The IV International Workshop on Gravitomagnetism and large-scale Rotation Measurement (GRM)

Long-term operation of a large-scale passive laser gyroscope

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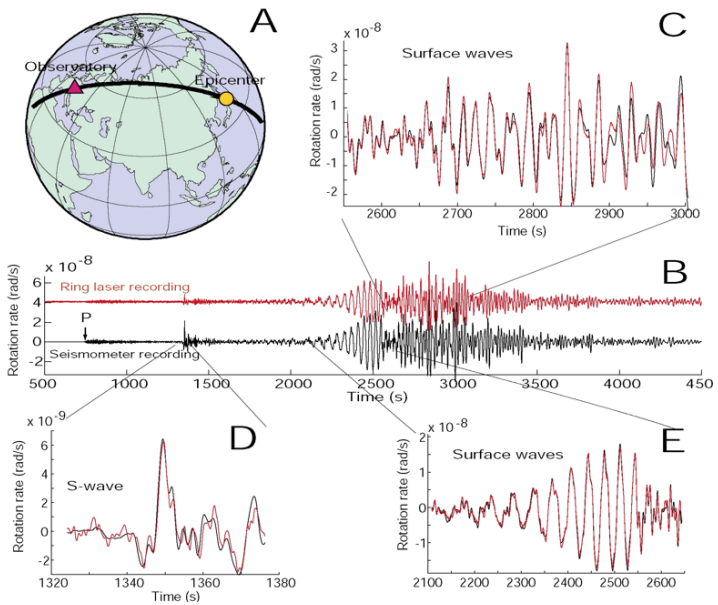
Outline

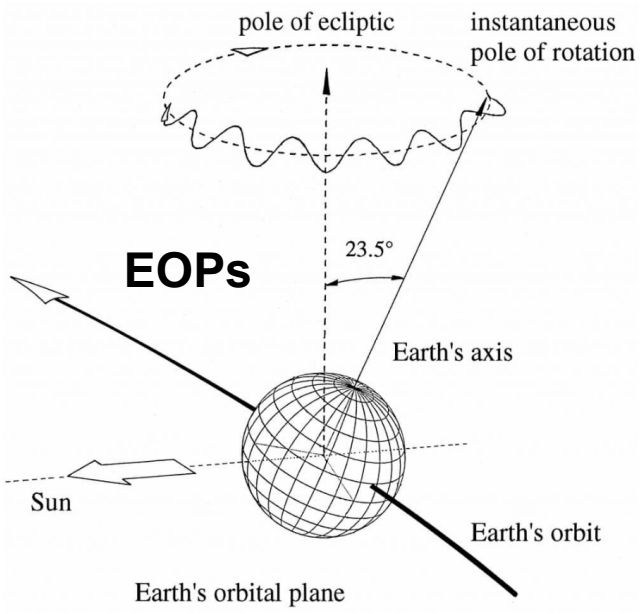
- Background
- Research on the 3 m×3 m gyroscope
- Summary

Background

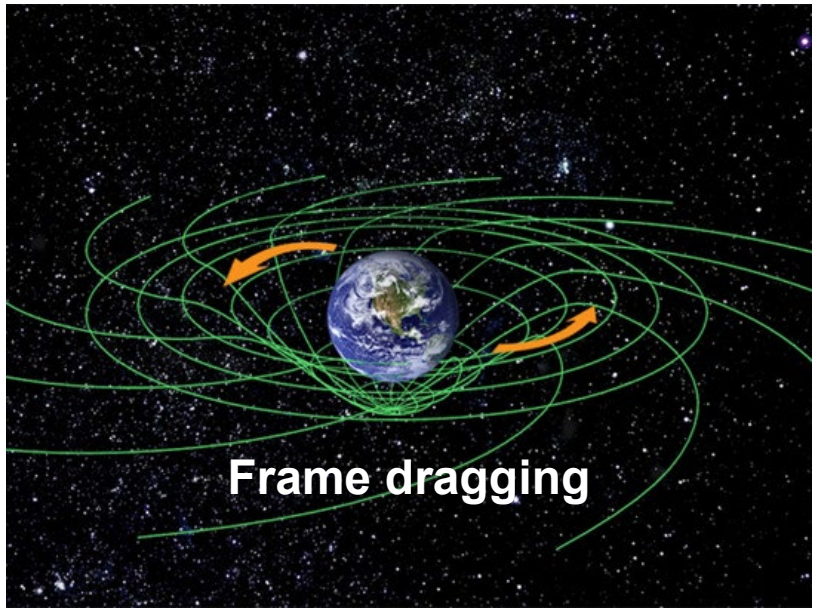
Rotational seismology



Earth Physics

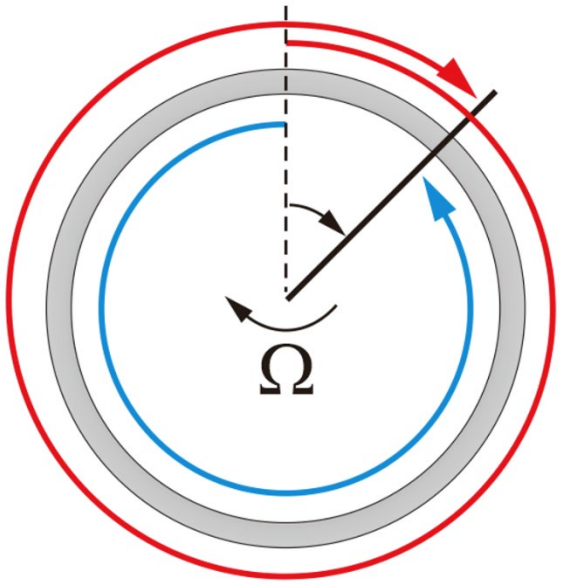


Fundamental Physics



Rev. Sci. Instrum. **84**, 041101 (2013)
Geophys. Res. Lett. **32**, L08309 (2005)

Sagnac effect

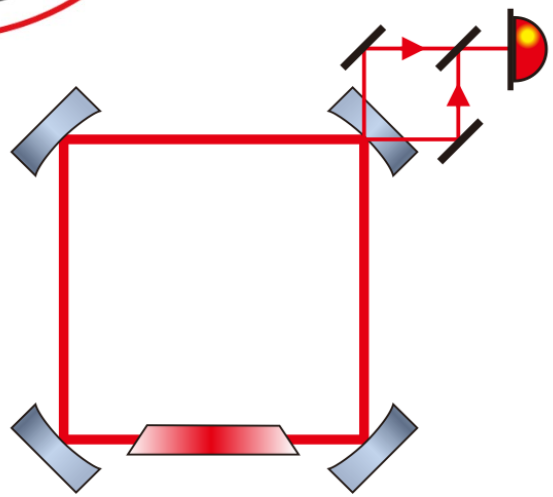


Sagnac frequency:

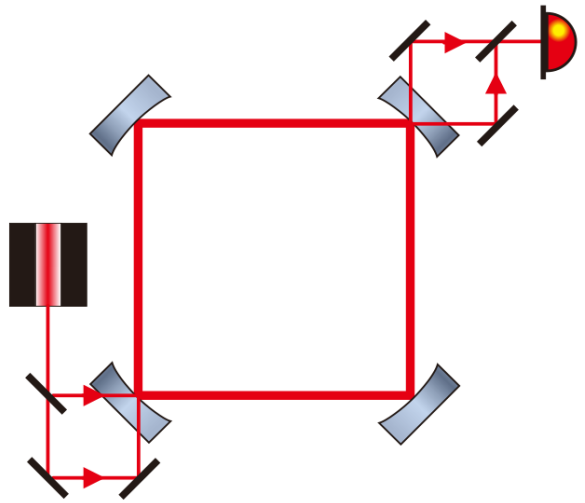
$$f_s = K_s \cdot \Omega = \frac{4A \cdot \Omega}{\lambda P}$$

Scale factor: $K_s = \frac{4A}{\lambda P}$

- Lasing medium
- Gain starving
- He-Ne gas
- Mature technique



Ring Laser Gyroscope (RLG)

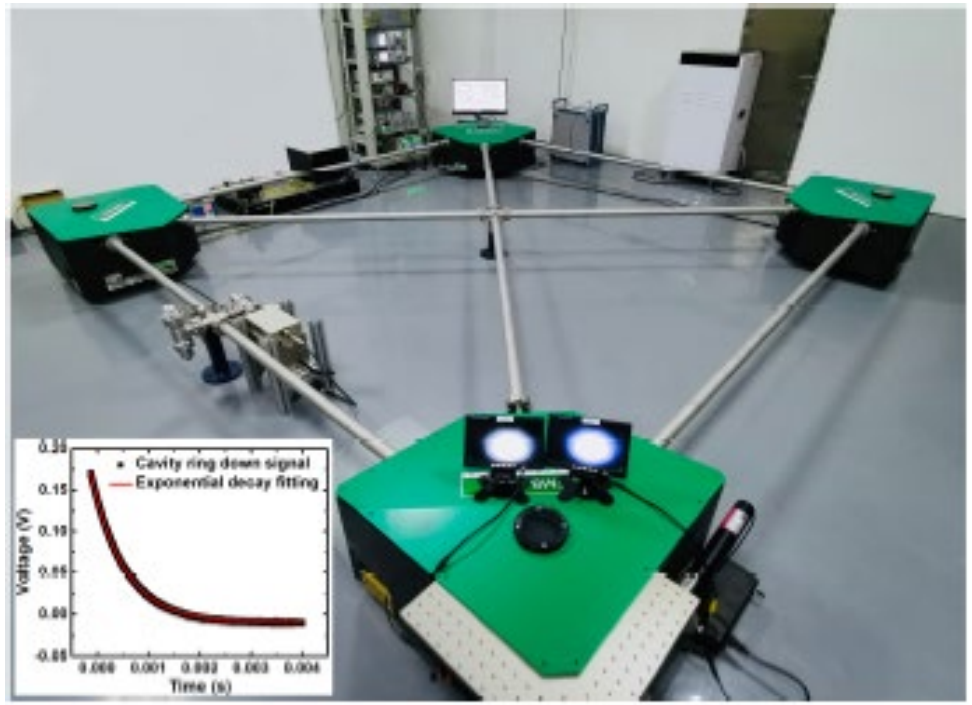


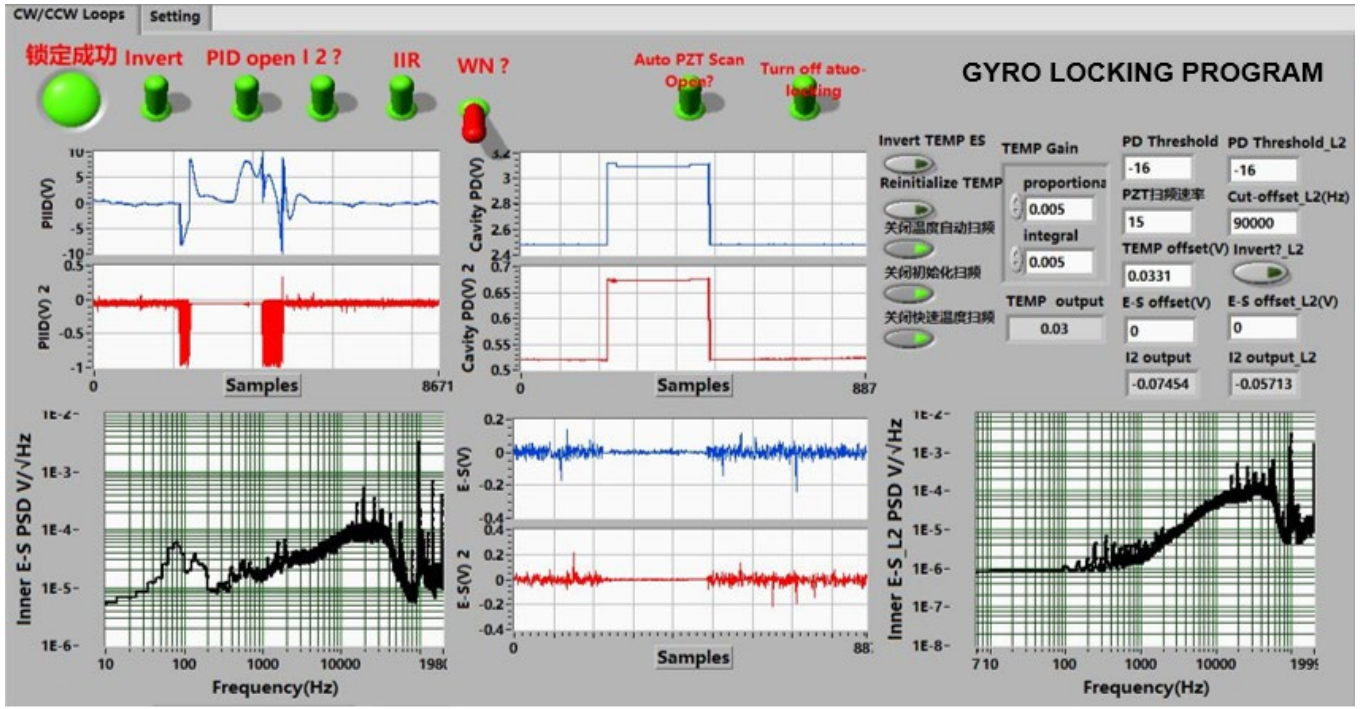
- External injection
- High power
- Vacuum
- Mode-hope free

Passive Resonant Gyroscope (PRG)

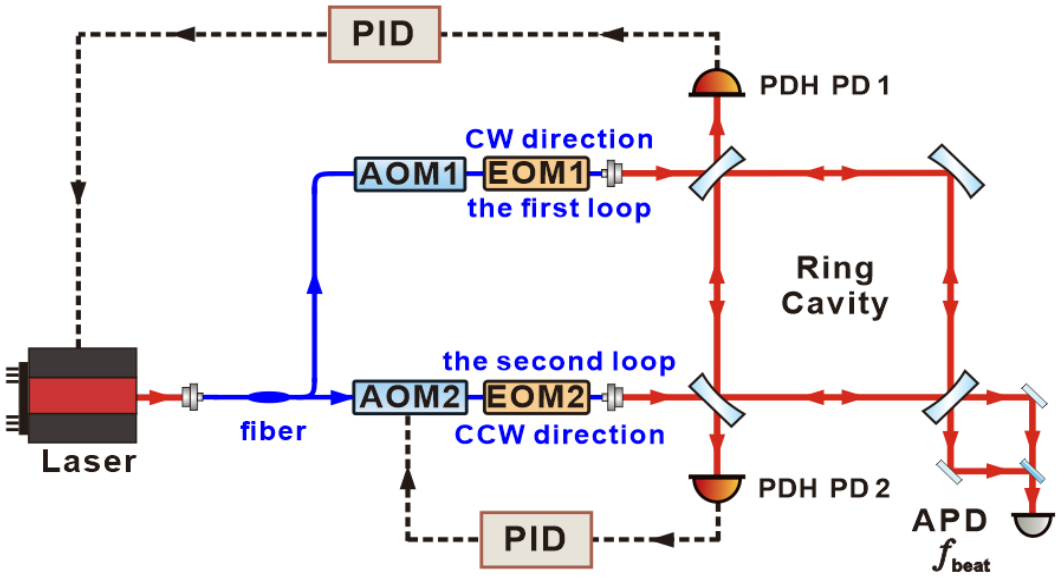
3 m×3 m PRG HUST-1

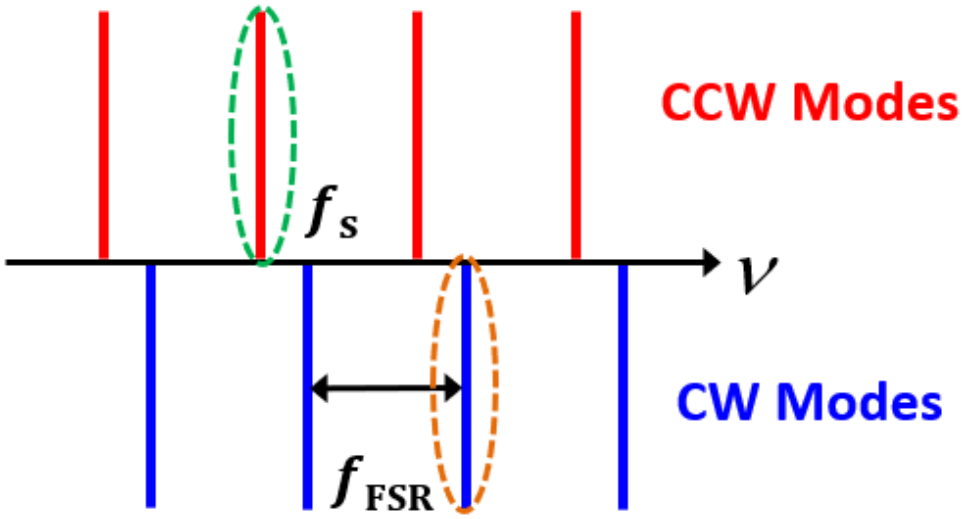
	Perimeter(m)	Area (m^2)	FSR (MHz)	Q factor	Finesse
HUST-1	12	9	25	$1.2x10^{12}$	10^5

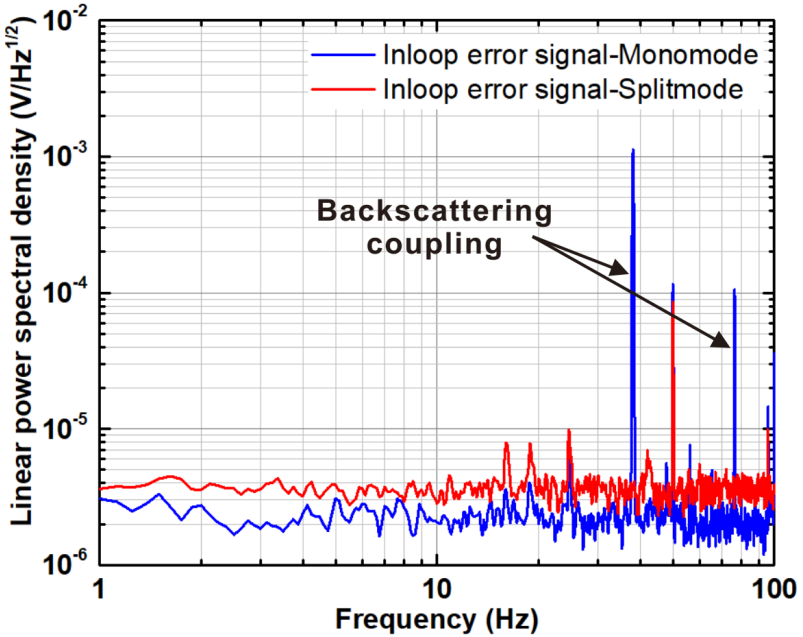




3 m×3 m PRG HUST-1



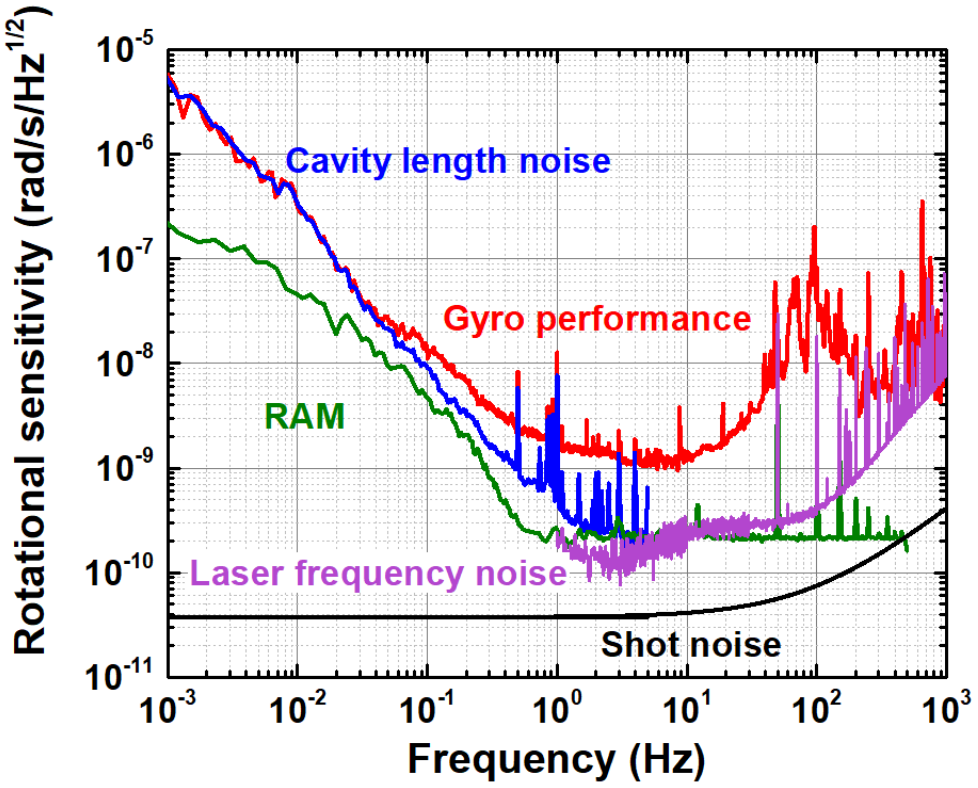


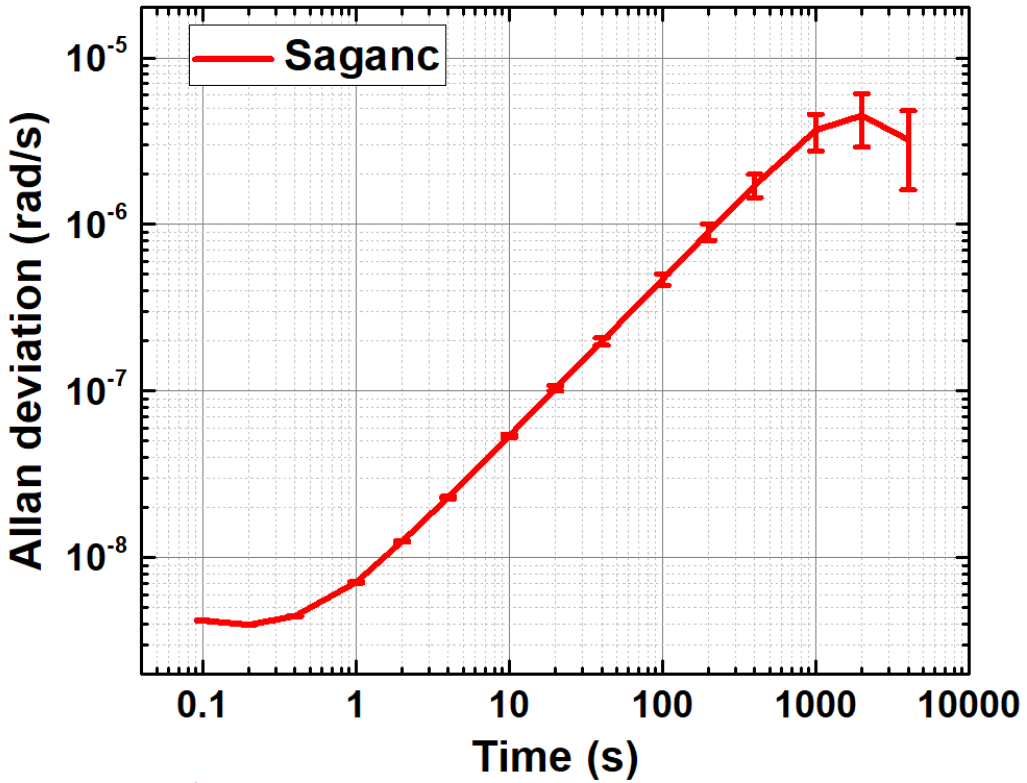


$$f_{beat} = f_s + f_{FSR}$$

$$\frac{\delta f_{FSR}}{f_{FSR}} = \frac{\delta P}{P}$$

Noise diagnosis



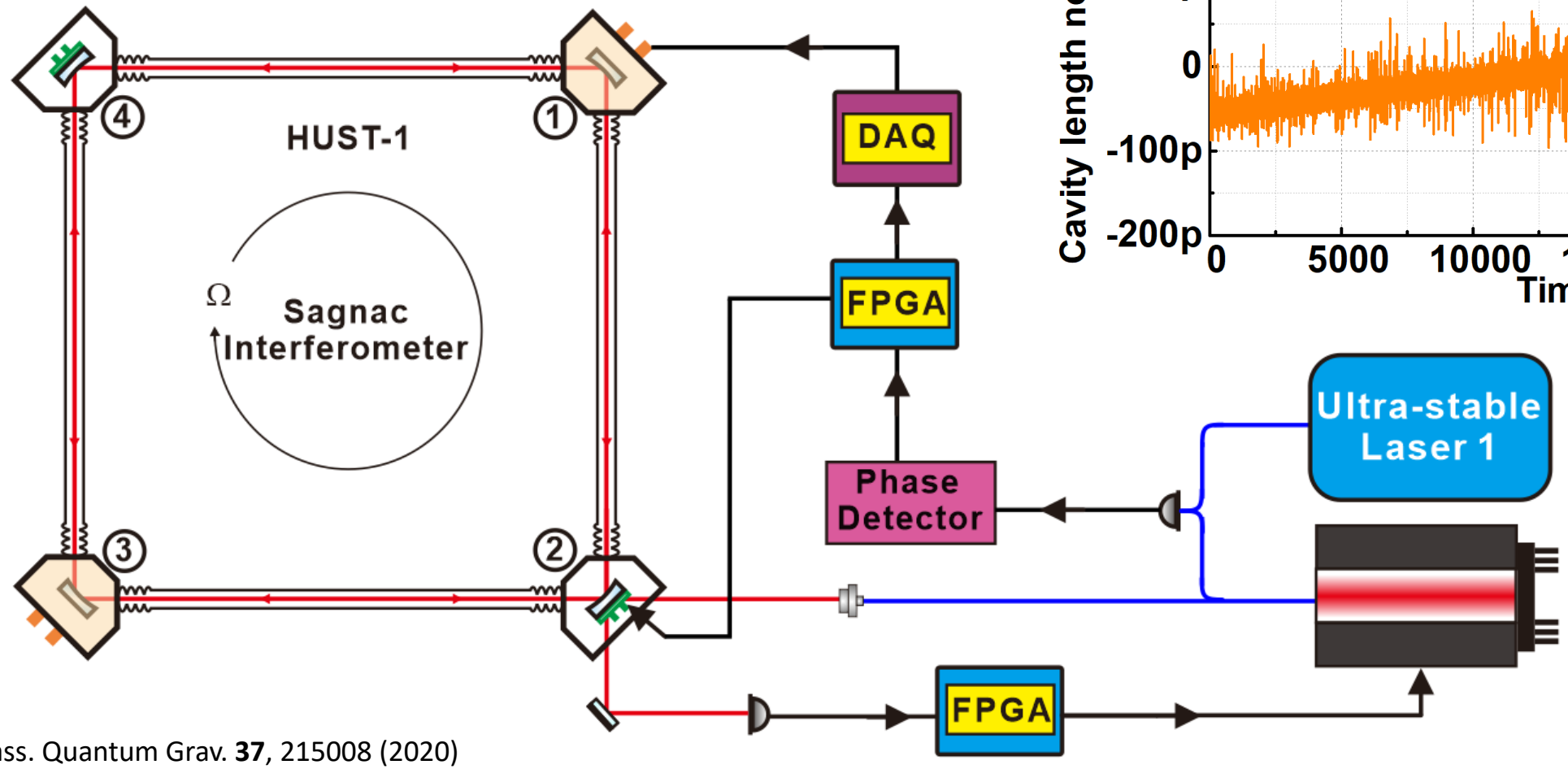


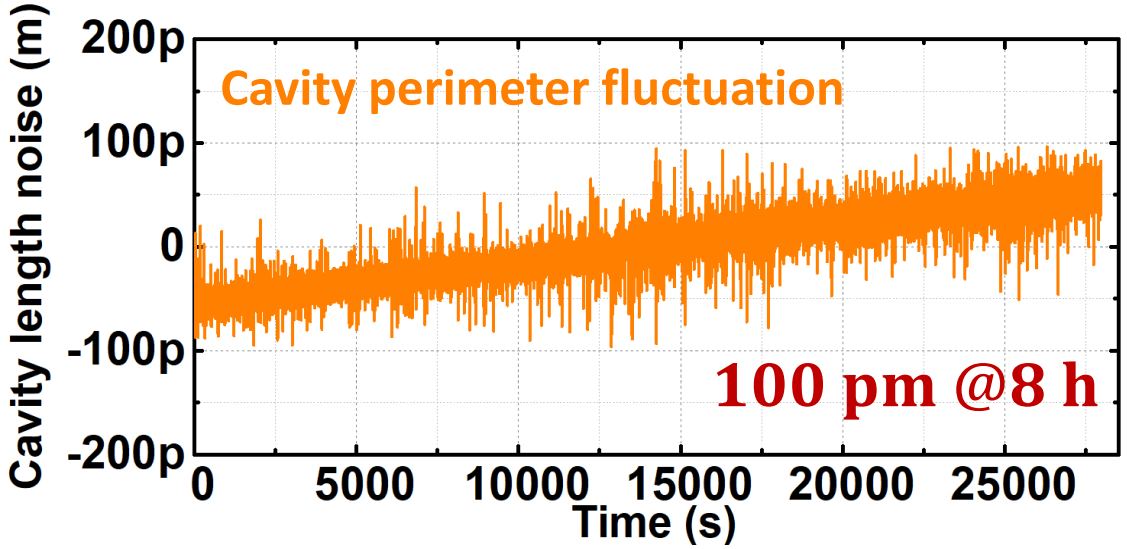
☐ Angular velocity resolution :4×10^{-6} rad/s @1000 s

- Cavity length fluctuation
- Laser frequency noise
- Residual amplitude modulation(RAM)

Cavity perimeter stabilization

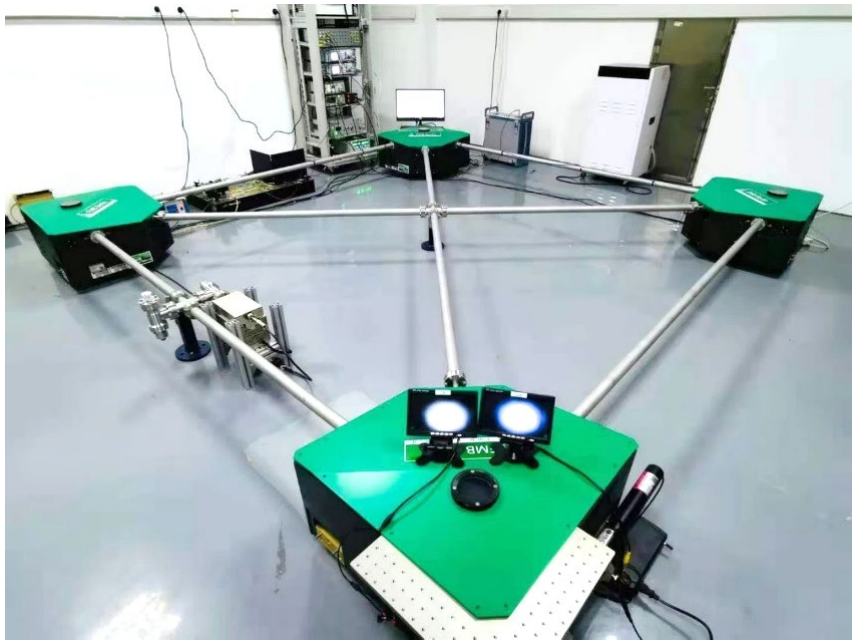
- Cavity perimeter control system
- Shor-term operation

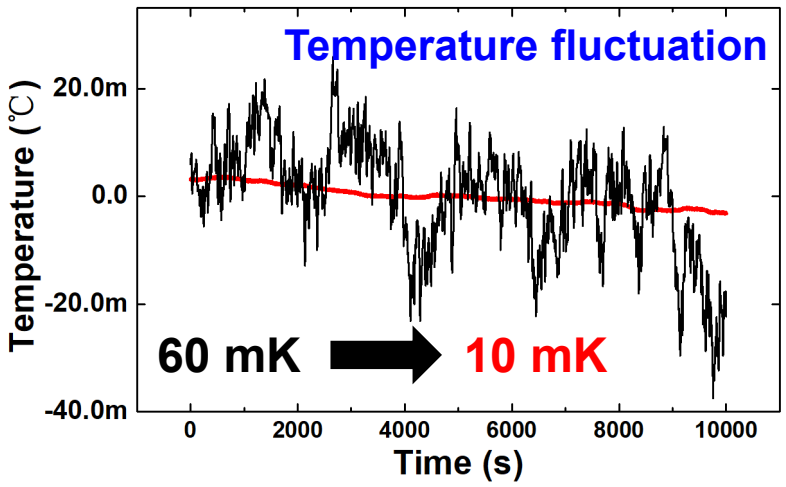


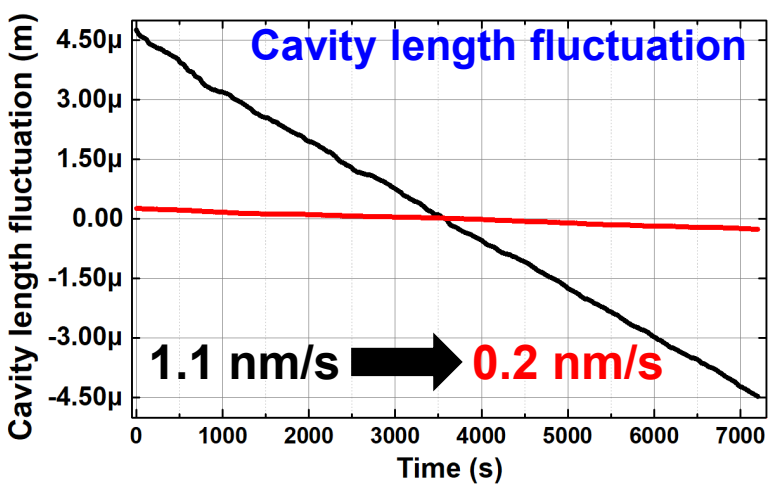


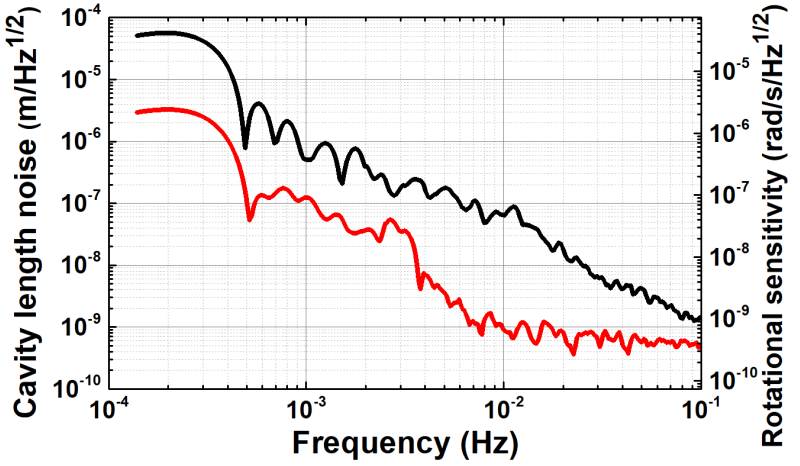
Class. Quantum Grav. **37**, 215008 (2020)

Environment optimization

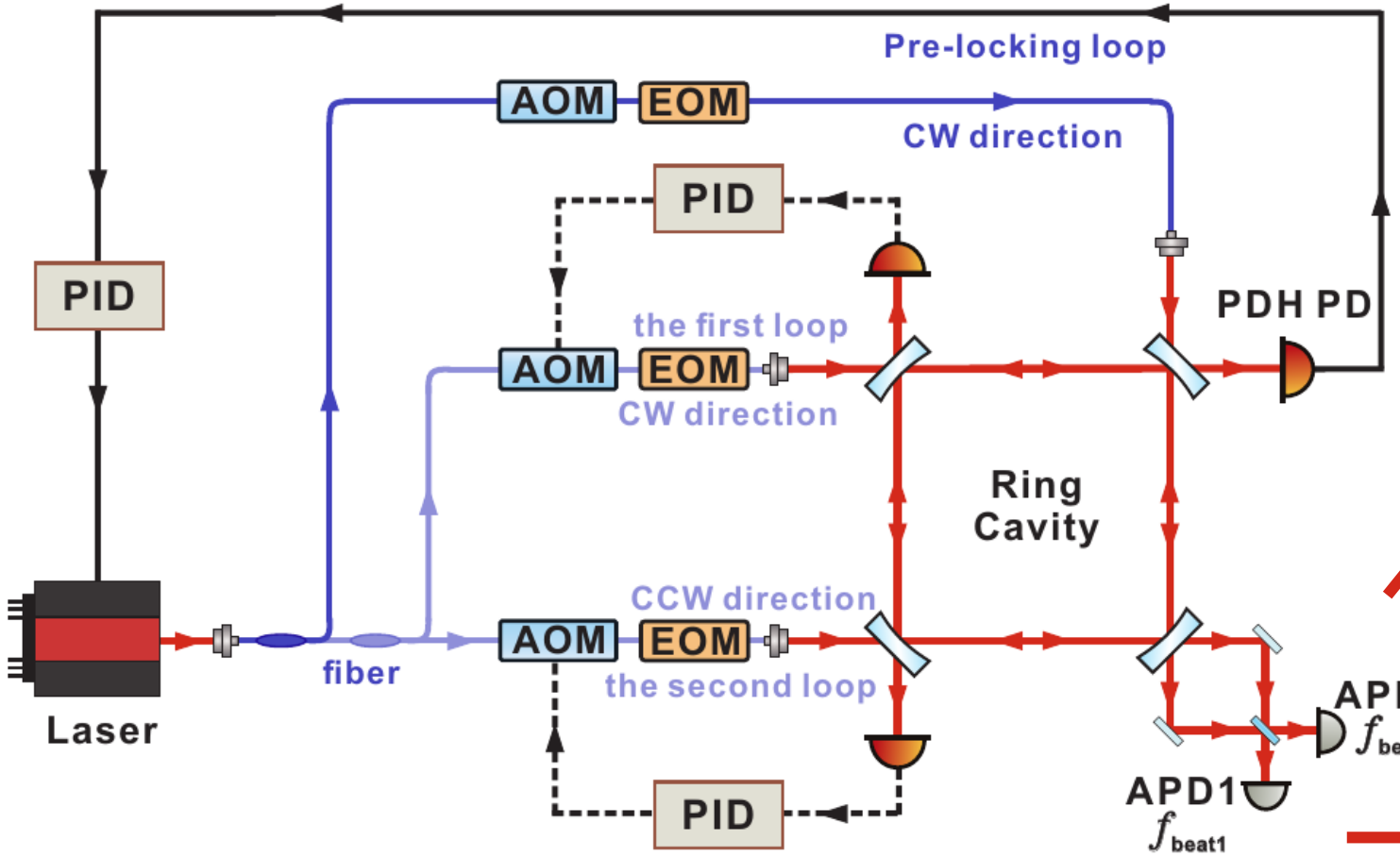




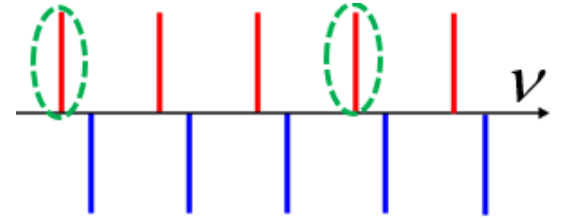




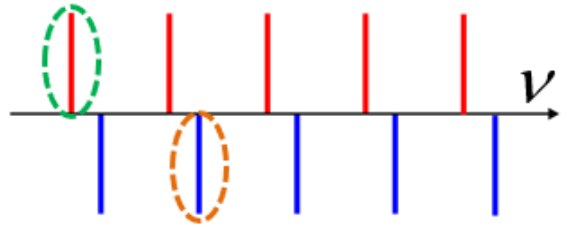
Three-wave locking scheme



- FSR *in-situ* measurement

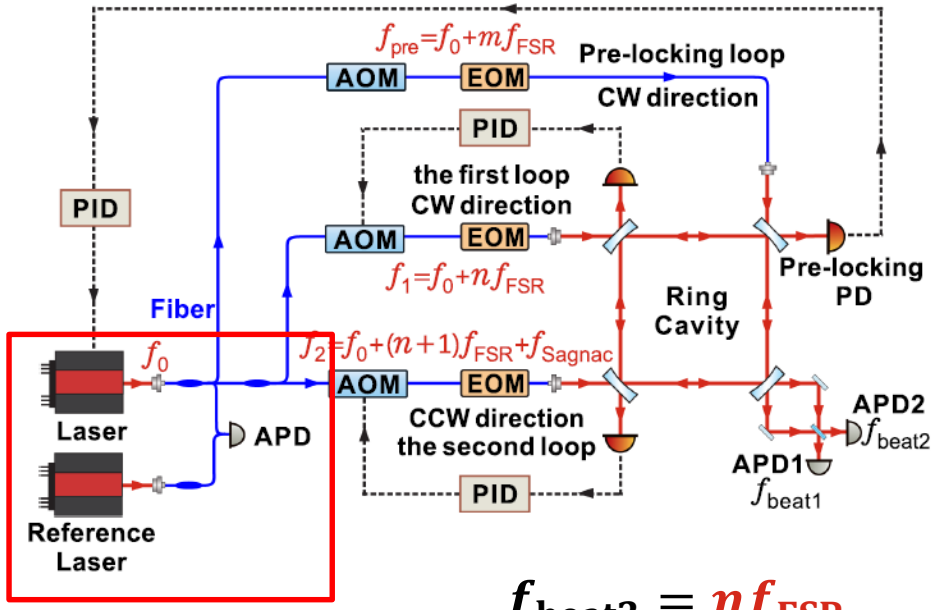


$$f_{beat2} = n f_{FSR}$$



$$f_{beat1} = f_{sagnac} + f_{FSR}$$

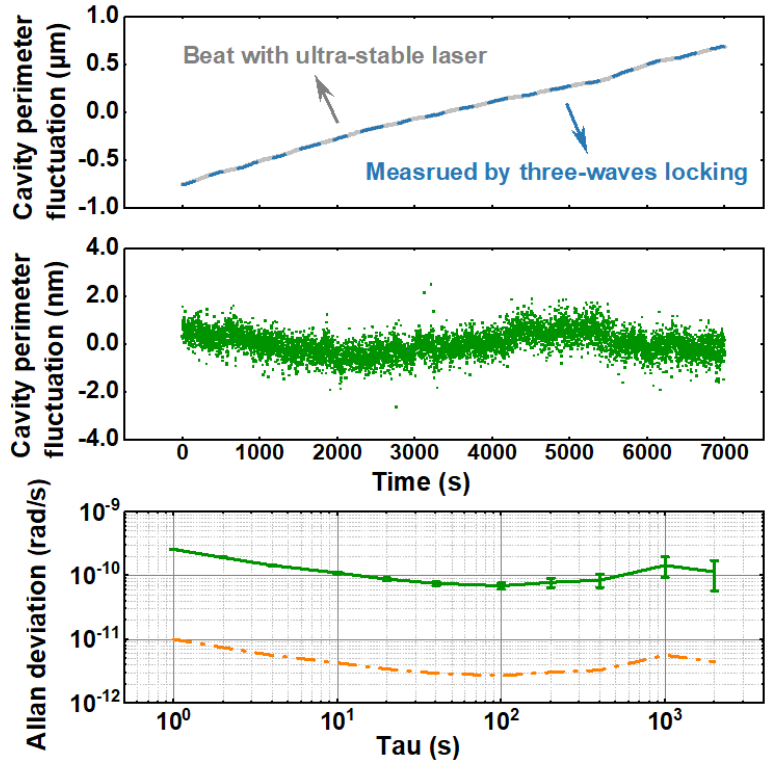
Unlock Sagnac frequency



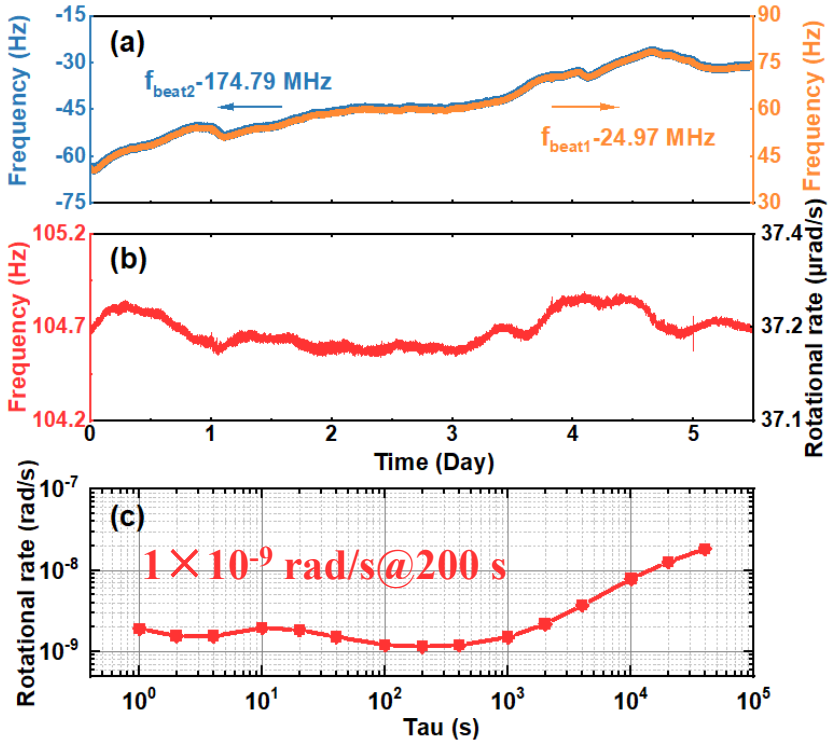
$$f_{\mathrm{beat2}} = nf_{\mathrm{FSR}}$$

$$f_{\mathrm{beat1}} = f_{\mathrm{sagnac}} + f_{\mathrm{FSR}}$$

Cavity-length-measurement evaluation scheme



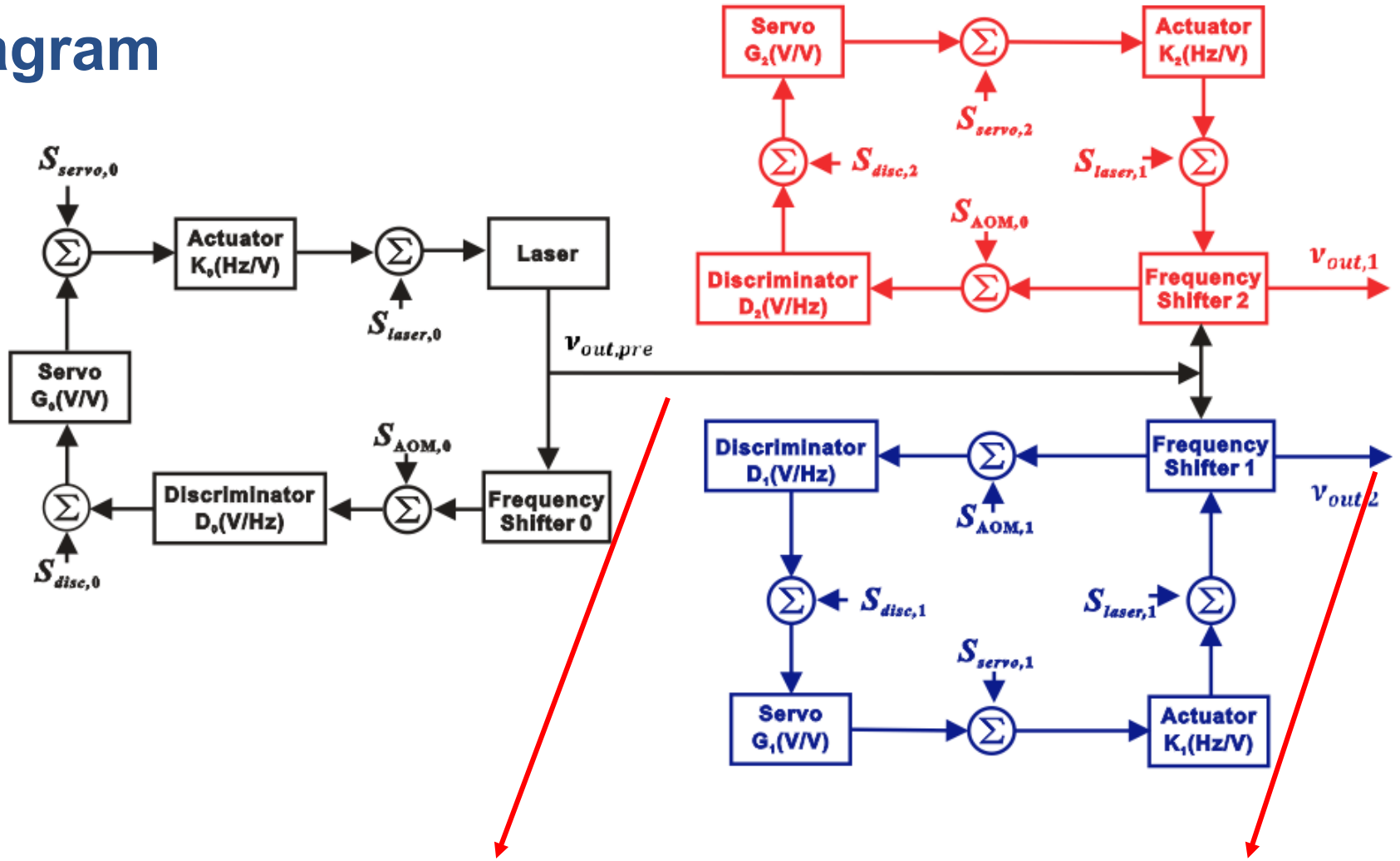
Cavity-length-fluctuation



Sagnac frequency unlock

Double-stage locking process

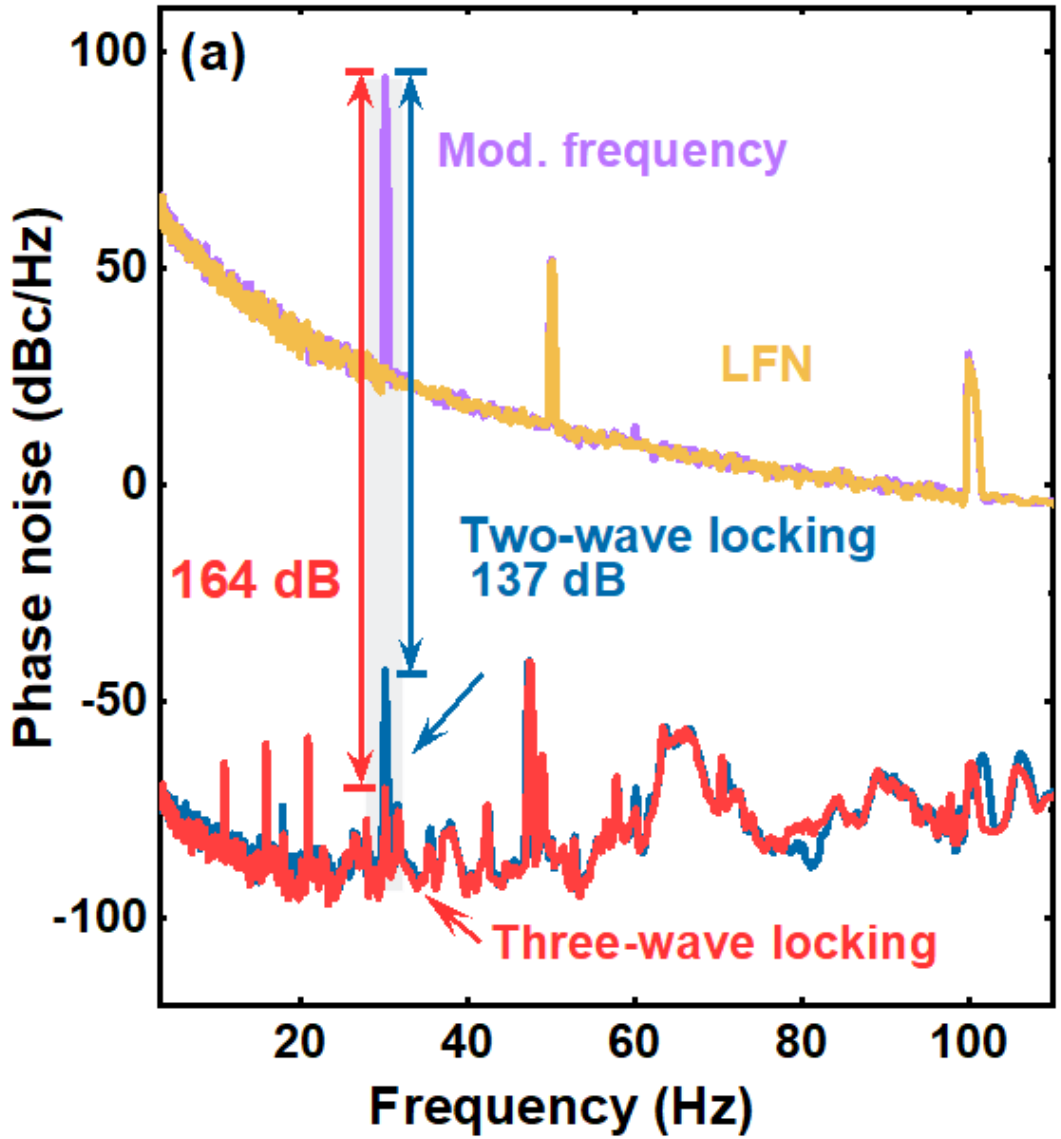
Control diagram

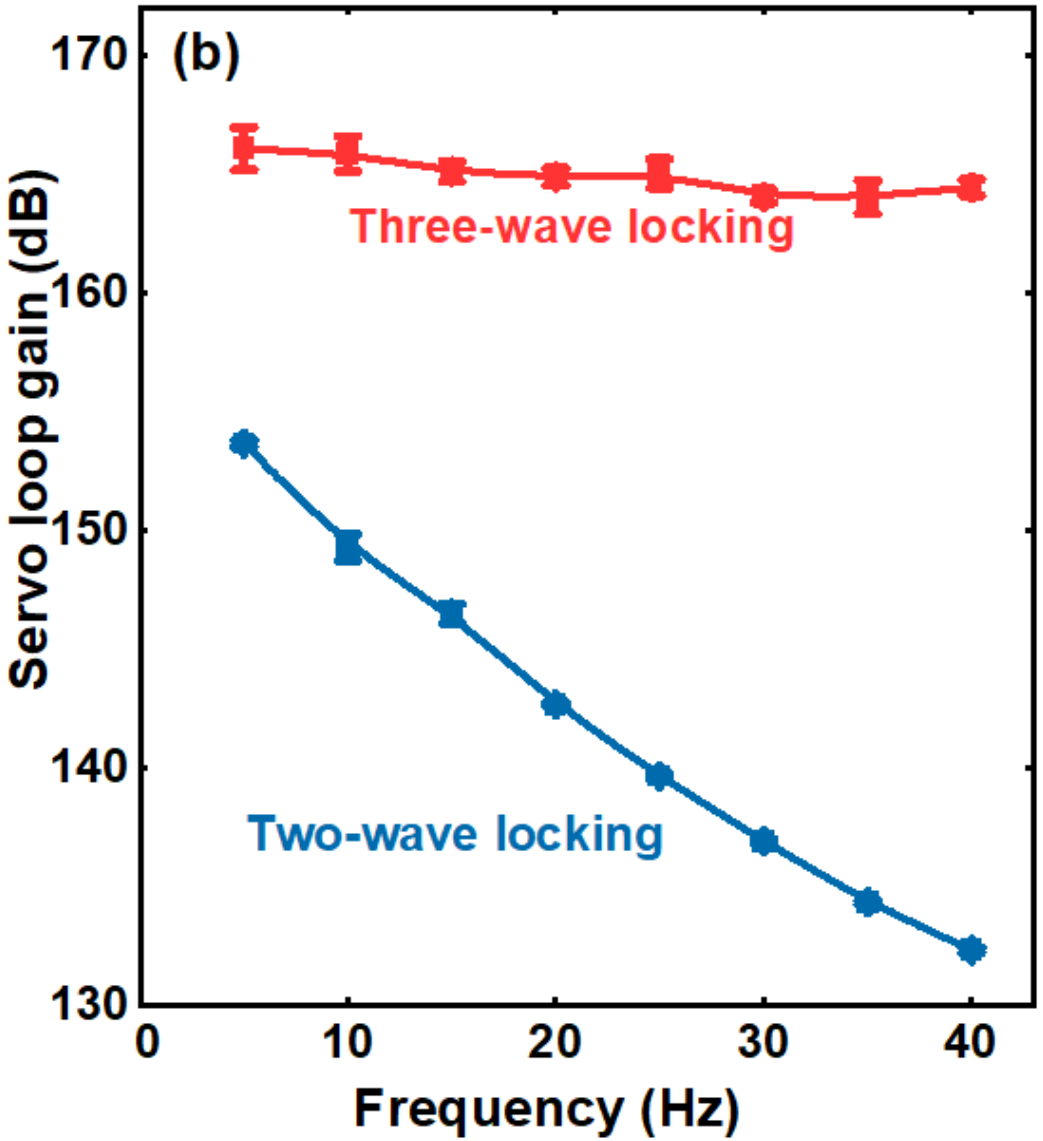


$$S_{\mathrm{LFN,pre}} \approx \frac{S_{\nu,\mathrm{laser}}}{G_{\mathrm{pre}}}$$

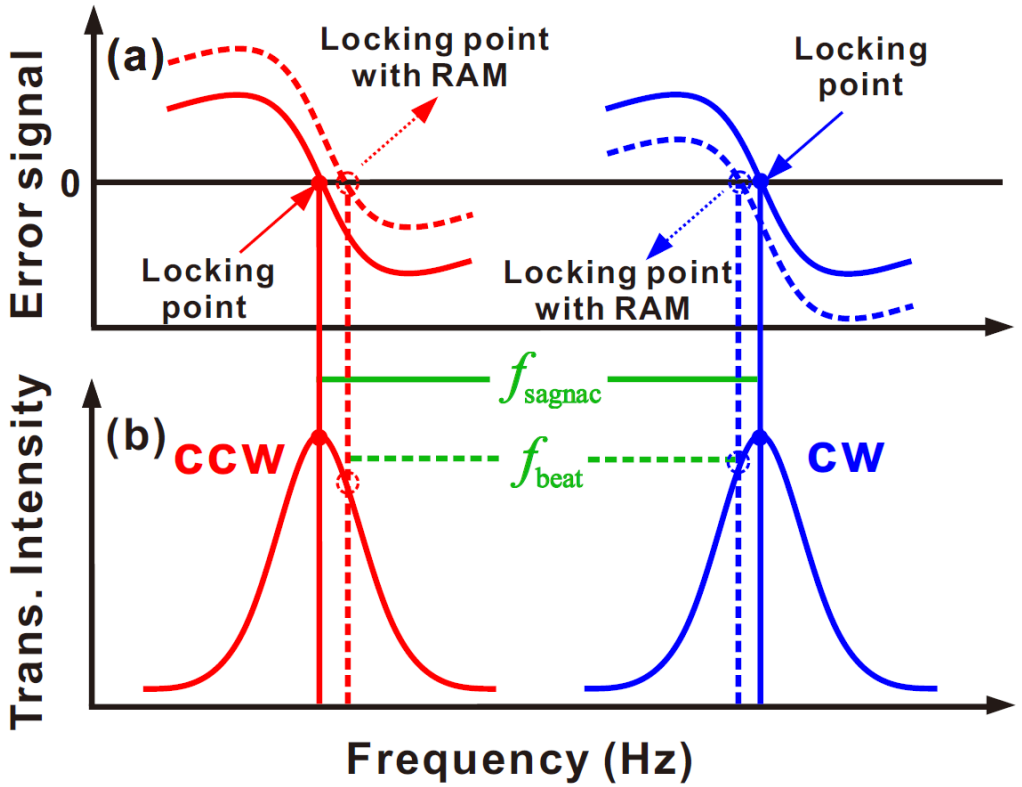
$$S_{\mathrm{LFN,out}} \approx \frac{S_{\mathrm{LFN,pre}}}{G_{\mathrm{i}}} \approx \frac{S_{\nu,\mathrm{laser}}}{G_{\mathrm{pre}} \cdot G_{\mathrm{i}}}$$

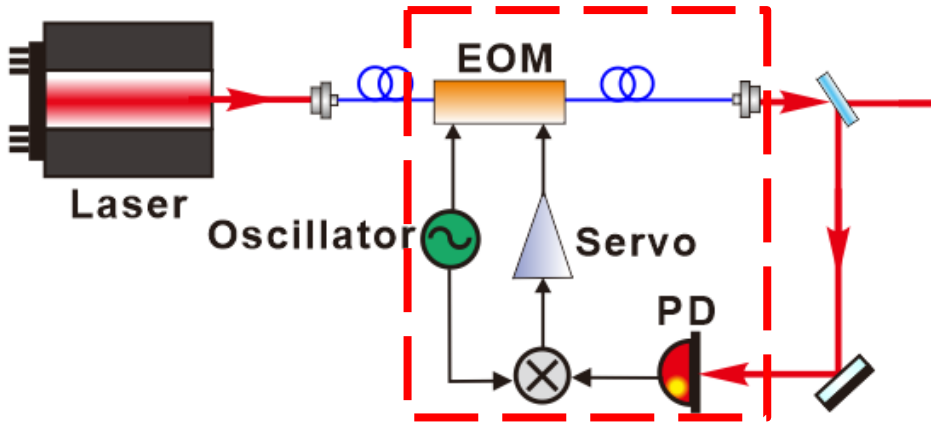
Double-stage locking process





RAM suppression

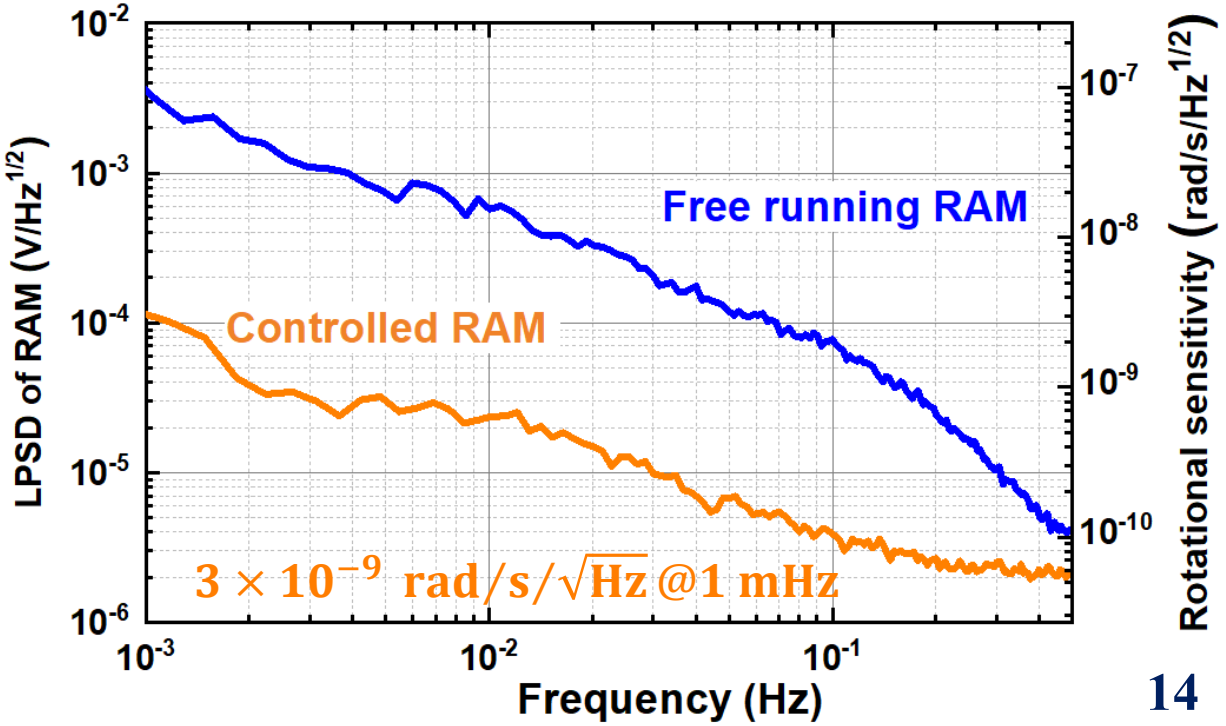




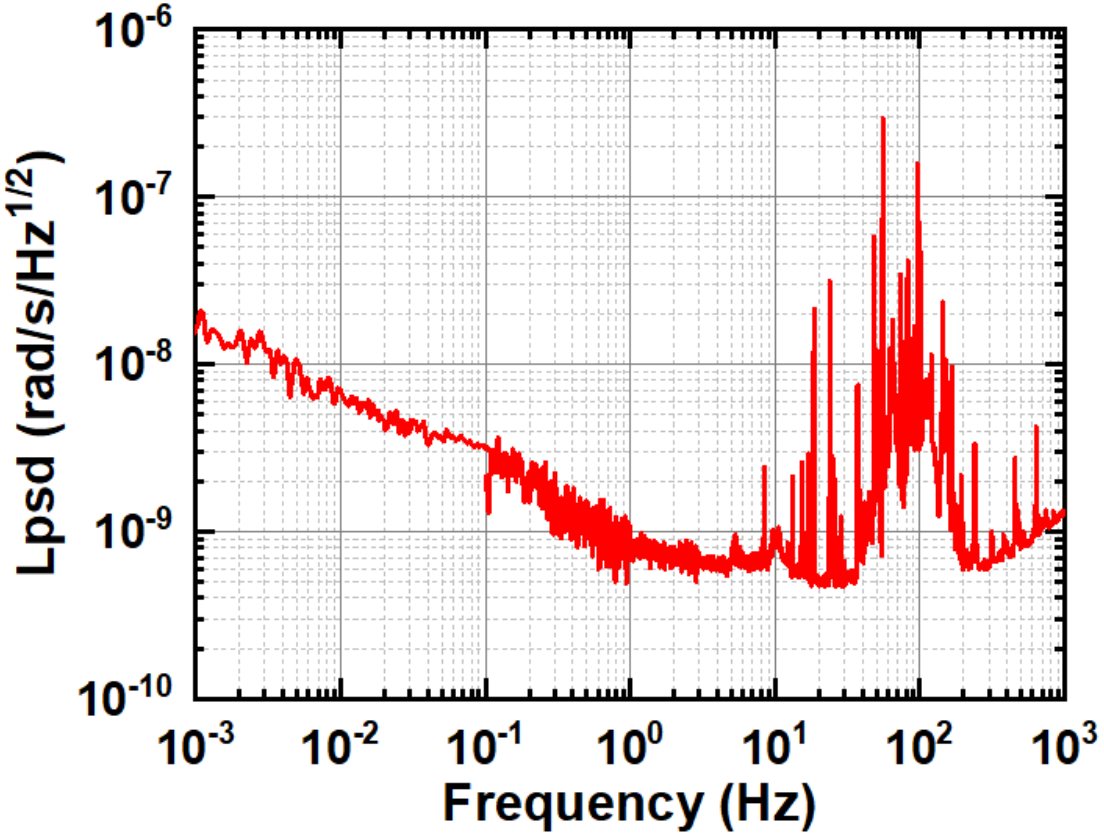
$$\Delta\nu_{\mathrm{offset}} = -\frac{V_{\mathrm{RAM}}}{D}$$

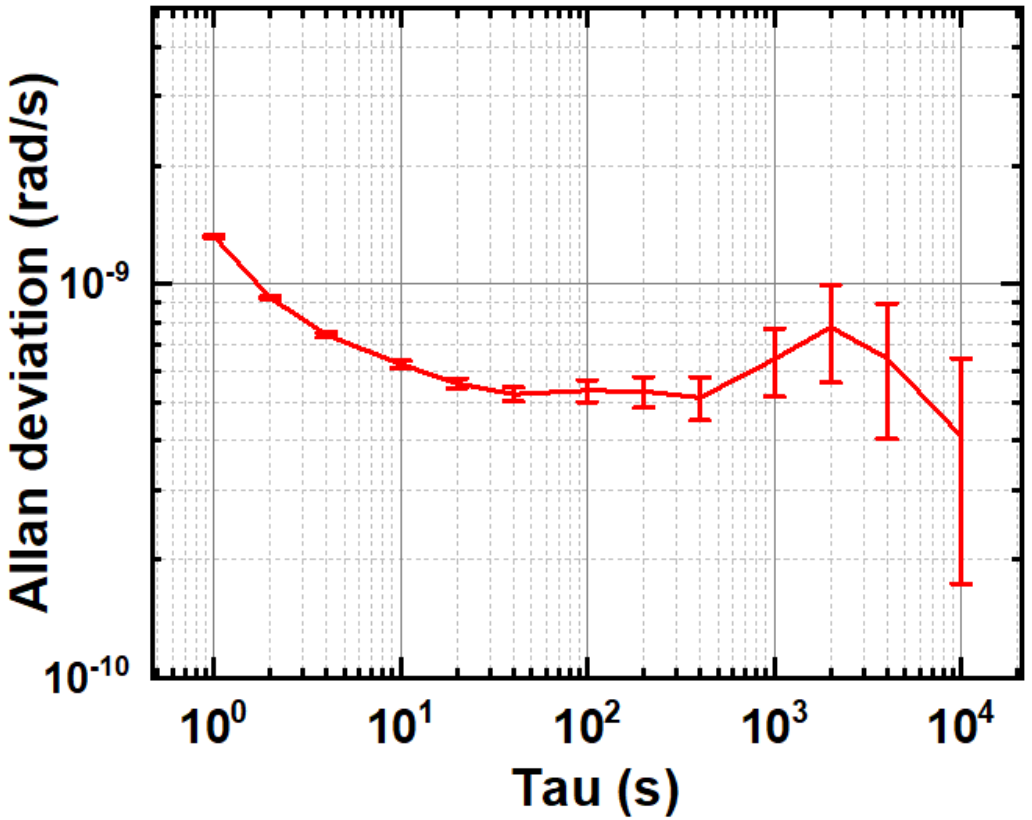
$$f_{\mathrm{beat}} = f_{\mathrm{sagnac}} + \Delta\nu_{\mathrm{offset,1}} + \Delta\nu_{\mathrm{offset,2}}$$

RAM contribution to rotational sensitivity



Gyroscope performance

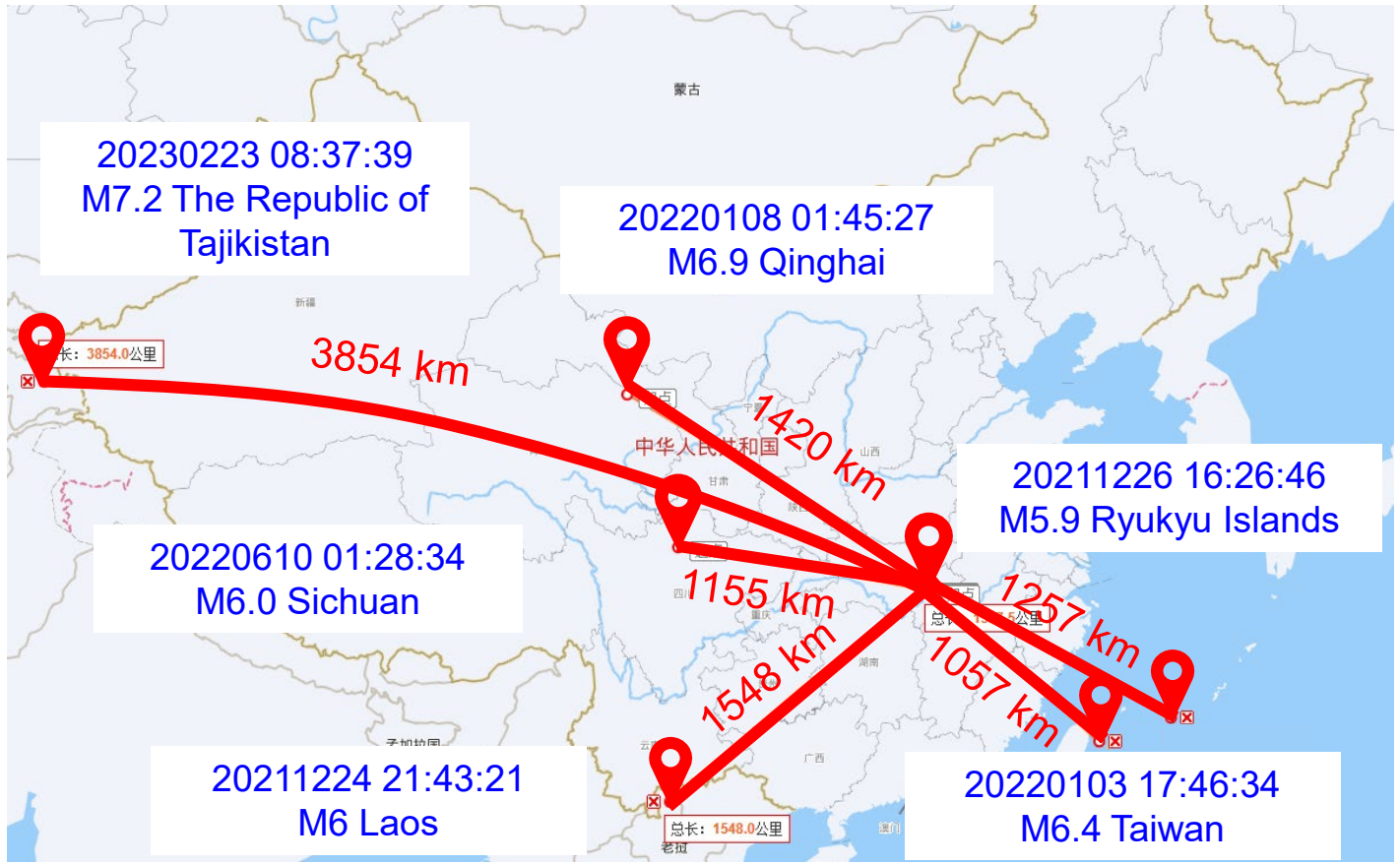


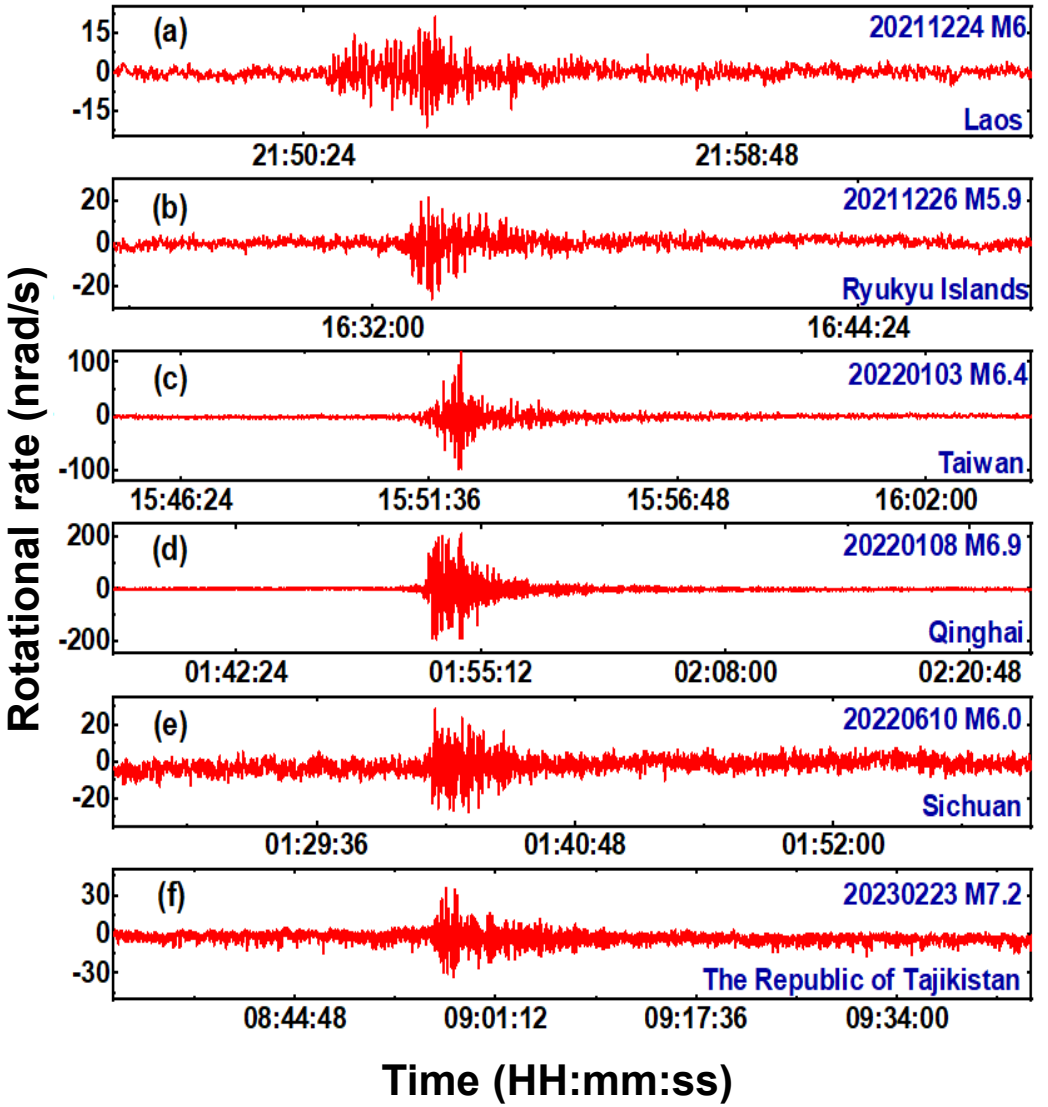


5×10^{-10} rad/s/√Hz @ 20 Hz

$4(2)\times10^{-10}$ rad/s @ 10000 s

Tele-seismic events recording





Continuously running over a year

Summary

- Environment optimization
- Three loops locking scheme
- Long-term operation
- Angular velocity resolution of HUST-1:

$$\mathbf{4(2) \times 10^{-10}\ rad/s\ @10000\ s}$$

Future plan

- Explore beam-jitter, back scattering, and other noises

Thanks!