LISA Laser Development in the US

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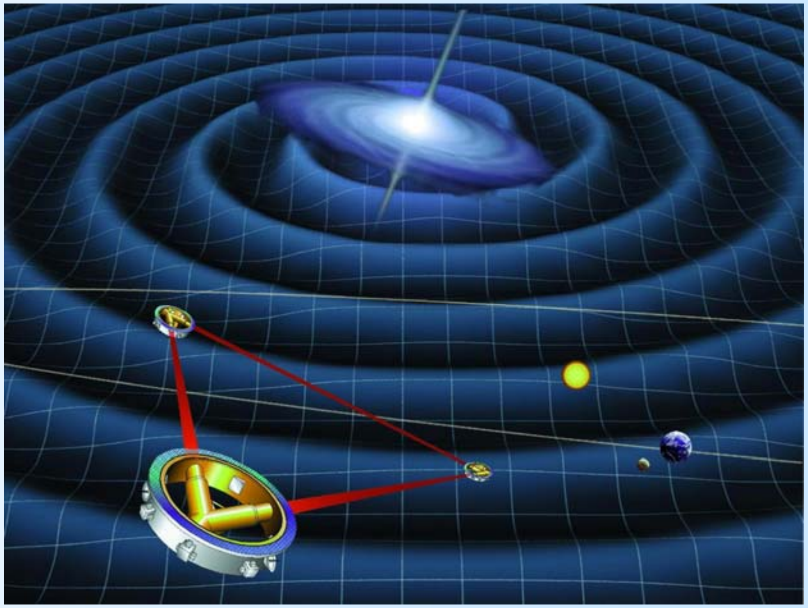
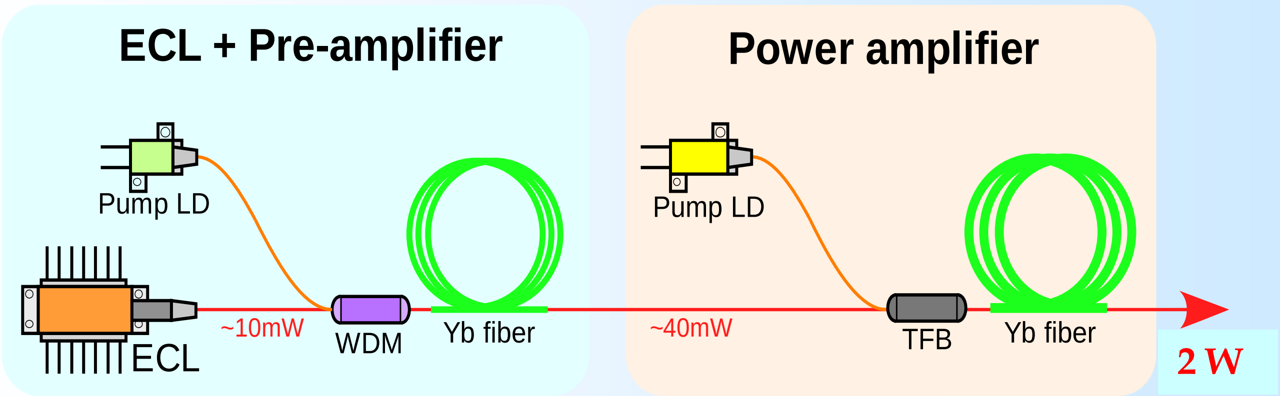
LISA – Search for Gravitational Waves

- A variety of astrophysical phenomena produce low-frequency gravitational waves
  - Massive BH binary coalescence
  - Massive BH capture of stellar mass BH
  - Galactic compact binaries



- LISA will measure strain from GW's of 10^{-21}
  - Measure position to 10^{-12} m, spacecraft separation of 5×10^{9} m
  - Need to isolate test masses from 10^{-16} N external forces

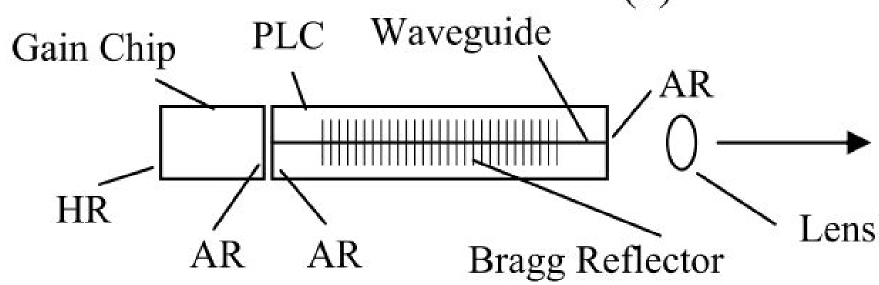
GSFC LISA laser design



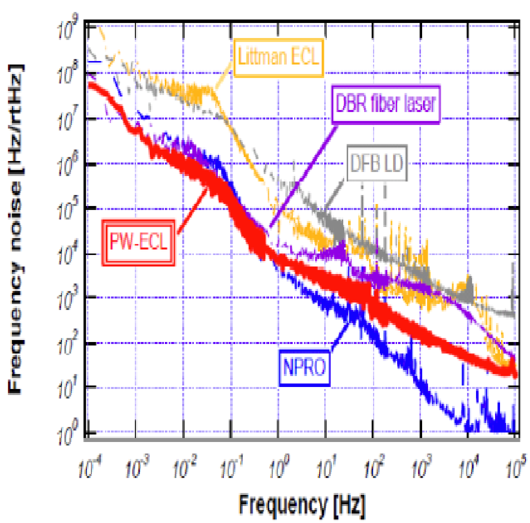
MOPA design
External Cavity Laser, fiber preamp, fiber amplifier
1064 nm wavelength
2 Watt output

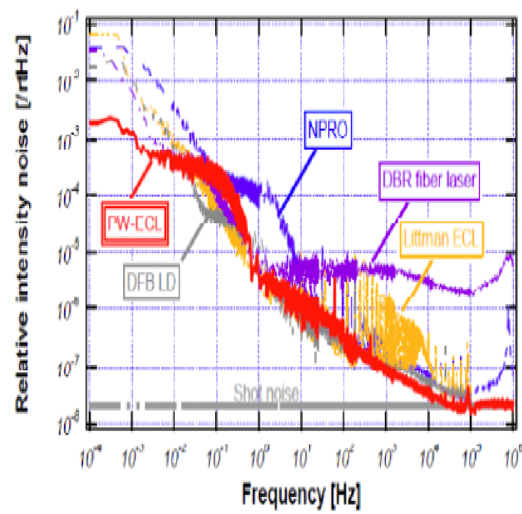
Oscillator: External Cavity Laser

(a)



(b)





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

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

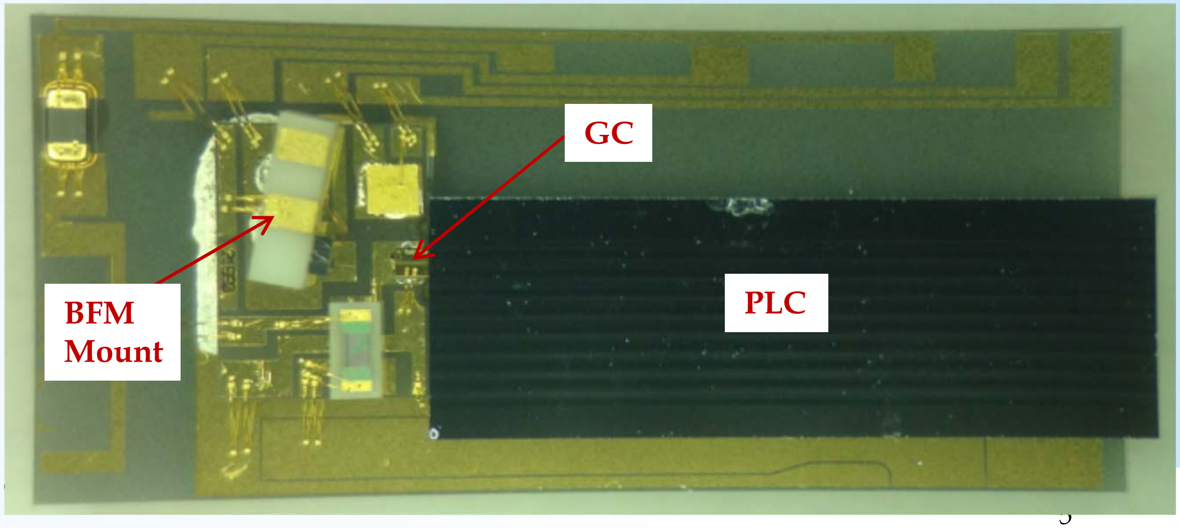
Numata, Camp, Krainak, Stolpner, OE 18, 22781

Conversion of ECL wavelength to 1064 nm

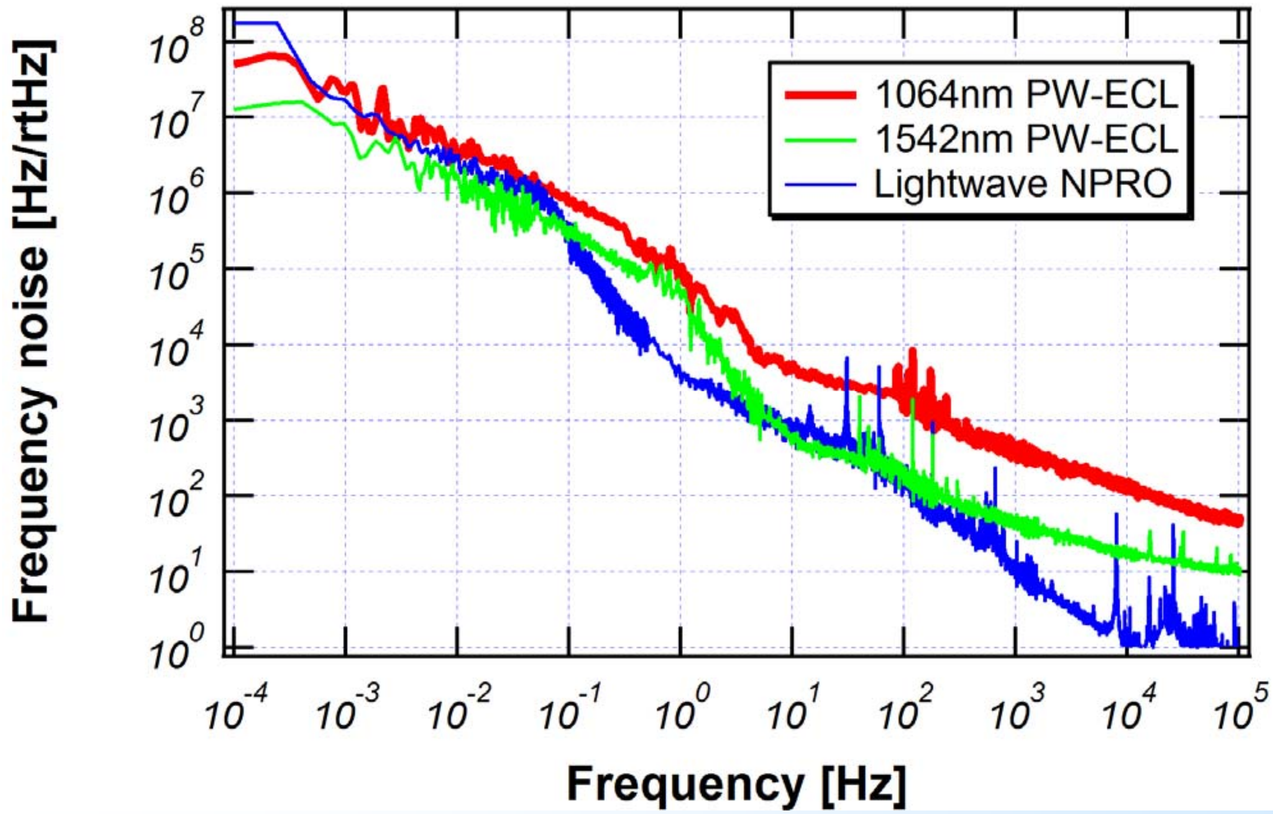
Gain Chip		
	RWG (1064nm)	BH (1550nm)
1	Complex epi design	epi design is decoupled from mode size converter
a	Use special design to expand beam size	Beam defined by BH and mode size converter
2	Waveguide defined by RWG	Waveguide defined by BH
a	Weak index guiding	Strong index guiding
b	Thermal and carrier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

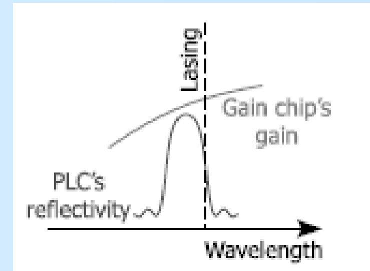
- PLC = Planar linear cavity
- GC = gain chip
- BFM = back facet monitor

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



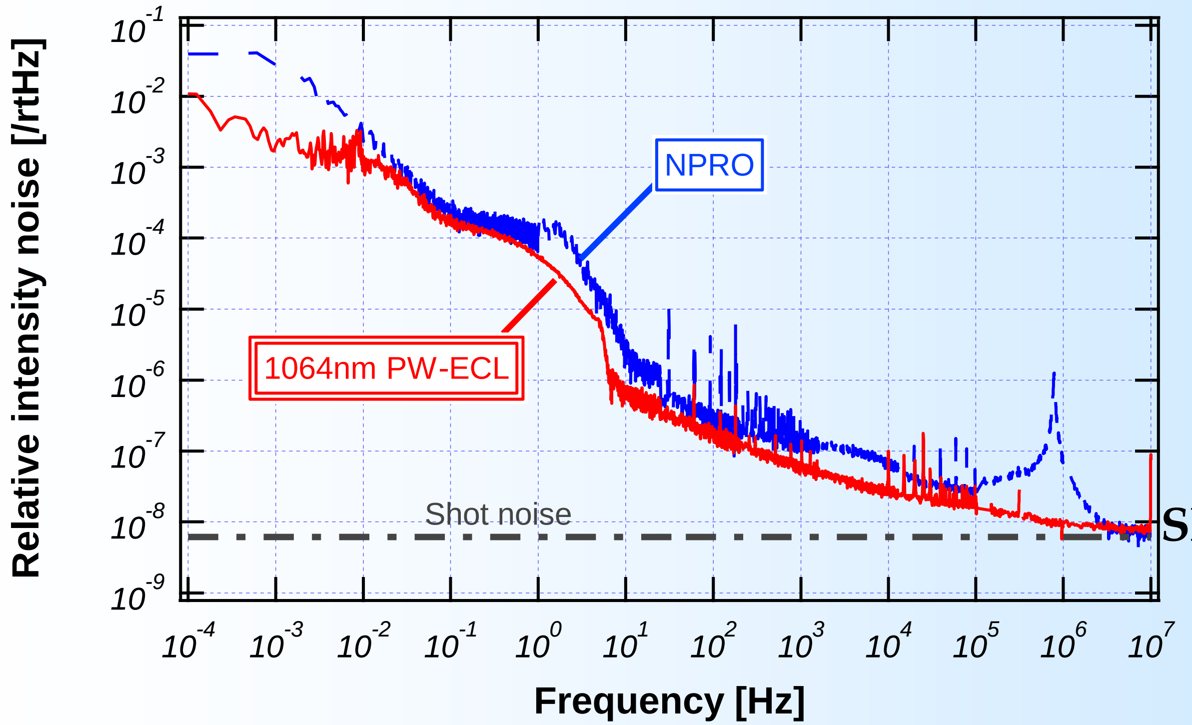
Frequency noise of world's 1st 1064 nm ECL (in Butterfly package)





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

Intensity Noise of 1064 nm ECL

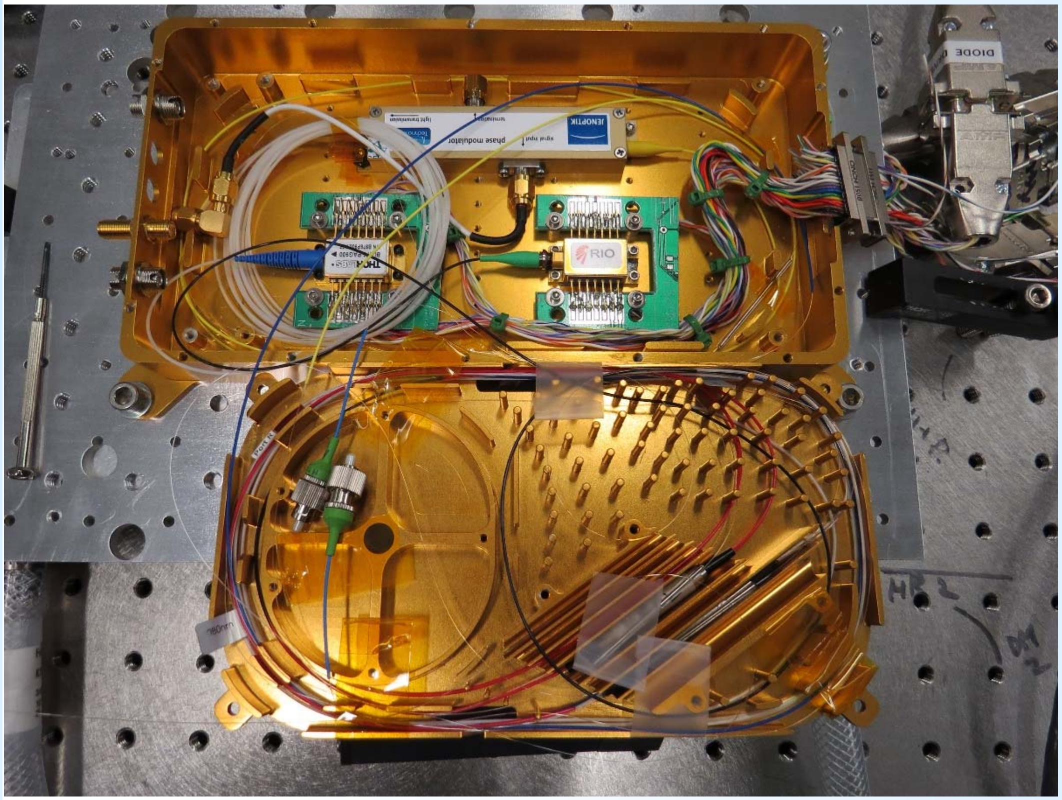


Shot noise ~ 10^{-8} / $Hz^{1/2}$

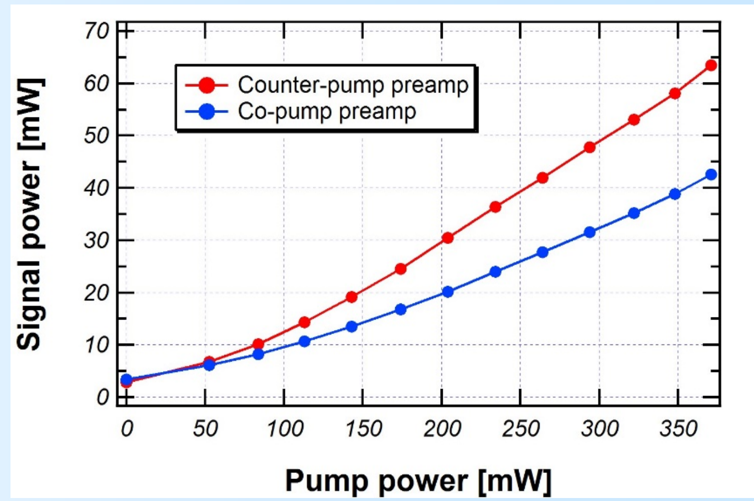
Below 5 MHz: intensity noise of ECL less than NPRO

Above 5 MHz: NPRO shot noise limited, ECL ~ 2 X shot noise

Oscillator and Preamp

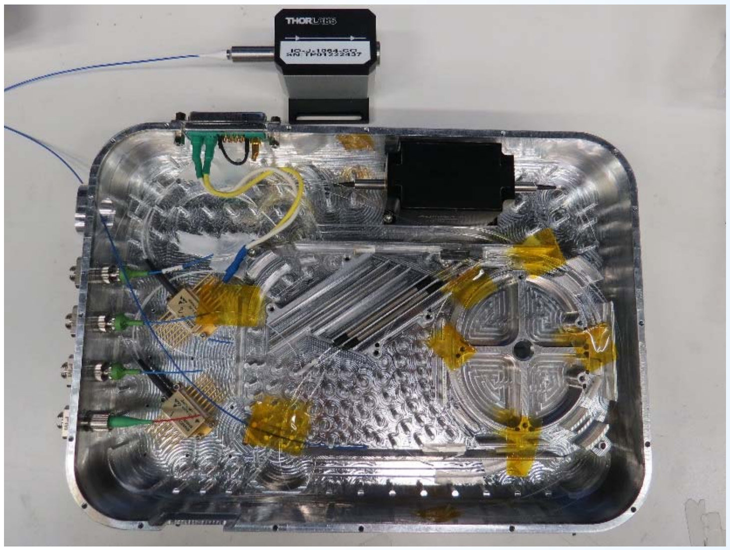


ECL + Fiber Preamp

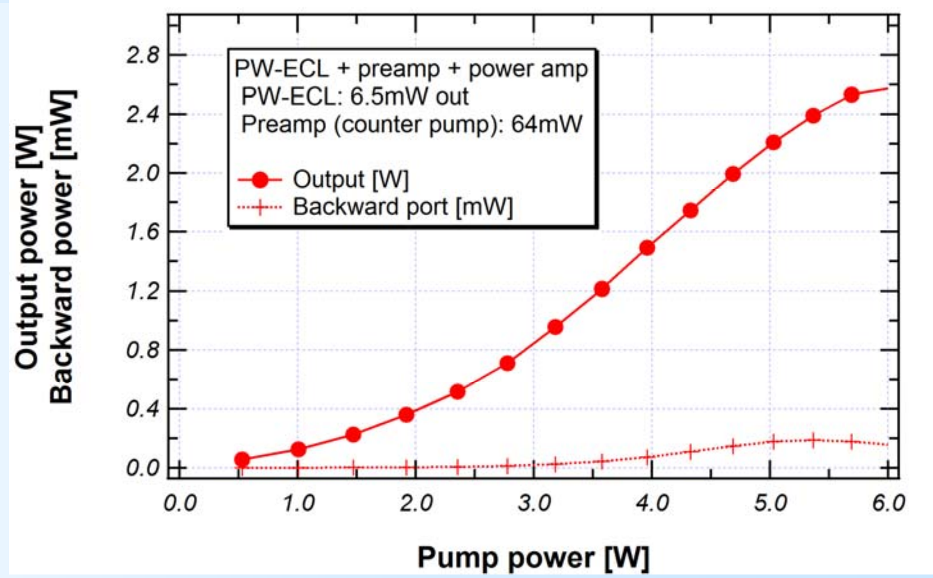


Preamp output

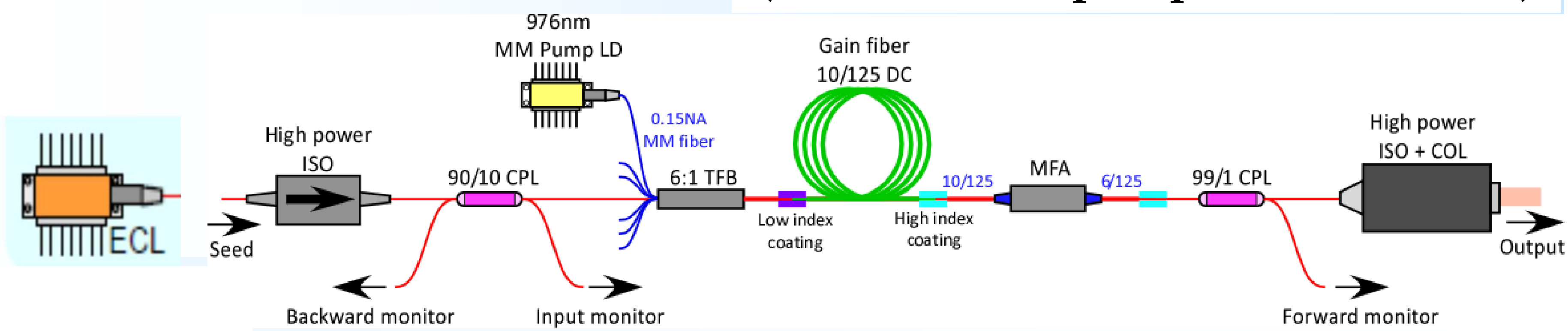
Preliminary Operation of Laser System



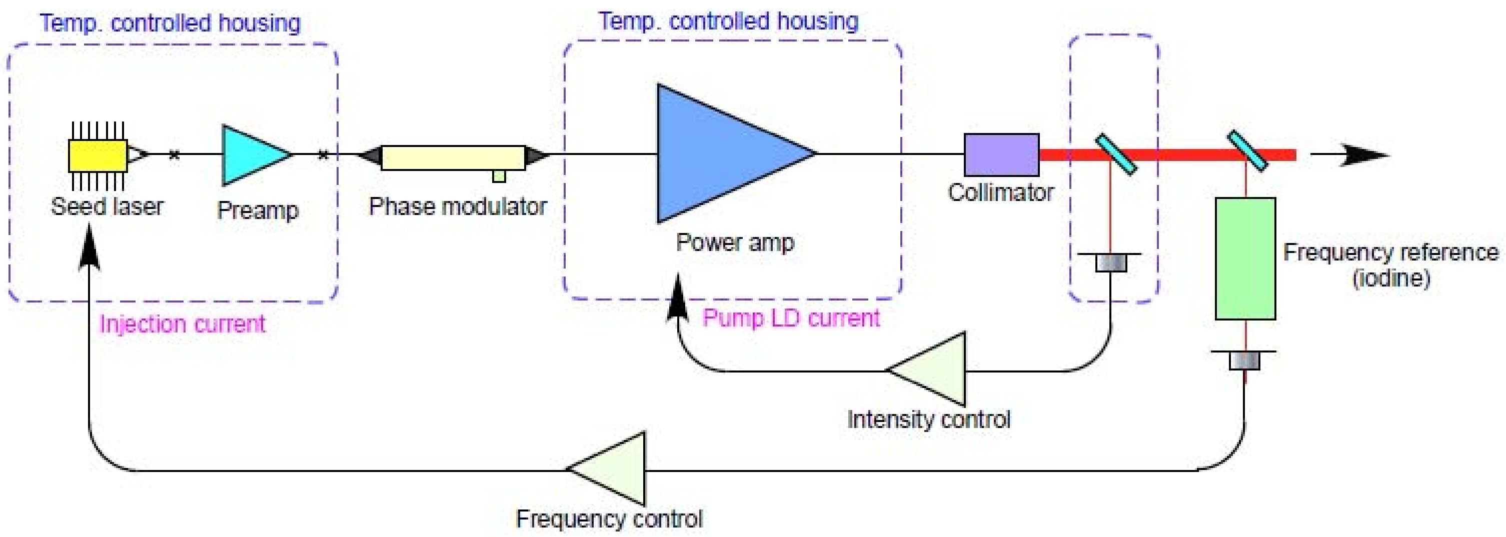
Fiber Amplifier



Laser System output
(flat backward port power → no SBS)



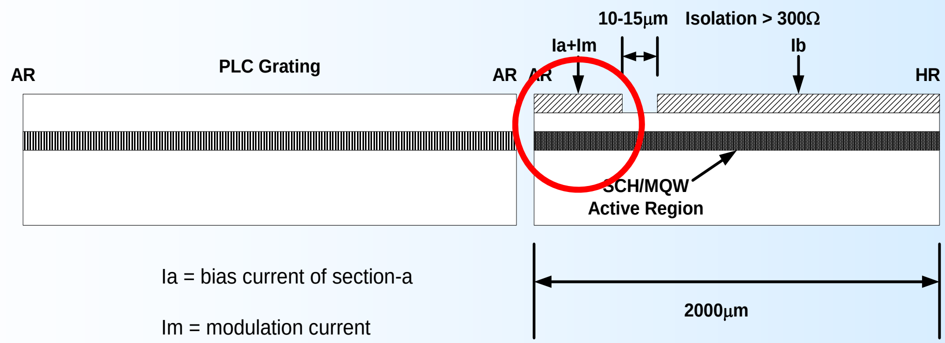
Planned Systems Tests for FY 2017

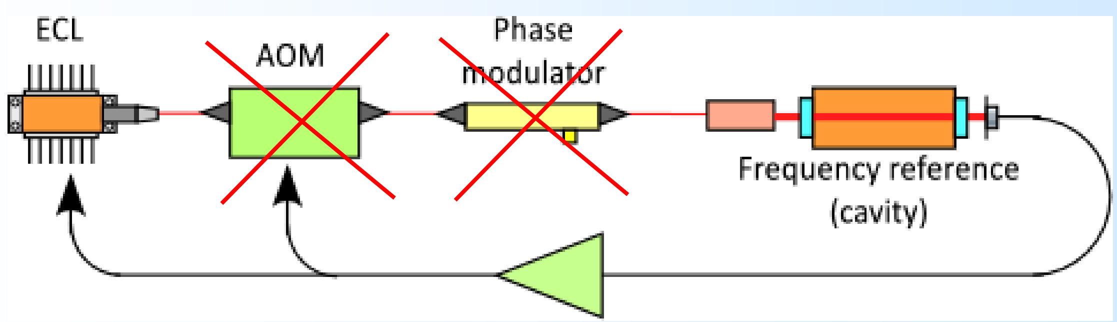


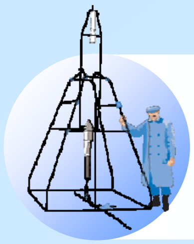
1064 nm ECL seed, preamp + power amplifier
Temperature stabilized environment
Tests: stabilized noise, thermal/vac, accelerated aging

Frequency Modulation of ECL on laser chip (to be implemented in FY 17)

- ❑ 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







Laser Development Schedule

- FY 2016
  - Finalize design of 1064 nm ECL planar cavity
  - Reliability testing of 1064 nm ECL (low risk since packaging same as 1550 nm)
  - Perform full laser system noise and reliability tests
- FY 2017
  - Implement on-chip frequency modulation
  - Perform full laser system noise tests
- FY 2018
  - Deliver TRL 5 laser system