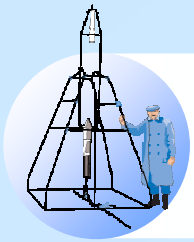


Development of a US Gravitational Wave Laser System for LISA

Jordan Camp

Kenji Numata*

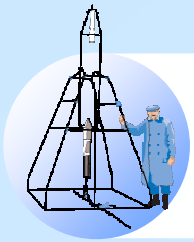
NASA Goddard Space Flight Center

*** University of Maryland, College Park**

APS April Meeting 2015

Apr. 13, 2015

GODDARD SPACE FLIGHT CENTER

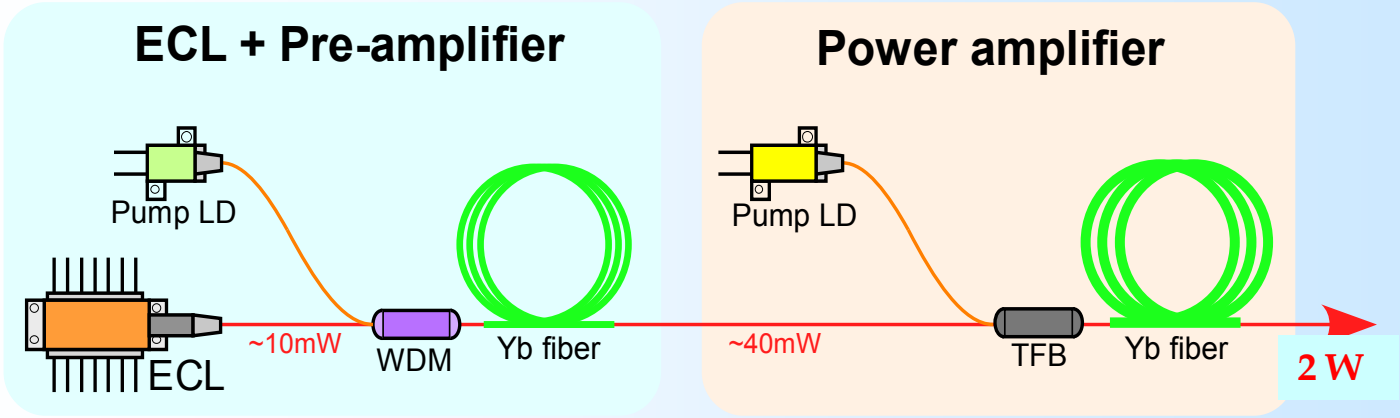


eLISA laser program at GSFC

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

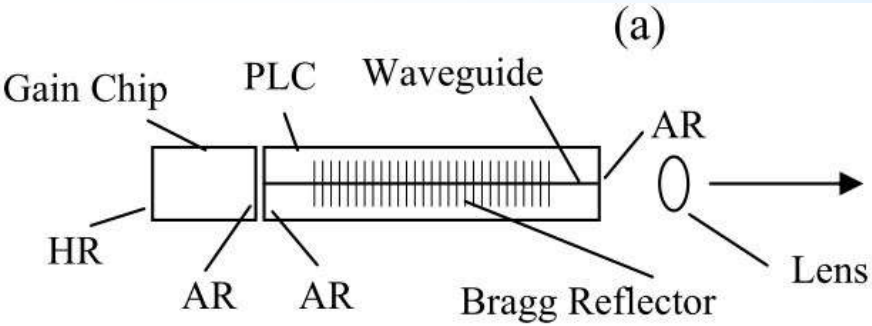
- Funding
  - SBIR (Small Business Innovative Research)
  - Internal GSFC R&D
  - LISA project funds
  - Strategic Astrophysics Technology award
  - ~ $3.5M over 6 years

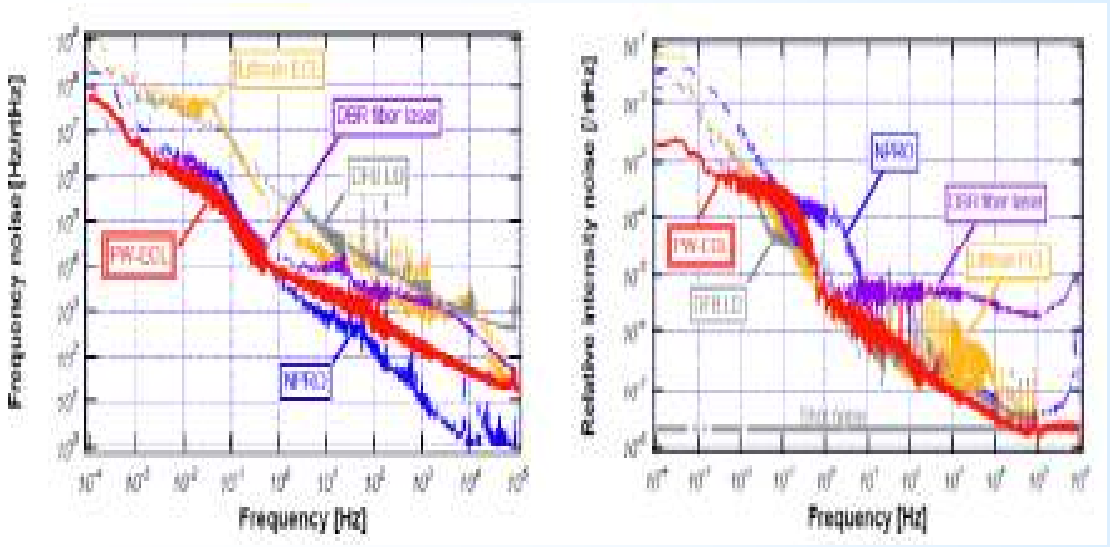
GSFC LISA laser design



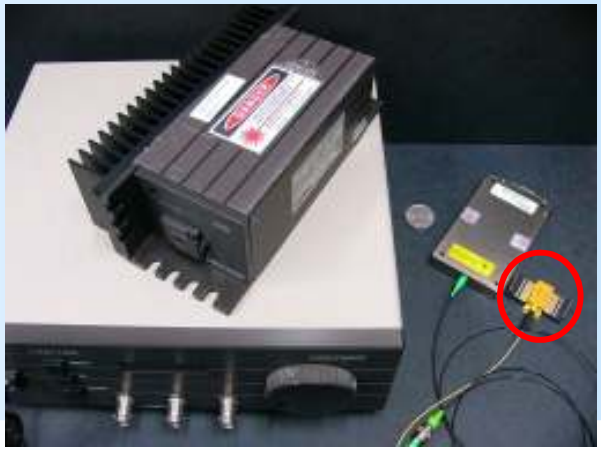
MOPA design
External Cavity Laser, fiber preamp, fiber amplifier
1064 nm wavelength
2 Watt output

Oscillator: External Cavity Laser





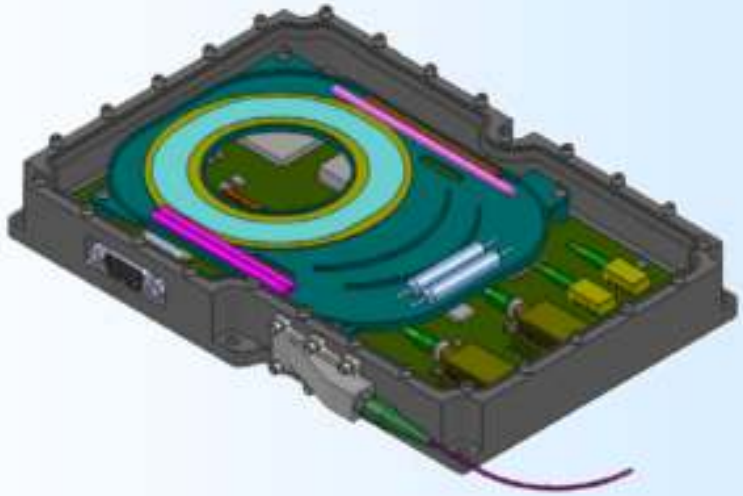
Simple, compact, low mass, highly reliable laser (butterfly package)



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

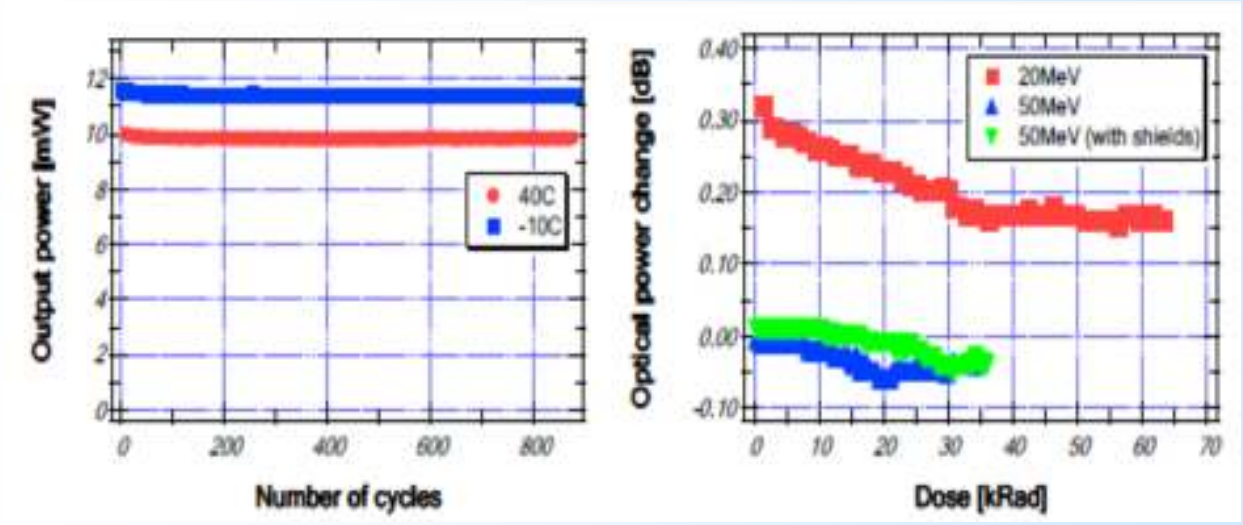
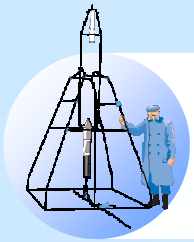


Fig. 5 Reliability testing of ECL a) thermal cycling b) proton irradiation

Other tests:

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

→ Robust design suitable for space operation

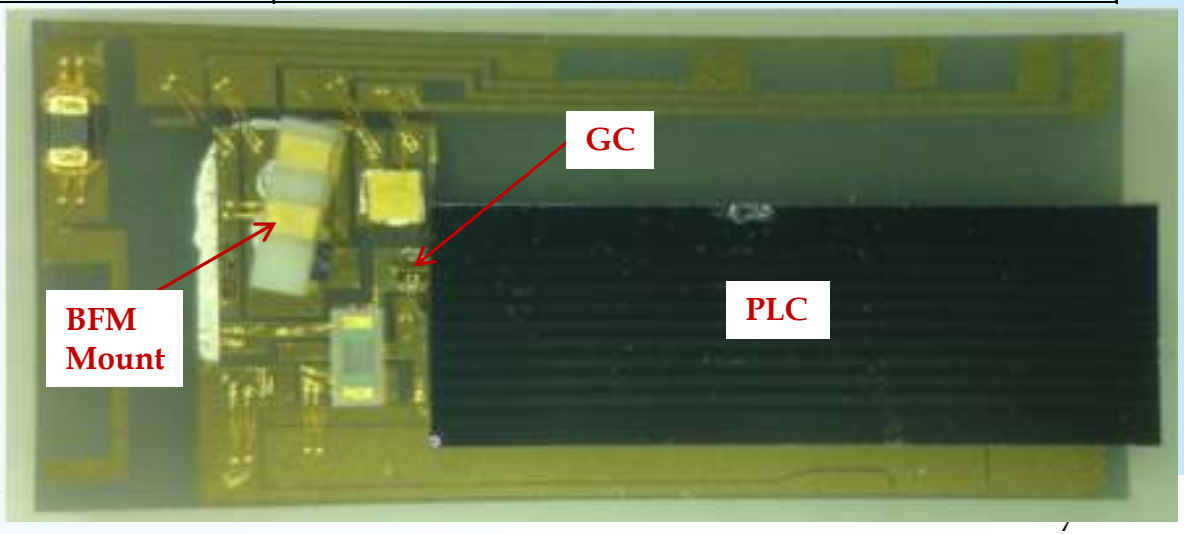


Conversion of ECL wavelength to 1064 nm

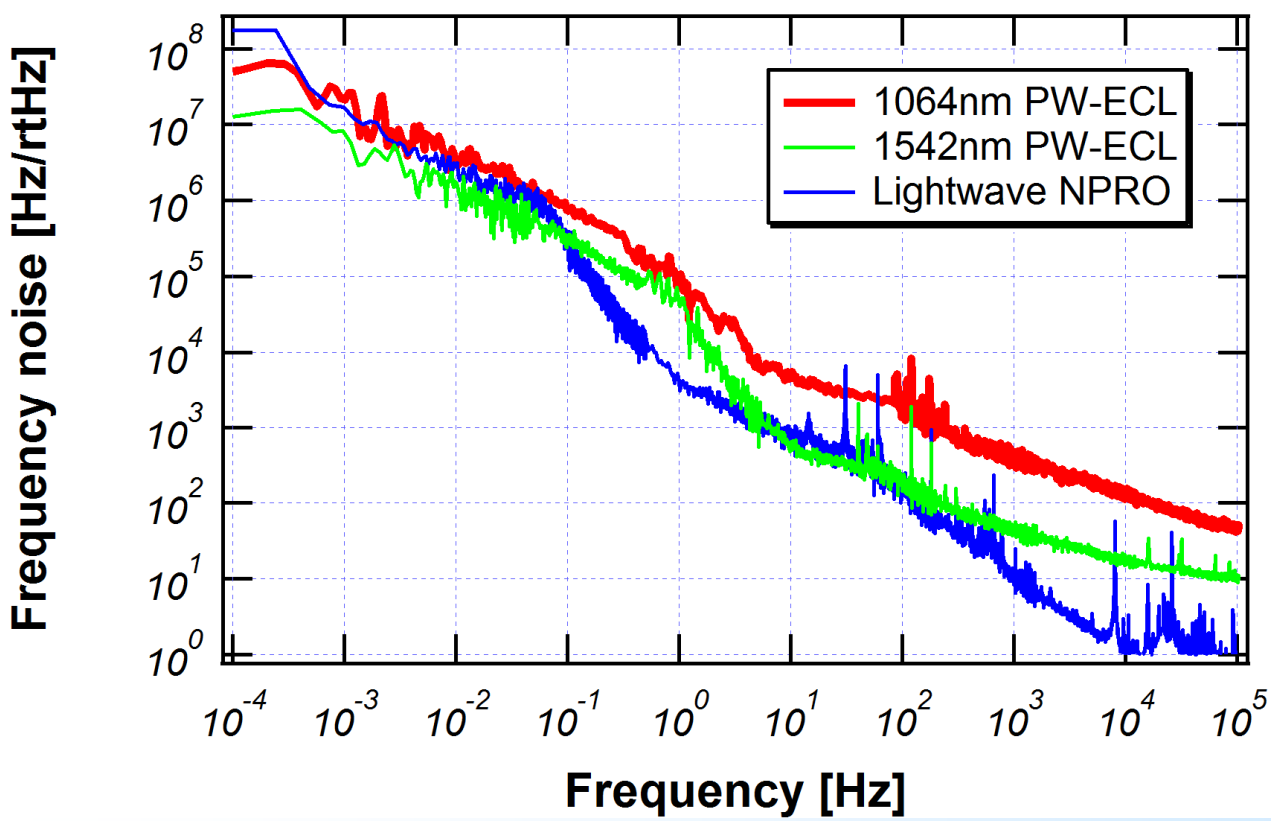
Gain Chip		
	RWG (1064nm)	BH (1550nm)
1	Complex epi design	epi design is decoupled from mode size converter
a	Use special design to expand beam size	Beam defined by BH and mode size converter
2	Waveguide defined by RWG	Waveguide defined by BH
a	Weak index guiding	Strong index guiding
b	Thermal and carrier 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

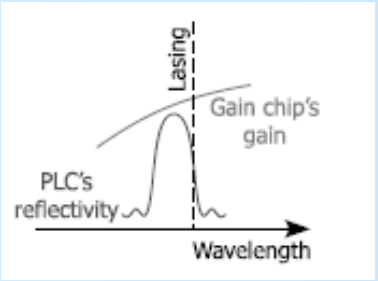
- PLC = Planar linear cavity
- GC = gain chip
- BFM = back facet monitor

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



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

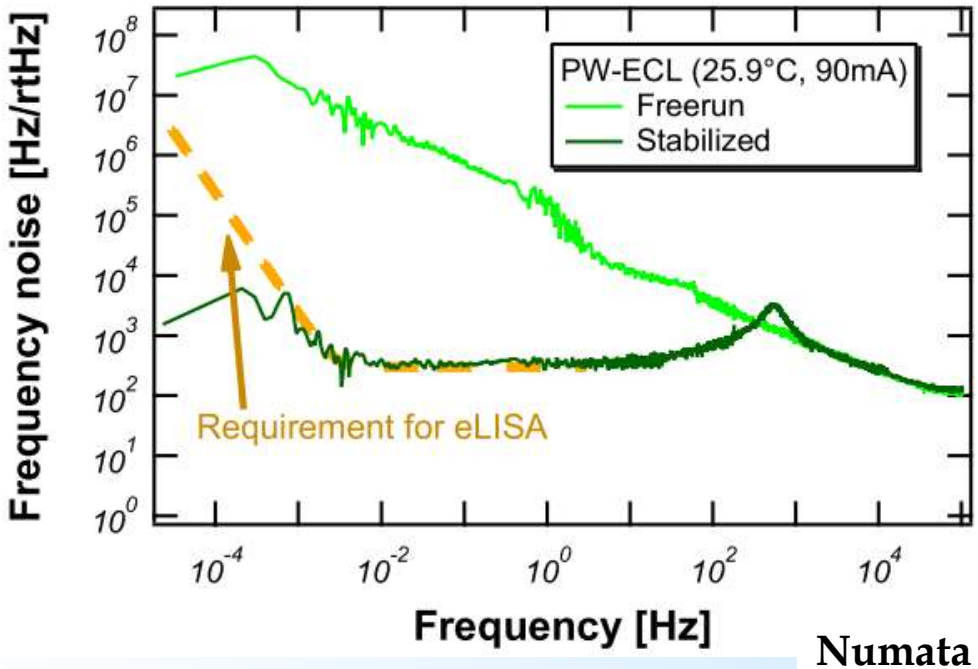




<u>Lowering phase noise:</u> 1) optimize optical cavity reflectivity slope → strong feedback→ low noise 2) optimize gain chip for low loss → low noise 3) select gain chip for lowest 1/f noise

Frequency stabilization with iodine

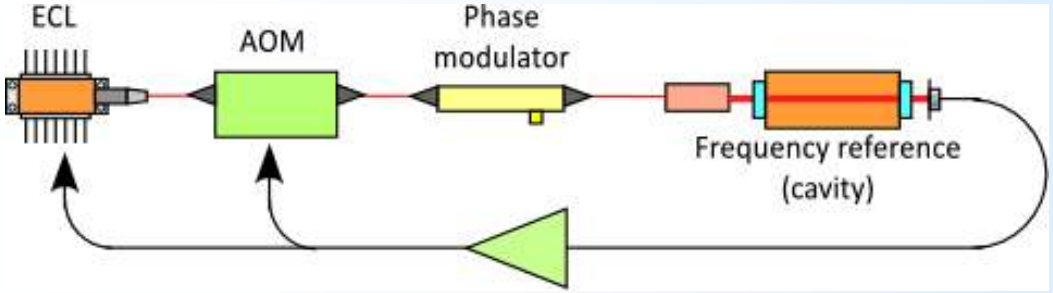
- 1064nm PW-ECL + Yb fiber amp + Waveguide doubler

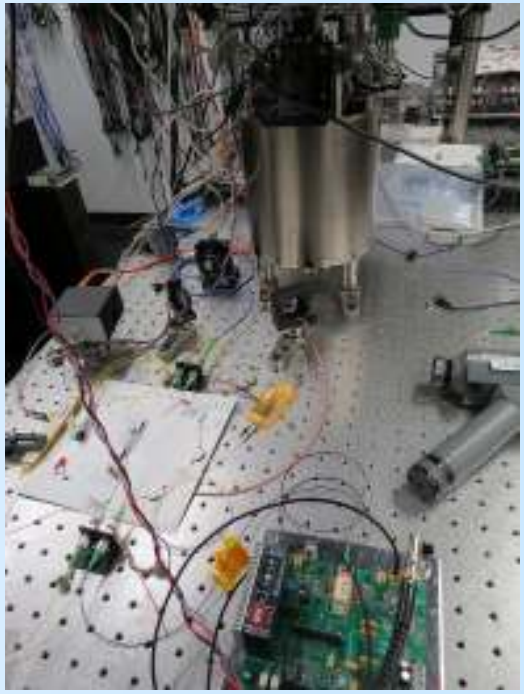


Numata et al., Opt. Lett 39, 2101

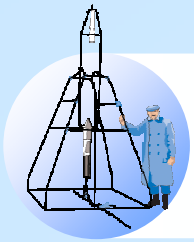
Satisfies the freq. noise requirement for eLISA at low frequency

Frequency stabilizing the ECL



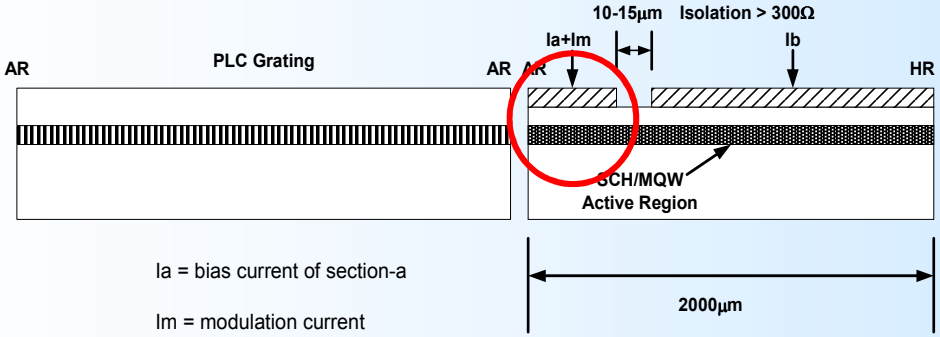


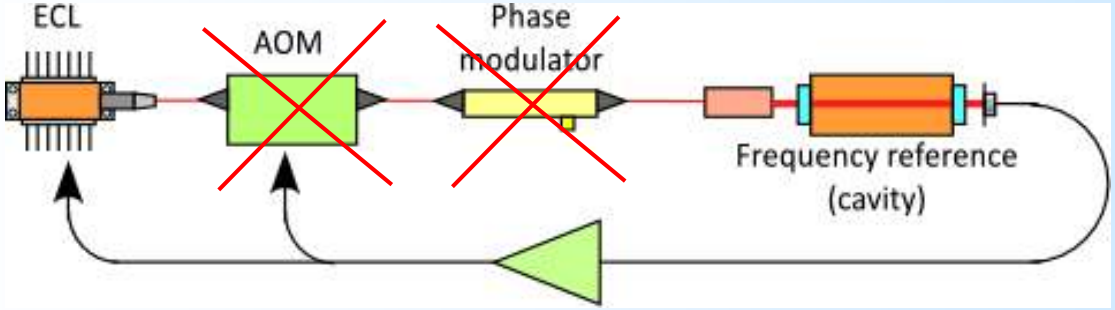
External AOM as frequency actuator to suppress frequency noise at high frequency

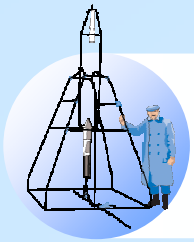


Frequency Modulation of ECL on laser chip (to be implemented)

- 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

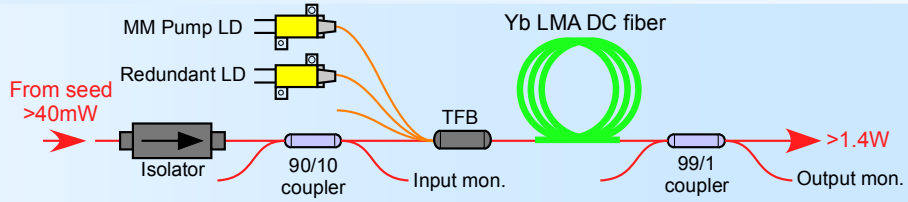


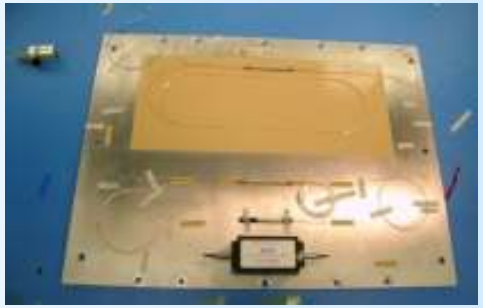


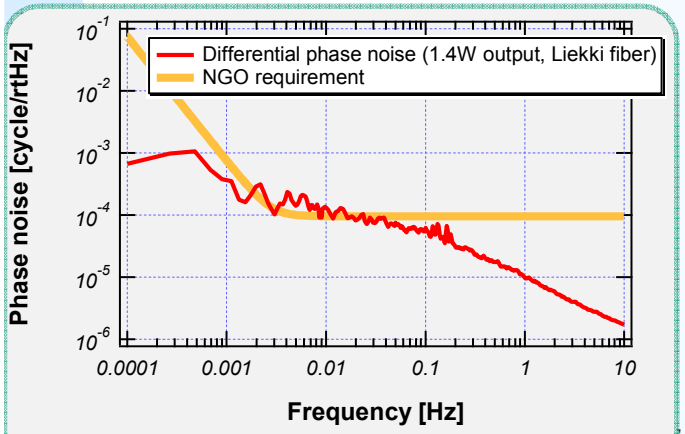


Power Amplifier

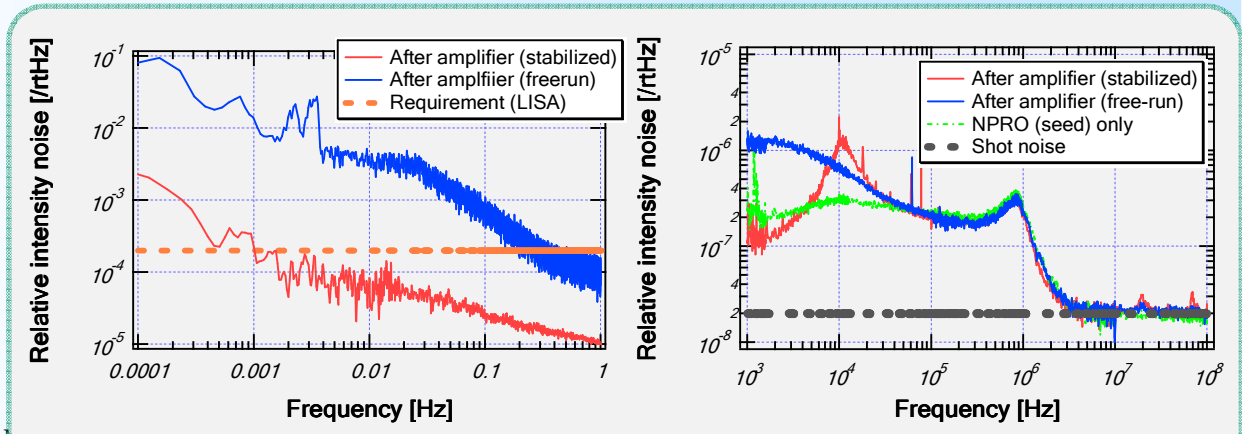
- **Design**
  - All fiber coupled
  - Large mode area, double-clad Yb fiber
  - Forward pump to avoid risk and noise sources
- **Noise performance**
  - No additional frequency noise
  - eLISA requirement level
    - Differential phase noise (@2GHz)
    - Stabilized low frequency RIN with feedback to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





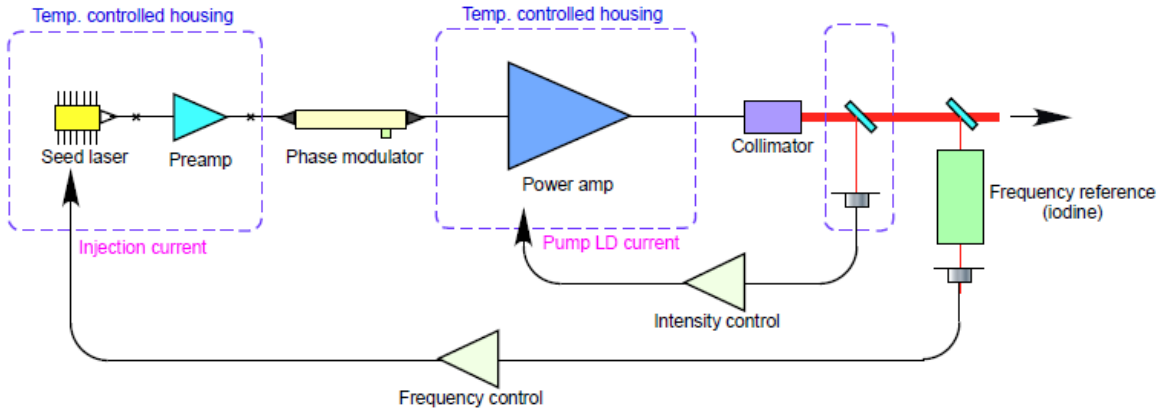


Differential phase noise

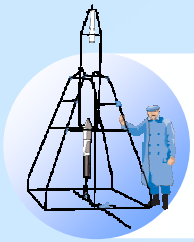


RIN and its stabilization (low/high frequency ends)

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
- FY 2015
  - Laser system testing with 1064 nm ECL
  - Achieve final frequency noise performance
- 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