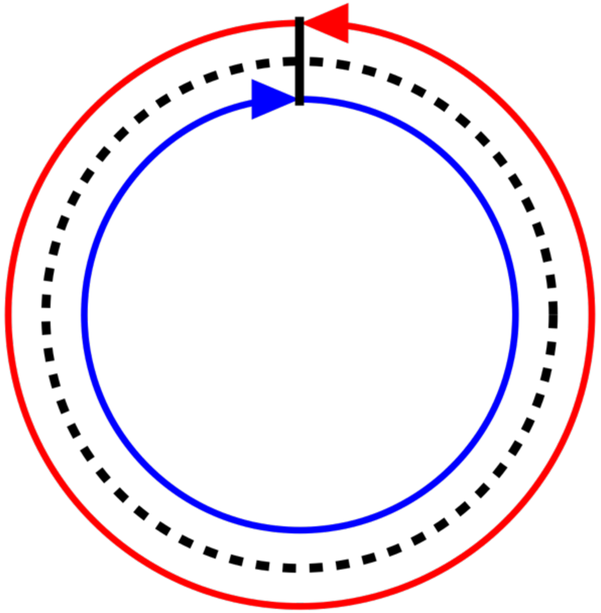
Large ring laser gyroscopes: geometry stabilization and control

Umberto Giacomelli

Outline

- Introduction to large ring laser gyroscopes
- GP2 and the idea of geometry control
- Diagonal and perimeter control

Sagnac Frequency



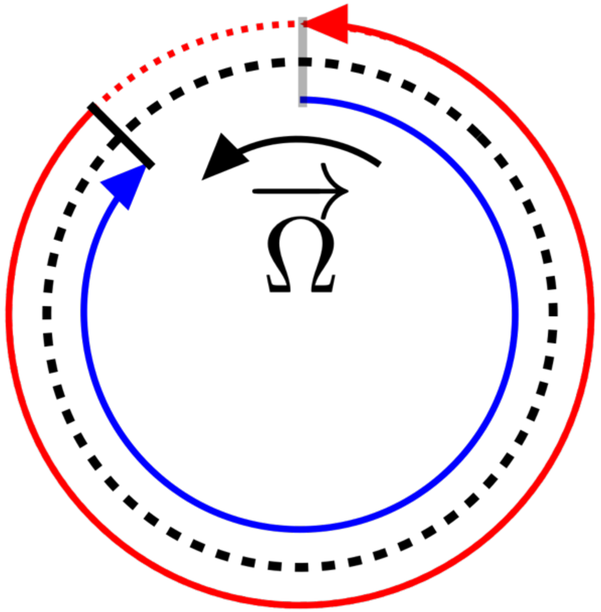
$$L_R = L_B$$

$$\lambda_R = \lambda_B$$

Reference frame rotation

$\Downarrow$

Frequency difference

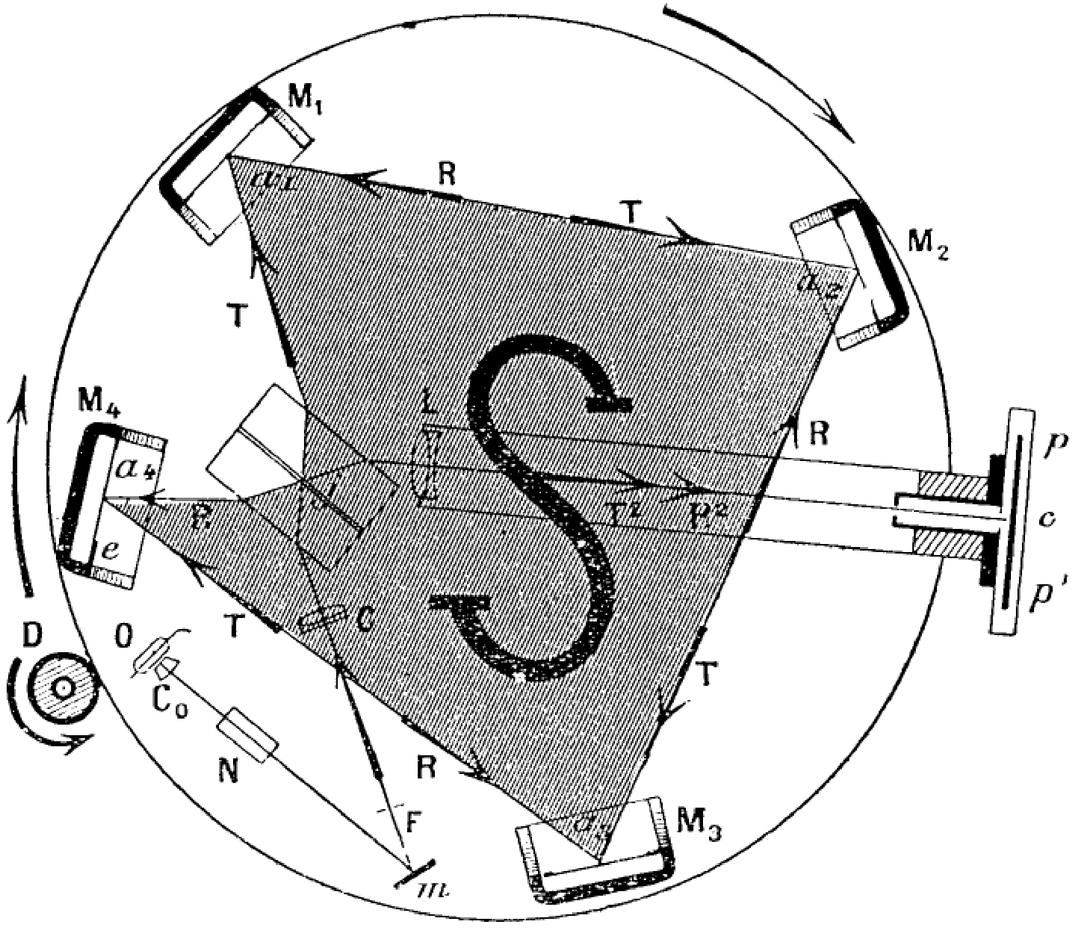


$$L_R > L_B$$

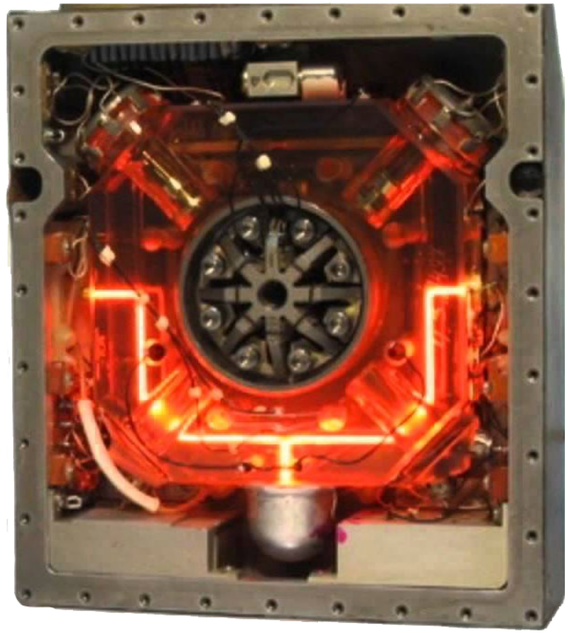
$$\lambda_R > \lambda_B$$

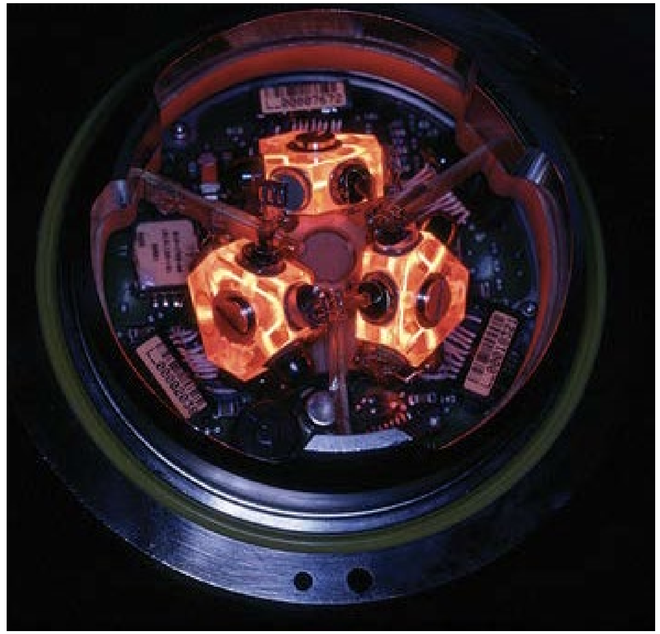
$$f_S = \frac{4A}{P\lambda}\hat{n} \cdot \overrightarrow{\Omega}$$

Ring Laser Gyroscope

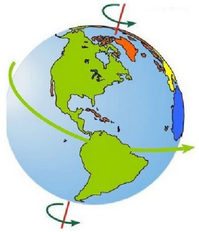


Georges Sagnac picture 1913

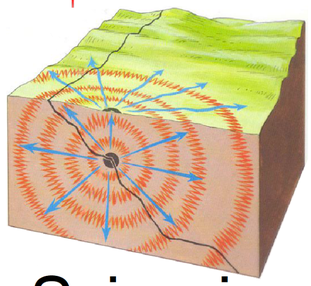




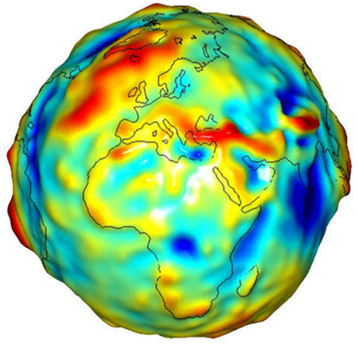
Ring Laser Gyroscope



Earth Rotation Rate



Seismic



Geodesy

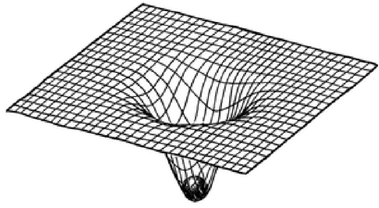
rad/s

10^{-4} 10^{-6} 10^{-8} 10^{-10} 10^{-12} 10^{-14}

Navigation

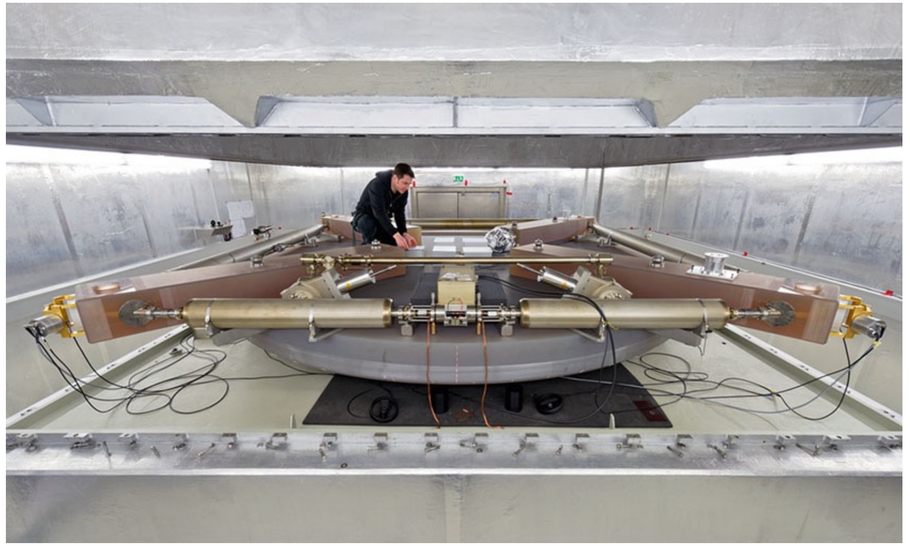
Earth Tides

General Relativity

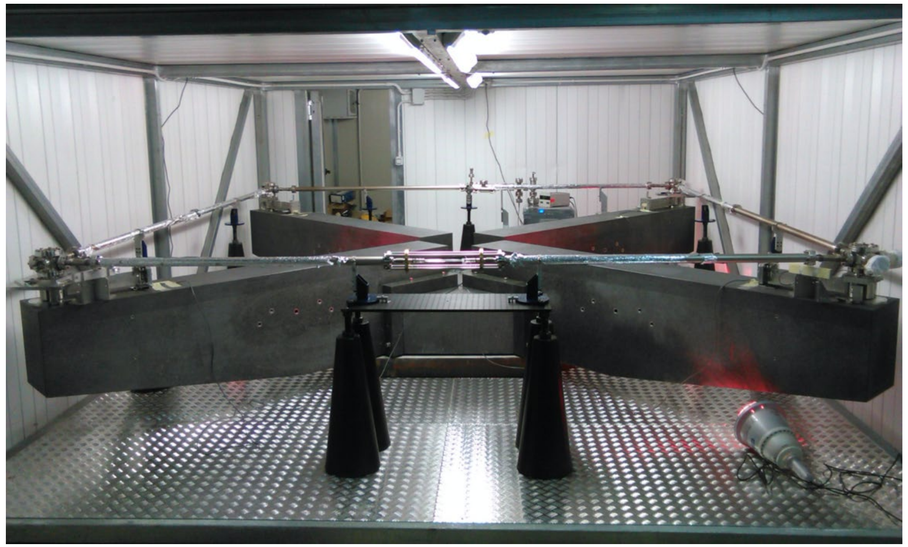


Large RLG

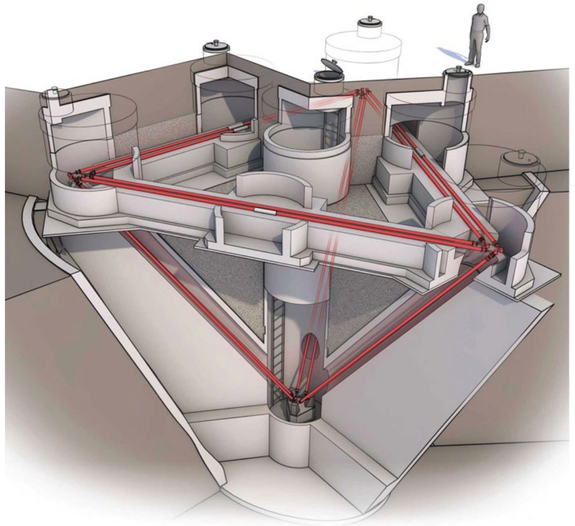
G



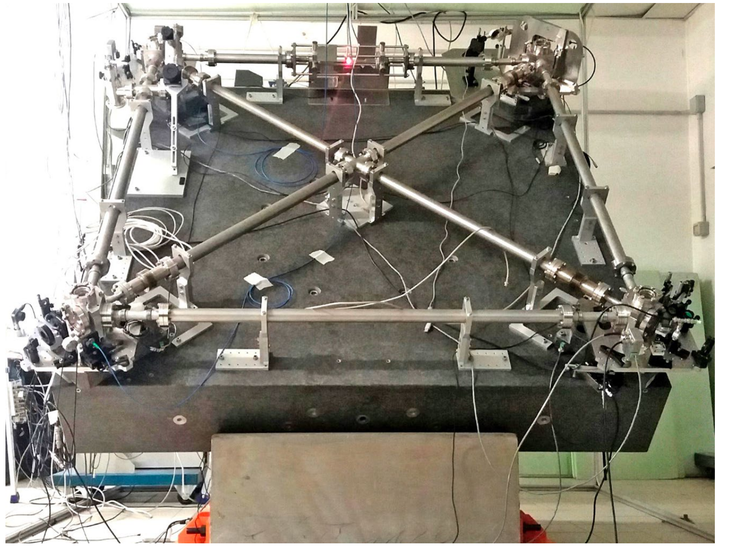
GINGERINO



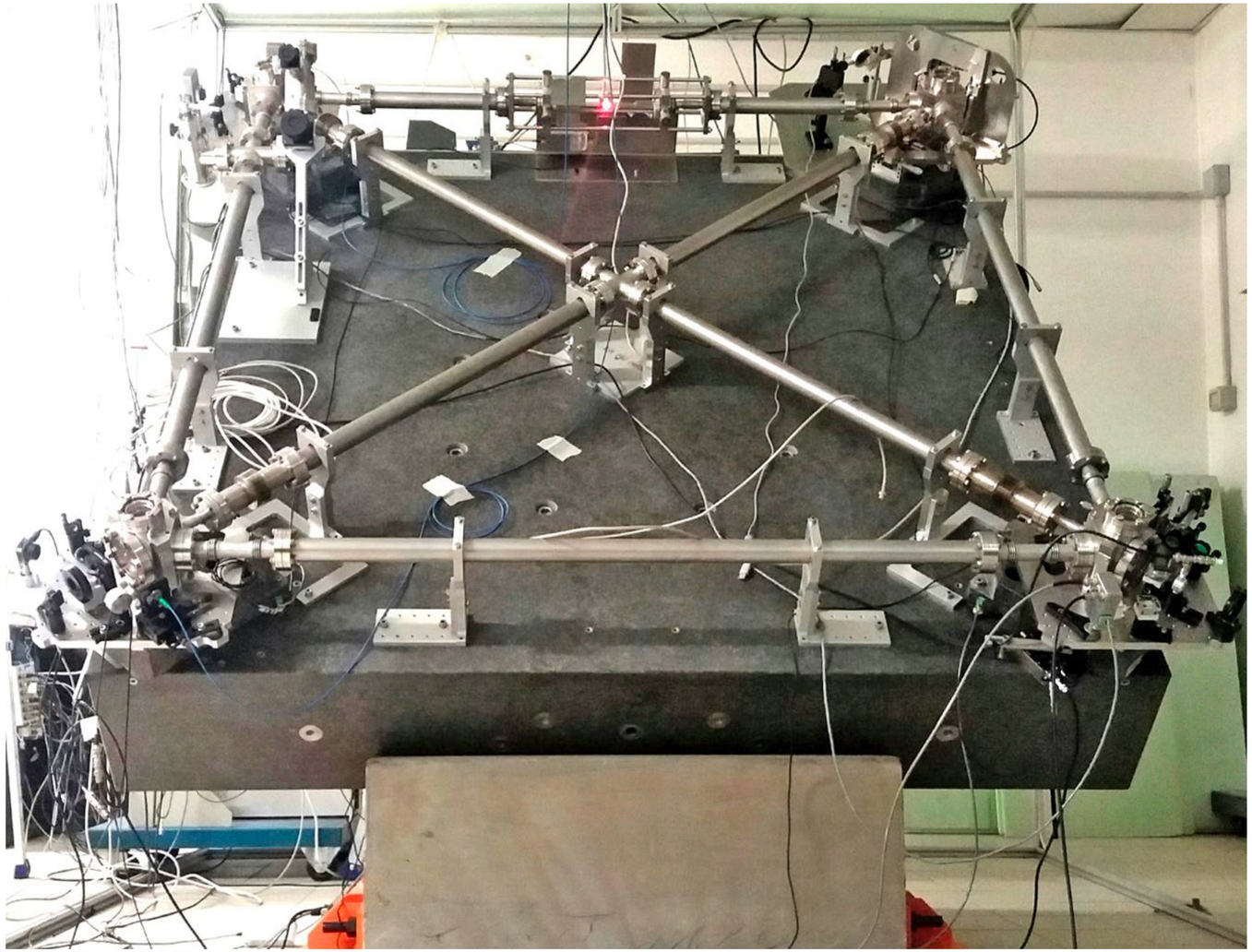
ROMY



GP2



GP2



Etherolithic RLG

1.6m Side

47° Tilted

4 PZT

Belfi J. et al. Class. Quant. Grav. 31, (2014)

RLG Geometry

$$f_S = \frac{4A}{P\lambda}\hat{n} \cdot \overrightarrow{\Omega}$$

RLG Geometry

Scale factor k

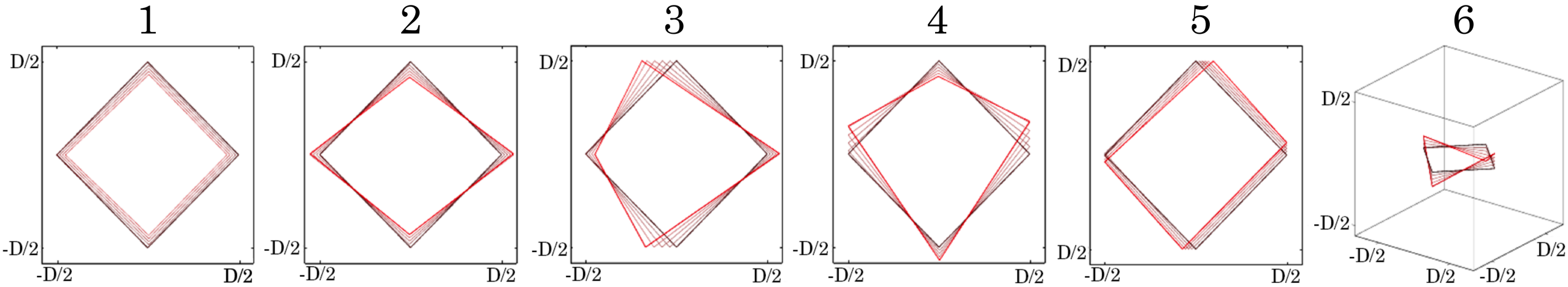
$$f_S = \frac{4A}{P\lambda}\hat{n} \cdot \overrightarrow{\Omega}$$

Geometry control and Stabilization

Diagonal or Perimeter

RLG Geometry

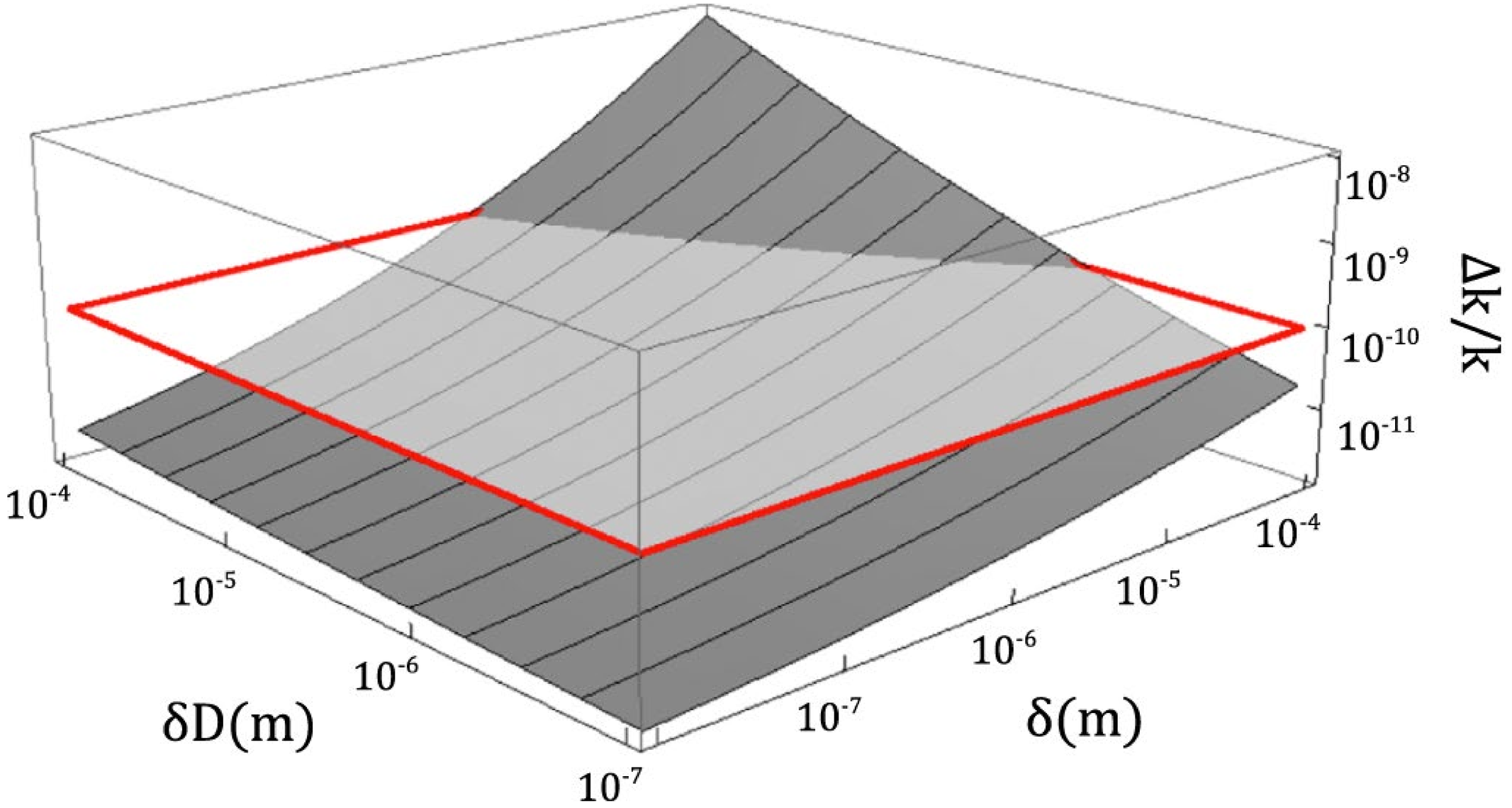
Hypothesis of small perturbation of perfect square



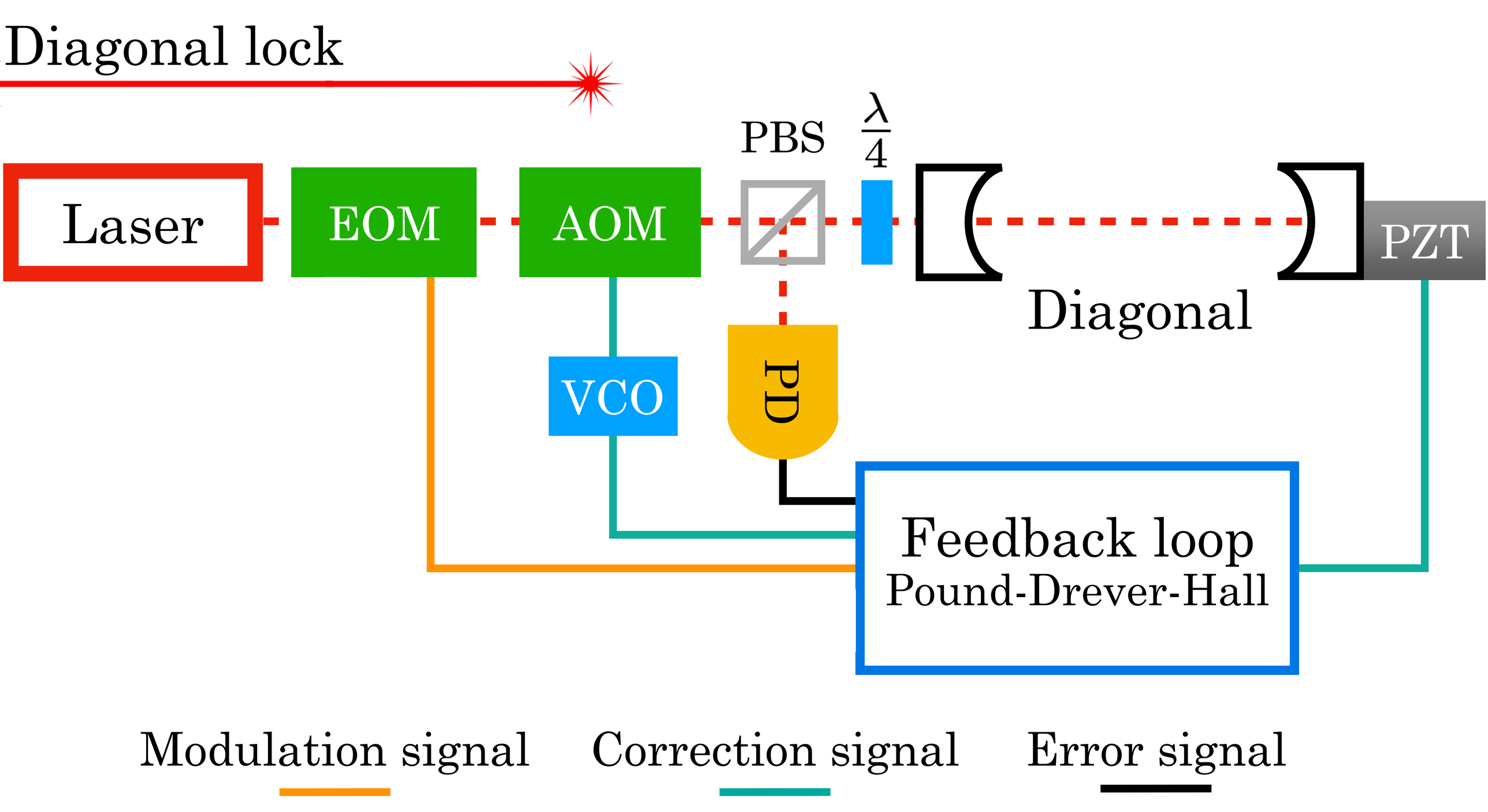
$$k = \frac{L}{\lambda}\left[1 - \frac{\tau_1}{\sqrt{2}L} + \frac{\tau_1^2}{2L^2} - \frac{\tau_2^2}{4L^2} - \frac{2L+\sqrt{2}r}{4L\left(r-\sqrt{2}L\right)^2}\left(\tau_3^2+\tau_4^2\right) - \frac{L+2\sqrt{2}r}{L\left(4r-\sqrt{2}L\right)^2}\tau_6^2\right]$$

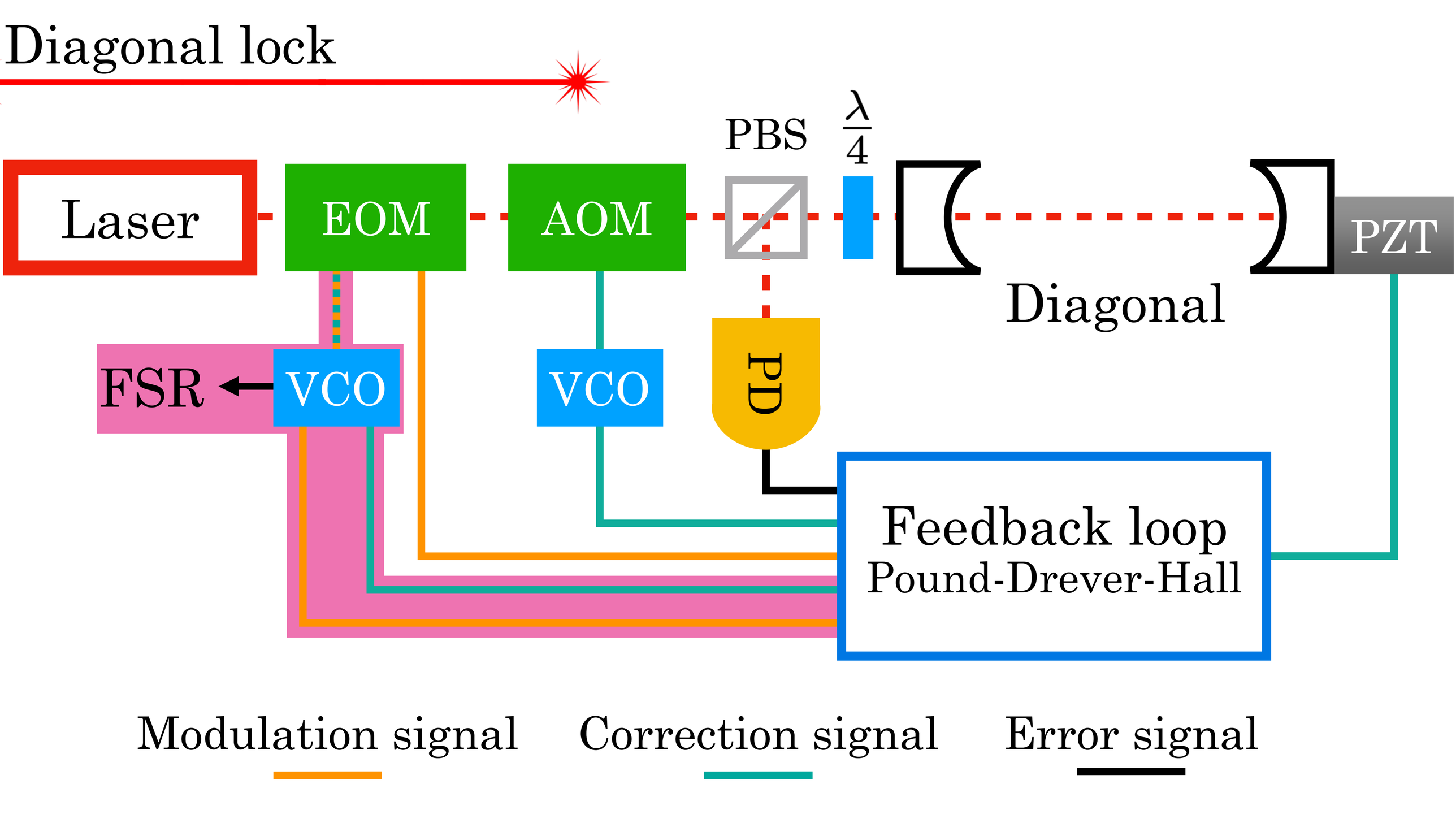
Santagata R. et al. Class. Quant. Grav. 32, (2015)

RLG Geometry



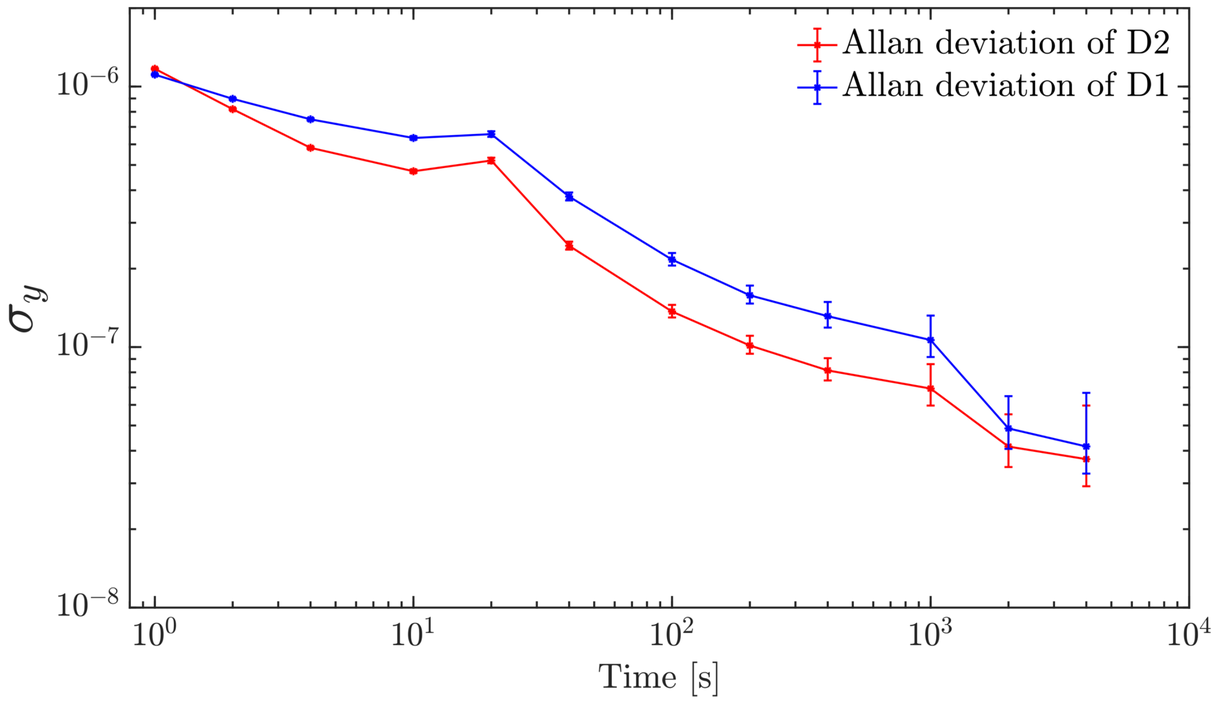
Santagata R. et al. Class. Quant. Grav. 32, (2015)


Diagonal lock
Laser
EOM
AOM
PBS
$\frac{\lambda}{4}$
PZT
Diagonal
VCO
PD
Feedback loop
Pound-Drever-Hall
Modulation signal
Correction signal
Error signal

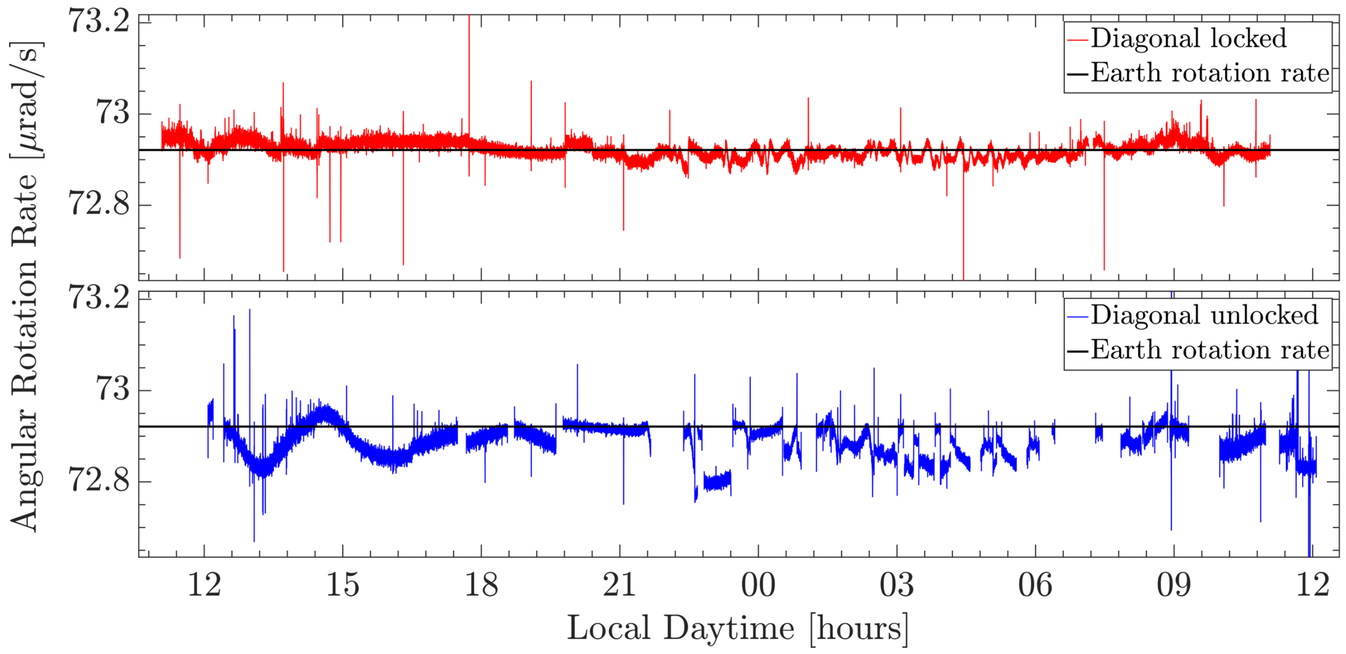

Diagonal lock
PBS
$\frac{\lambda}{4}$
Laser
EOM
AOM
PZT
Diagonal
FSR
VCO
VCO
PD
Feedback loop
Pound-Drever-Hall
Modulation signal
Correction signal
Error signal

Diagonal lock

Implementation of geometrical stabilization

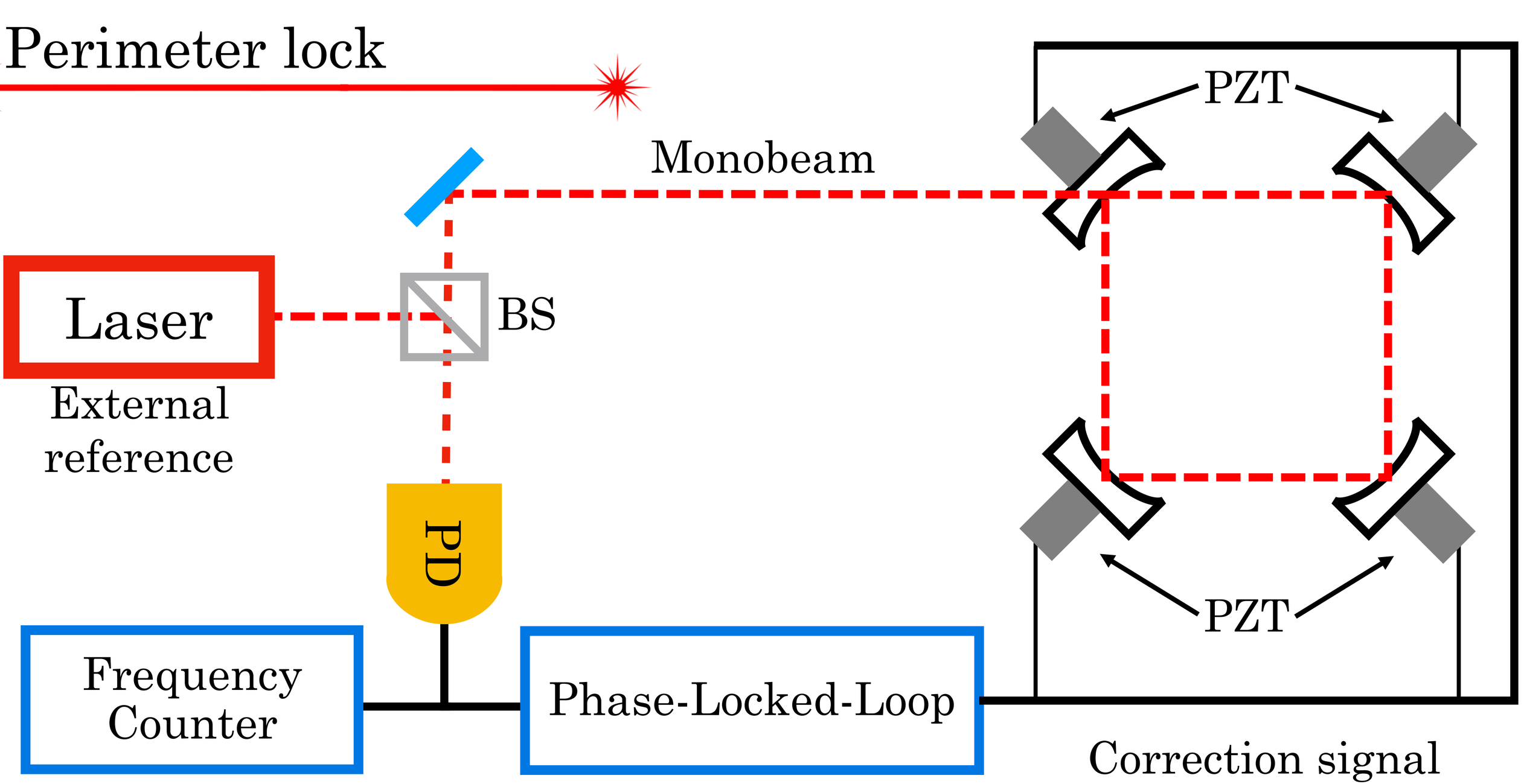


Diagonals length stability



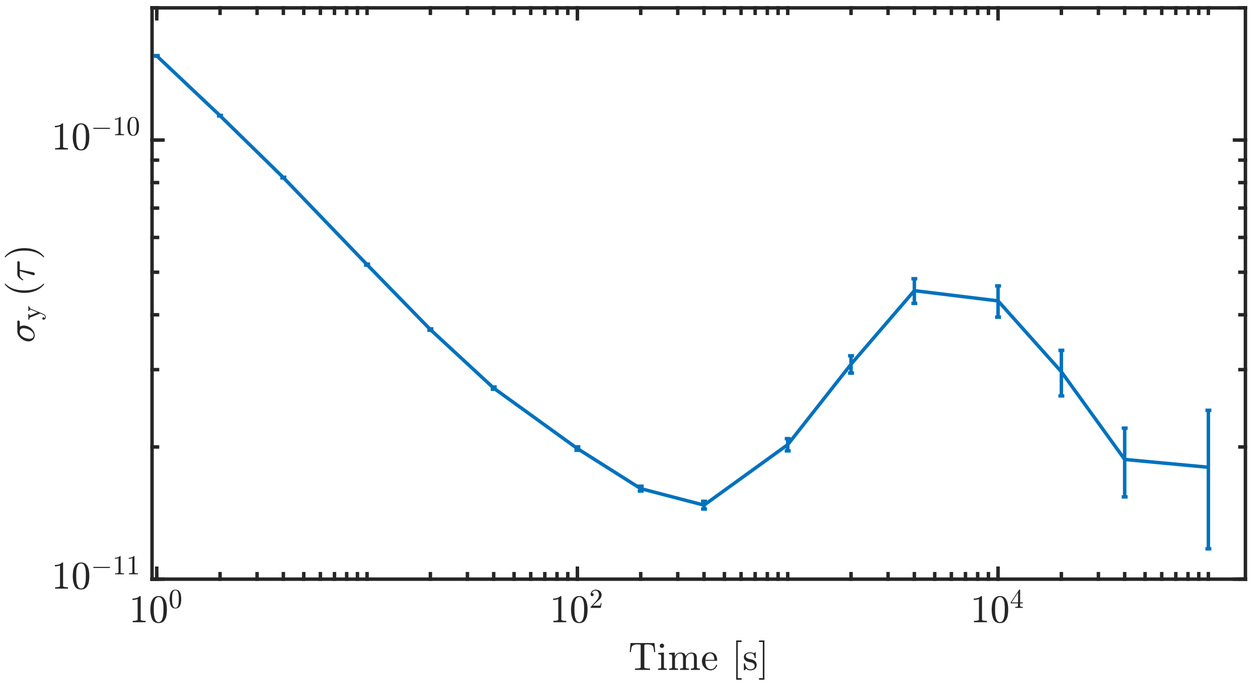
GP2 Earth angular rotation rate measurement while diagonals are locked (top) and free run (bottom)

N. Beverini et al Class. Quantum Grav. 37 065025 (2020)

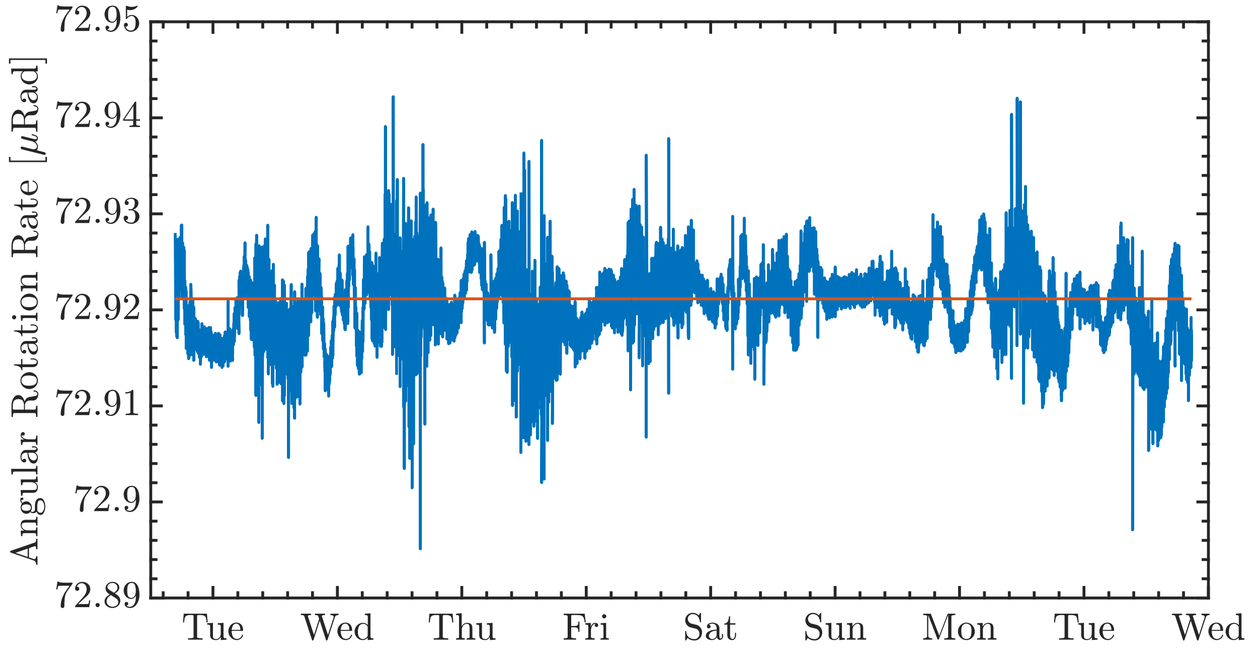

Perimeter lock
Monobeam
PZT
PZT
Laser
External reference
BS
PD
Frequency Counter
Phase-Locked-Loop
Correction signal

Perimeter lock

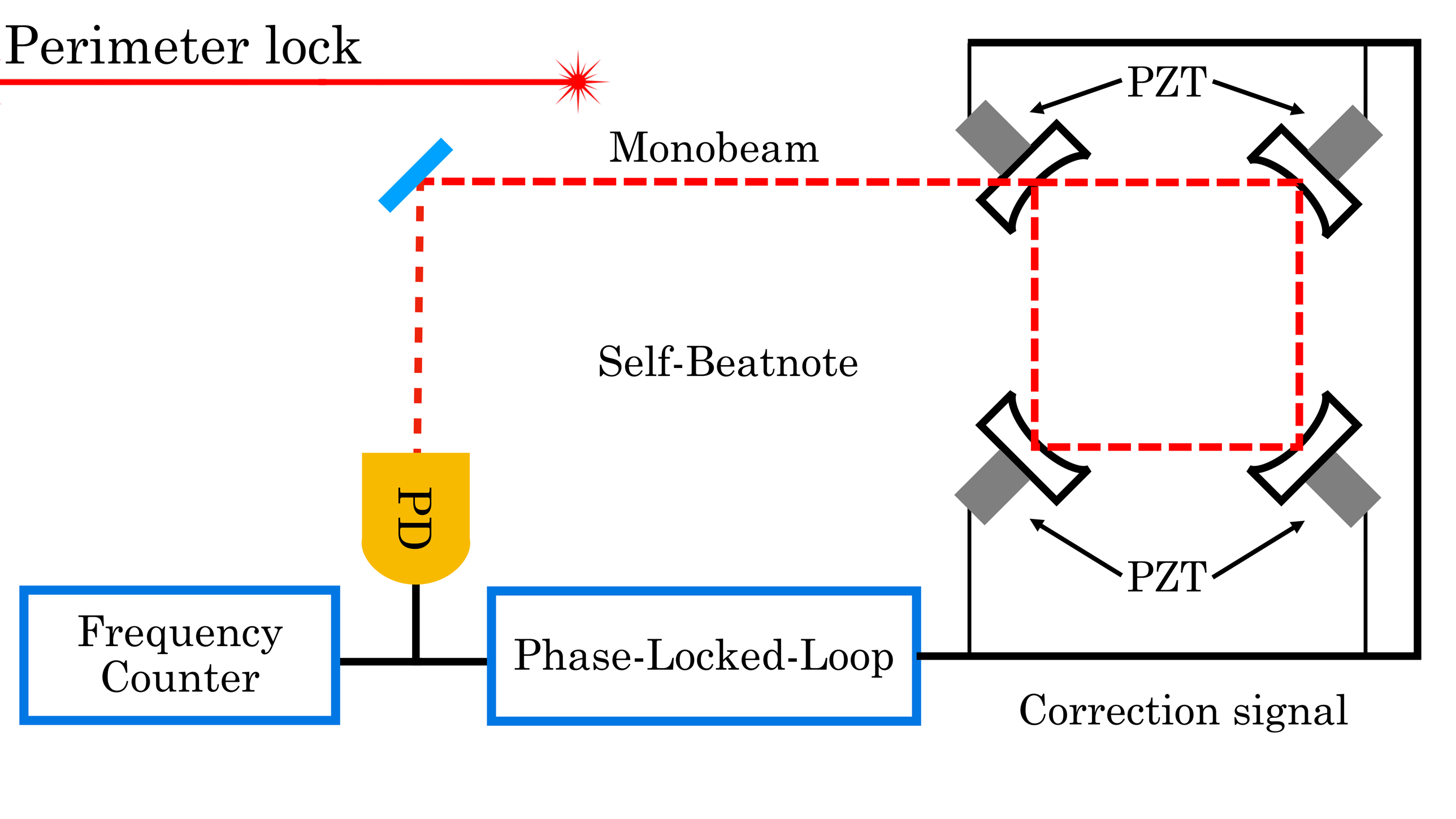
Implementation of geometrical stabilization



Wavelength stability



GP2 Earth angular rotation rate measurement while perimeter is locked


Perimeter lock
Monobeam
PZT
PZT
Self-Beatnote
PD
Frequency Counter
Phase-Locked-Loop
Correction signal

Conclusion

Mathematical model and experimental results demonstrate that the diagonal control is feasible to achive target stability for GR

Perimeter control could be a valuable alternative especially using the self-beatnote technique

Conclusion

Mathematical model and experimental results demonstrate that the diagonal control is feasible to achive target stability for GR

Perimeter control could be a valuable alternative especially using the self-beatnote technique

Thanks for your attention