Measuring Changes in Magnetic Field Using Index of Refraction

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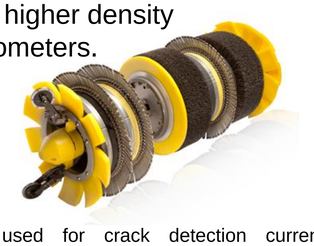
Abstract

High density magnetometers for use in pipeline crack detection can be created by measuring the change in index of refraction of a magnetorefractive material in response to a changing magnetic field. Performing this measurement with Bragg gratings enables the creation of higher density magnetometers. A proof of concept device can be created using an interferometer, which also functions off of changes in index of refraction. In order to relate changes in magnetic field to changes in index of refraction involves the use of an interferometer. Pouring glycerin with an index of 1.47 over a film of water with an index of 1.33 on the sensing arm of the interferometer creates a change in index of refraction. By measuring the accumulation of interference cycles, the sensitivity of the interferometer can be calculated. From this test, the sensitivity of the interferometer is 4.43 x 10^{-4} RIU/cycle. In future tests, the magnetorefractive material Lanthanum Strontium Manganite (LSMO) coupled with an electromagnet can replace the function of glycerin, allowing changes in index of refraction in a magnetic material to be measured.

Motivation

There is a need for high density magnetometers for crack detection in oil pipelines. Current devices are not capable of detecting small cracks in pipelines due to lower density magnetometers. Magneto-refractive materials coupled with interferometers can be used to develop higher density magnetometers.



Device used for crack detection currently utilizing lower density magnetometers

Background

- Index of Refraction: a measure of how fast light travels through a material.
- Magneto-refractive Effect: change in index of refraction in response to change in magnetic field.
- Lanthanum Strontium Manganite (LSMO) is a magneto-refractive material.
- Interferometer: a device that splits a light source into two branches, exposing one branch, the sensing arm, to the environment, and recombines the two branches, interfering the two light waves.

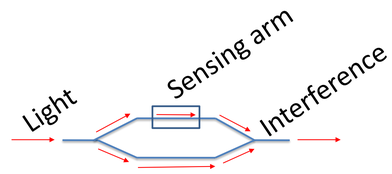
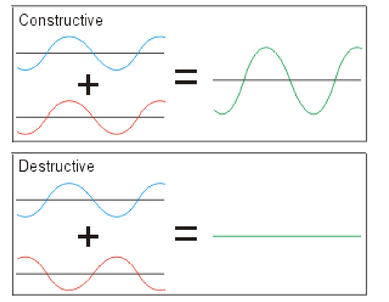


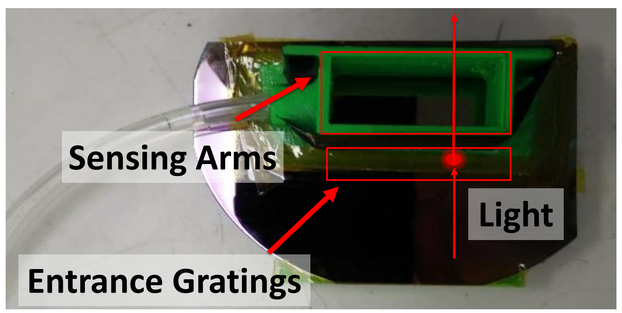
Diagram of an interferometer



Types of interference

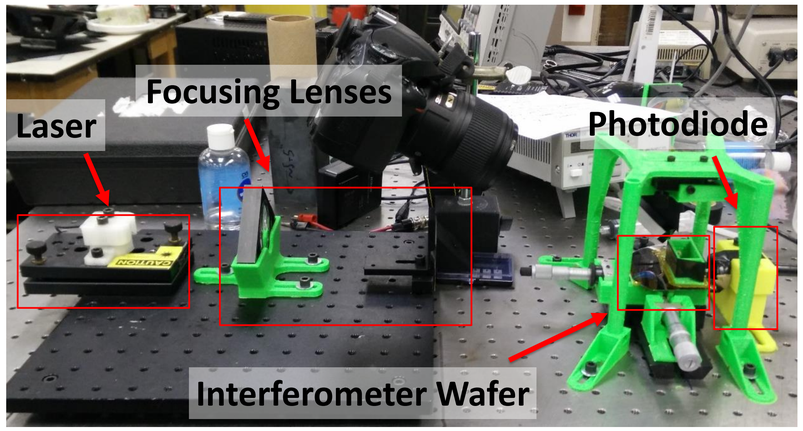
Process

1. Couple laser light into interferometer grating
2. Pour film of water into sensing arm well
3. Pour glycerin into sensing arm well
4. Measure light intensity over time

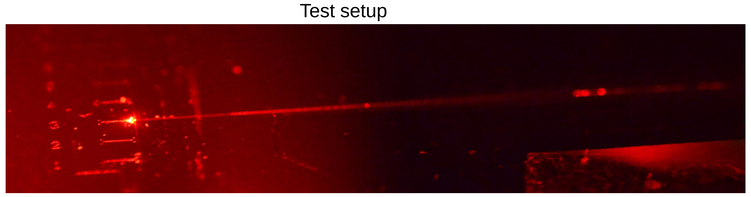


Silicon Wafer

As glycerin is added to the well, the index of refraction of the sensing arm increases, causing an increasing phase shift of the light traveling through the sensing arm. As a result, interference cycles occur.



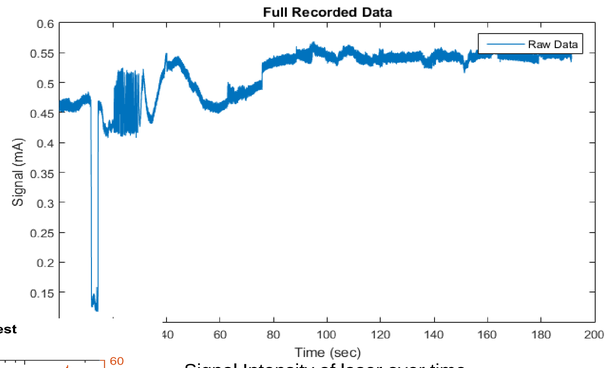
Test setup



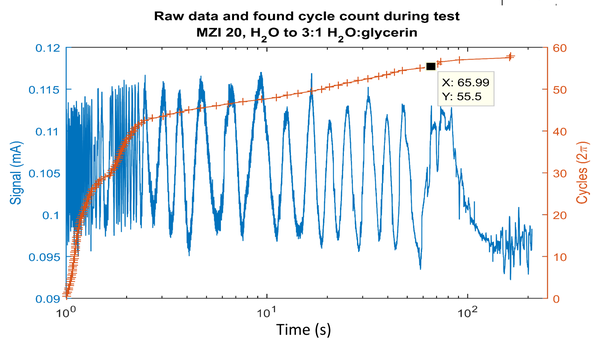
Laser coupling into interferometer grating and traveling through waveguide

Data

In the graph (right), the initial sharp decrease in signal strength marks the beginning of the test. Glycerin is then added to the sensing arm well. This point in time is marked by rapid cycles of interference.



Signal Intensity of laser over time

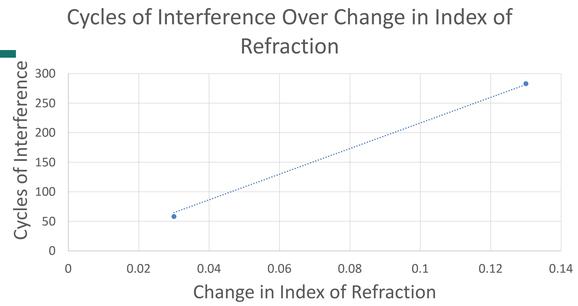


Cycles of constructive and destructive interference (red) over time

In the graph (left) of the same test as above, the red curve denotes the accumulation of cycles of interference. Rapid change in index of refraction leads to many cycles of interference.

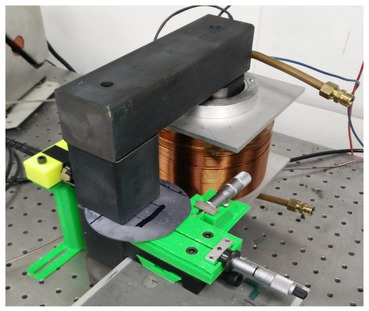
Summary of Results

By testing with glycerin and water, the sensitivity of the interferometer was found to be 4.43 x 10^{-4} RIU/cycle.



Future Work

Because the sensitivity of the interferometer has been measured, further tests involving magnetorefractive materials can proceed. Applying LSMO to the sensing arms of the interferometer allows changes in magnetic field to be detected. The magnetic field can be generated by an electromagnet. As the strength of the magnetic field changes, cycles of inference from the interferometer should be detected.



Future setup using electromagnet to generate magnetic field

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