manufacturing selected from these trials based on the properties measured.

[Image: http://www.us.schott.com/newsfiles/com/versuchsschmelze_271640.jpg]
LG960: The Balancing act of Development

- LG-940 vs the higher thermal load capable LG-960, same active ion concentration profile
- Goal: Laser performance cannot decrease for the same Er-Yb codoping as compared to the current commercialized materials

<table>
<thead>
<tr>
<th></th>
<th>LG-940</th>
<th>LG-960</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Thermal Shock Resistance, R_s</td>
<td>0.39</td>
<td>0.56 (+43%)</td>
</tr>
<tr>
<td>Er Emission Cross Section (x10^{-20}cm^2)</td>
<td>0.77</td>
<td>0.67 (-14%)</td>
</tr>
<tr>
<td>Yb Absorption Cross Section(x10^{-20}cm^2)</td>
<td>1.34</td>
<td>1.23 (-9%)</td>
</tr>
</tbody>
</table>

* TM – FOM = R_s = \frac{k(1 - \nu)K_{IC}}{E\alpha} \left[ W/m^2 \right]
LG960: Flashlamp pumped cavity output

In cavity measurement results, 1 shot/5 seconds

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<th>Glass ID</th>
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<th>LG-960</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longpulse, flashlamp pump, multi-kW, 5ms 1 (Joule)</td>
<td>4.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Longpulse, flashlamp pump, multi-kW, 15ms (Joule)</td>
<td>8.8</td>
<td>8.6</td>
</tr>
<tr>
<td>Longpulse, flashlamp pump, multi-kW, 15ms (Joule)</td>
<td>12.3</td>
<td>12.0</td>
</tr>
</tbody>
</table>

Performance loss (average of two rods)                                      -2%

Calculated Laser FOM difference obtained using Judd-Ofelt Theory           -14%

Excellent shot-to-shot stability for all glasses, less than 1% roll-off after 500+ shots
LG960: Diode Pumped

- Diode pumped systems are much smaller in architecture and more efficient
  - Lower thermal load than flashlamp systems
  - Price of diodes decreasing making architecture more feasible
- Recently tested for Laser Range Finder and LIDAR systems
  - Ranging >7km easily achieved
  - Rep rate increased to 10 Hz without damage to sample
  - mJ’s of output in nanosecond pulses

![Lidar pulses and returns](image.png)
Thanks for your attention!