eLISA Laser Development in the US

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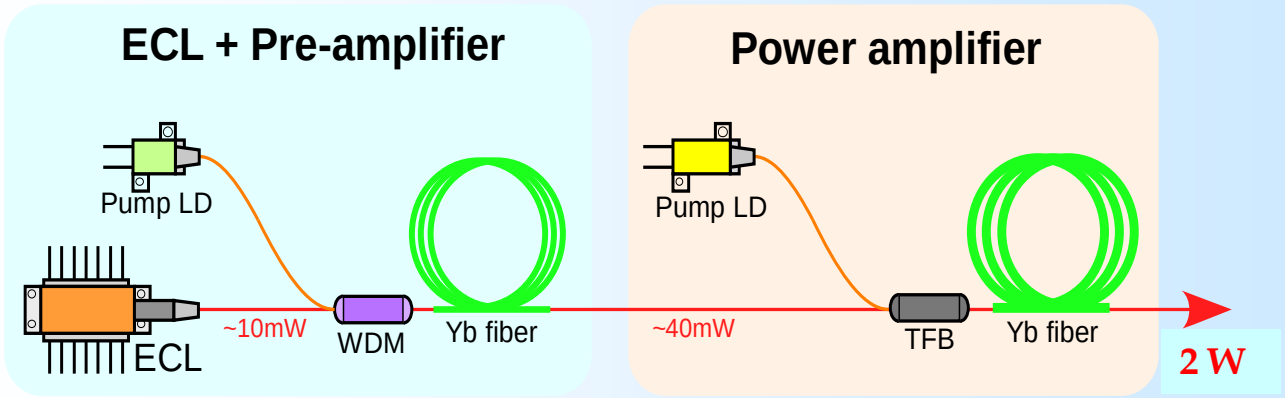
eLISA laser program at GSFC

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

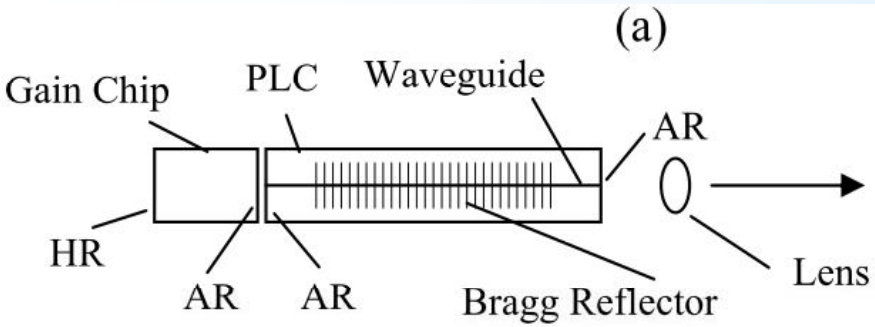
- Funding
  - SBIR (Small Business Innovative Research)
  - Internal GSFC R&D
  - LISA project funds
  - Strategic Astrophysics Technology award
  - ~ $3.5M over 6 years

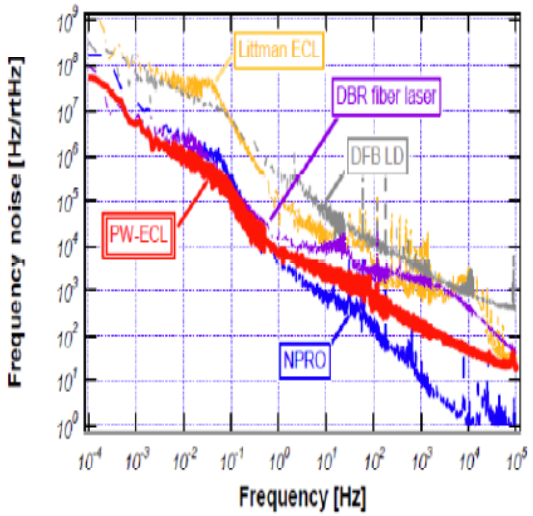
GSFC LISA laser design

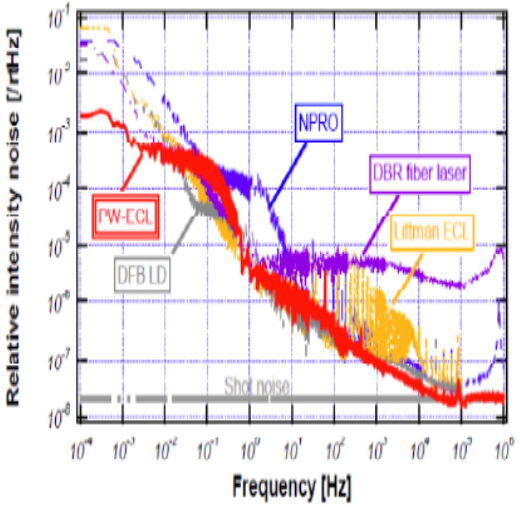


MOPA design
External Cavity Laser, fiber preamp, fiber amplifier
1064 nm wavelength
2 Watt output

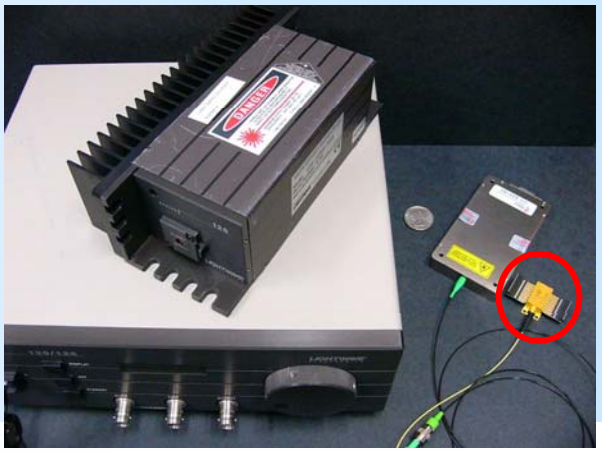
Oscillator: External Cavity Laser







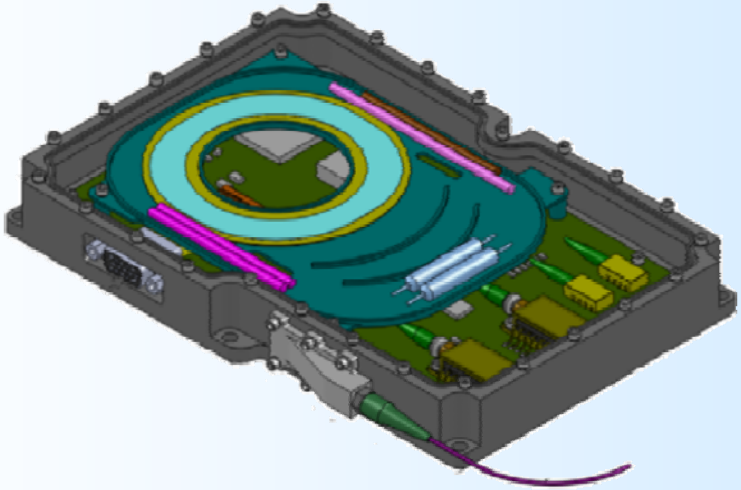
Simple, compact, low mass, highly reliable laser (butterfly package)



NPRO: $25K **ECL: $5K**

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

Packaging of ECL and Preamp



2 ECLs
2 Preamp Diodes

10 cm x 5 cm x 1 cm
50 mW output

Redundant ECL and Preamplifier package

1550 nm ECL is space qualified

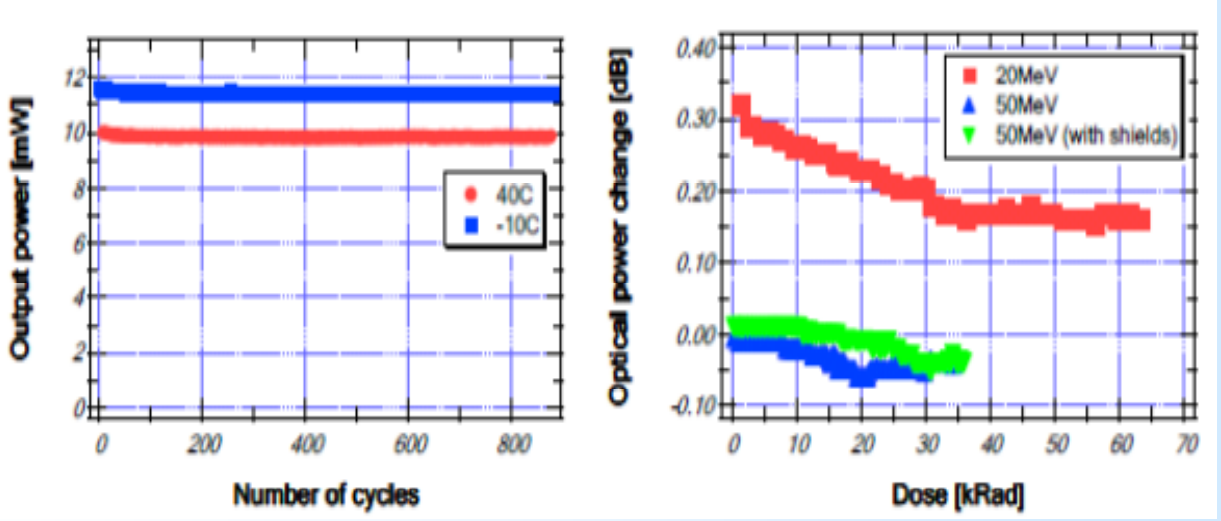


Fig. 5 Reliability testing of ECL a) thermal cycling b) proton irradiation

Other tests:

- **Hermiticity**
- **Gamma-ray exposure**
- **Accelerated aging**

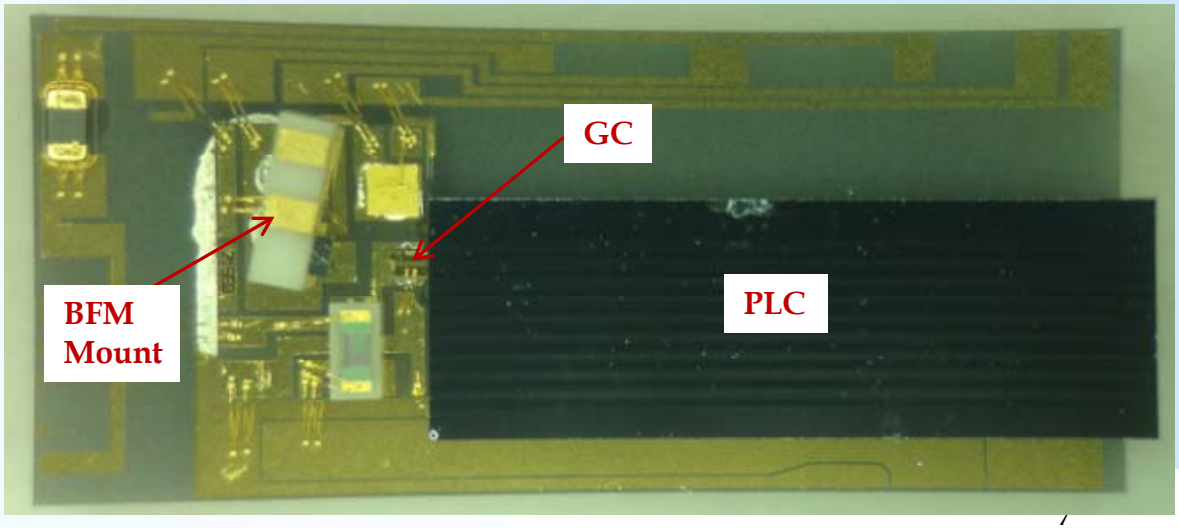
→ Robust design suitable for space operation

Conversion of ECL wavelength to 1064 nm

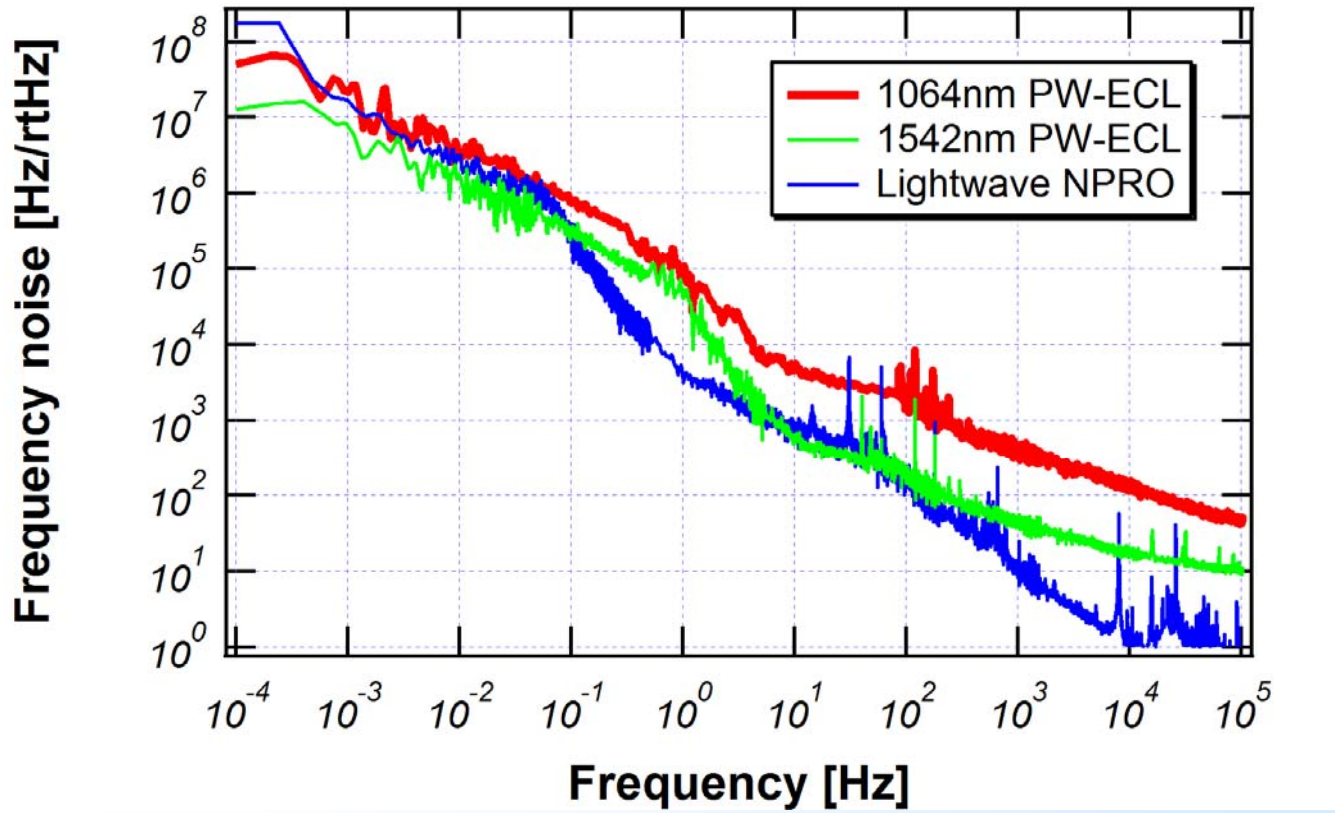
Gain Chip		
	RWG (1064nm)	BH (1550nm)
1	Complex epi design	epi design is decoupled from mode size converter
a	Use special design to expand beam size	Beam defined by BH and mode size converter
2	Waveguide defined by RWG	Waveguide defined by BH
a	Weak index guiding	Strong index guiding
b	Thermal and carrier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

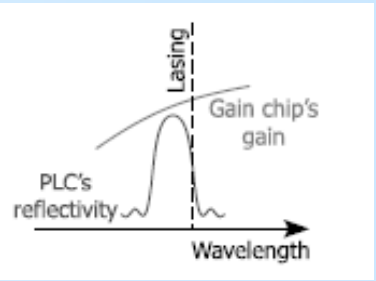
- PLC = Planar linear cavity
- GC = gain chip
- BFM = back facet monitor

Numata, Alalusi, Stolpner, Camp, Krainak, OL 39, 2101 (2014)



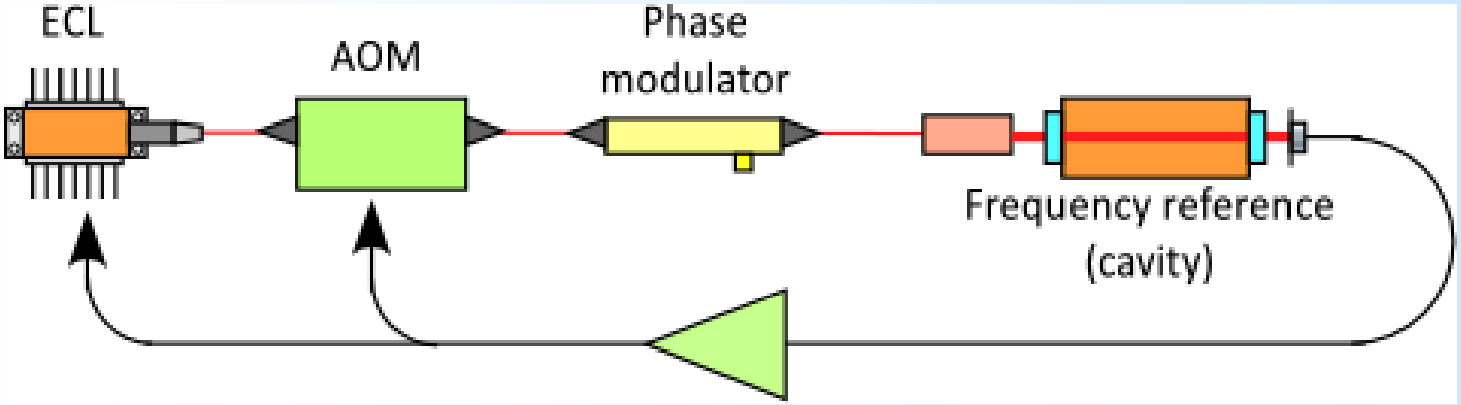
Frequency noise of world's 1st 1064 nm ECL (in Butterfly package)





<u>Lowering phase noise:</u> 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

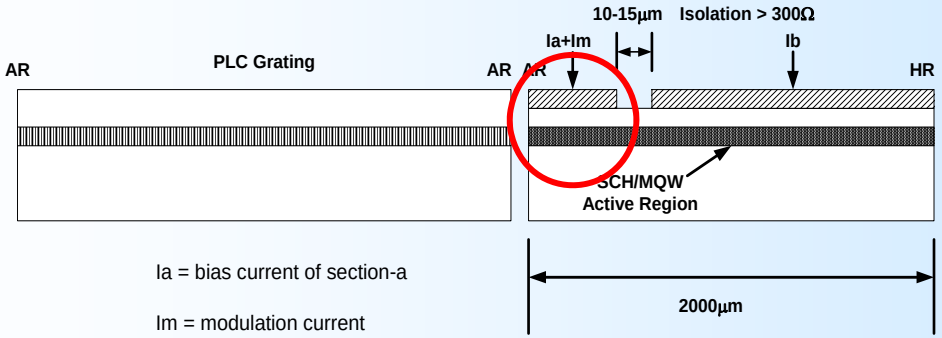
Frequency stabilizing the ECL

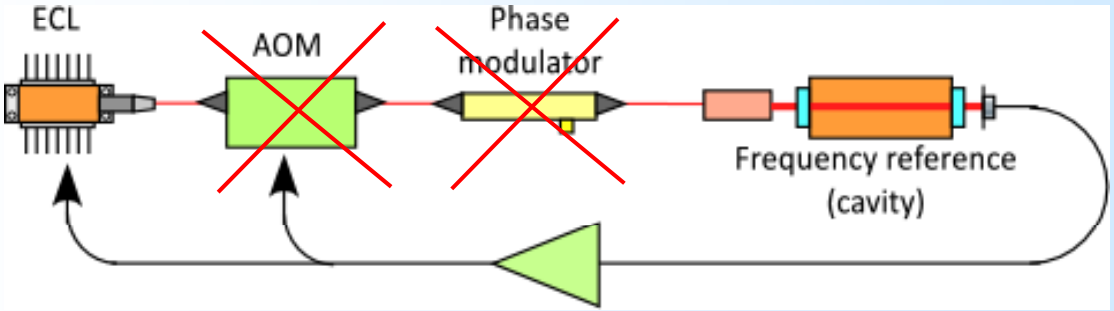


Need external AOM as frequency actuator to suppress frequency noise

Frequency Modulation of ECL on laser chip (to be implemented)

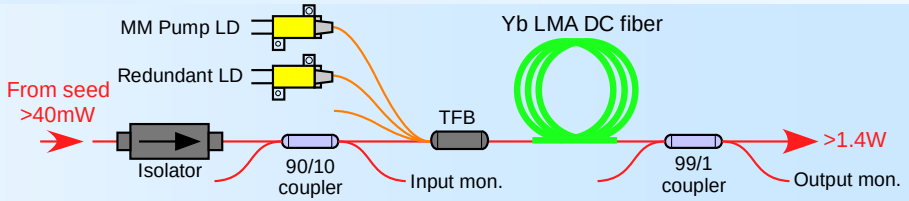
- Modulation of the effective refractive index inside the cavity, results in frequency modulation of the external wavelength up to 100 MHz
- FM section on the gain chip, separated from gain section by etching

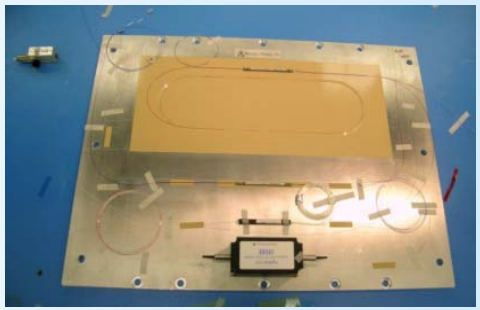


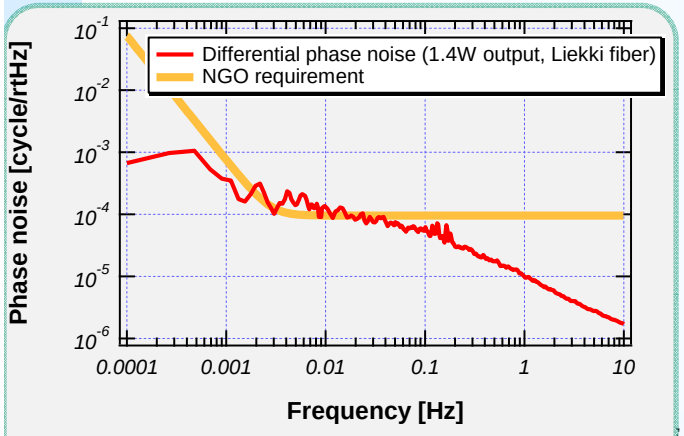


Power Amplifier

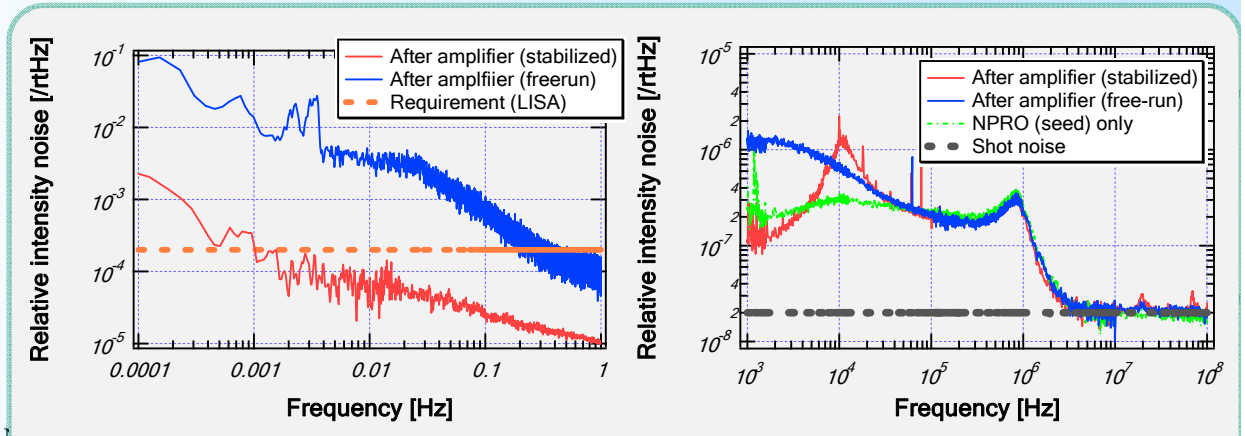
- **Design**
  - All fiber coupled
  - Large mode area, double-clad Yb fiber
  - Forward pump to avoid risk and noise sources
- **Noise performance**
  - No additional frequency noise
  - eLISA requirement level
    - Differential phase noise (@2GHz)
    - Stabilized low frequency RIN with feedback to pump diode





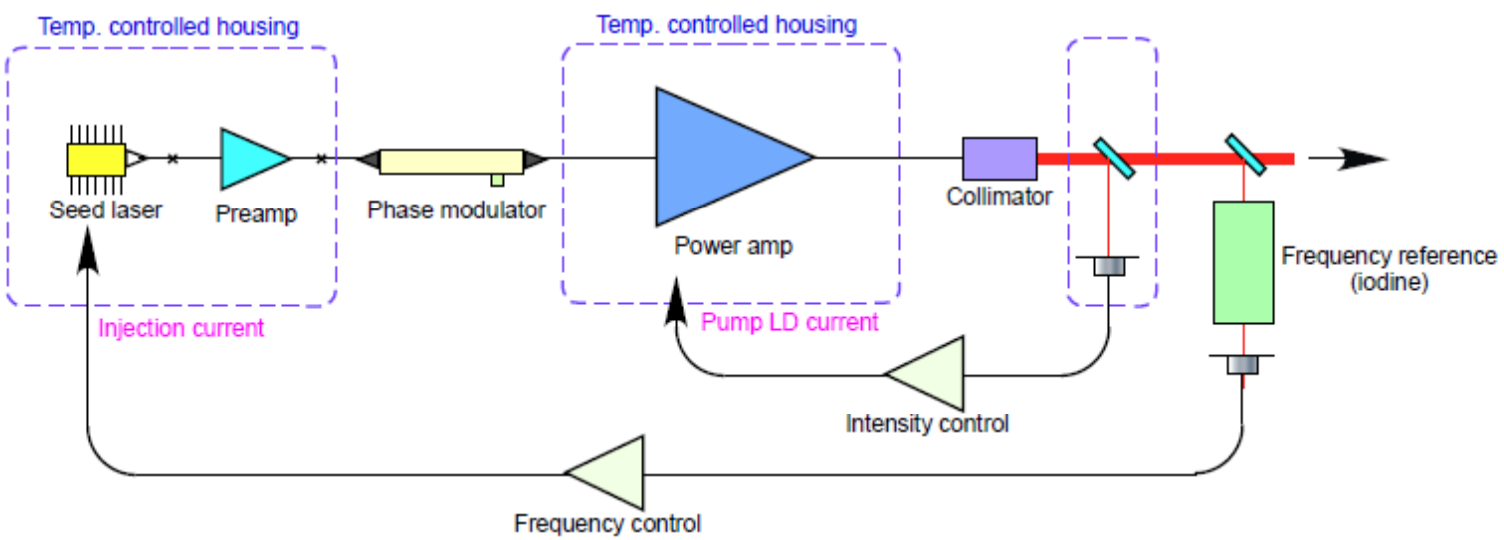


Differential phase noise



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