Passive and Active Ring Lasers for Geodesy

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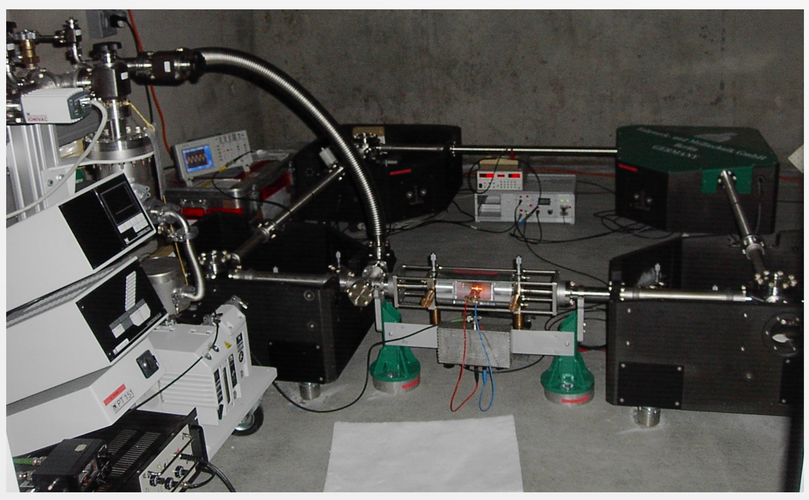
Gyroscope

Motivation

Ring laser gyroscopes (RLGs) have drastically improved in terms of sensitivity and stability in the last decades. This makes them a powerful sensor in the fields of geodesy and seismology, and might allow for new approaches to explore fundamental phenomena in special relativity. Highly stable RLGs come in two flavors: active and passive, where the laser gain medium is placed inside and outside of the resonator. We study the technological limitations of both approaches, and we present early results and future plans. This work emerges from a close collaboration between the teams at Wettzell/TU Munich, the University of Vienna, and the University of Bonn.

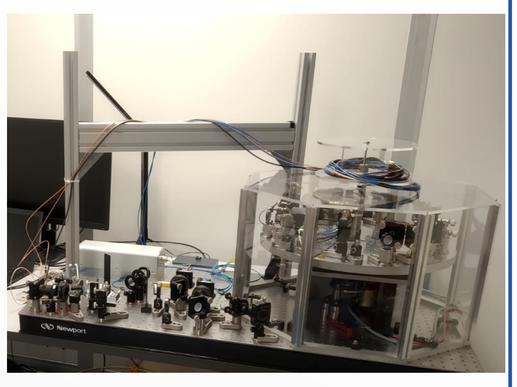
GeoSensor

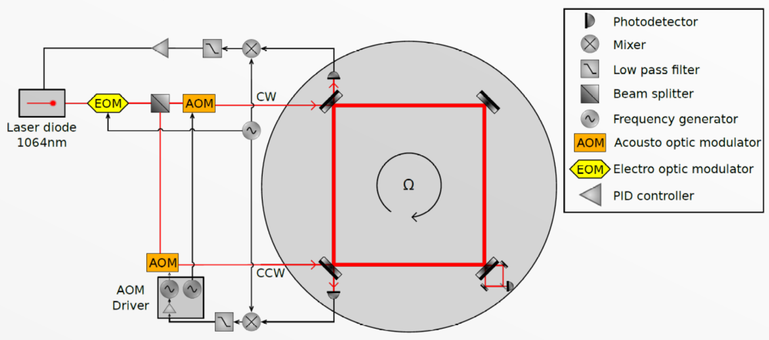
- World first approach for simultaneous active and passive operation
- Moved from Southern California to Bonn in 2022
- Increase arm length from 1.6 m to 3.5 m
- Finesse = 300 000
- Sensitivity = 108 prad/s/sqrt(Hz)
- Systematic study relevant for the G-ring in Wettzell:
  influence of fluctuations in the plasma, isotope composition, B field,...



Prototype: Heterolythic Passive Gyroscope

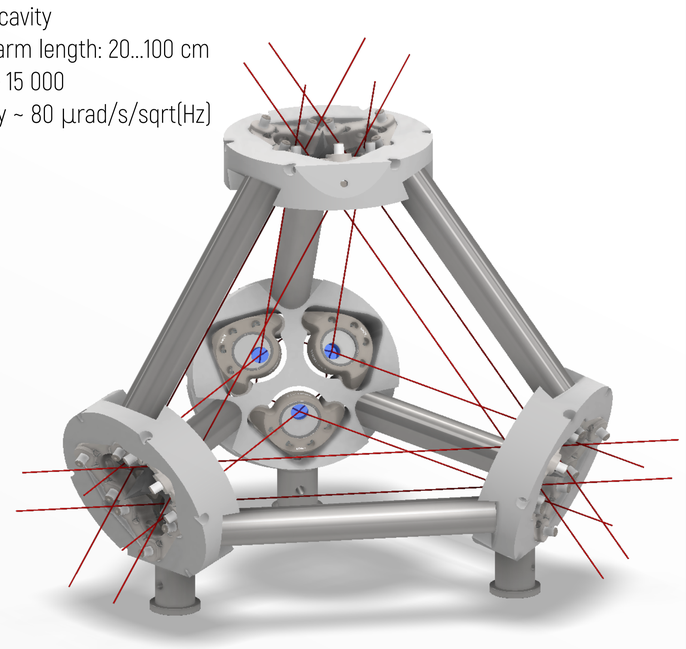
- Passive gyroscope
- Constructed from descrete optical elements
- Part of the Students' Masters practical course
- Study electronic possibilities of PDH locking, beat read-out and pre-stabilization to ULE cavity
- Familiarize with backscatter and the lock-in effect
- Arm length: 25 cm
- 1064 nm laser
- Finesse = 8 000
- Sensitivity = 290 µrad/s/sqrt(Hz)





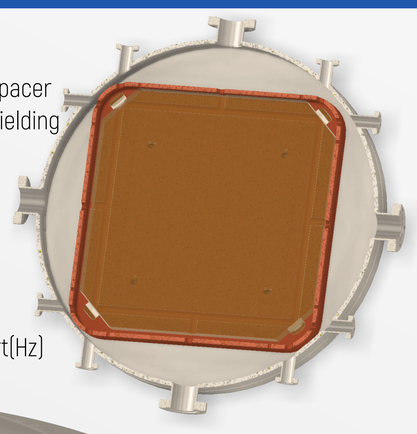
3D Heterolythic Passive Gyroscope

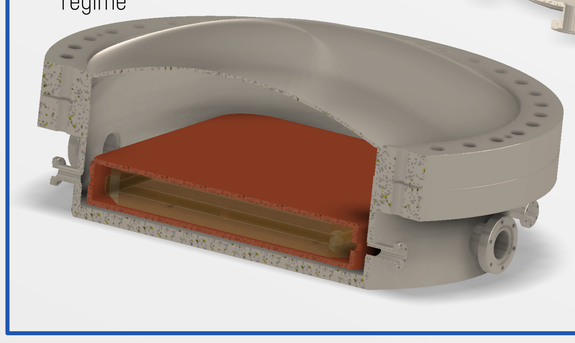
- Prototype
- 4 passive cavities
- Study 3D geometry
- Probe technical and geometrical possibility and analyse complications
- Split laser light to 8 channels and lock them to cavity
- Variable arm length: 20...100 cm
- Finesse > 15 000
- Sensitivity ~ 80 µrad/s/sqrt(Hz)



Planar Monolythic Gyroscope

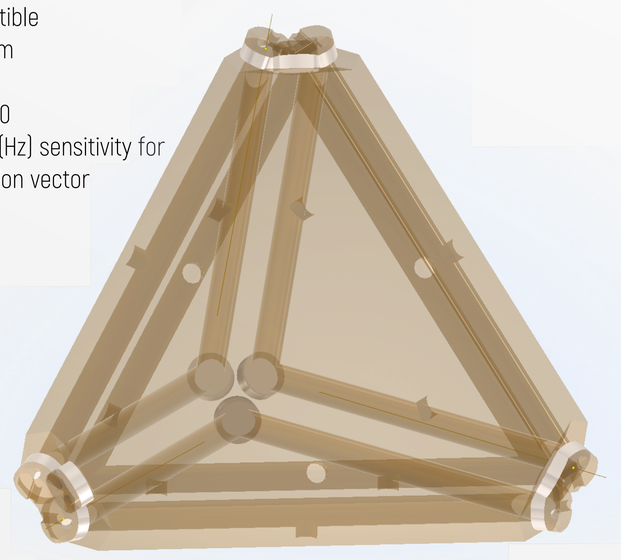
- Passive planar gyroscope
- Optically contact 4 mirrors to ULE spacer
- Stabilize temperature via copper shielding
- Ultra high vacuum chamber
- Geodetic use, while transportable
- Arm length: 30 cm
- 1550 nm laser
- Finesse ~ 300 000
- Laser power of 10 mW
- High 1D sensitivity in the prad/s/sqrt(Hz) regime





Monolythic 3D Prototype

- Passive tetraedrical gyroscope
- Optically contact all 12 mirrors to a single tetraedrical ULE spacer
- Seismology applicable and highly transportable
- Borehole compatible
- Arm length: 10 cm
- 1550 nm laser
- Finesse ~ 100 000
- Sub nrad/s/sqrt(Hz) sensitivity for the full 3D rotation vector



INFOBOX: Sagnac Freqency

The measured Sagnac beat δf is proportional to the rate of rotation Ω of the apparatus:

$$\delta f = \frac{4A}{\lambda P}\cos(\theta)\,\Omega$$

Possible methods of improving the sensitivity $\delta\Omega$ are increasing the finesse F of the cavity or increasing the laser power P_{light}:

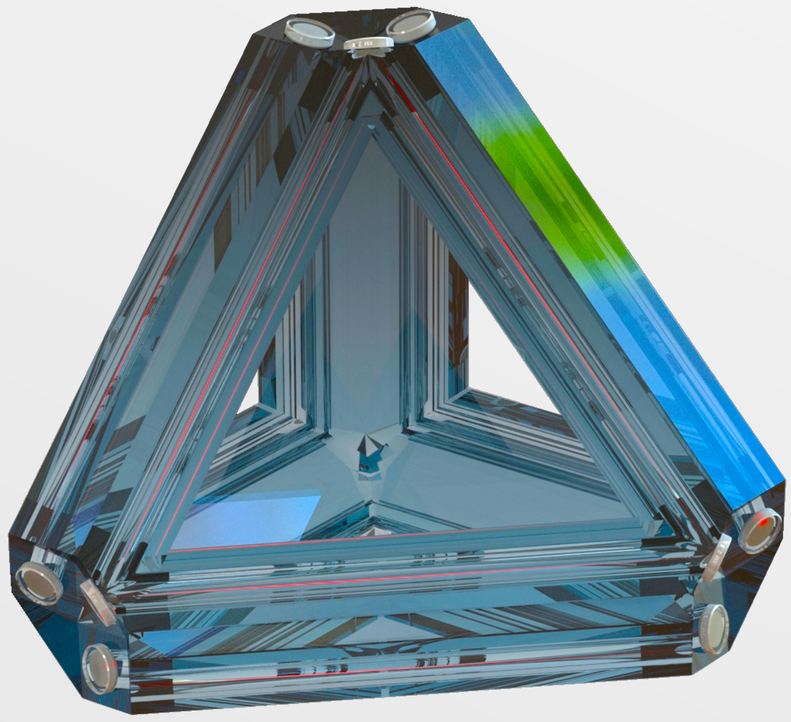
$$\delta\Omega = \frac{1}{4}\frac{c}{AF}\sqrt{\frac{hc\lambda}{P_{light}}\frac{1}{\tau}}$$

To measure a Sagnac beat, one has to overcome the lock-in threshold Ω_L:

$$\Omega_L = \frac{c\lambda^2 r_s}{32\pi A d}$$

Large Monolythic 3D Gyroscope

- Next generation 3D gyroscope for geodesy applications
- Transportable to set up at different locations
- Larger arm length of 30 cm
- 1550 nm laser
- Finesse ~ 300 000
- Sensitivity in the prad/s/sqrt(Hz) regime for the full 3D rotation vector



Acknowledgements

This work is supported by the University of Bonn, the German-American Fulbright Program and the European Comission.

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