


# Fibre optic gyroscope

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*Course*: Sensor orientation

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# Motivation

## Beyond mechanical gyros

- No moving parts → lower maintenance
- High *sensitivity* and *rate capability*
- Wide dynamic range
- Output independent of environmental conditions

## Complementing RLG

✓ Lighter, smaller, lower power consumption, longer lifetime, cheaper

✗ Higher sensitivity (0.1°/h vs 0.001°/h)

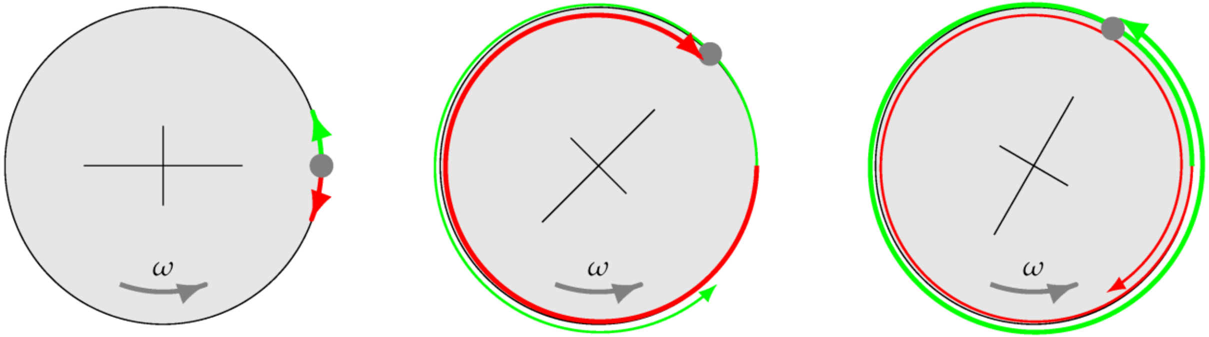
# Sagnac effect

**Core idea**

A phase shift occurs between two counter-propagating light waves when an optical loop is rotating.

**Key takeaway**:

The phase shift is directly proportional to the angular velocity Ω




Emitted forward and backward beams. $t = 0$

Encountered the backward beam. $t = t_-$

Caught by the forward beam. $t = t_+$

Clockwise path, $t_1 = \dfrac{2\pi R + \Delta L_+}{c}$

Anti-clockwise path, $t_2 = \dfrac{2\pi R - \Delta L_-}{c}$

$$\Delta L_+ = R\Omega t_1$$

$$\Delta L_- = R\Omega t_2$$

$$\Delta L = \frac{4\pi R^2 \Omega}{c}$$

$$\Delta L = \frac{4A\Omega}{c}$$

# Basic configuration

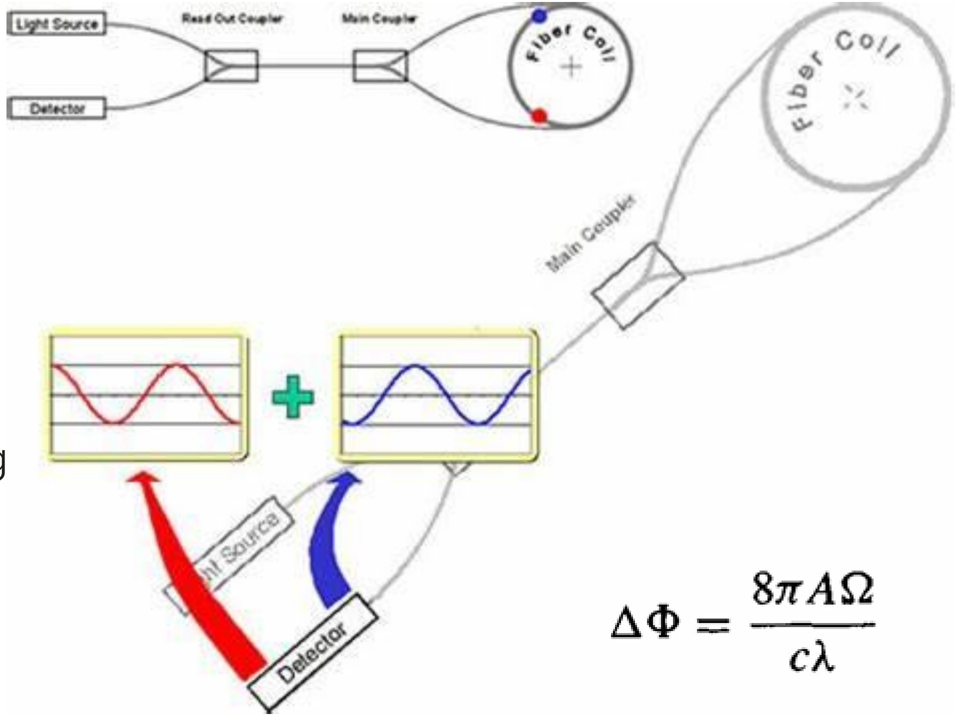
## Elementary components:

- Light source
- Beam splitter
- Fiber coil
- Photo-detector

## Principle of operation:

1. Light split into two beams, propagating in opposite directions
2. Beam combined to form an interference pattern read by the photo detector

Phase shift → decreased intensity pattern




$$\Delta\Phi = \frac{8\pi A\Omega}{c\lambda}$$

# Open loop operation

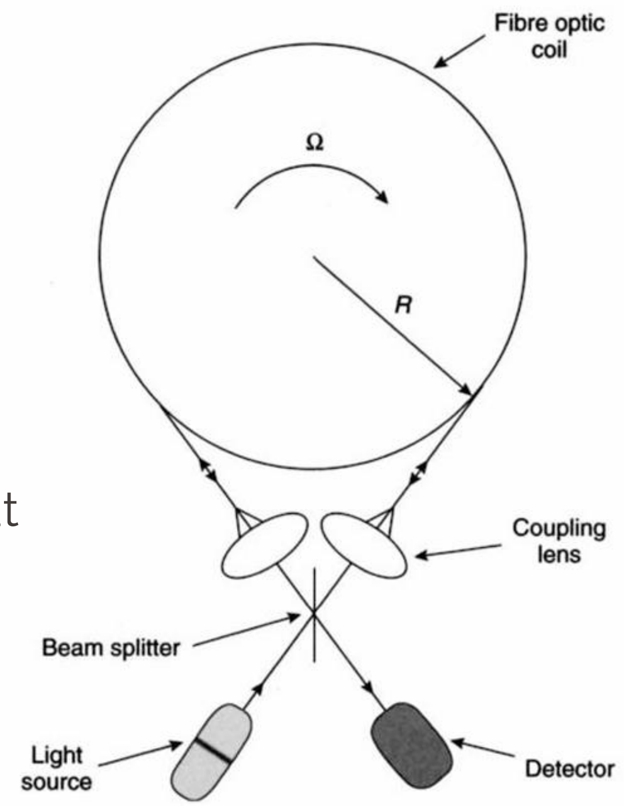
- Measures the phase shift **directly from interference**

$$I = I_0 \cos\left(\frac{8\pi A\Omega}{\lambda c}\right)$$

- **Limitations:**

Close to 0, the cosine function is almost flat and non- linear

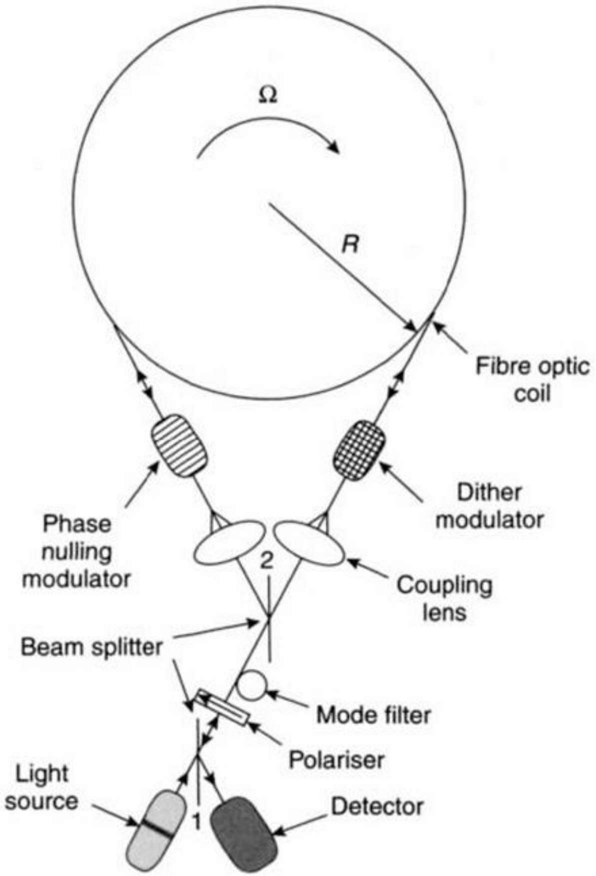
Difficult to precisely compute Ω



# Closed loop operation

- Uses **phase modulation feedback** to nullify the phase shift.
- A phase modulator (PZT-based) introduces a **controlled phase shift** to **counteract** the Sagnac shift.
- The **feedback voltage** required to keep the phase shift at zero is **proportional** to Ω.

Ensures **high sensitivity** at all angular rates



# Advantages



- **High accuracy & stability**: minimal drift since no friction due to absence of moving components
- **Long lifespan & higher reliability**: no mechanical degradation, very little maintenance
- **Immunity to electromagnetic interference**: (almost) unaffected by magnetic fields or other environmental interference that can degrade the performance of mechanical or electronic gyroscopes
- **Compact, lightweight, and scalable**: much smaller and lighter than mechanical or ring laser gyroscopes, adapted for different sensitivity levels by adjusting the length and properties of the optical fiber
- **Fast response time & wide dynamic range**

# Sources of error



- **Thermal effects**: changes in the refractive index and the physical length of the fibre
- **Strong acceleration and vibration**: can cause a distortion of the coil and the fibre
- **Birefringence**: Optical fibres are not perfectly uniform; variations in stress, temperature, and manufacturing defects
- **Polarization**: If polarization changes unpredictably (due to birefringence or external stress), it distorts the phase shift measurement

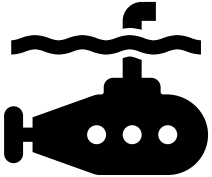
but still better performances when compared to mechanical gyros

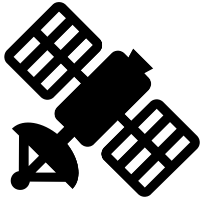
# Performance

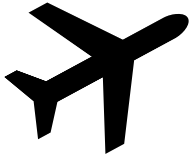
| Performance characteristics | Values |
| --- | --- |
| g-independent bias | 0.5-50°/h |
| g-sensitive | bias ~ 1 *°/h/g* |
| Scale-factor errors | 0.05-0.5% |
| Bandwidth | > 100 Hz |
| Maximum input rate | > 1000°/s |

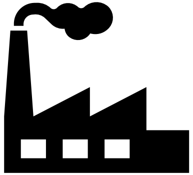
# Applications

- Inertial Navigation Systems
- Platform Stabilization
- Space Applications
- Robotics and Autonomous Vehicles
- Industrial Applications









## Boreas D70 & D90

Utilizing world-first Digital FOG technology, the Boreas D70 and D90 deliver high-precision GNSS/INS performance with automatic Gyrocompassing, with the D90 offering an ultra-high accuracy INS and a 40% reduction in SWaP-C (Size, Weight, Power, and Cost) compared to standard solutions.

| | D70 | D90 |
|---|---|---|
| Roll & Pitch | 0.01 ° | 0.005 ° |
| Heading (Gyrocompass) | 0.1 ° seclat | 0.01 ° seclat |
| Bias Instability | 0.01 °/hr | 0.001 °/hr |
| Position Accuracy | 10 mm | 10 mm |

From Advanced Navigation

# Example of commercial products

Dimensions: 160 x 140 x 115.5 mm

Weight: 2.8 kg

Smaller if less sensitive or mono/double axis

# Thank you for listening!

# Appendix 1: Additional components in closed loop FOG

| | |
|---|---|
| **POLARIZER** | Ensures a single polarization state, eliminating polarization-induced phase errors. |
| **MODE FILTER** | Eliminates higher-order modes, reducing phase noise and ensuring stable interference. |
| **DITHER MODULATOR** | Prevents lock-in at low angular rates by introducing a small phase oscillation |

# References

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