Present status of the laser system

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Outline

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- Present setup
  - Fiber optics
  - Coherent addition
  - Solid-state amplifier
- Experimental results
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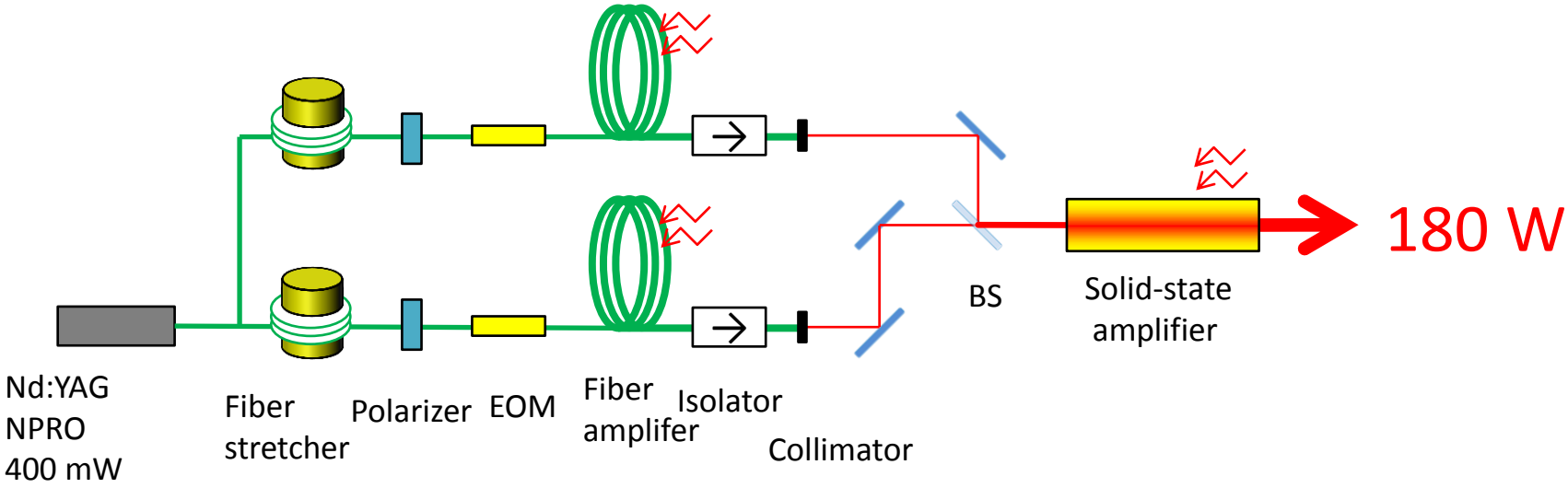
  - Control system
- Summary & Future work

Laser system & requirements

Requirements		
• Laser power	180 W	• Linear polarization
• Single frequency	1064 nm	• Low intensity noise
• Single transverse mode	TEM_{00}	• Low frequency noise



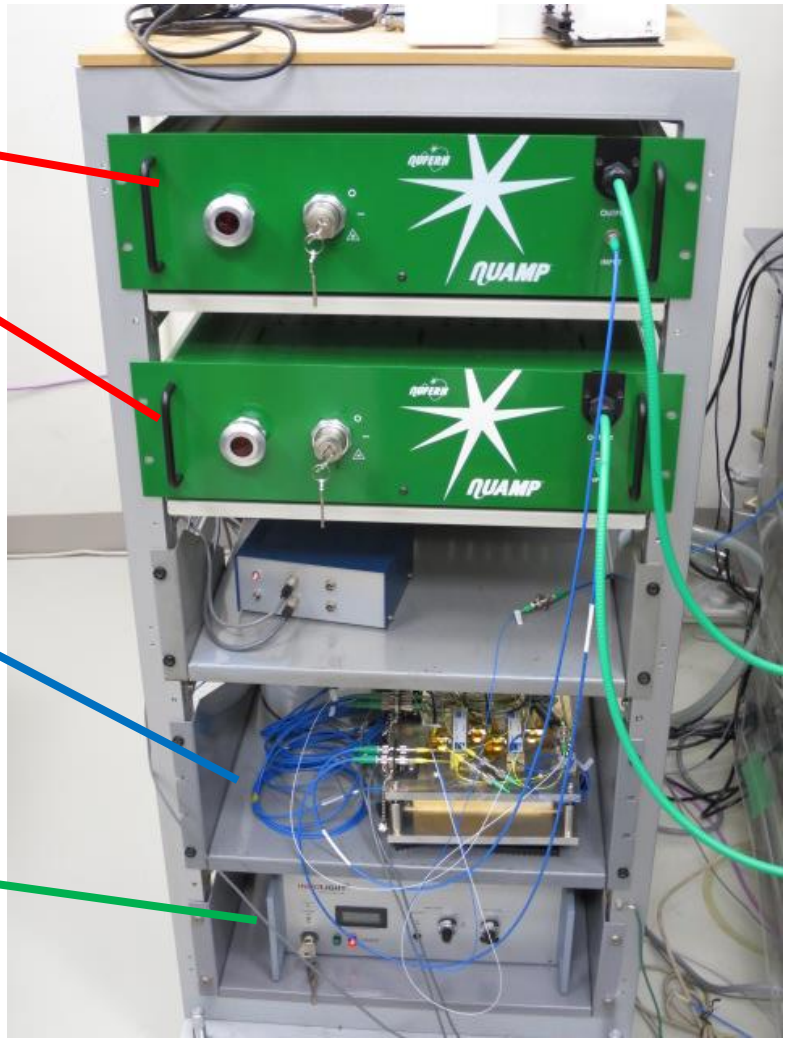
- MOPA
  - Fiber amplifier
  - Solid-state amplifier
- Coherent addition
  - Phase correction is maintained by fiber stretcher

Present setup – fiber optics

Fiber amplifiers

Fiber components
- Isolator
- Coupler
- Polarizer
- EOM
- Stretcher

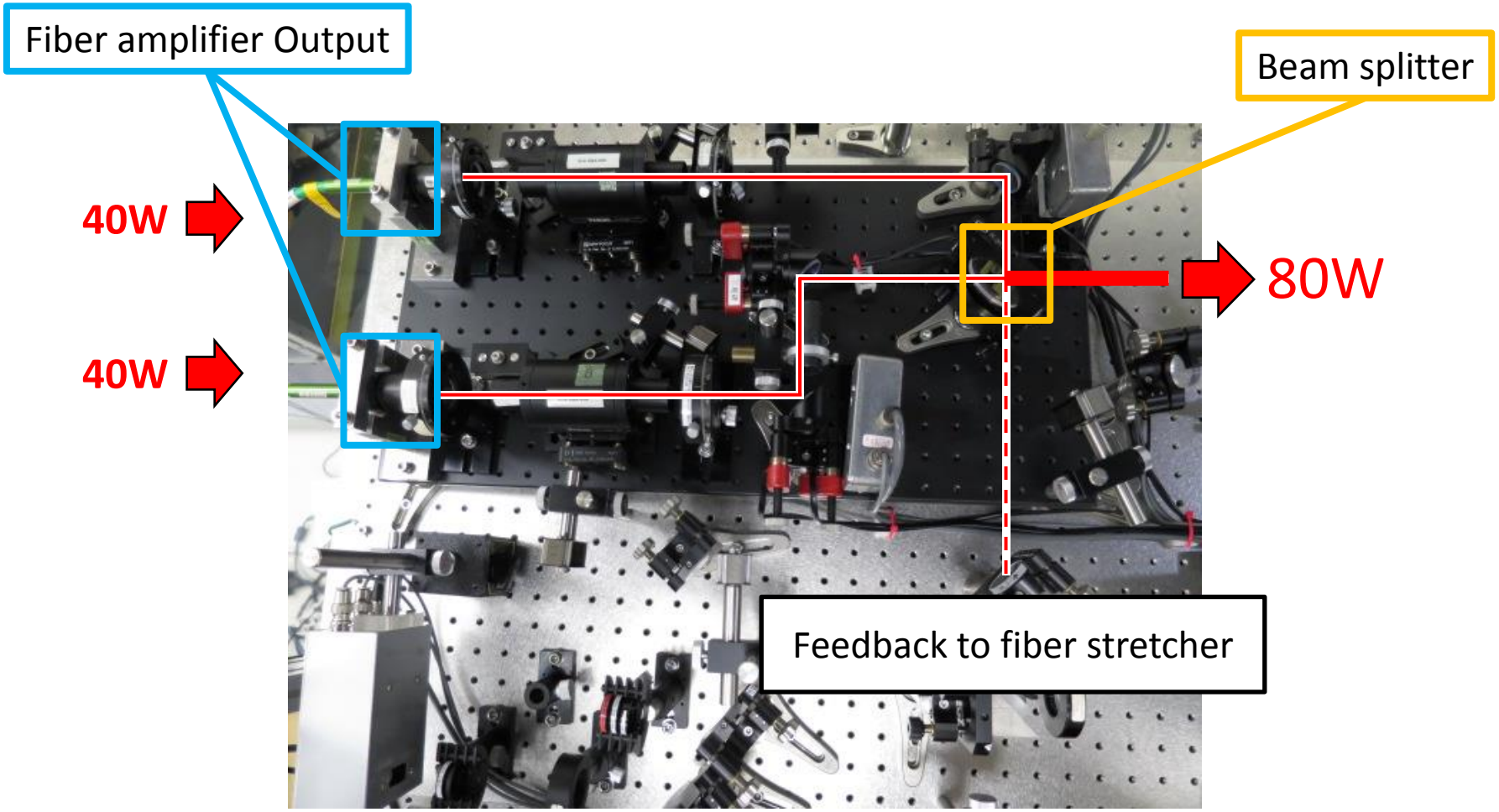
Seed laser
NPRO 400 mW



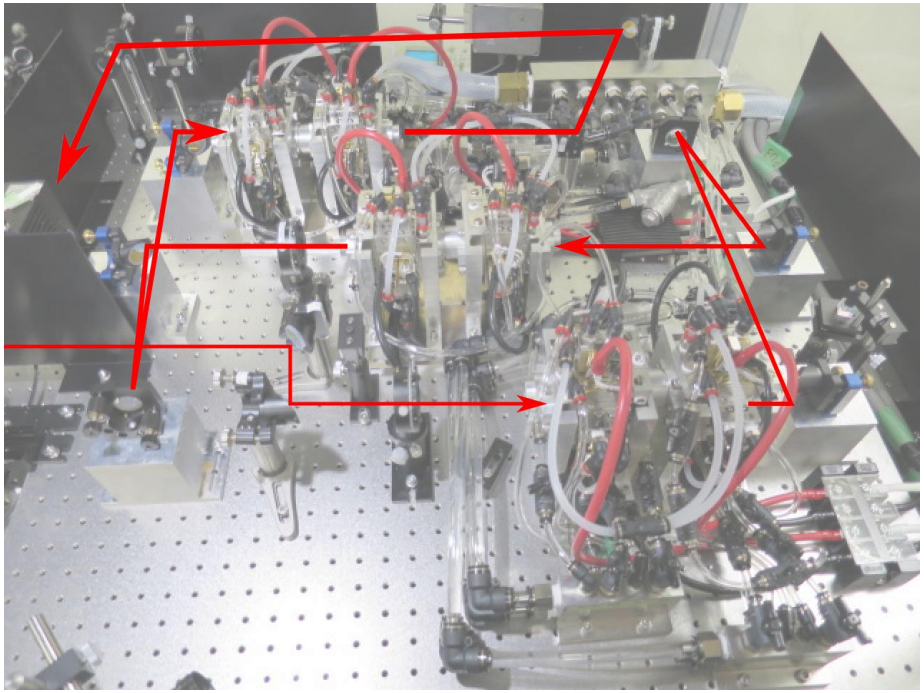
40W

40W

Present setup – coherent addition

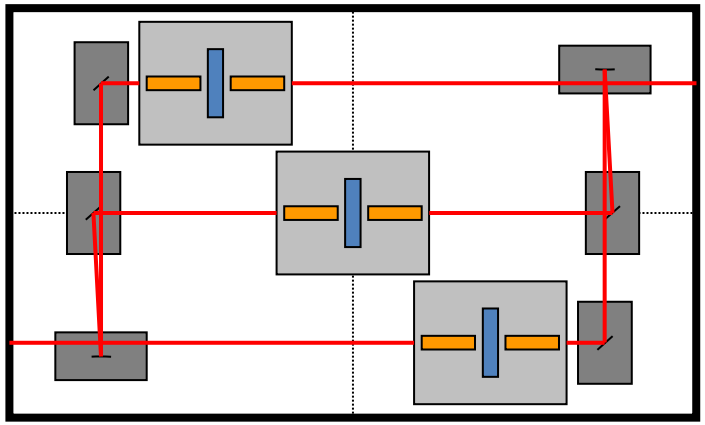


Present setup – solid-state amplifier



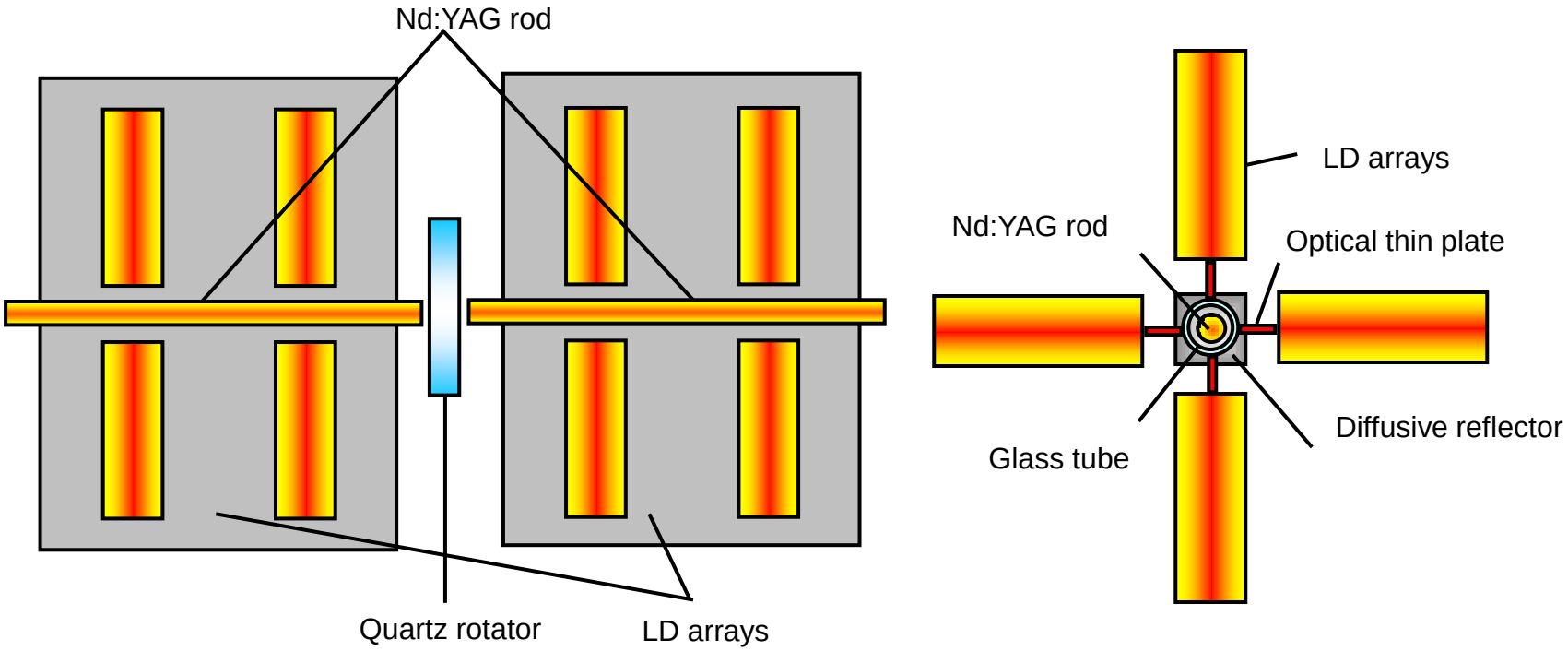
Coherent addition output

80W



180W

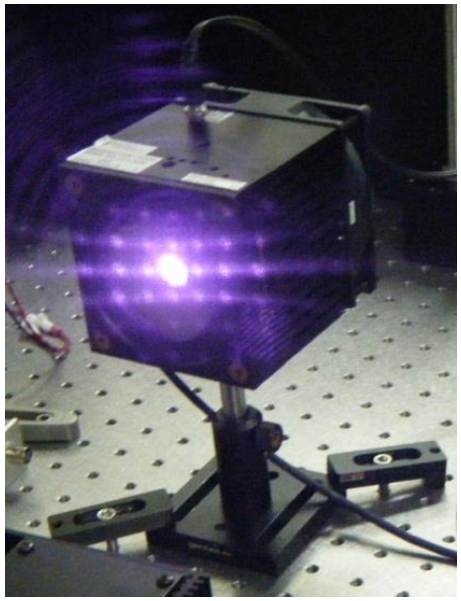
Solid-state amplifier

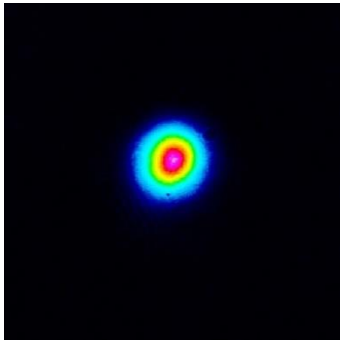


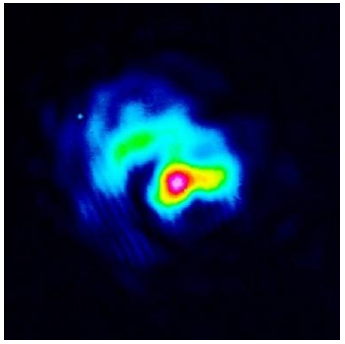
- 3 modules in the system
- One module has 2 YAG rods and 16 LD arrays
- 50 W amplification / module is expected

Result High-power output of coherent addition

- 78.9 W was obtained by coherent addition
- This is instant value, not stable

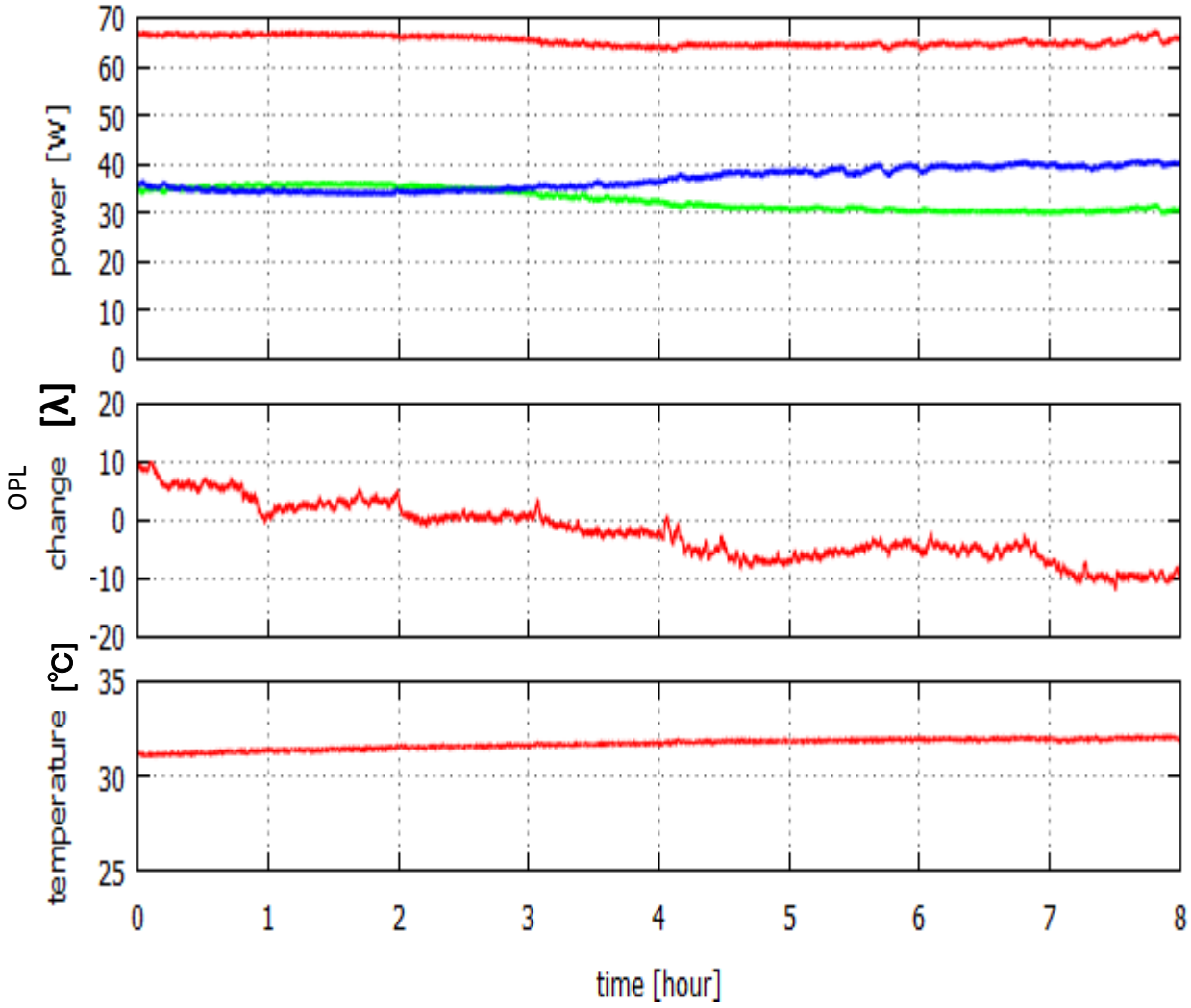






Bright port Dark port

Result Long-term operation

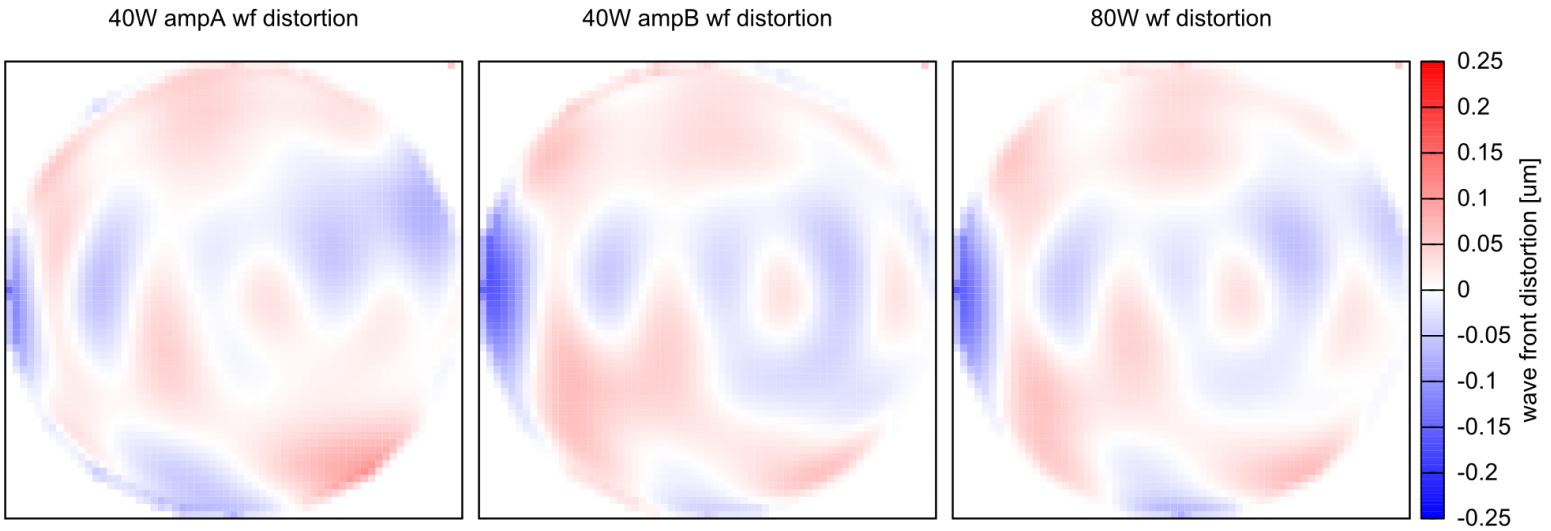


Coherent addition
Fiber amplifier A
Fiber amplifier B

- Operation time was extended
  - 5 → 8 hours
- Coherent addition power was declined after 4 hours operation
  - Due to amp A ?
- Temperature change

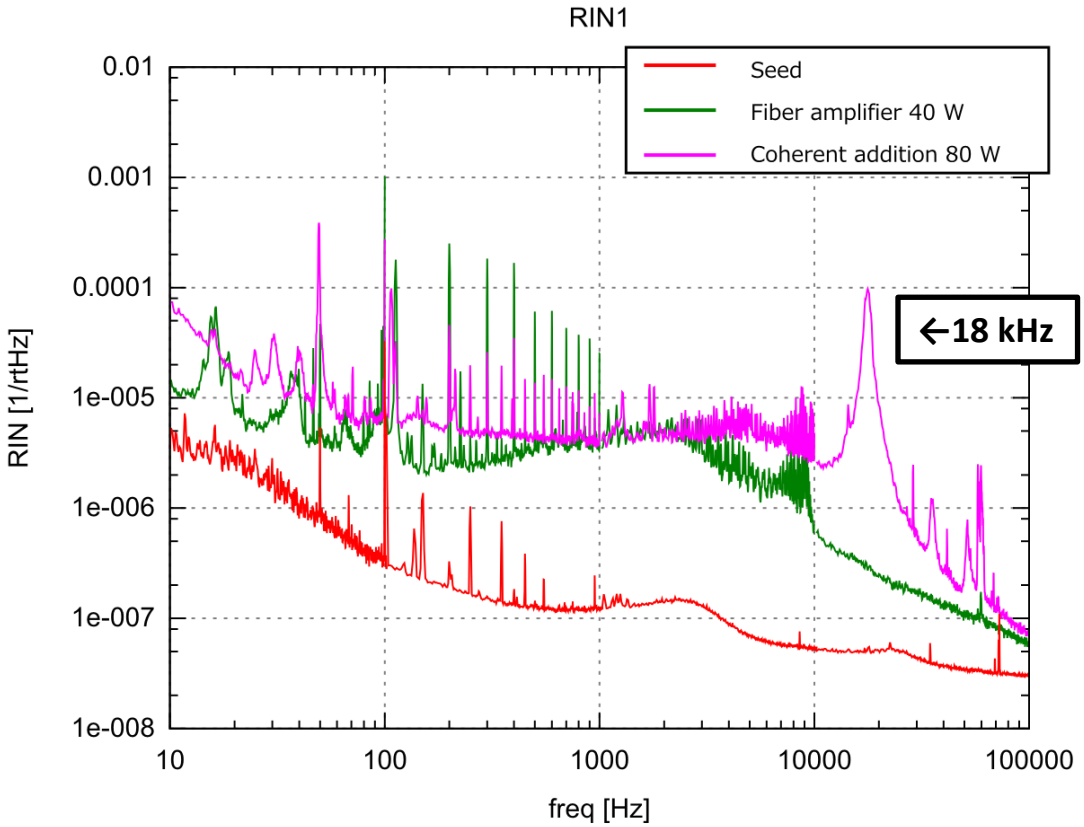
Result WF distortion

- Wave front distortion was measured before and after coherent addition
- Low-order components (0th,1st and defocus) of Zernike polynomials are eliminated



Distortion	A	B	80W A+B
Standard deviation [nm]	31.8	35.1	31.6

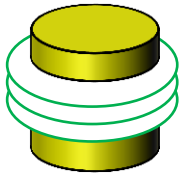
Result Intensity noise after coherent addition

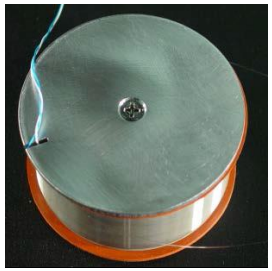


- Intensity noise becomes worse after amplification and coherent addition
- Bumping at 2-3 kHz is due to NPRO
- Bumping at 8-10 kHz is due to fiber amplifiers
- Noise peak in 18 kHz on coherent addition signal

Fiber stretcher

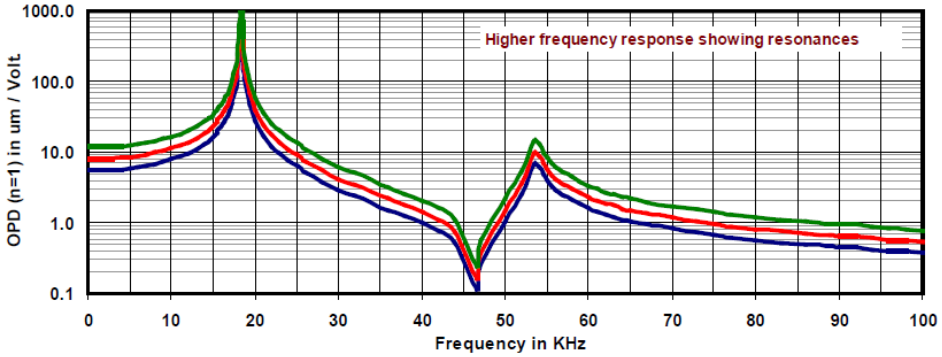
- Wide control range (max ±2240 μm @±400V)
- Using 2 stretchers differentially
  - Extend the dynamic range
- Mechanical resonance
  - Limit the control bandwidth

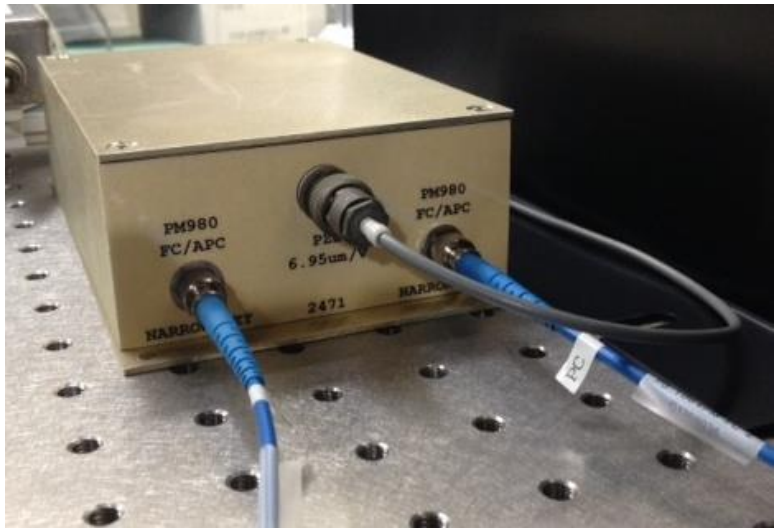




http://www.optiphase.com/data_sheets/PZ2_Data_Sheet_Rev_F.pdf

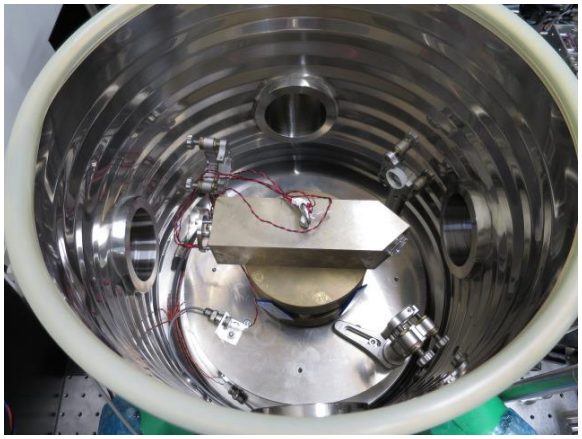
18 kHz



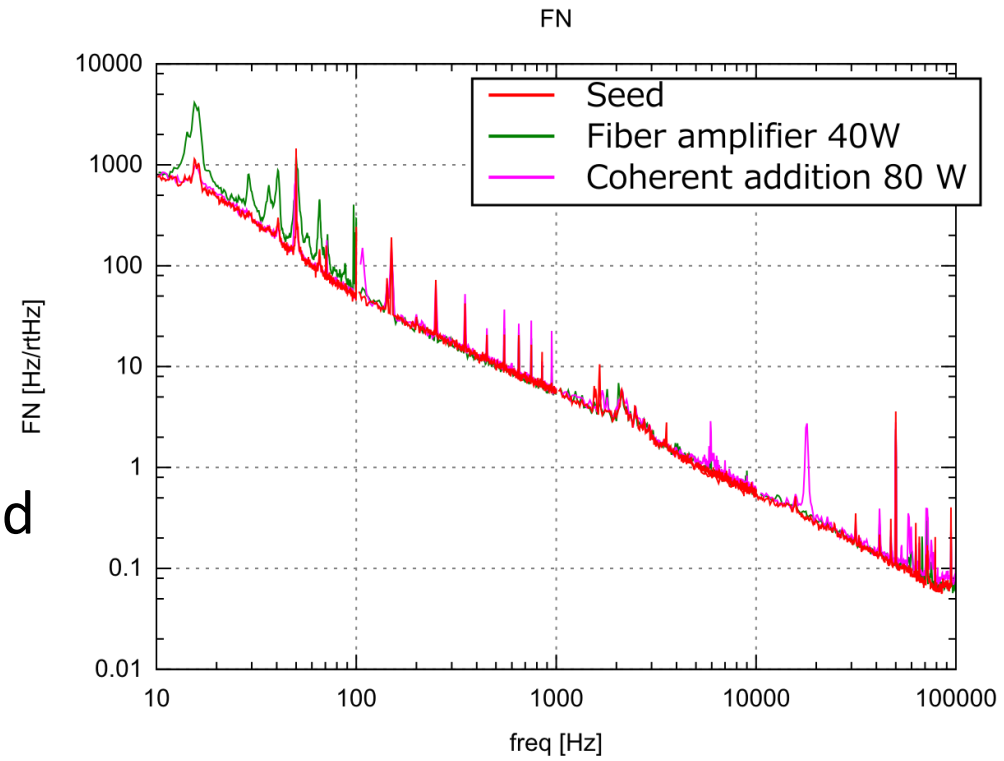


Result Phase noise

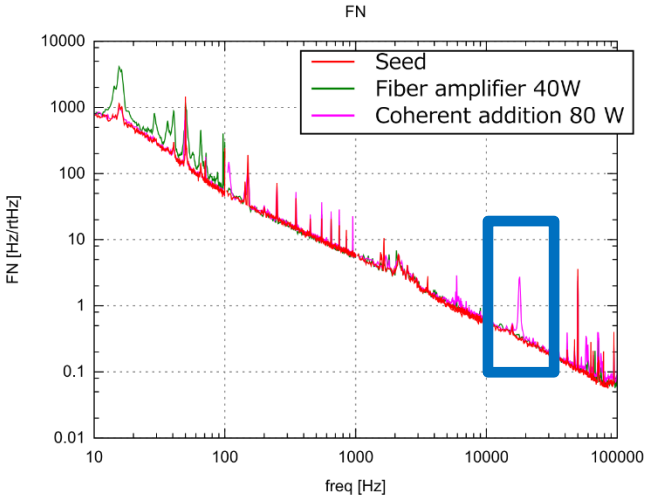
- Laser frequency was locked to rigid cavity with PZT on NPRO
- By using a vibration isolated table, seismic noise was declined
- By using vacuum chamber, sound noise was declined

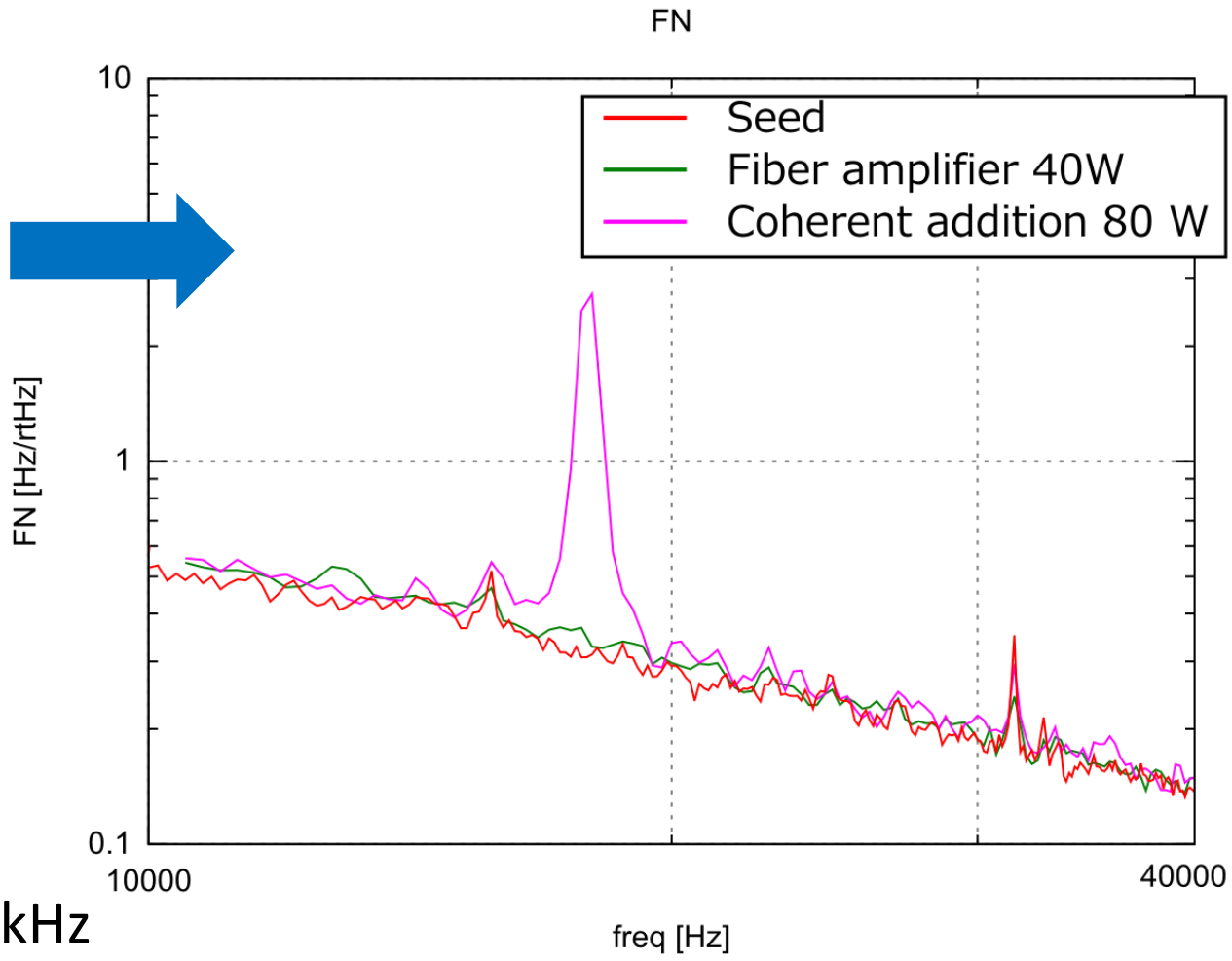


- Noise floor was determined by NPRO
- Peak @ 18 kHz



Result Phase noise

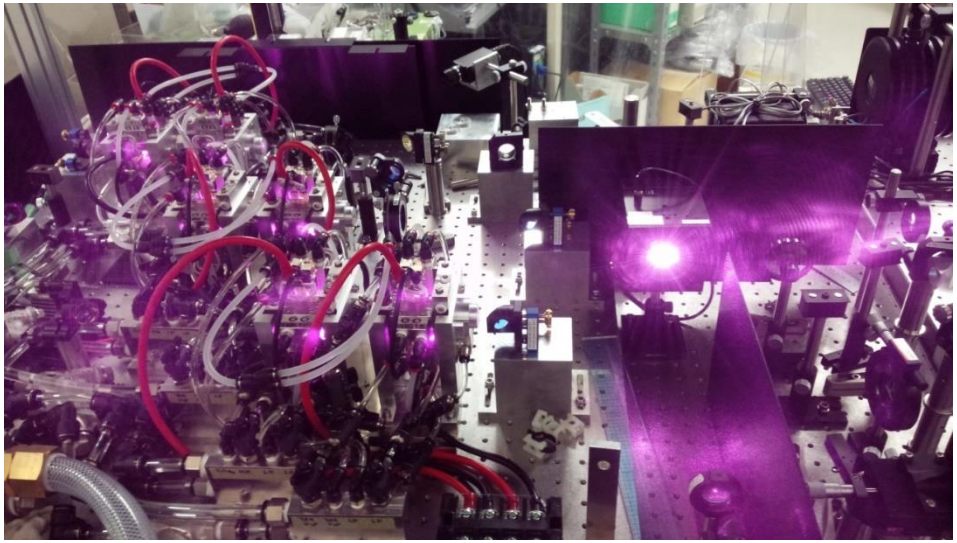




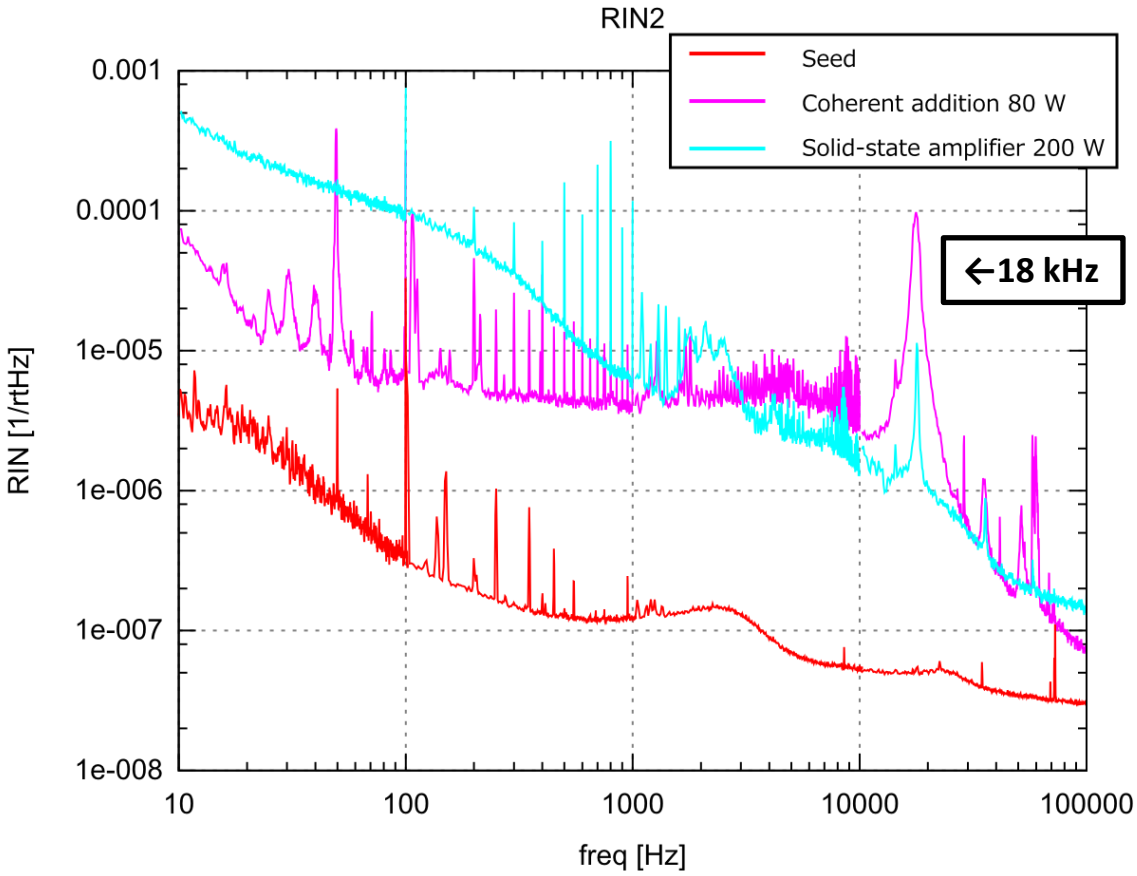
- Noise peak in 18 kHz

Result High-power output of solid-state amplifiers

- 210 W was obtained by solid-state amplifiers
- Adjustment of optics is not perfect
- It is difficult to realize good alignment
  - Dangerous due to its high power
  - When the input beam power changes, thermal lensing effect in the laser module also changes

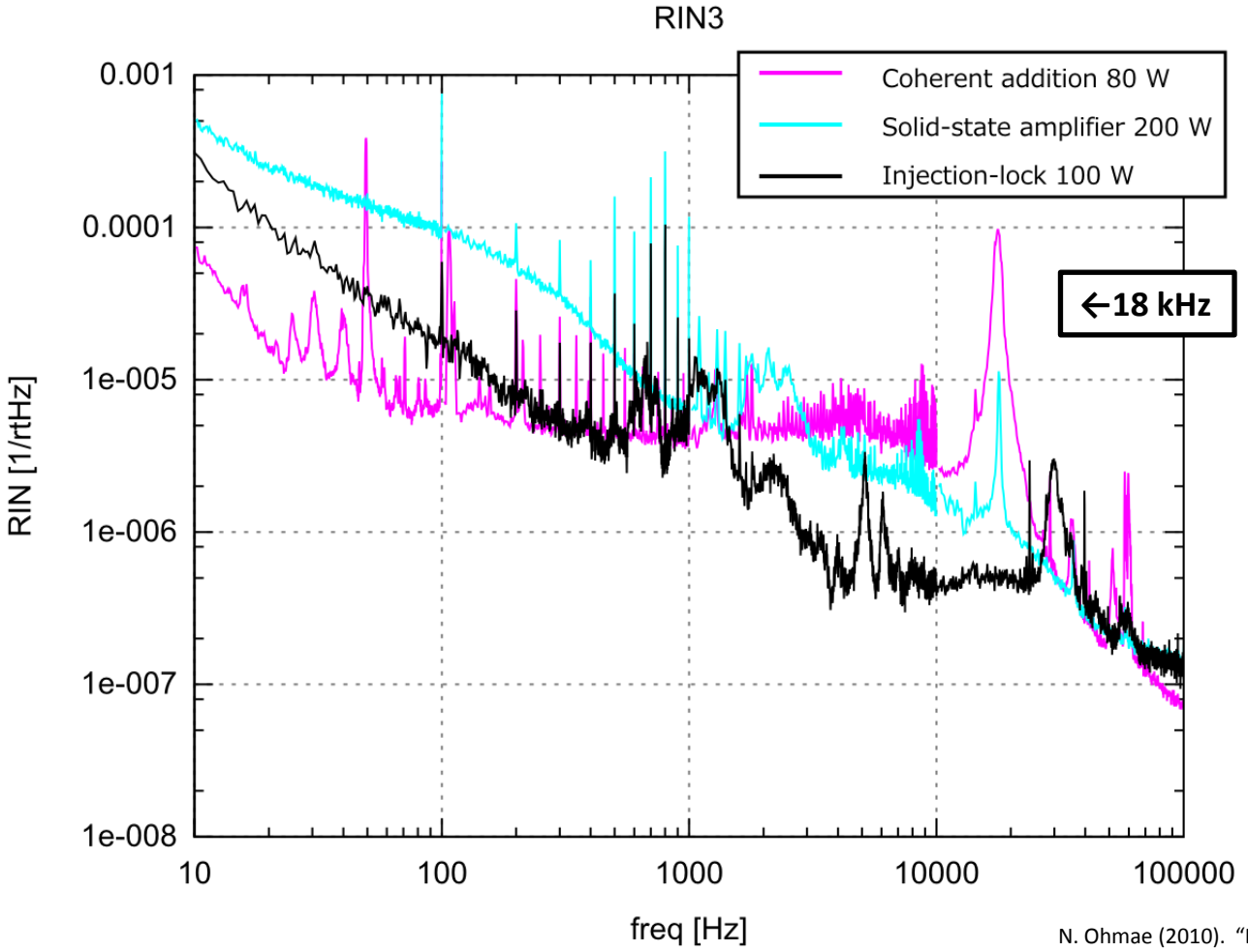


Result Intensity noise after solid-state amplifier



- 18 kHz peak on noise of 200 W beam
- RIN of the 200 W beam is decreased at high frequency

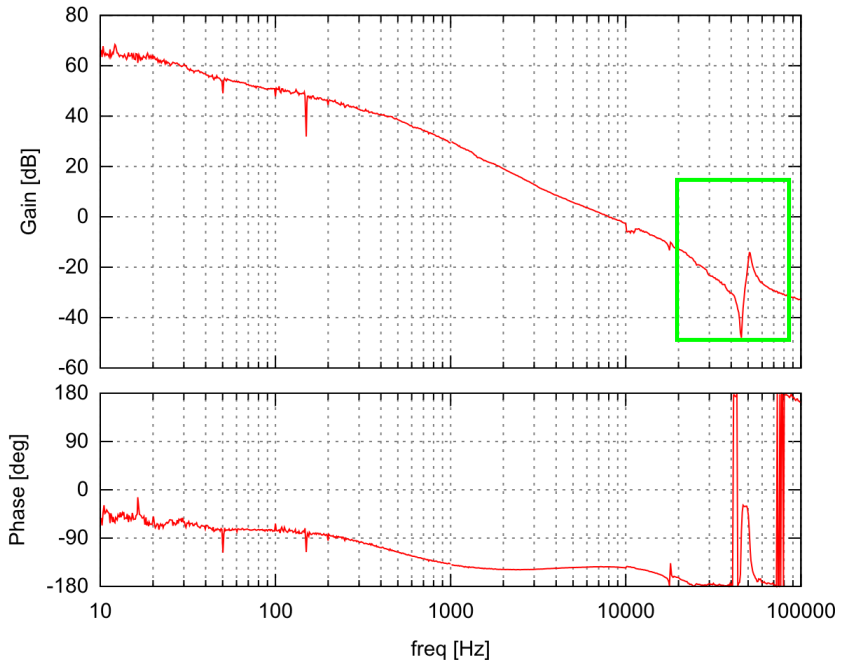
Result Intensity noise – comparison with previous work



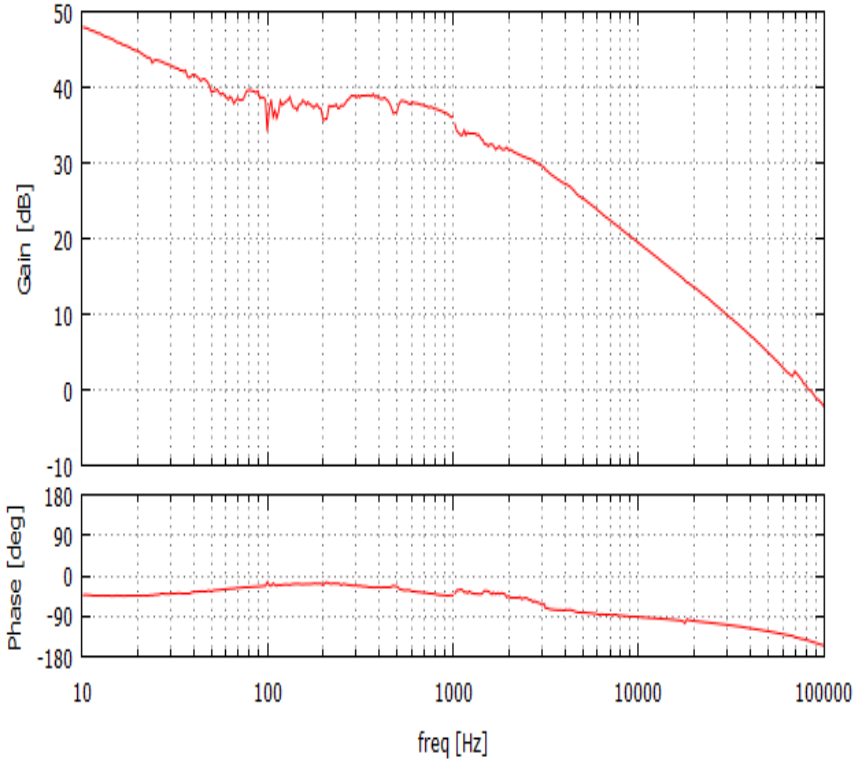
N. Ohmae (2010). "Laser System for Second-Generation Gravitational-Wave Detectors"

- Comparison with previous work
  - Less intensity noise at some frequency range
- Peak @ 18 kHz

Result Control system



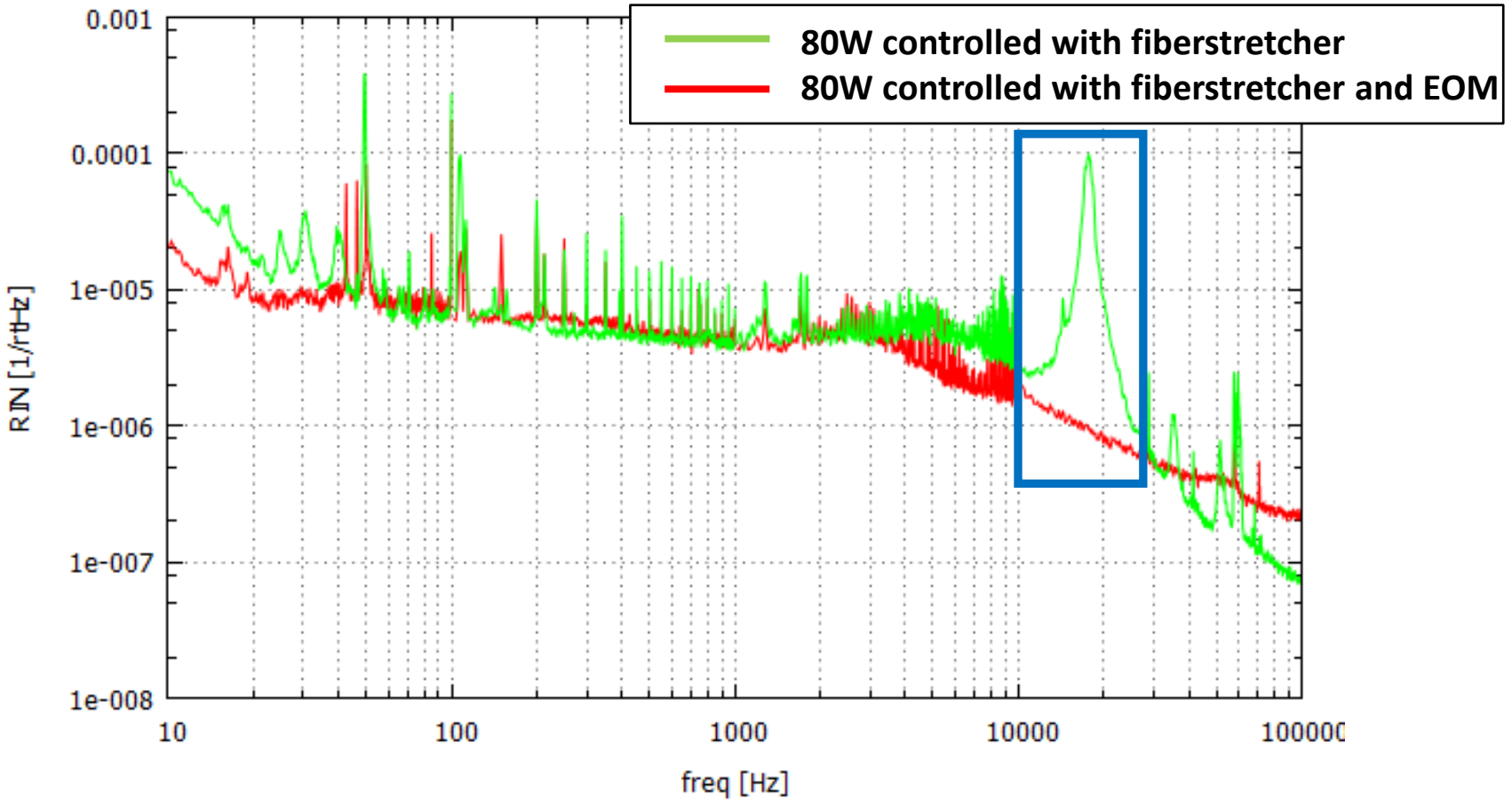
with old filter



with new filter

- Fiberstretcher + EOM
- Unity gain frequency is about 80 kHz

Result Control system



- Resonance peak was diminished

Summary & Future work

- 78.9 W was achieved by coherent addition
- 210 W was achieved by solid-state amplifiers
- Coherent addition was maintained for 8 hours
- Output power changed in time
- Atmosphere temperature changed in time
- 18 kHz noise peak was diminished

- Stabilize output power, frequnecy
  - Stabilize temperature?
- Evaluate the noise of the 210-W beam
- Interlock