A 10 W narrow-linewidth thulium fibre master oscillator power amplifier

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Motivation

LIGO Voyager

- LIGO Voyager
  - Cryogenically cooled Silicon mirrors
  - Transmission in silicon >1.3um
  - Reduced coating absorption in a-Si at 2 μm [1]
- Require new 200W 2um laser

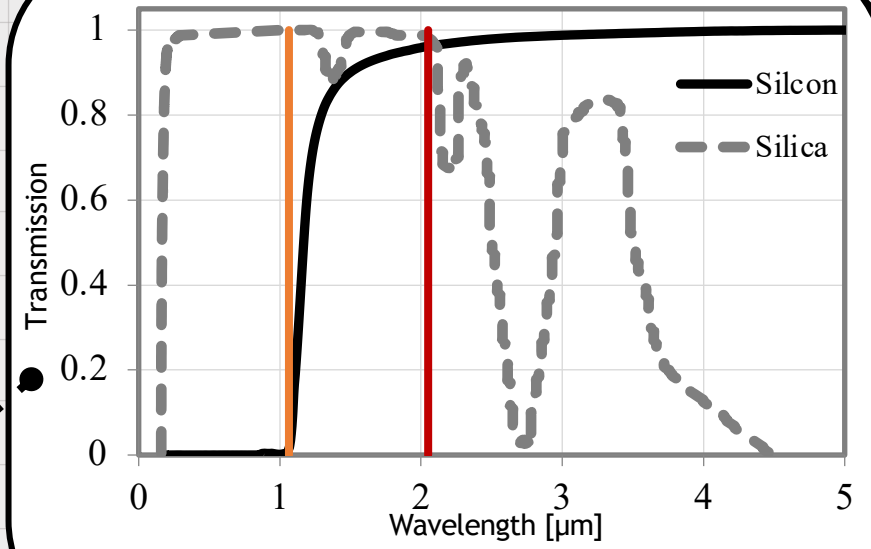


Fig 1 - Comparison of silicon and fused silica transmission [2]

Single transverse mode and single longitudinal mode

Seed laser with equivalent performance to non-planar ring oscillator (NPRO)

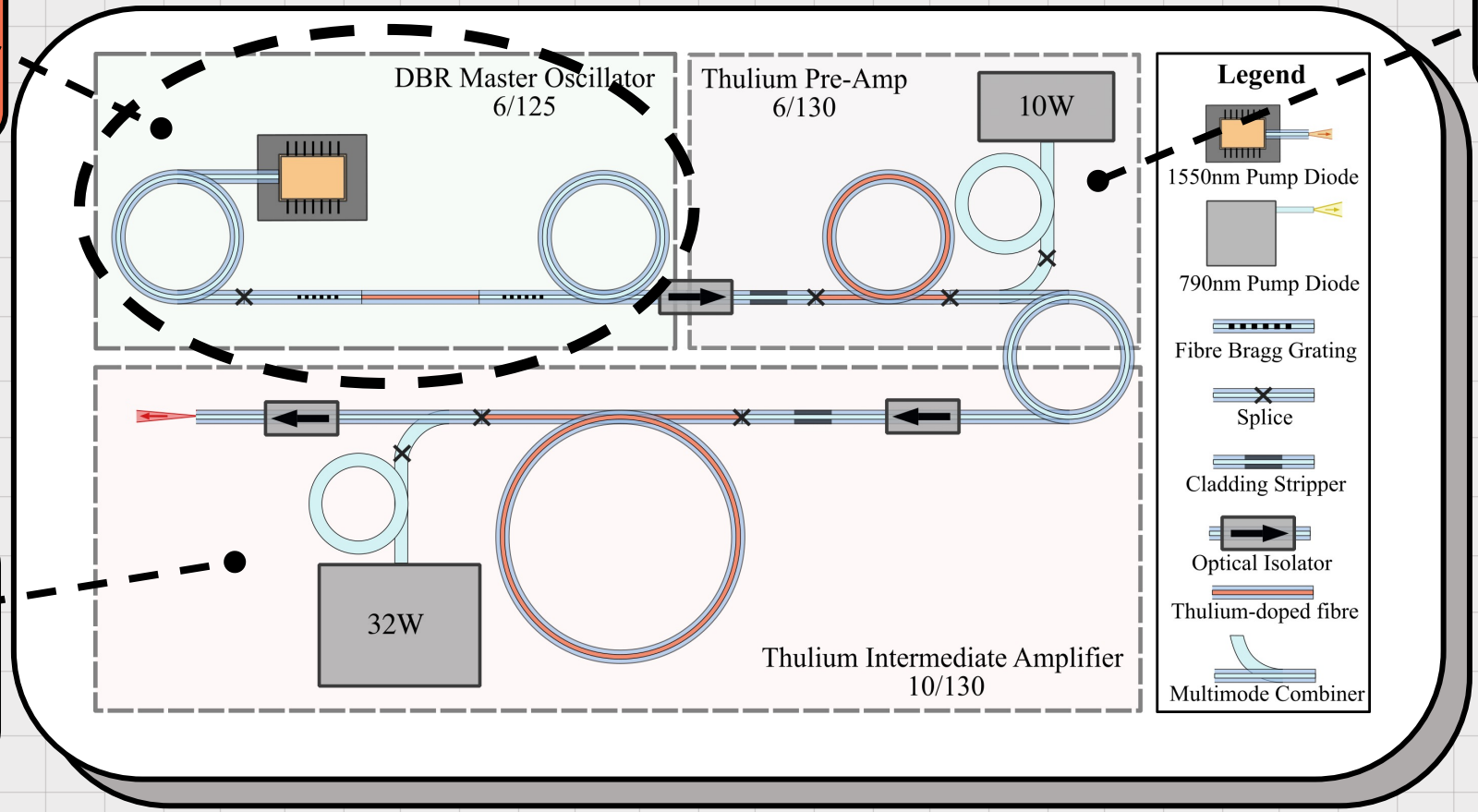
[1] J. Steinlechner, et. al. Phys. Rev. Lett. 120, 263602 2018
[2] ThorLabs.com

Master oscillator power amplifier

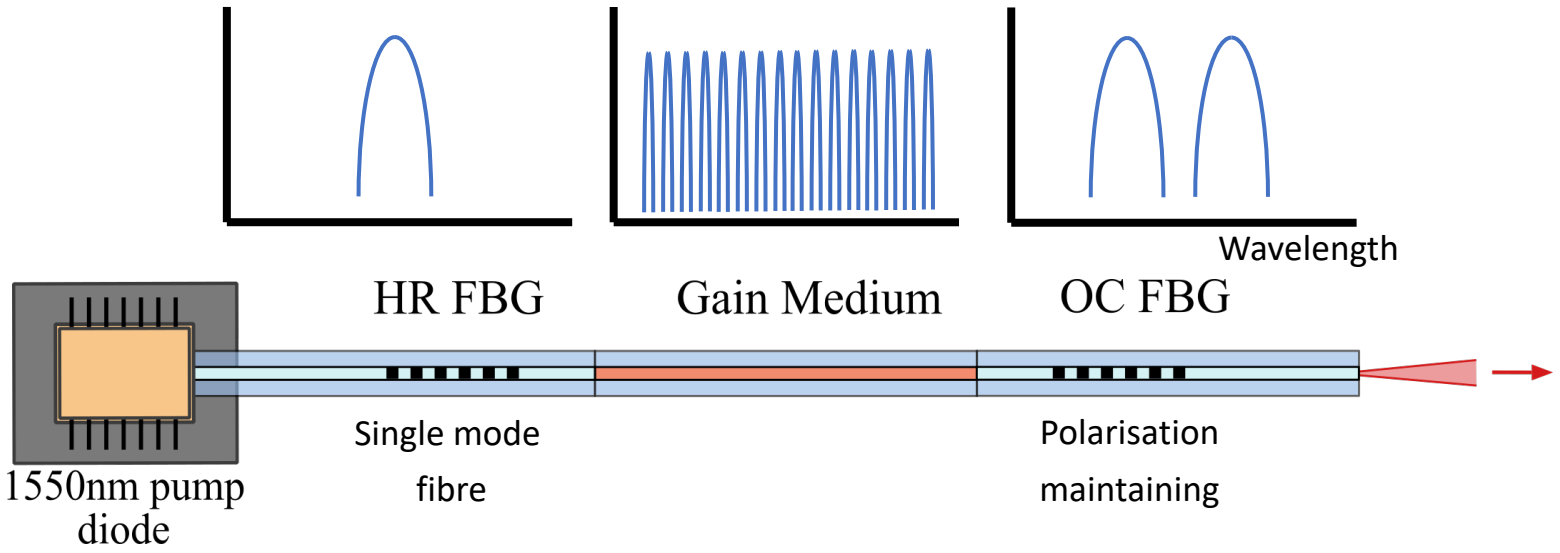
Master oscillator

Pre-amplifier

10W amplifier stage



Distributed Bragg reflector fibre laser



Short 25mm cavity with high concentration thulium doped fibre (8wt%)

30mm fibre Bragg gratings (FBGs)

Polarisation maintaining

Pump laser choice

Short cavity requires core pumping with high brightness source

1550nm single-mode diodes and Erbium fibre lasers have strong absorption

790nm diodes can be used as pump sources for amplifiers

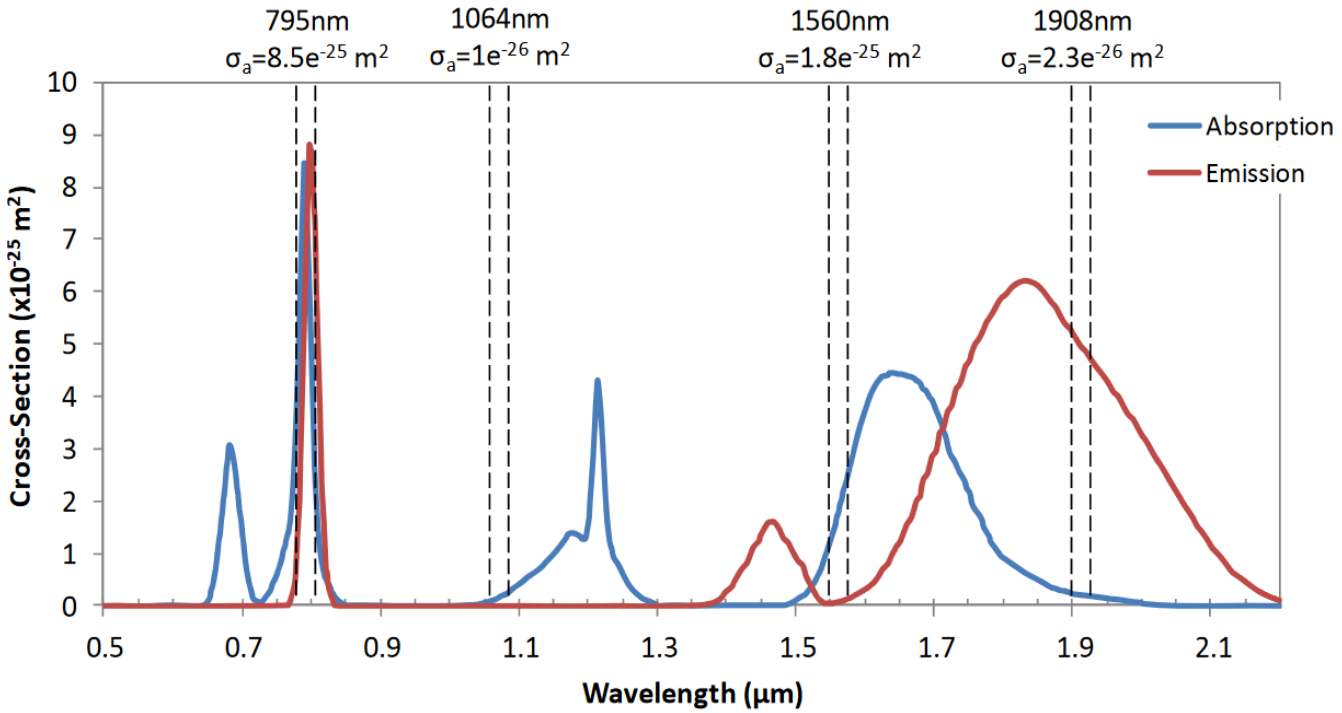
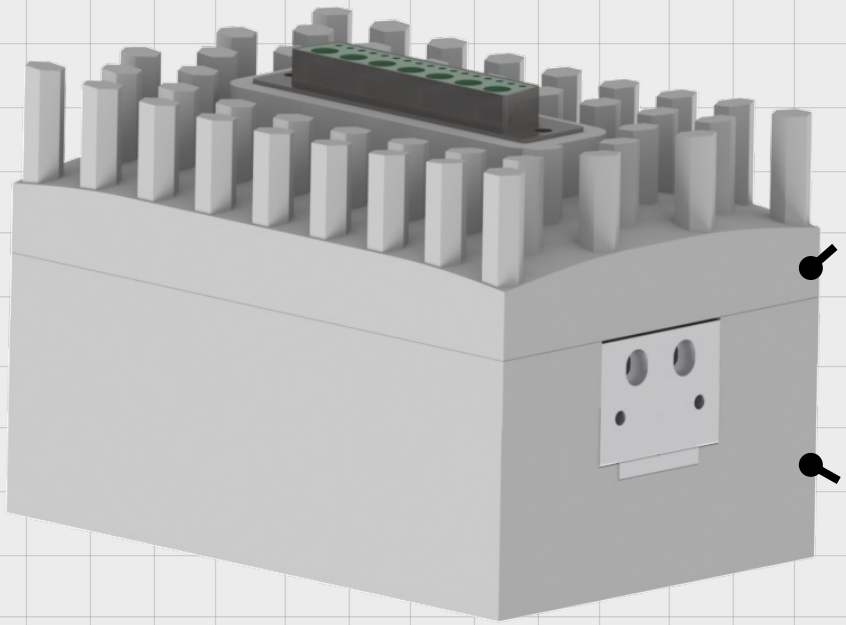


Fig 2 - Thulium absorption and emission spectra [3]

[3] D. Creeden, et. al. 2014 Opt. Express 22, 29067-29080

Temperature control mount



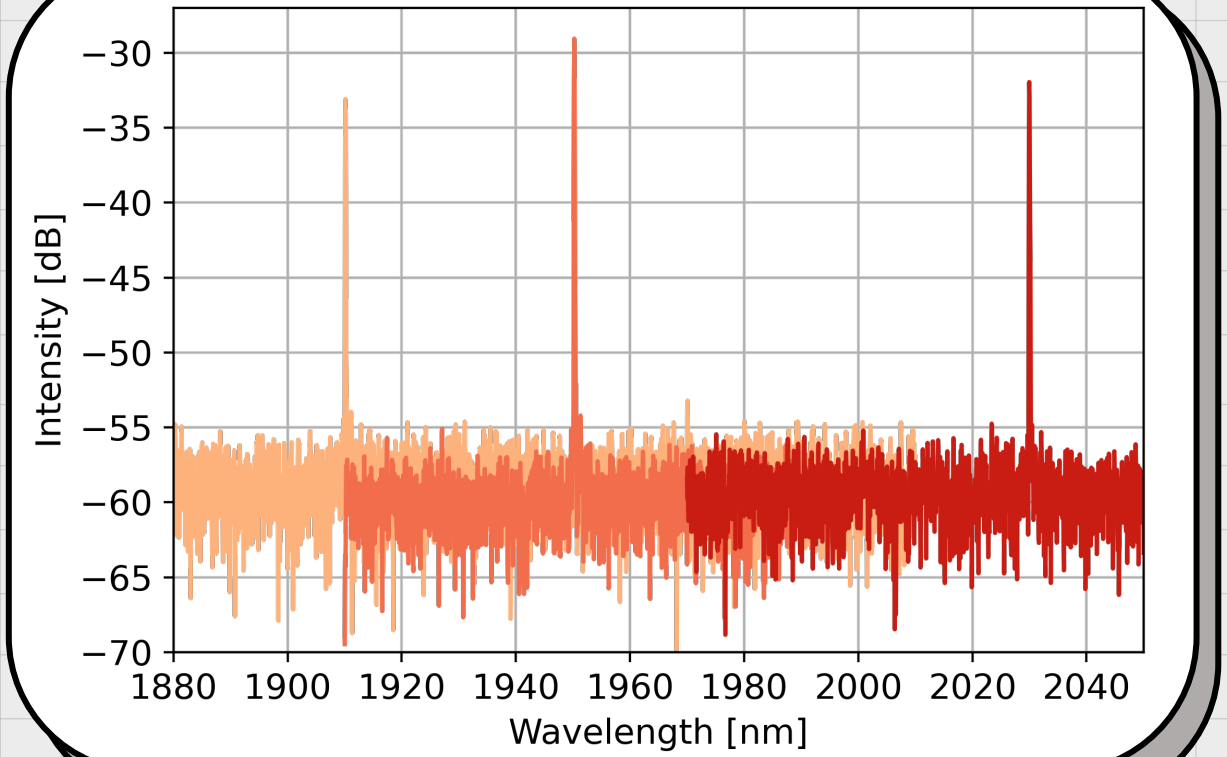
Independently temperature control of FBGs with TECs

Thermal isolation from external environment

DBR lasers between 1910nm to 2030nm

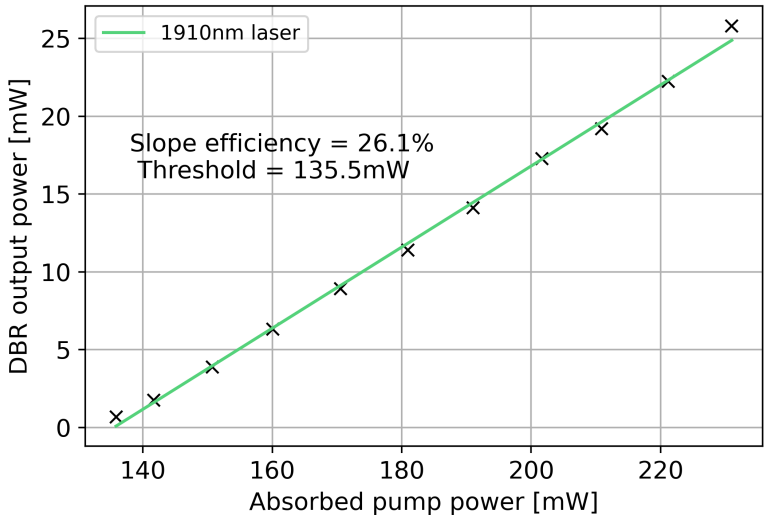
Emission at 1910.1nm, 1950.2nm, and 2030nm

Peaks at least 22dB above noise floor



DBR slope efficiencies

1910nm laser

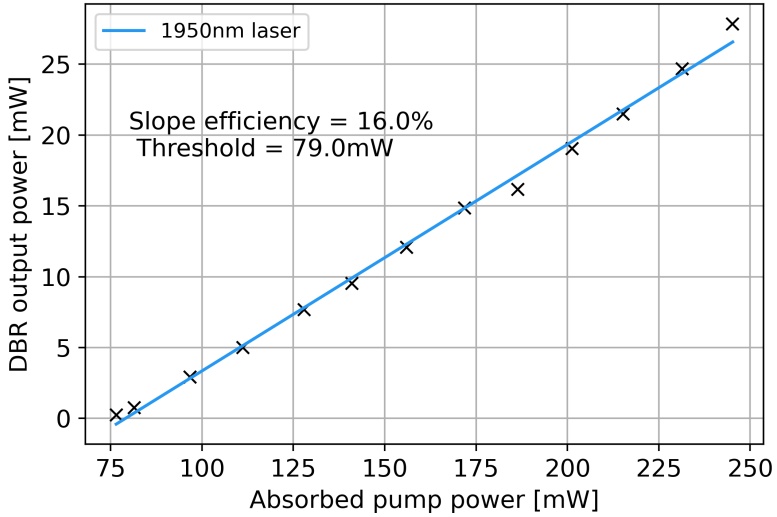


Max power: ~25.7mW

Efficiency: ~ 26%

Threshold: ~136mW

1950nm laser



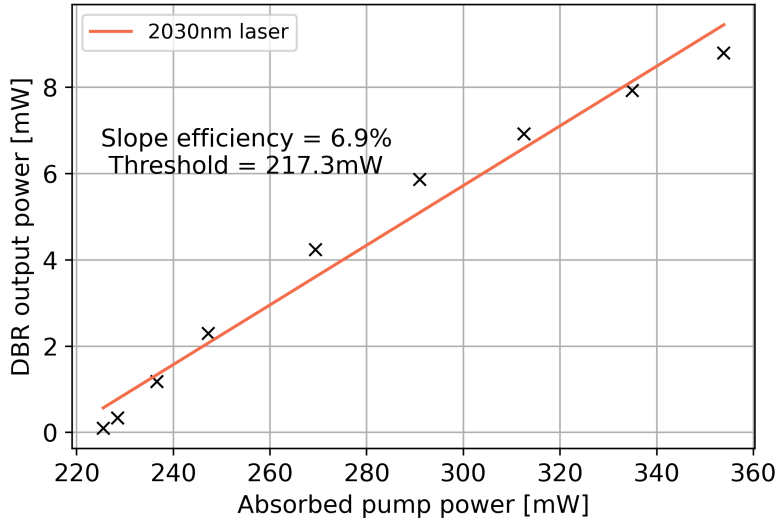
Max power: ~27.8mW

Efficiency: ~ 16%

Threshold: ~76mW

Non-optimal reflectivities

2030nm laser



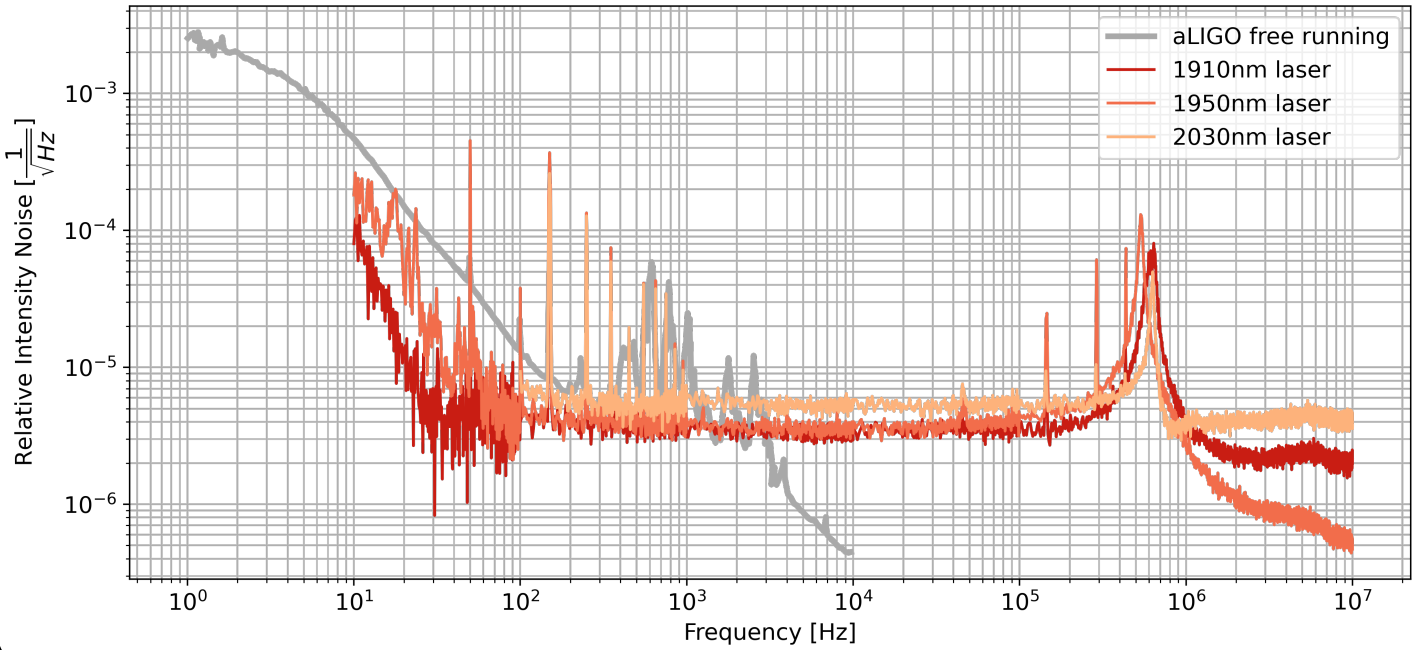
Max power: ~8.7mW

Efficiency: ~ 7%

Threshold: ~ 226mW

DBR relative intensity noise (RIN)

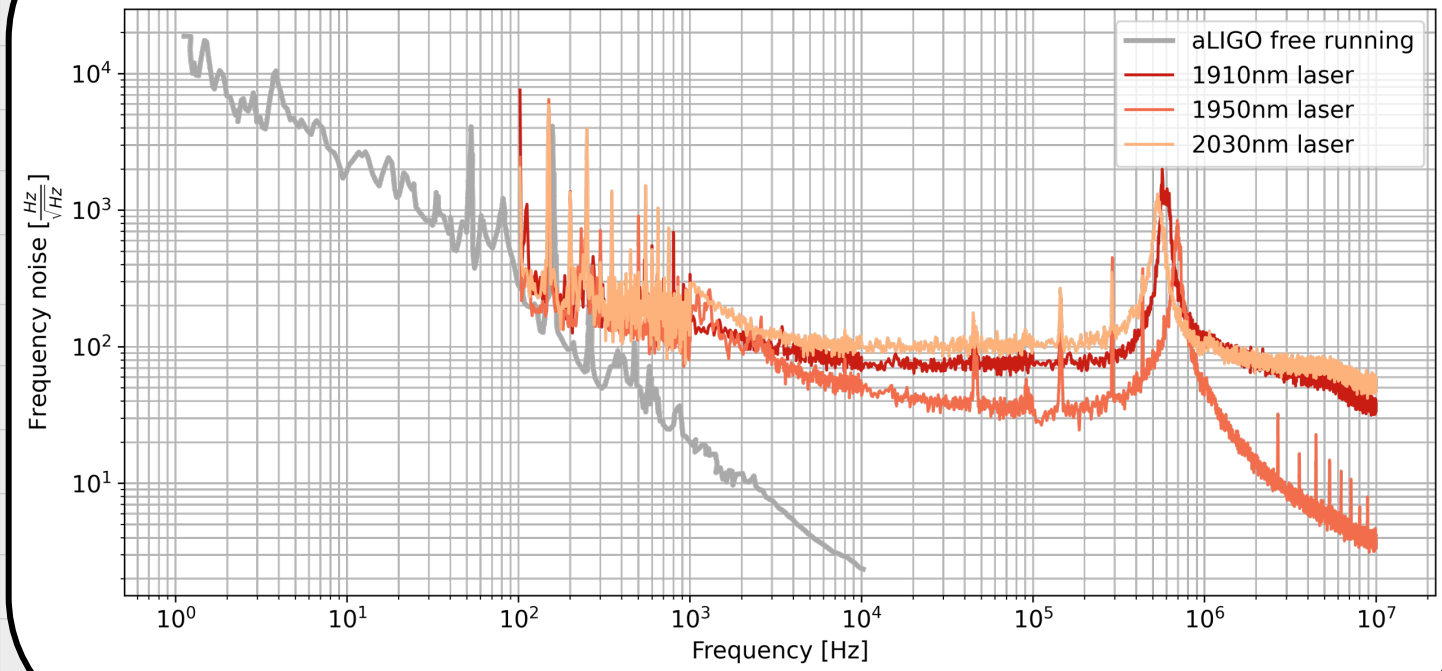
- Comparable RIN to free-running aLIGO NPRO below 1kHz
- Similar noise performance between 1910nm, 1950nm and 2030nm DBRs



[4] P. Kwee, et. al. Opt. Express. 20, 10 2012

DBR frequency noise

- Comparable RIN to free-running aLIGO NPRO below 1kHz
- Frequency noise suppression required for frequencies >1kHz



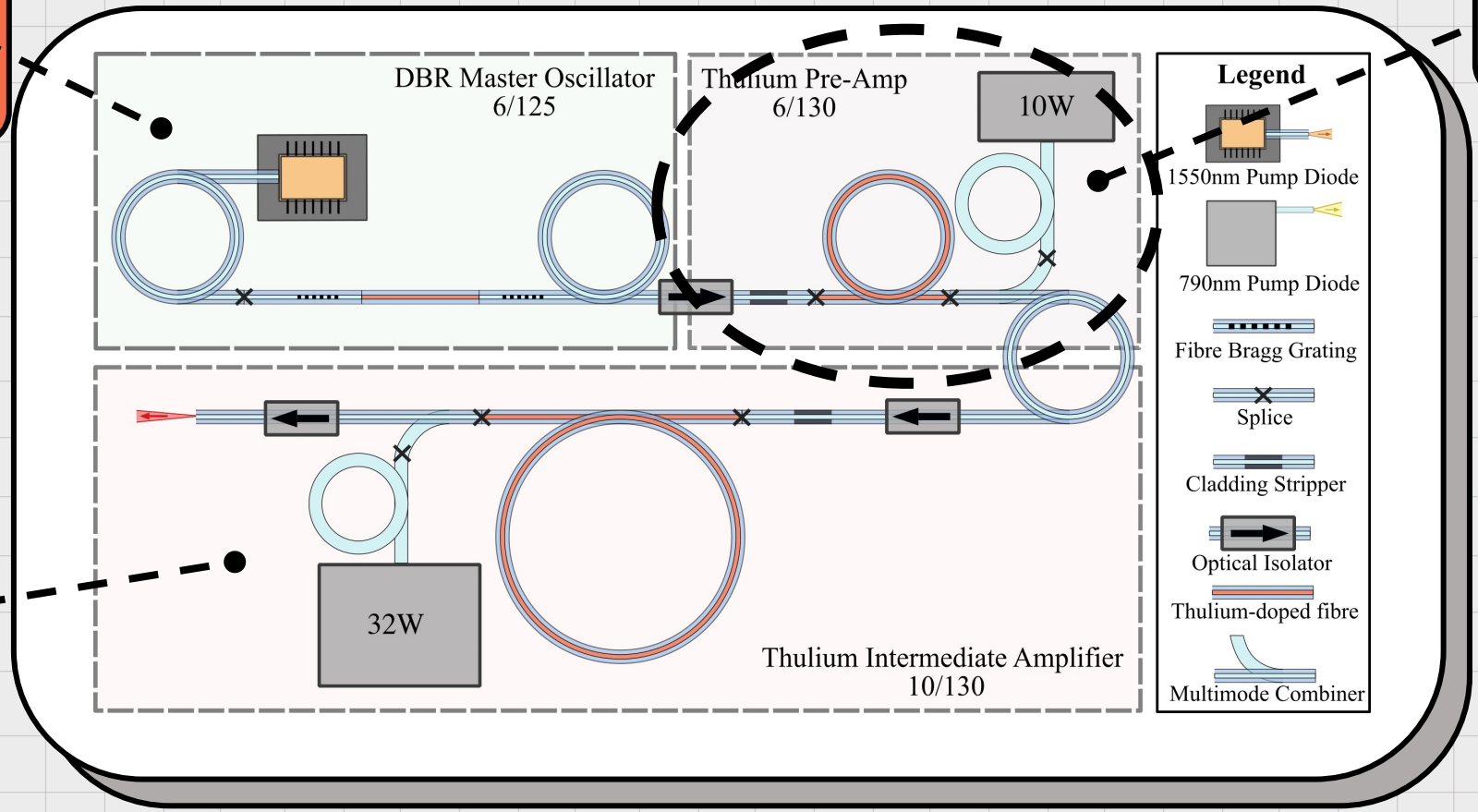
[4] P. Kwee, et. al. Opt. Express. 20, 10 2012

Master oscillator power amplifier

Master oscillator

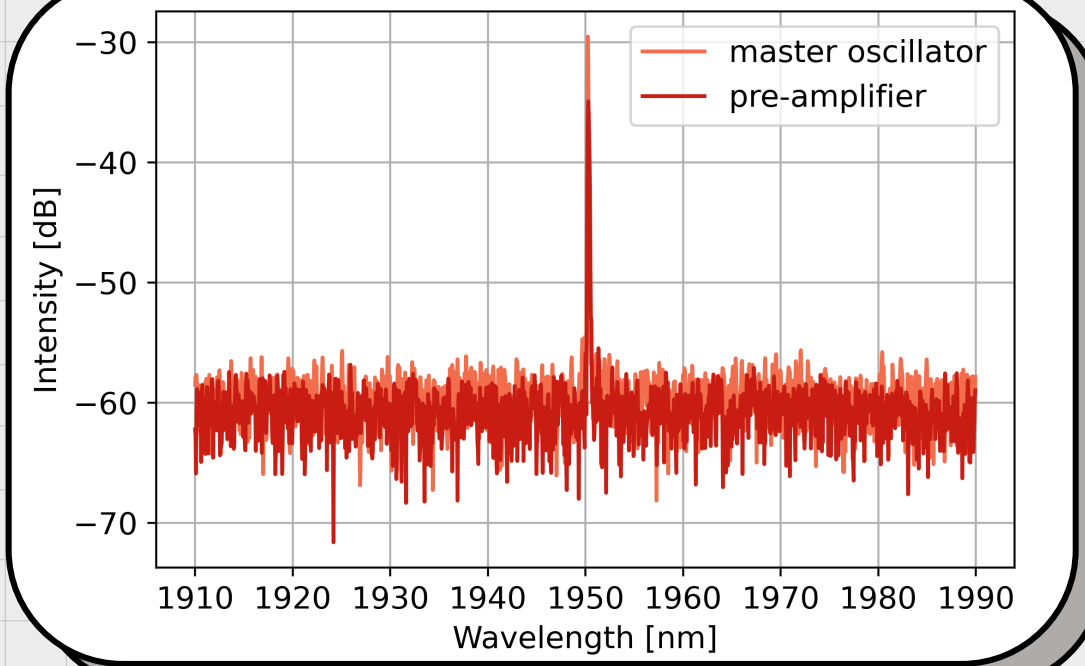
Pre-amplifier

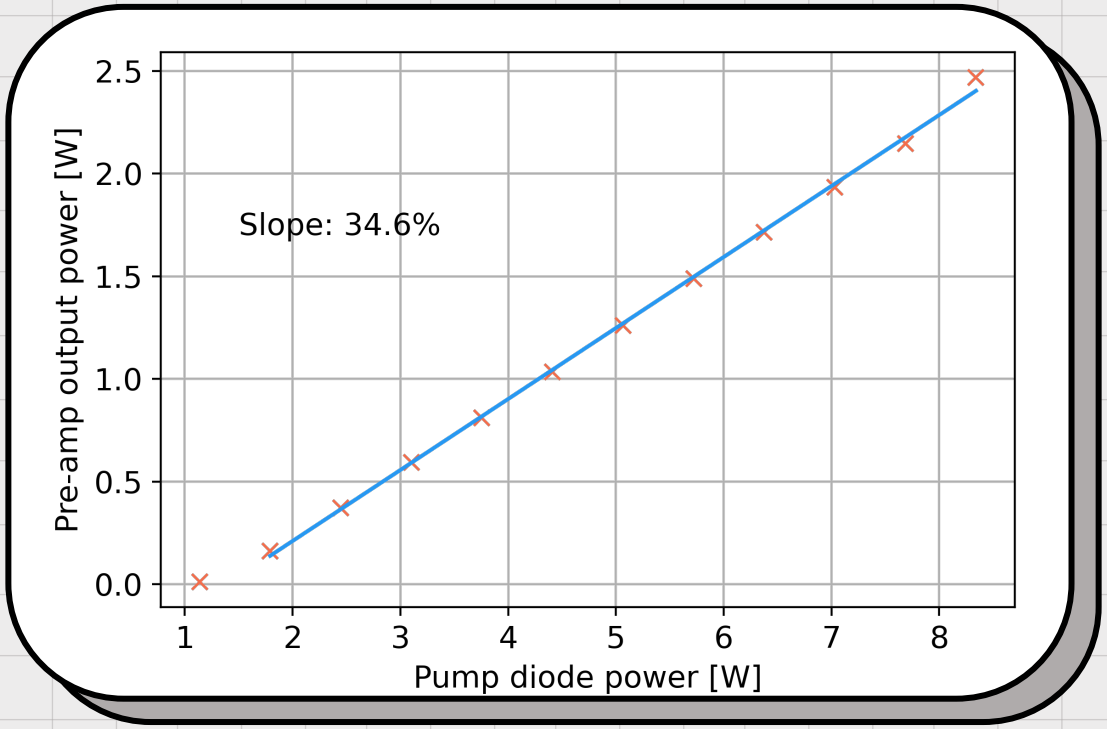
10W amplifier stage



Pre-amplifier

- 11W 793nm pump diode
- DBR input power: 20mW at 1950nm



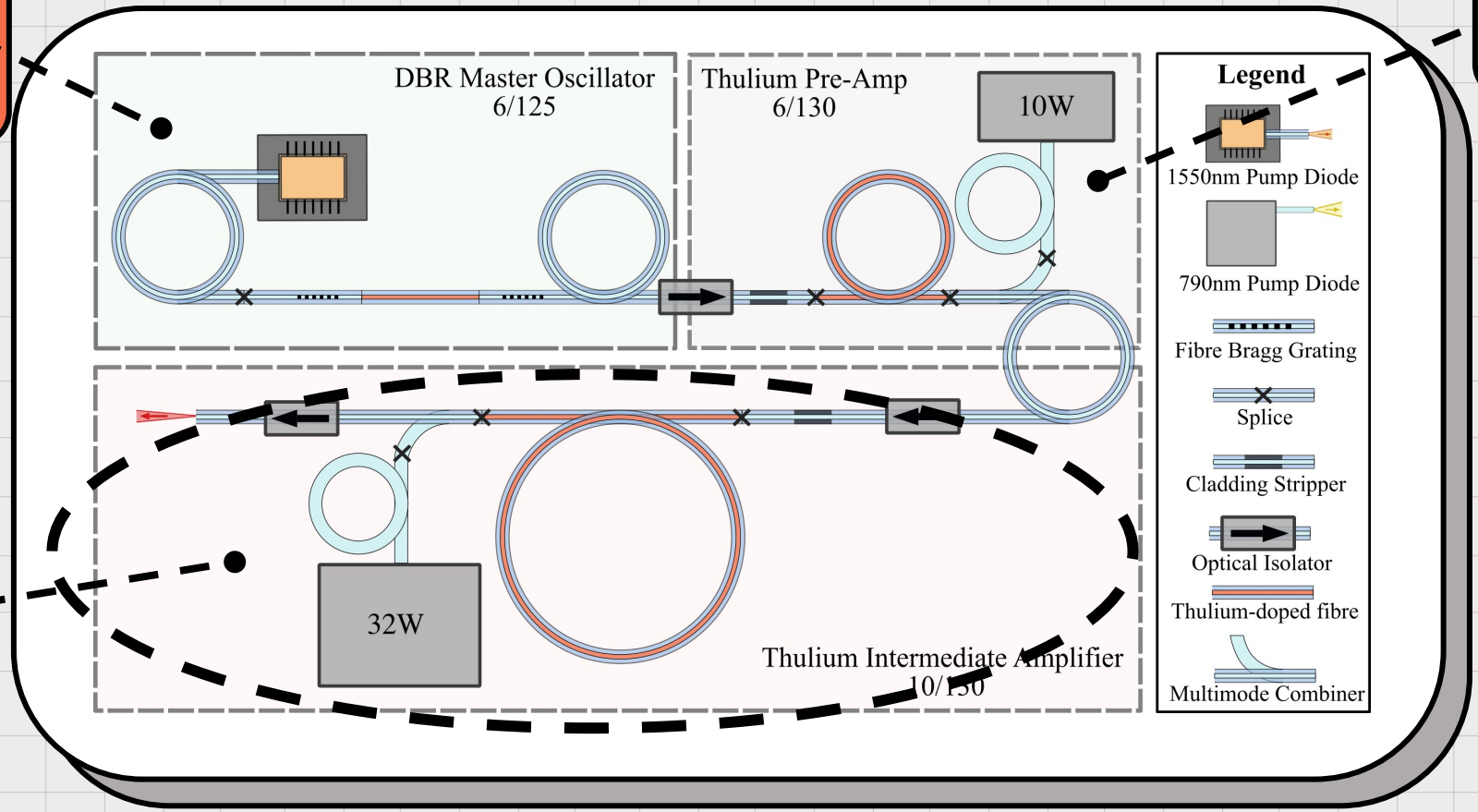


Master oscillator power amplifier

Master oscillator

Pre-amplifier

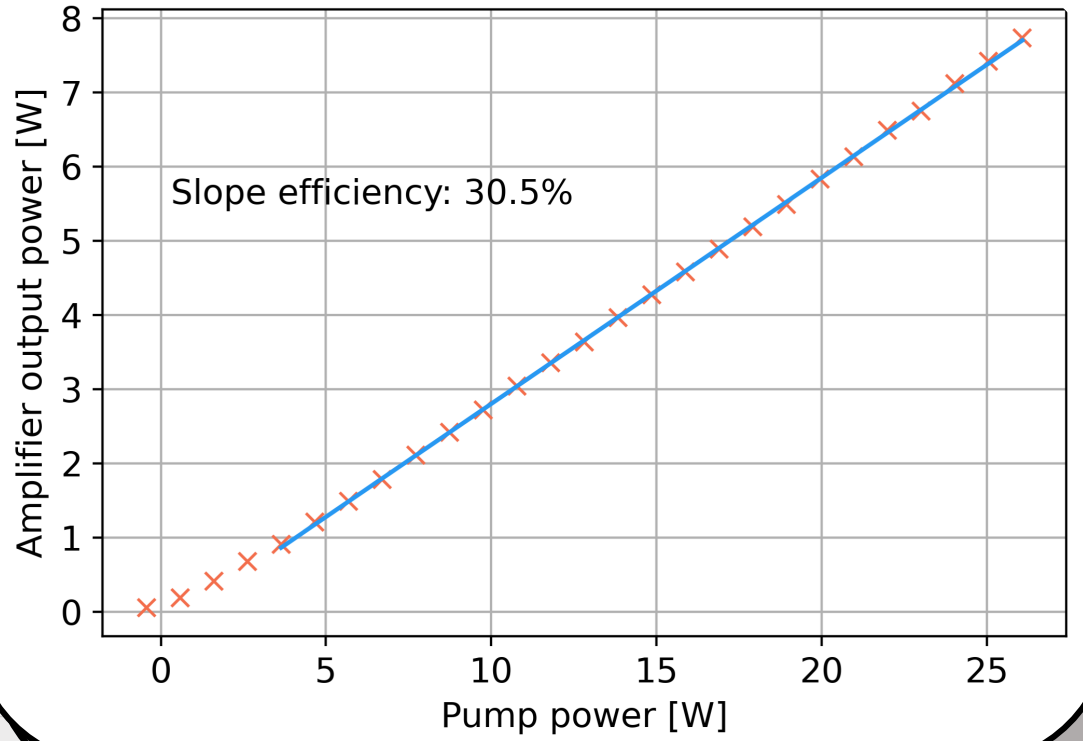
10W amplifier stage



10W amplifier stage

Slope efficiency

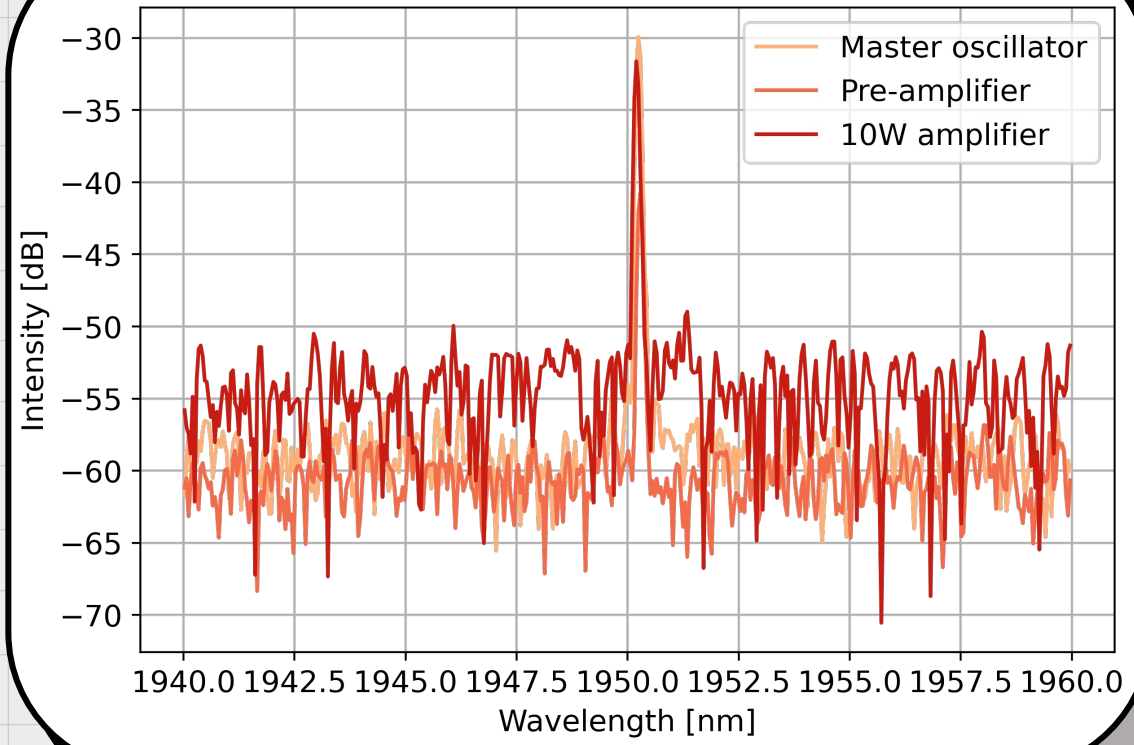
- 32W 793nm pump diode
- ~20mW from DBR
- ~880mW from pre-amp
- Max output ~7.7W
- Slope efficiency ~30.5%



10W amplifier stage

Spectral output

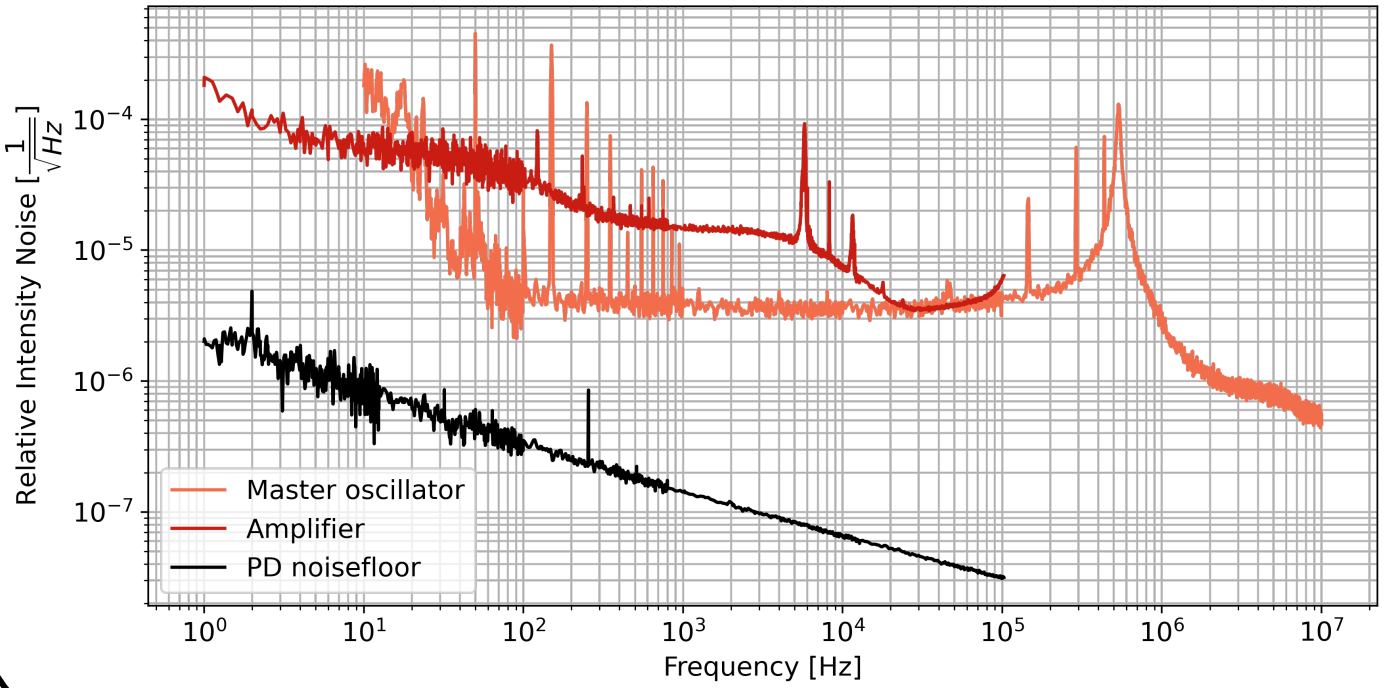
- Amplification at 1950nm
- No evidence of amplified spontaneous emission (ASE)
- 5dB of fluorescence/noise observed



10W amplifier stage

RIN

- Increase in noise below 10kHz
- Similar noise to seed at 100kHz
- Frequency noise to be measured



Summary

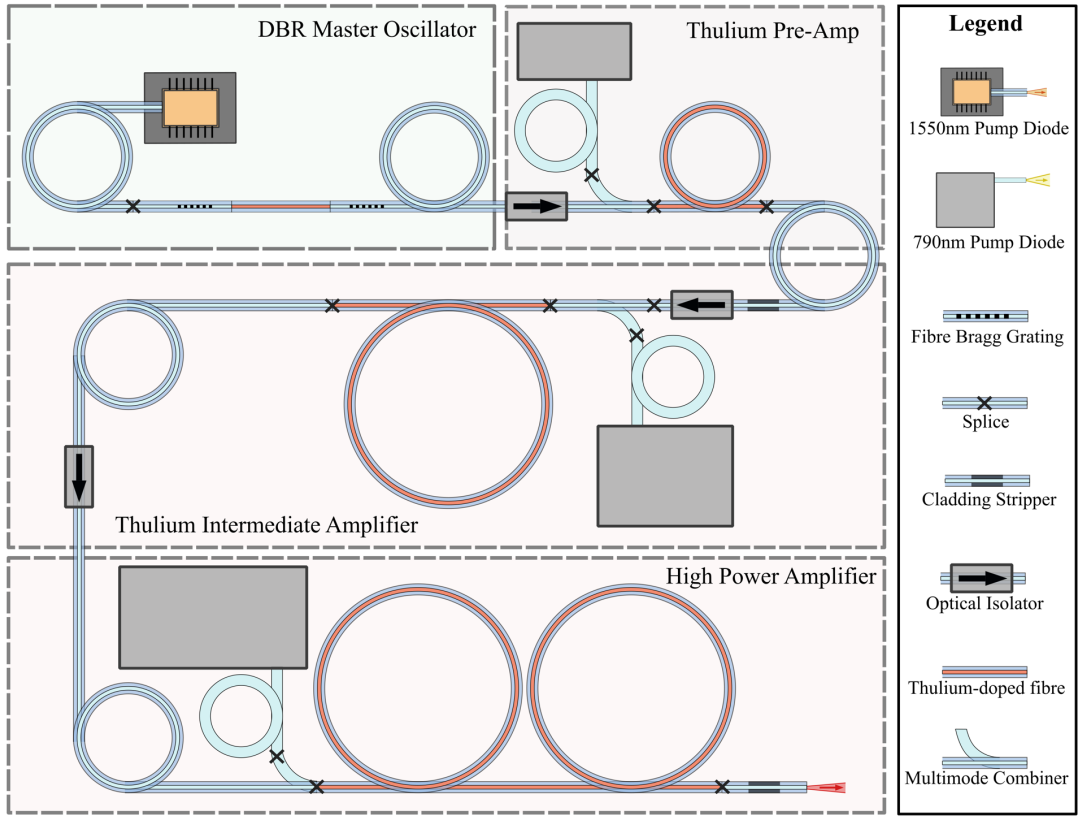
DBR master oscillators between **1910nm and 2030nm**

Suitable noise < 100 Hz for gravitational wave detectors

Thulium fibre amplifier system with **7.7W** output at **1950nm** with **30%** efficiency

Amplifier noise suppression required

100W amplifier stage to be built



Thank you

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Fibre mounts assembled at the Adelaide OptoFab Node by Evan Johnson

Optofab ANFF

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