Development of fiber-based laser systems for LISA
Kenji Numata, Jordan Camp

Abstract

We present efforts on fiber-based laser systems for the LISA mission at the NASA Goddard Space Flight Center. A fiber-based system has the advantage of higher robustness against external disturbances and easier implementation of redundancies. For a master oscillator, we are developing a ring fiber laser and evaluating two commercial products, a DBR linear fiber laser and a planar-waveguide external cavity diode laser. They all have comparable performance to a traditional NPRO at LISA band. We are also performing reliability tests of a 2-W Yb fiber amplifier and radiation tests of fiber laser/amplifier components. We describe our progress to date and discuss the path to a working LISA laser system design.
Development of fiber-based laser systems for LISA

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5. Summary

Jul. 1, 2010

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1. Introduction

NPRO (Non-planar ring oscillator) has been used traditionally.
- Compact crystal cavity gives high stability.
- “Black box” in many cases
  - E.g.) TESAT NPRO for LPF

All fiber/waveguide solution
- Fiber laser/amplifier technologies matured rapidly
- Higher robustness

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Fiber laser offers significant advantages over NPRO laser

<table>
<thead>
<tr>
<th>Traditional: NPRO laser</th>
<th>New: Fiber laser</th>
</tr>
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<tbody>
<tr>
<td>Typical Material: Nd:YAG</td>
<td>WDM Yb-doped fiber</td>
</tr>
<tr>
<td>Pump Beam (808 nm)</td>
<td>Pump LD</td>
</tr>
<tr>
<td>Output Beam (1064 nm)</td>
<td>Output coupler</td>
</tr>
<tr>
<td>Mirror Coating HT@808nm 99%@1064nm (typ)</td>
<td>Isolator</td>
</tr>
</tbody>
</table>

Difficult alignment
No alignment needed
Glue/solder needed
No glue needed
Need to couple back into fiber
Laser light within fiber
Strong magnet needed
No strong magnet
Contamination sensitive (sealed package)
No contamination
Distorted Gaussian beam
Mode & polarization cleaned by fiber

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Fiber amp has:

- Higher beam quality, lower sensitivity to alignment etc., easier cooling
- Higher reliability, **higher optical/wallplug efficiency**
  - E.g. Commercial fiber amp: >10% wallplug efficiency
  - ~2% efficiency in solid state amps in flight missions

Easier addition of redundancy

- Many (~90%?) laser failures come from pump LD
- No geometrical constraints
2. Fiber-based lasers

- GSFC fiber ring laser
  - Commercial highly-doped gain fiber + fiber Bragg gratings

- NP photnics/Fibertek DBR fiber laser
  - Special phosphosilicate glass fiber + fiber Bragg gratings

- RIO external cavity diode laser (ECL)
  - InP semiconductor gain chip + planar-waveguide Bragg reflector
**Features**

- Design & built in house
- Commercial components only
  - No special gain fiber
  - No patent issues
- Two FBGs for single-mode selection
- Fast frequency tuning by waveguide EOM
- Low power (~2mW)

**Status**

- Design fixed
- Iodine stabilization
- Digital system design
Noise performance

**Frequency noise**

- Low frequency: comparable to (better than) NPRO
- High frequency: increased noise due to relaxation oscillation
- Stabilization experiments
  - Frequency: Planned using iodine or cavity.
  - Intensity: Done after Yb amplifier and satisfied LISA requirement at low frequency.

**Intensity noise**
Features

- Built by NP Photonics
- Highly-doped phosphate glass fiber
  - Short cavity length
- Low reliability of splice
- Patented

Status

- Qualification tests by Fibertek
  - “Space version” passed thermal cycling
- Noise evaluations
Features

- Compact & simple
- **Low cost**
  - \(~5k\)
- **Lowest noise** at LISA band
- Unconditionally single-mode
- Low power (\(~15mW\))
- Telecom C-band only

Status

- Frequency stabilization done
- Phase locking experiment
- 1064-nm version
- **Lowest free-running noise levels**
  - Stabilization by saturation signal of acetylene at 1542nm.
  - Controllability

- **High frequency noise @ high frequency**
  - Under investigations
3. Fiber amplifier

Features
- Built by Lucent Government Solutions (LGS)
  - Clad pump, LMA fiber, ~4W maximum
- Focused on reliability
  - Detailed risk analysis
  - Passed thermal cycling tests

Status
- Noise measurements at GSFC
- Stabilization experiments
4. Other activities

Space qualification tests

- To be done in collaboration with LGS
  - Proton test (@ UC Davis)
  - Gamma test (@ GSFC, 7/19~)
  - Fiber components to be radiated
    - Fiber bragg grating (FBG), circulator (isolator), Band-pass filters, gain fibers, etc.
  - Outgass, pyroshock

All-fiber frequency stabilization

- FBG Fabry-Perot cavity
  - Finesse ~300
5. Summary

Fiber approach very promising for space applications
- Higher robustness, cleaner output, no strong magnet, etc.
- Redundancy can be easily added.
- New technology introduced frequently
- No choice for solid-state amp for LISA-type CW, low-power applications

Fiber-based lasers
- At low frequency, NPRO is not the best anymore.
- Custom-made fiber laser possible.
- Possible issue is high frequency noise at higher frequency
  • Can be suppressed by fast frequency actuators (e.g. waveguide EOM)

Current & future activities
- Radiation tests
- Full stabilization & metrology experiments