Sagnac Fiber Optic Gyroscope

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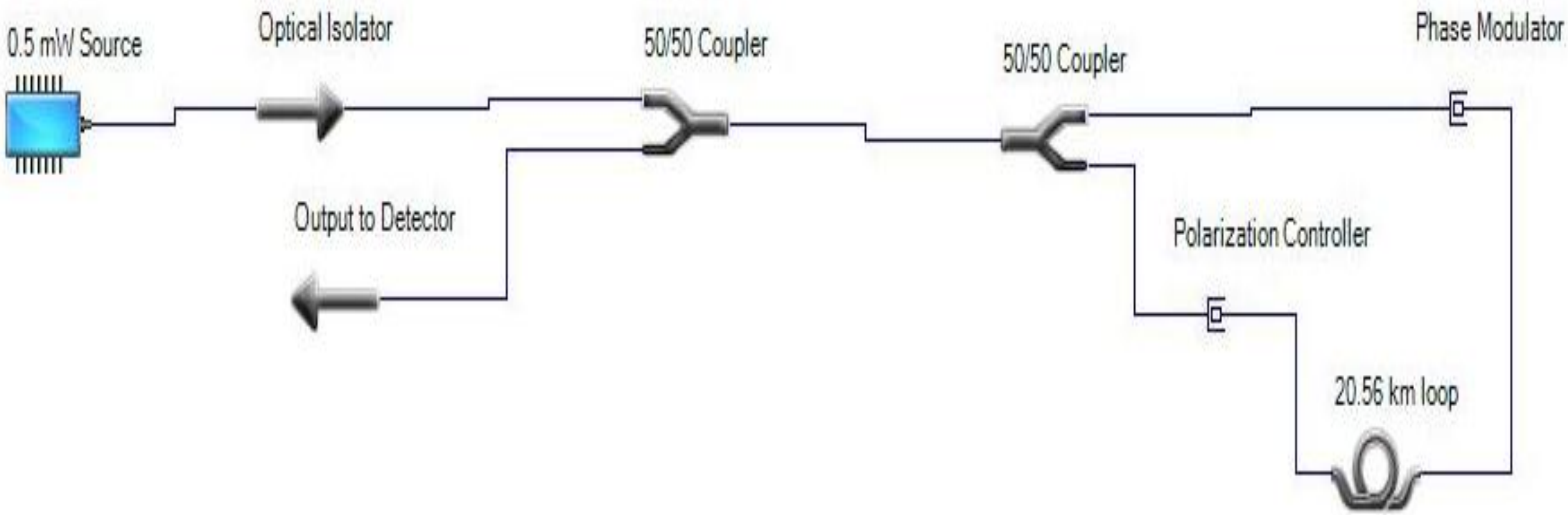
Sagnac Fiber Optic Gyroscope

- The Basics
- Improvements
  - Phase Modulator, APC, Isolation
- Phase Modulator
  - Creation
  - Characterization: Mach-Zehnder
  - Application
- Calibration of Sagnac
- Recommendations

Sagnac Fiber Optic Gyroscope



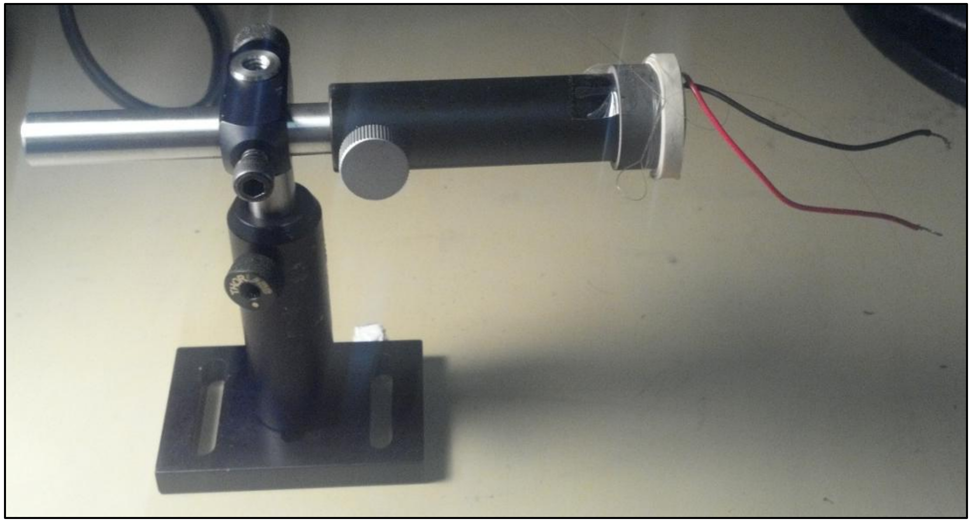
Improvements

- Signal initially very unstable
- High uncertainty in slow rotations (<0.3 rad/s)

Instability Sources	Solutions
Back reflections causing unwanted interference	Replace Flat-Polished Connectors with Angle-Polished Connectors
Any vibration causes signal fluctuation	Isolate system from vibration
Noise in system from various sources (thermal, vibrations, reflections, etc.)	Implement a phase modulator and lock-in amplifier

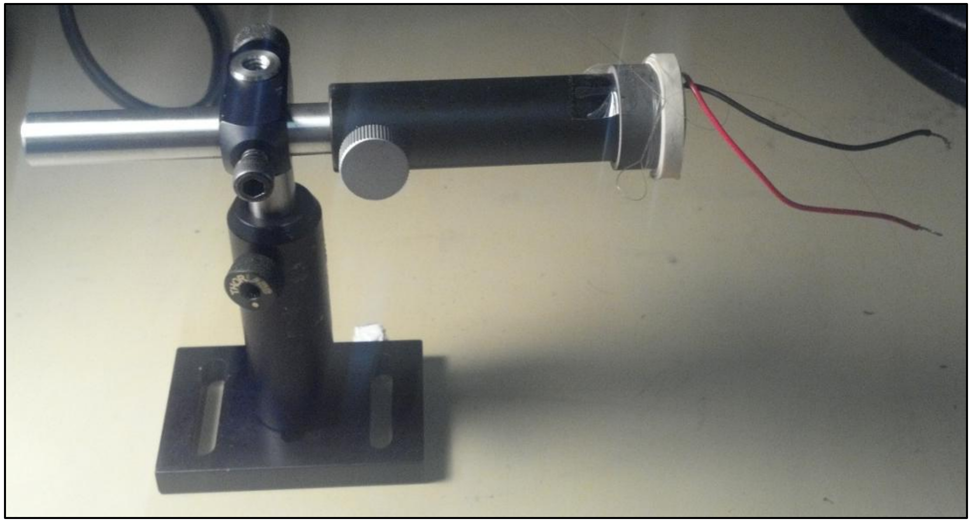
Phase Modulator

- Fiber wrapped around piezoelectric cylinder
- When voltage is applied to PZT, optical path length through the fiber changes.



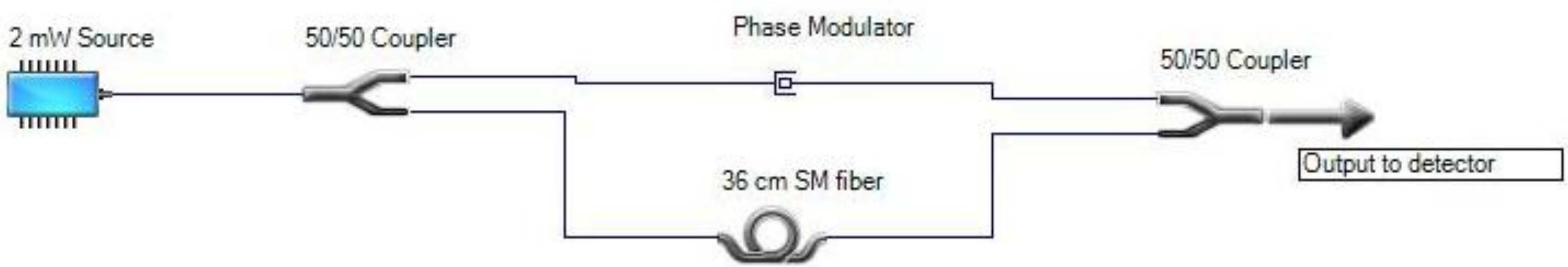
Creating the Phase Modulator

- Characterized PZT to determine the ideal number of wraps
- Chemically stripped fiber
- Carefully wrapped the PZT (≈4.5 wraps)
- Secured with epoxy



Characterizing the Phase Modulator

- Set up a Mach-Zehnder interferometer
  - Angle-Polished Connectors
  - Coherence length
  - Interference from vibration and thermal fluctuation



- Found that application of ≈18.9V creates a 2π phase change

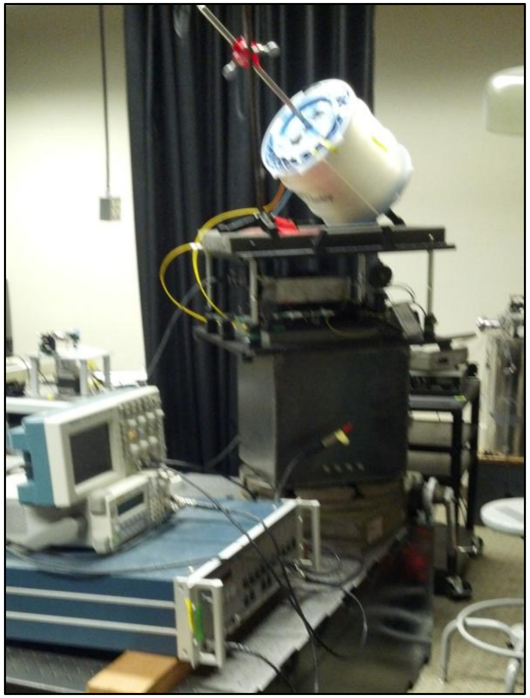
Application of Phase Modulator

- Integrated into Sagnac loop

- Driven to modulate signal for lock in amplifier
  - Frequency determined by loop transit time
  - f=1/transit time=c/nL=9.96 kHz
  - Experimental optimization at 9.92 kHz

Calibration of Sagnac

- Output of photodiode is a voltage
- Need to be able to connect this to a phase change and rotation rate
- Idea: Calibrate using Earth's rotation
  - Varied alignment of Sagnac axis
  - Perpendicular vs parallel
  - Problem: long-term signal instability
  - Unable to reproducibly measure such small rotation

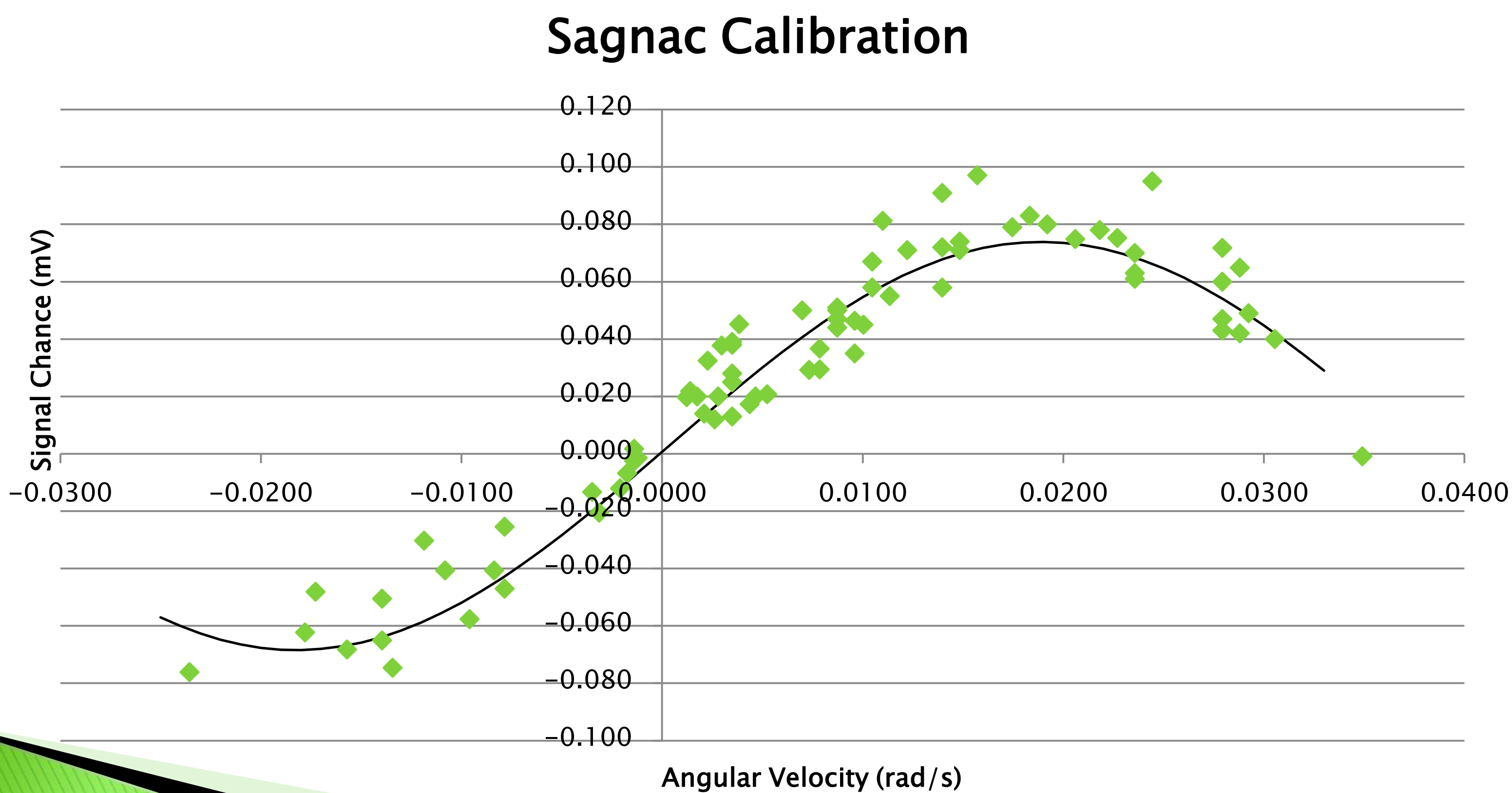


Calibration of Sagnac

- Used rotary table to calibrate at an angular velocity greater than the Earth's.
- Rotation rate necessary for π phase shift was experimentally found to be 0.0371 rad/s.
- Sagnac equation prediction was 0.0383 rad/s
  - $\phi = 4\pi L R n \Omega / \lambda c$
  - L- length of loop
  - R-radius of coil
- These results match well (3.2% error) given the drift in the system and the inconsistency of rotation.

Sagnac Calibration Data

- Minimum measurable rotation of 0.0012 rad/s
  - 0.3 rad/s in 2011



Recommendations

- Improve long-term stability to measure even smaller rotations (Earth's is 0.00007 rad/s)
  - Polarizer implementation potential
    - The polarization drift may be causing significant drift
  - Use broader source
    - Shorter coherence length – Raleigh scattering and back reflection will average to zero much more quickly
- Develop a better method of rotation
  - Earth's rotation (if system is stabilized)
  - Controllable rotation of rotary table
    - Using sprockets and chain identified in lab notes from McMaster-Carr and stepper motor

References / Additional Information

- R. A. Bergh, H. C. Lefevre, and H. J. Shaw, "All-single-mode fiber-optic gyroscope," Opt. Lett. 6,198 (1981).
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- R. Ulrich, “Fiber-optic rotation sensing with low drift,” Opt. Lett. 5, 173 (1980).