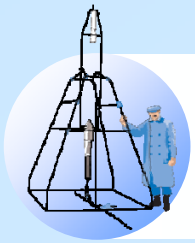
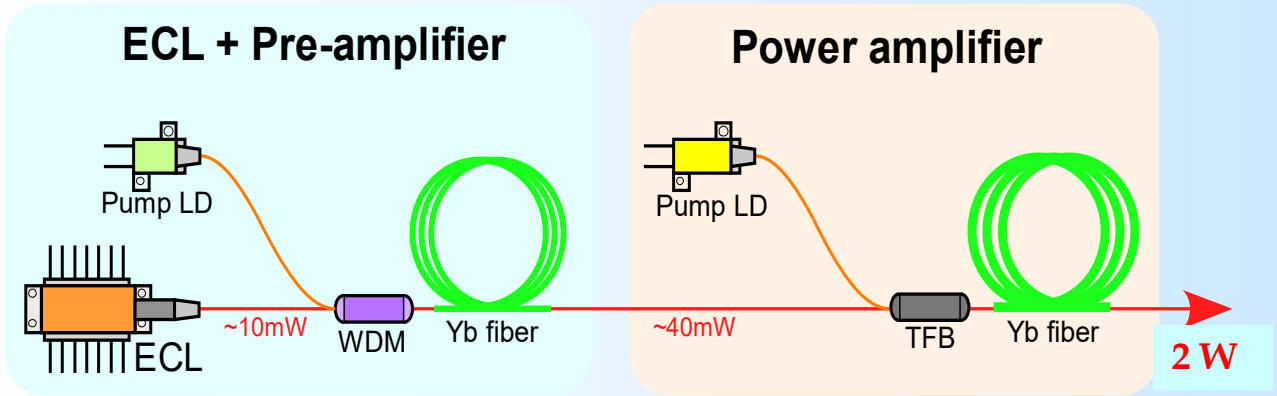


# LISA Laser Development in the US

**Jordan Camp, Kenji Numata**
**NASA Goddard Space Flight Center**

**LISA XI Symposium**
**Zurich**
**Sept 6, 2016**

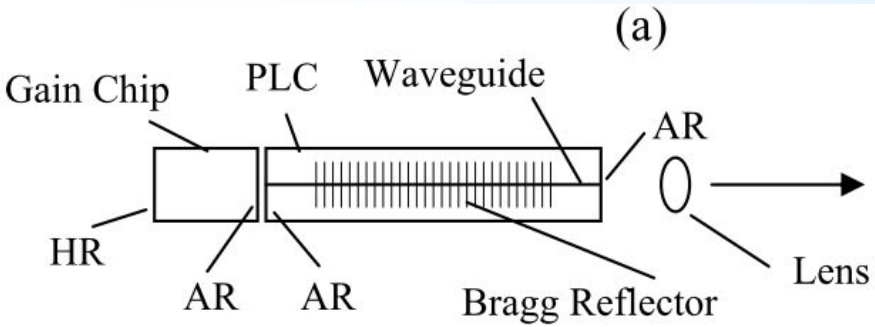
# GSFC LISA laser design



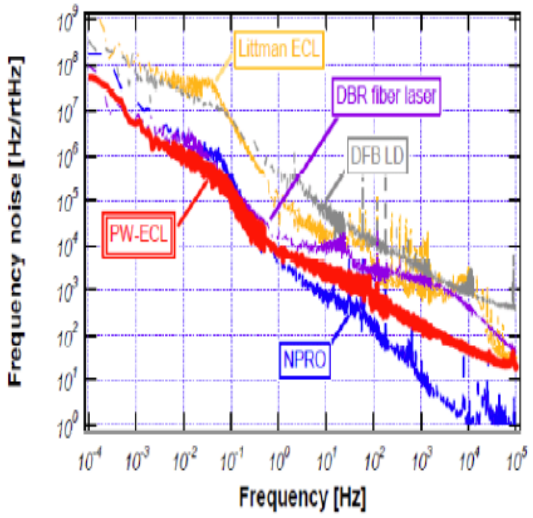

**MOPA design**
**External Cavity Laser, fiber preamp, fiber amplifier**
**1064 nm wavelength, 2 Watt output**
**Fully transparent design (M. Trobbs, collaborator)**

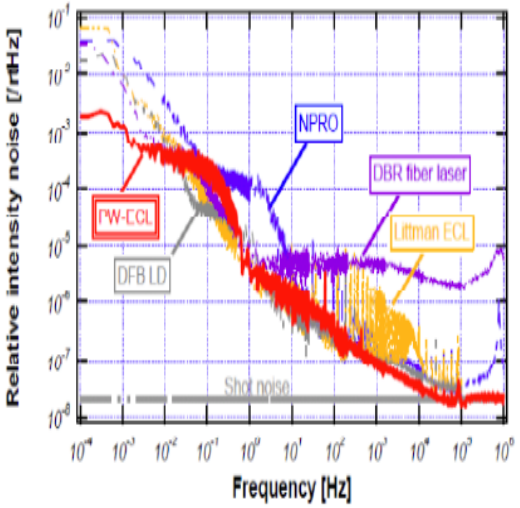
**(ESA is interested…)**

# Oscillator: External Cavity Laser

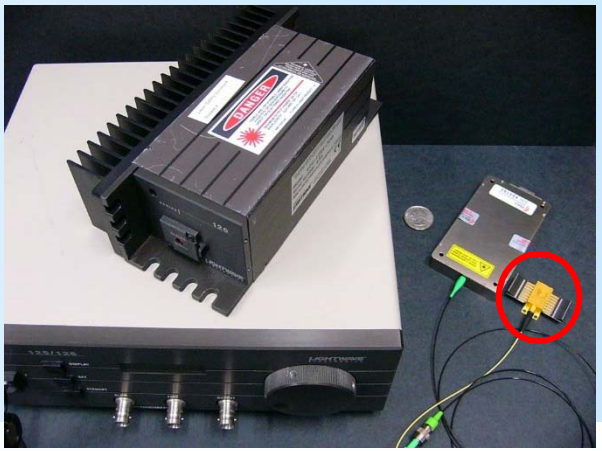







**Simple, compact, low mass, space qualified laser (butterfly package)**



**NPRO** **ECL**

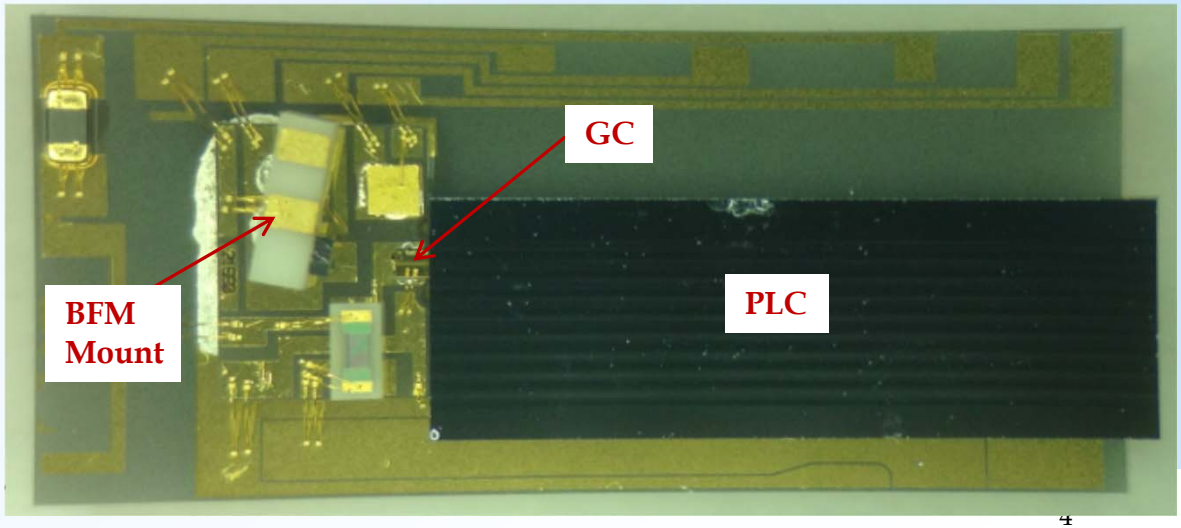
**Numata, Camp, Krainak, Stolpner, OE 18, 22781**

# Conversion of ECL wavelength to 1064 nm

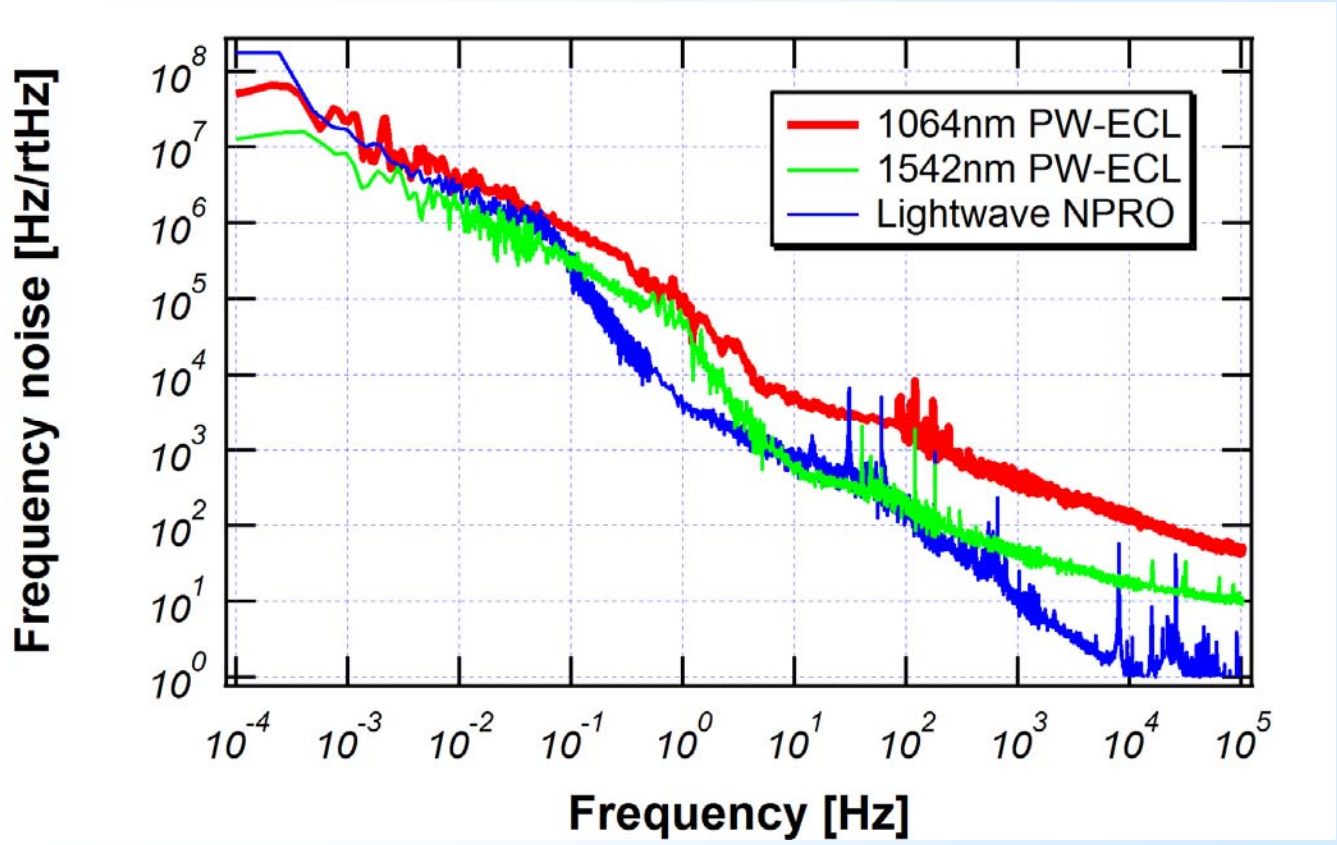
| Gain Chip | | |
|---|---|---|
| | RWG (1064nm) | BH (1550nm) |
| 1 | Complex epi design | epi design is decoupled from mode size converter |
| a | Use special design to expand beam size | Beam defined by BH and mode size converter |
| | | |
| 2 | Waveguide defined by RWG | Waveguide defined by BH |
| 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 |

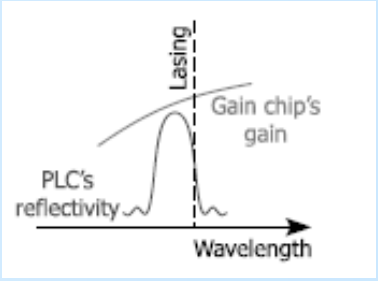
- PLC = Planar linear cavity
- GC = gain chip
- BFM = back facet monitor

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



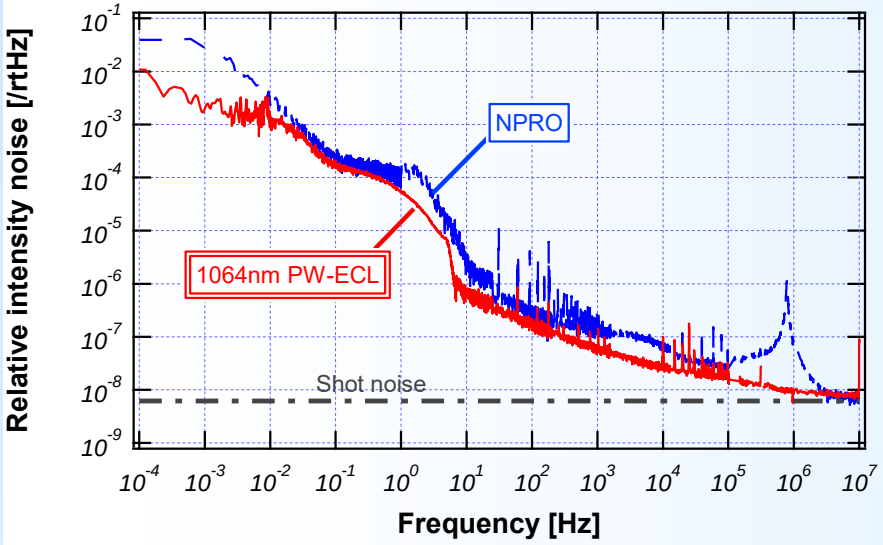
# Frequency noise of world's 1st 1064 nm ECL (in Butterfly package)

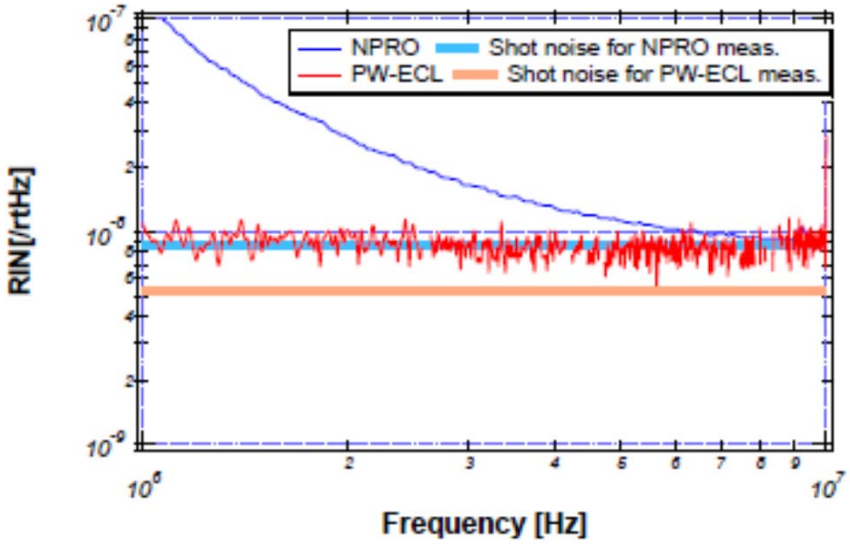



**<u>Lowering phase noise:</u> 1) optimize optical cavity reflectivity slope → strong feedback 2) optimize gain chip for low loss and low 1/f noise 3) ellipticity of beam**

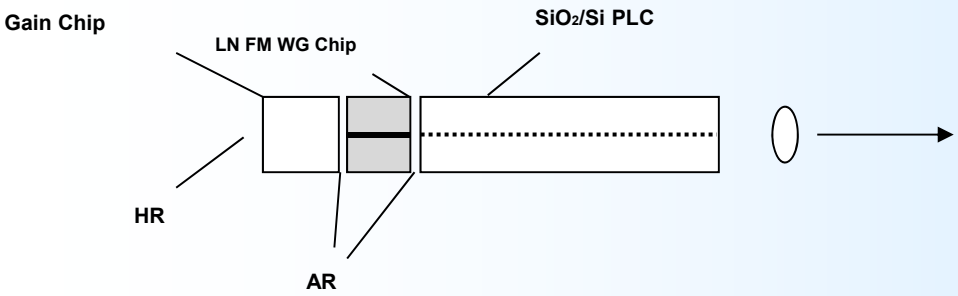
# Intensity Noise of 1064 nm ECL



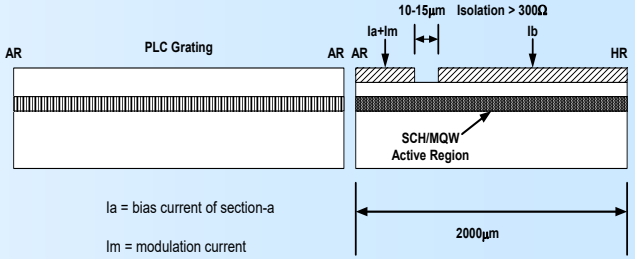




**Intensity noise of ECL less than NPRO below 6 MHz: ,**
**with shot noise ~ $10^{-8}$ / rtHz**

# Internal Frequency Modulation of ECL (to be investigated in FY 17)

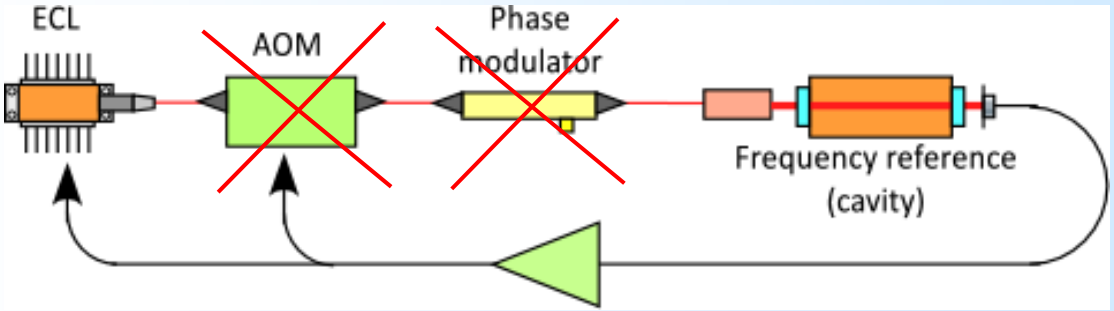



Intracavity modulator




Gain chip modulator

- Implementation of FM in ECL
  - ~ 1 GHz bandwidth



# Laser system packaging

- Seed (ECL), preamp, phase modulator and fiber amplifier, are one integrated unit

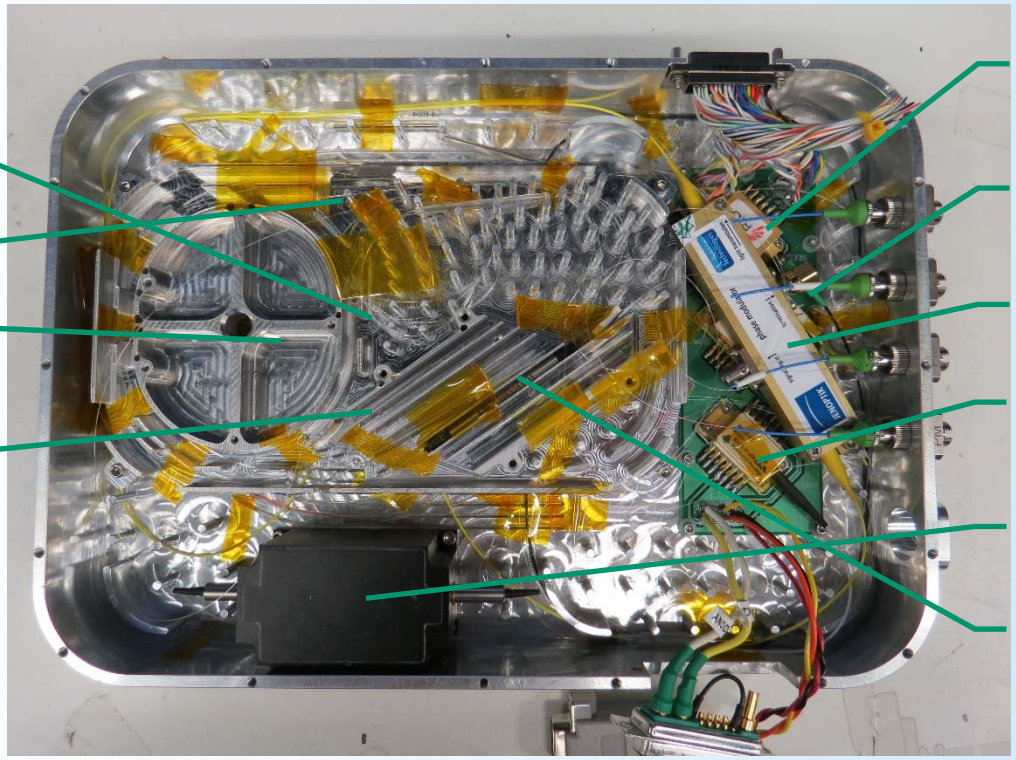
Under the tray

Gain fiber

Pump combiner

Mode field adapter

Cladding power stripper



Master oscillator (PW-ECL)

Preamplifier (SOA)

Phase modulator

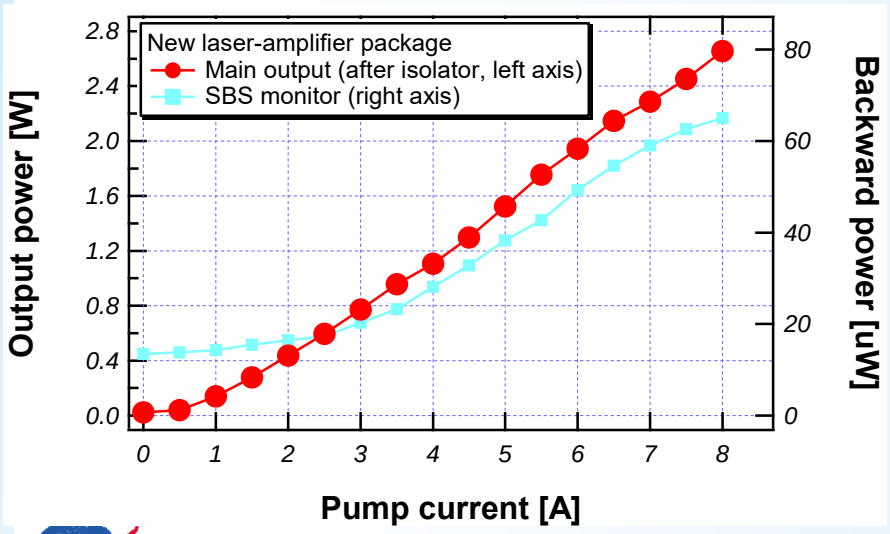
Pump LD for power amplifier

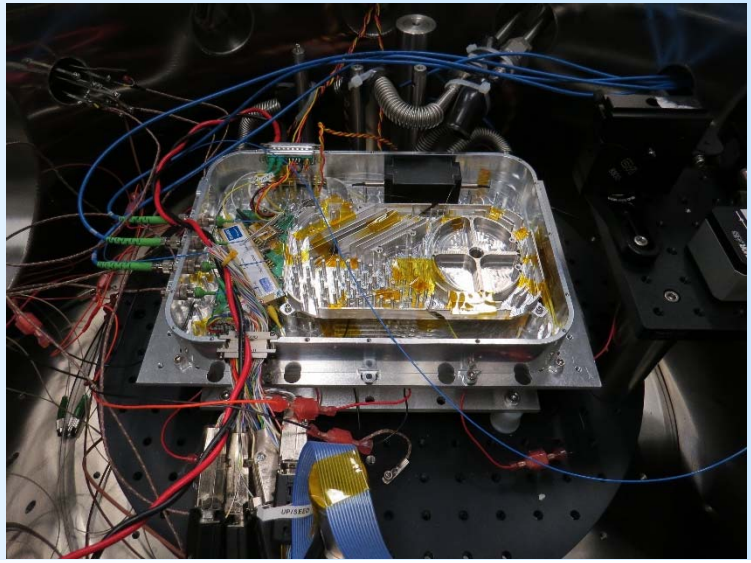
Optical isolator

Fused coupler (for main pow mon)

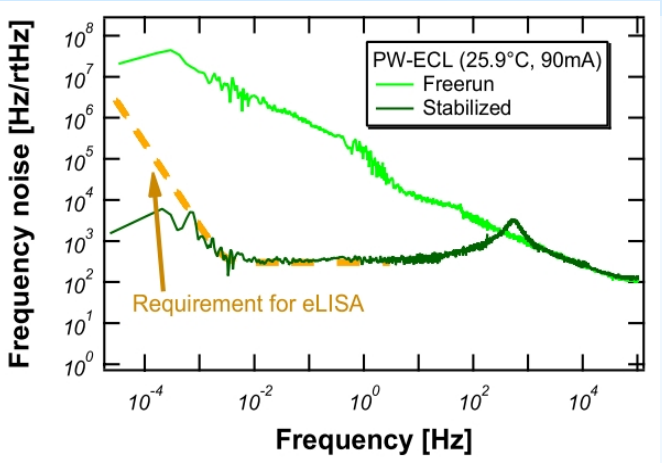
# Laser System Operation

- Performance testing
  - Max power: > 2.6W
    - Low SBS level
  - >50 hours operation under vacuum
    - No damage/degradation observed

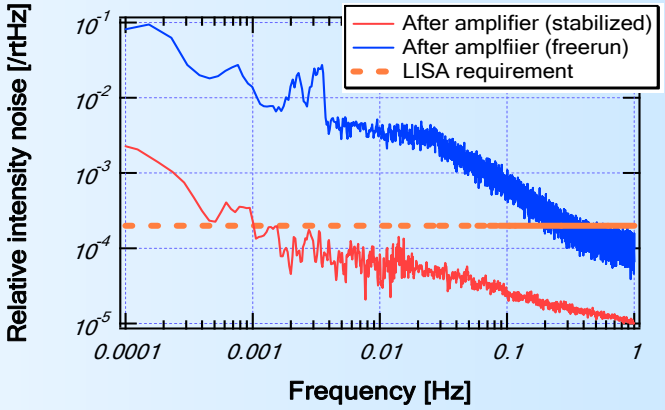


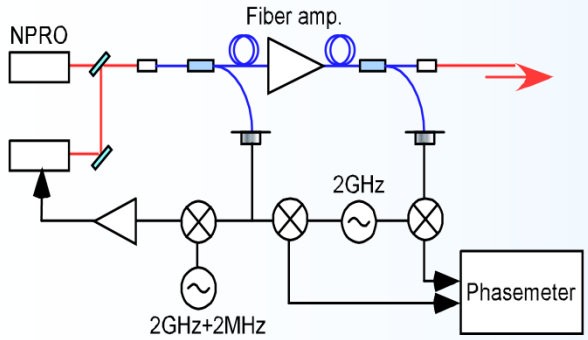
# Noise performance of laser system

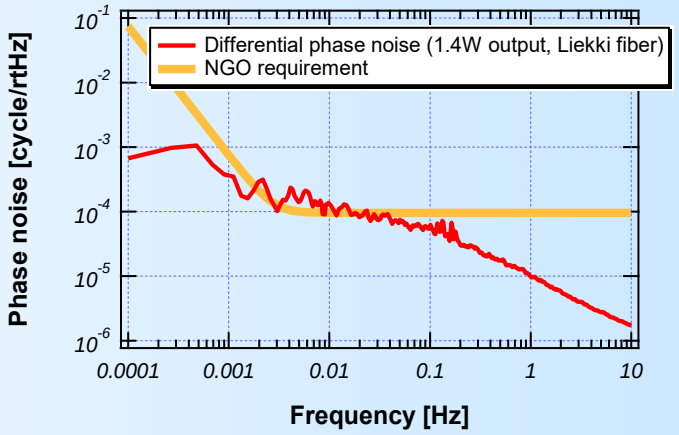



**Frequency Noise**



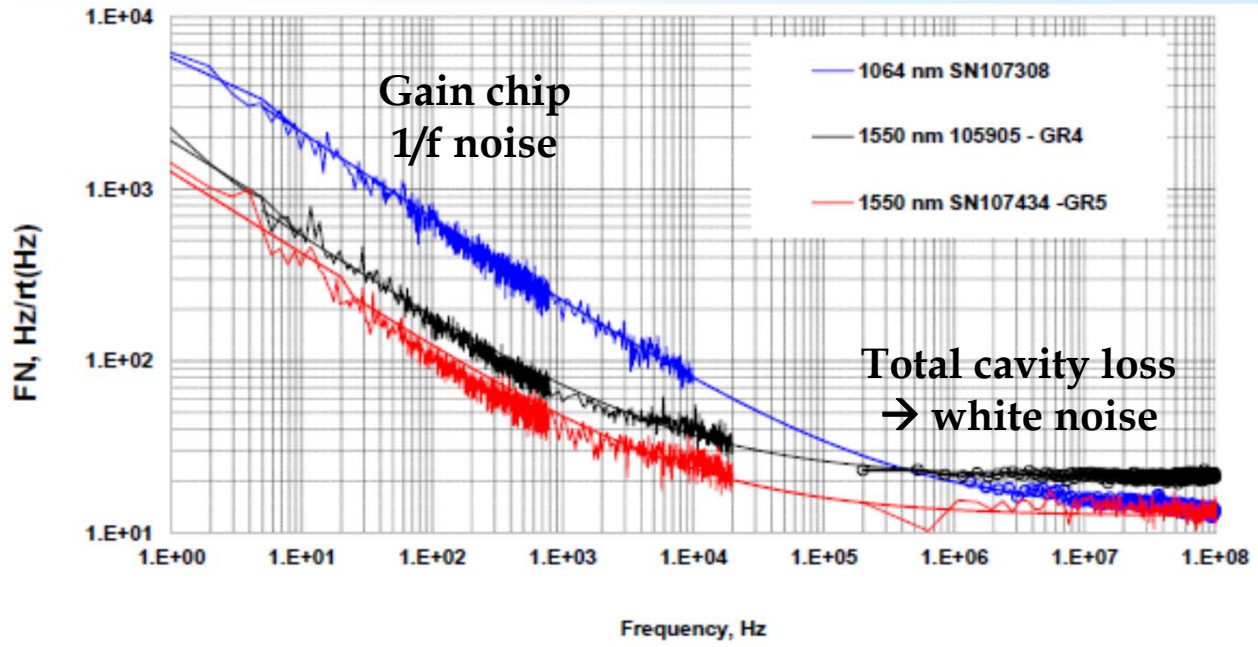

**Intensity Noise**



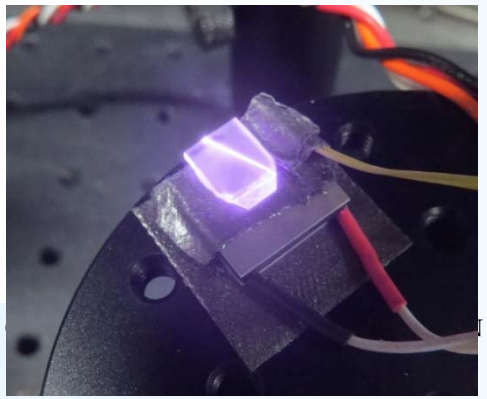

**Differential Phase Noise**

# Frequency Noise at 100 kHz

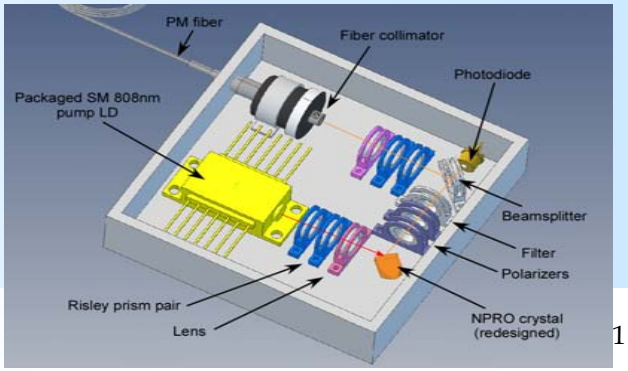



**ECL: progress in phase noise**

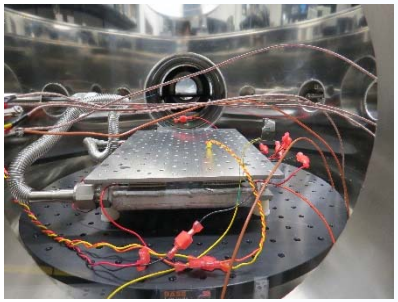
**3 new RIO products**



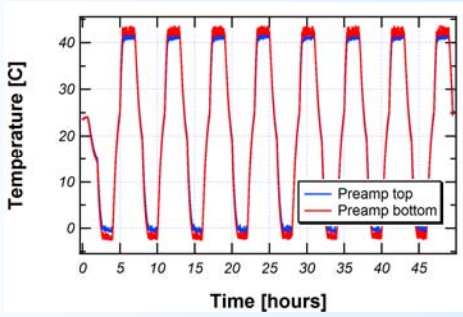
**NPRO: option under development**



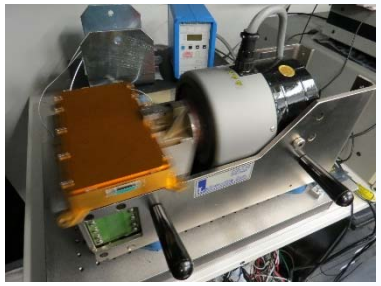
# Laser Preamp Environmental Testing: Thermal, Vibration, Radiation



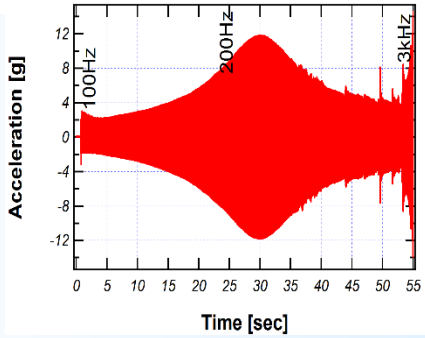
Vacuum thermal cycling apparatus, including thermal plate and heating/cooling lines



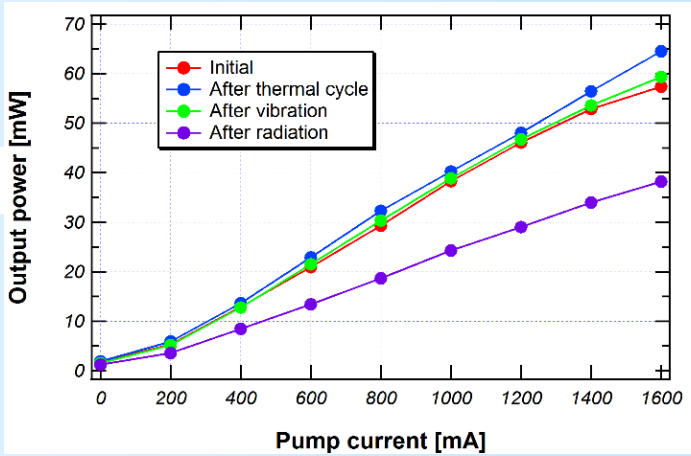

Temperature profile of thermal cycling



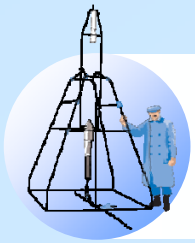
Vibration instrument shaking preamp/ECL




Acceleration from vibration instrument




**Result of environmental testing on ECL + preamp laser power**



# Possible Laser Development Schedule

| Deliverable | Date |
|---|---|
| ECL phase noise reduction | Q2 FY18 |
| Intracavity Frequency Modulator (?) | Q4 FY18 |
| Space Qualified NPRO | Q2 FY18 |
| Seed laser downselect | Q3 FY18 |
| Laser system lifetime | Q4 FY19 |

# Summary

- Preamp, amp ~meet specs (noise, environmental tests)
- ECL needs x5 reduction in phase noise at 100 kHz
  - starting development of NPRO as backup option
    - downselect in 2018
- Laser lifetime tests in 2019 will demonstrate TRL6
- Collaboration with AEI (M. Trobs) to keep ESA colleagues fully knowledgeable about US laser work
  - Trobs to visit Goddard this fall