eLISA Laser Development in the US

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LISA X Symposium
May 20, 2014
**eLISA laser program at GSFC**

- **Provide TRL 5 laser system by 2016**
  - Modern, fiber-based design
  - Technical details to be made available to all LISA members

- **Funding**
  - SBIR (Small Business Innovative Research)
  - Internal GSFC R&D
  - LISA project funds
  - Strategic Astrophysics Technology award
  - ~ $3.5M over 6 years
GSFC LISA laser design

ECL + Pre-amplifier

Power amplifier

MOPA design
External Cavity Laser, fiber preamp, fiber amplifier
1064 nm wavelength
2 Watt output
Oscillator: External Cavity Laser

Simple, compact, low mass, highly reliable laser (butterfly package)

Numata, Camp, Krainak, Stolpner, OE 18, 22781

NPRO: $25K
ECL: $5K
Packaging of ECL and Preamp

Redundant ECL and Preamplifier package

2 ECLs
2 Preamp Diodes
10 cm x 5 cm x 1 cm
50 mW output
1550 nm ECL is space qualified

Fig. 5 Reliability testing of ECL  a) thermal cycling  b) proton irradiation

Other tests:
• Hermiticity
• Gamma-ray exposure
• Accelerated aging

→ Robust design suitable for space operation
Conversion of ECL wavelength to 1064 nm

<table>
<thead>
<tr>
<th>RWG (1064nm)</th>
<th>BH (1550nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Complex epi design</td>
<td>epi design is decoupled from mode size converter</td>
</tr>
<tr>
<td>a Use special design to expand beam size</td>
<td>Beam defined by BH and mode size converter</td>
</tr>
<tr>
<td>2 Waveguide defined by RWG</td>
<td>Waveguide defined by BH</td>
</tr>
<tr>
<td>a Weak index guiding</td>
<td>Strong index guiding</td>
</tr>
<tr>
<td>b Thermal and carrier lensing affect beam profile</td>
<td>No thermal and carrier lensing</td>
</tr>
<tr>
<td>c Beam profile depends on operating current</td>
<td>Beam profile does not depend on operating current</td>
</tr>
<tr>
<td>d Excitation of TEM(_{01}) could degrade noise</td>
<td>Only TEM(_{00})</td>
</tr>
<tr>
<td>f High ellipticity</td>
<td>Almost circular</td>
</tr>
<tr>
<td>g High GC-PLC coupling loss</td>
<td>Low GC-PLC coupling loss</td>
</tr>
<tr>
<td>h Requires facet passivation</td>
<td>Does not require facet passivation</td>
</tr>
<tr>
<td>i One-step growth</td>
<td>Two-step growth</td>
</tr>
</tbody>
</table>

- PLC = Planar linear cavity
- GC = gain chip
- BFM = back facet monitor

Numata, Alalusi, Stolpner, Camp, Krainak, OL 39, 2101 (2014)
Frequency noise of world’s 1st 1064 nm ECL (in Butterfly package)

Lowering phase noise:
1) Optimize optical cavity reflectivity slope → strong feedback → low noise
2) Optimize gain chip for low loss → low noise
3) Select gain chip for lowest 1/f noise
Frequency stabilizing the ECL

Need external AOM as frequency actuator to suppress frequency noise
Frequency Modulation of ECL on laser chip (to be implemented)

- Modulation of the effective refractive index inside the cavity, results in frequency modulation of the external wavelength up to 100 MHz
- FM section on the gain chip, separated from gain section by etching

![Diagram of laser chip with labels](image.png)

- $I_a =$ bias current of section-a
- $I_m =$ modulation current
- 10-15 $\mu m$ Isolation $> 300 \Omega$
- 2000 $\mu m$
Power Amplifier

- **Design**
  - All fiber coupled
  - Large mode area, double-clad Yb fiber
  - Forward pump to avoid risk and noise sources

- **Noise performance**
  - No additional frequency noise
  - eLISA requirement level
    - Differential phase noise (@2GHz)
    - Stabilized low frequency RIN with feedback to pump diode

**Graphs**
- Differential phase noise
- Relative intensity noise
- RIN and its stabilization (low/high frequency ends)
Planned Systems Tests for FY 2015

1064 nm ECL oscillator, rebuilt power amplifier
Temperature stabilized environment
Tests: noise, accelerated aging, etc.
Laser Development Schedule

- FY 2014 - 2015
  - Iterate design of 1064 nm ECL gain chip, planar cavity
  - Achieve final frequency noise performance

- FY 2015
  - Laser system testing with 1064 nm ECL

- FY 2016
  - Reliability testing of 1064 nm ECL
    - Low risk since same packaging as 1550 nm, also Eagleyard data indicates reliable 1064 nm gain chips
    - Implement on-chip frequency modulation