TANMS

AERO Institute & NASA Armstrong

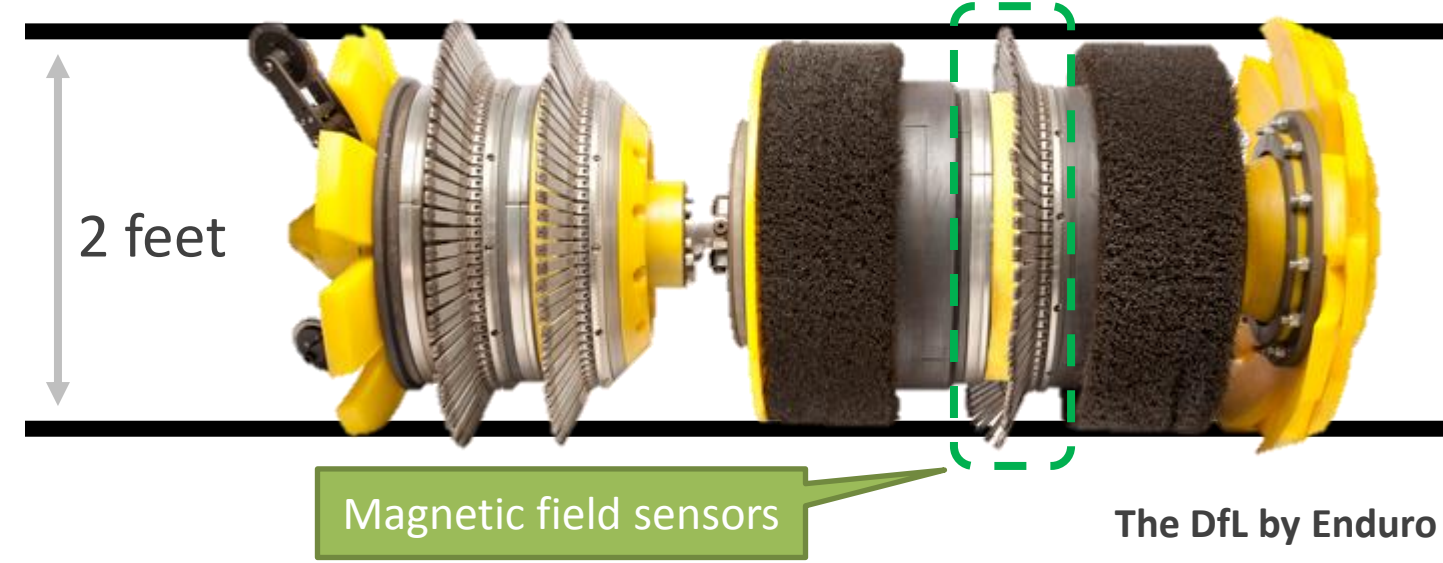# Characterizing Sensitivity of Refractive Index to Magnetic Field

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Motivation

Current magnetic field sensors are not detecting pre-cursor cracks in oil pipeline failures. One solution is to create a low-profile magnetic field sensor capable of taking a dense set of readings.

Oil-Pipeline Cracks Evading Robotic 'Smart Pigs'
Probes used by Exxon and other companies aren't spotting flaws that cause massive spills

By TOM FOWLER and DANIEL GILBERT
Updated Aug 16, 2013 7:01 p.m. ET
In February, Exxon Mobil Corp. sent a small robotic device known as a "smart pig" through a 60-year-old oil pipeline in central Arkansas to find cracks or other problems.

2 feet

Magnetic field sensors
The DfL by Enduro

Background & Approach

Fiber Bragg gratings (FBGs) are regions of an optical fiber which reflect a single wavelength. Using glass effected by magnetic field, would make them magnetometers.

$$\lambda = 2\Lambda n(H)$$

Magnetic field (H)

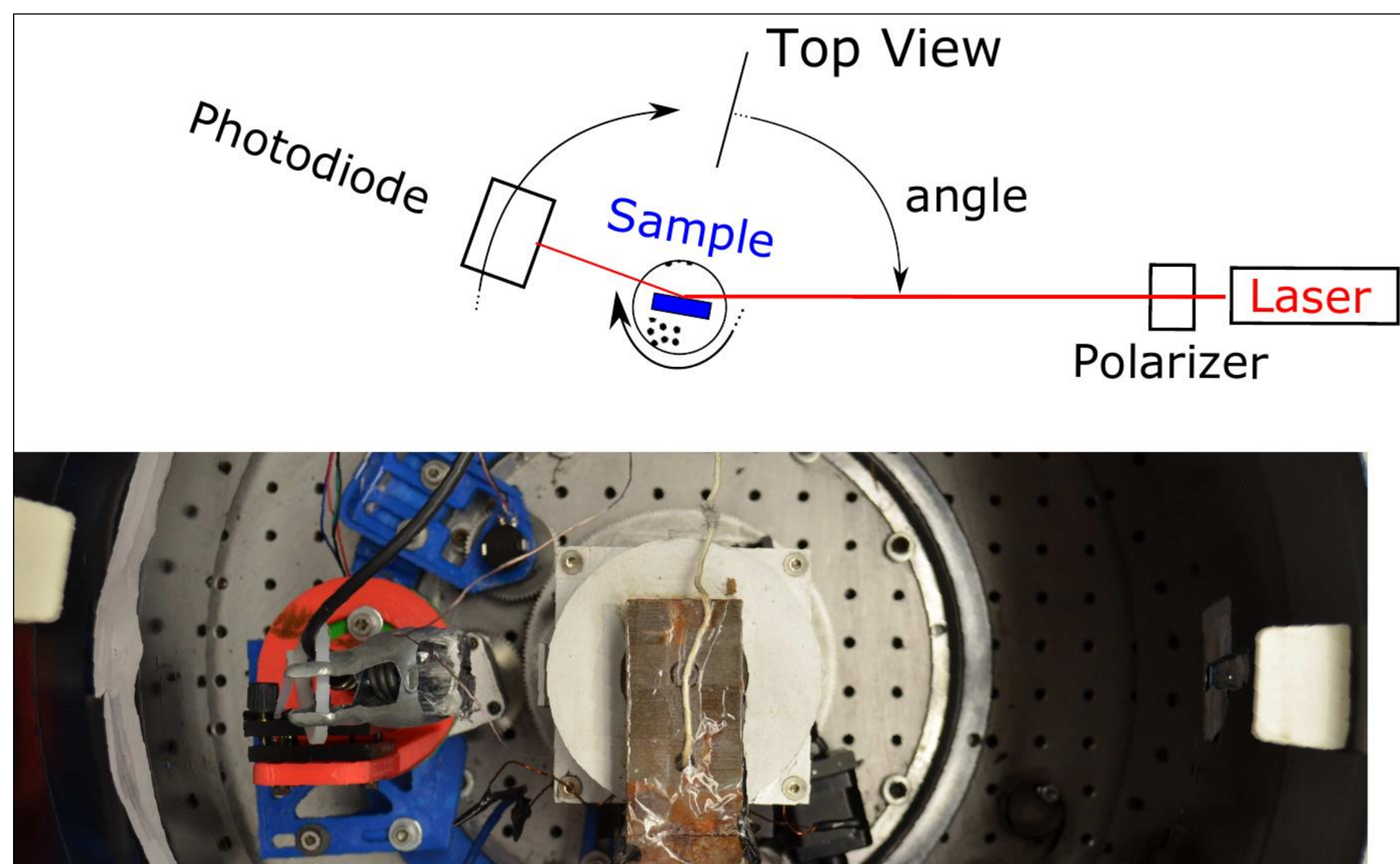System Diagram
FBGs
Fiber Reader
Optical Fiber

Harvey N. Davis (1913)
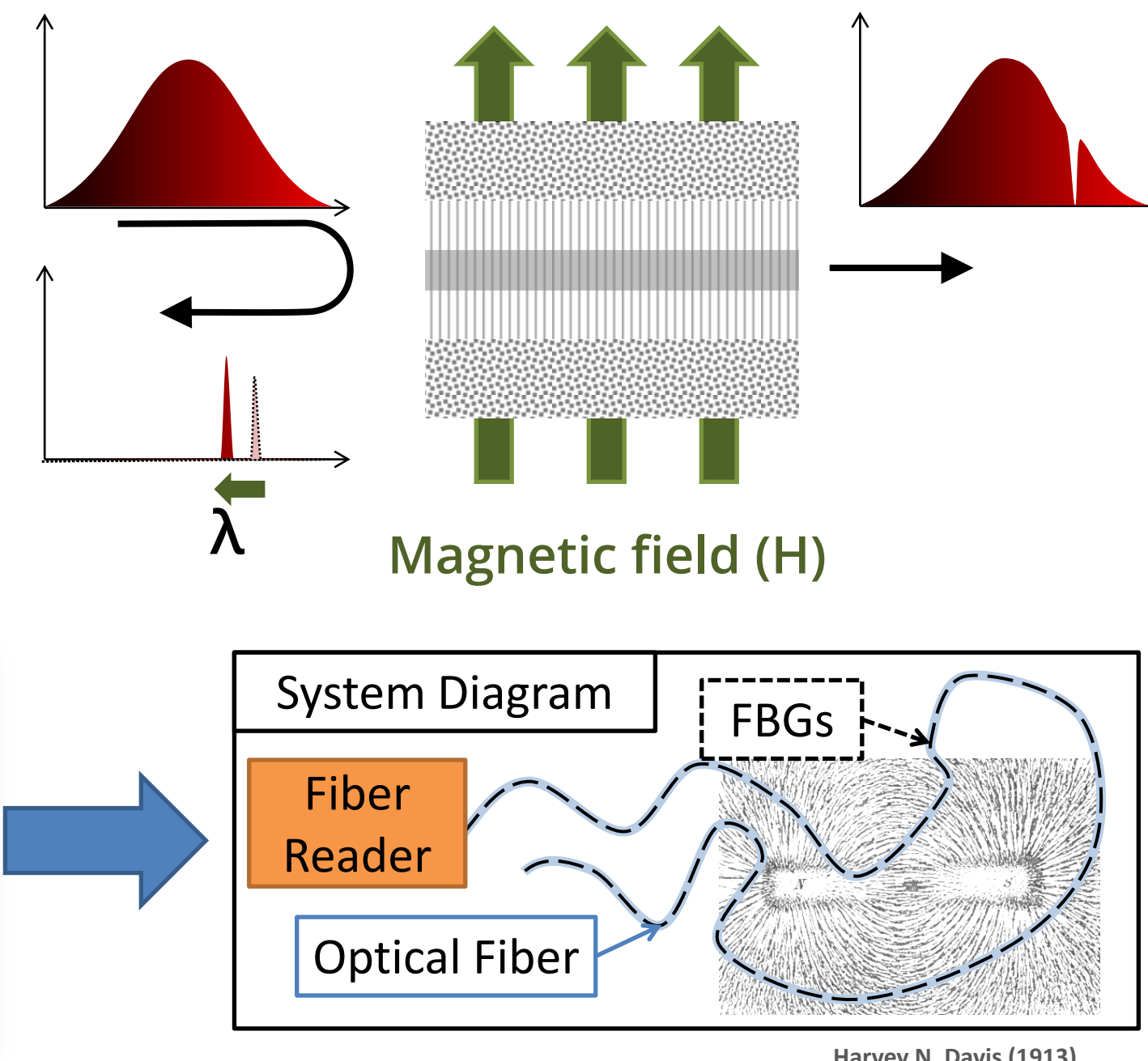
Representative Results

Top View
Photodiode
Sample
angle
Laser
Polarizer

Figure 1. Diagram and image of test setup to measure index of refraction and apply magnetic field.

Reflectivity vs. Angle, for Three Field Strengths

0 Oe,	n = 1.8464
2149 Oe,	n = 1.8417
0 Oe,	n = 1.8461

$$R = \left(\frac{n_2^2 \cos\theta - n_1\sqrt{n_2^2 - n_1^2\sin^2\theta}}{n_2^2 \cos\theta + n_1\sqrt{n_2^2 - n_1^2\sin^2\theta}} \right)^2$$
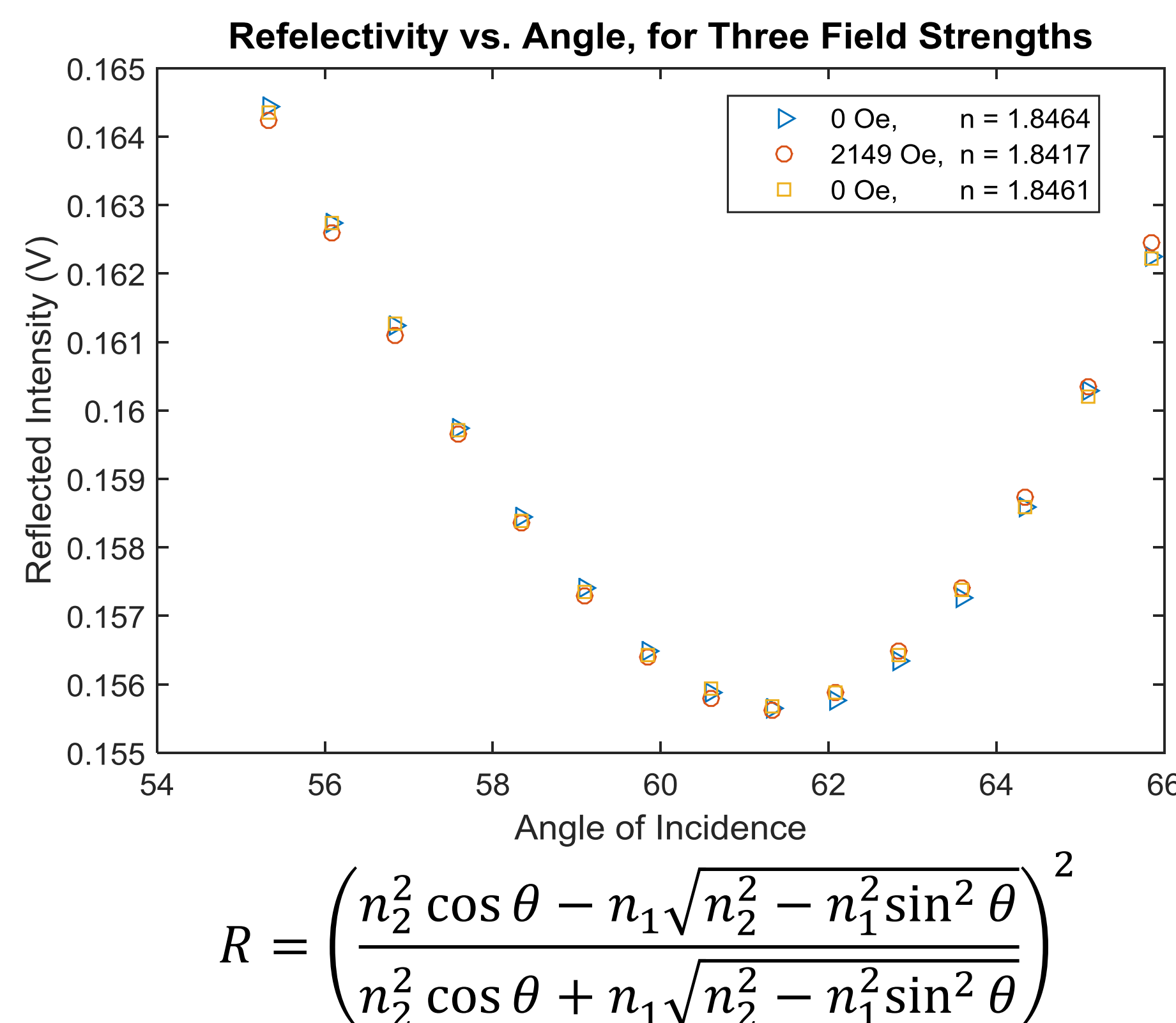
Figure 2. Example of three scans, at two fields, and equation for fitting index of refraction to reflectivity.

Index of Refraction vs Temperature
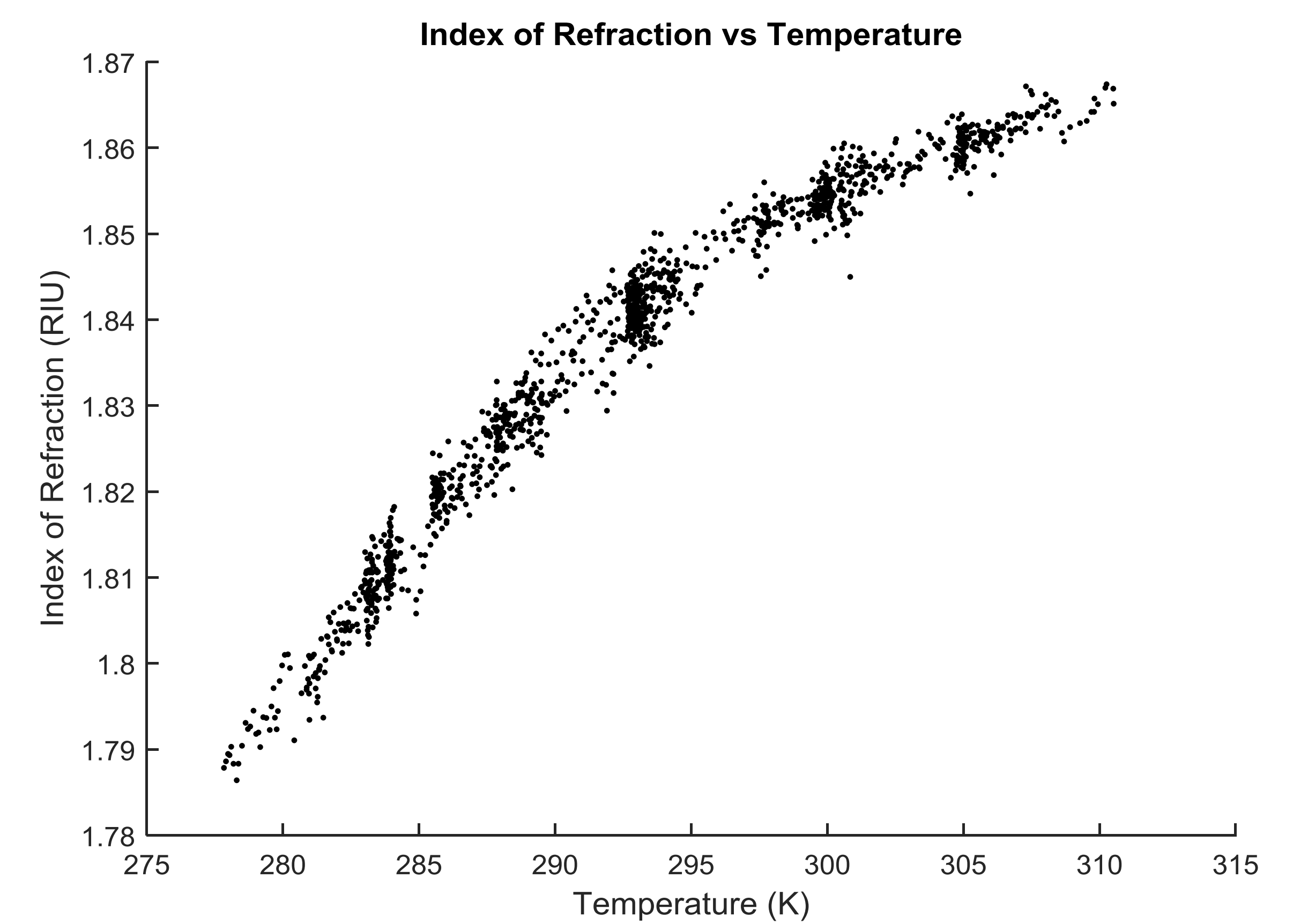
Figure 4. Index vs. Temperature, to show it can be controlled for.

Raw Characterization Data

Field
Temperature
Index

Sample number, time progression --->
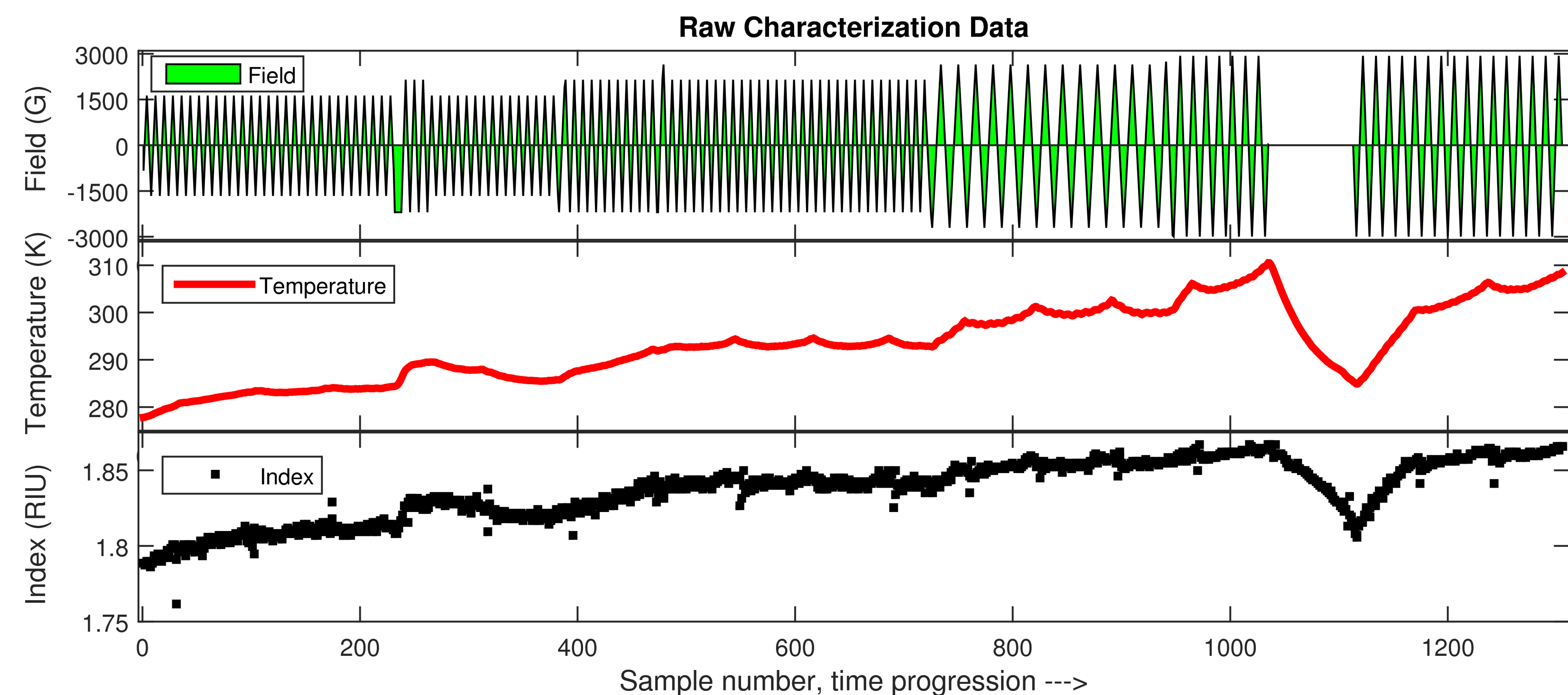
Figure 3. Tests over time, varying magnetic field, tracking temperature, and tracking index of refraction.

Index, Controling for Temperature Induced Fluctuation
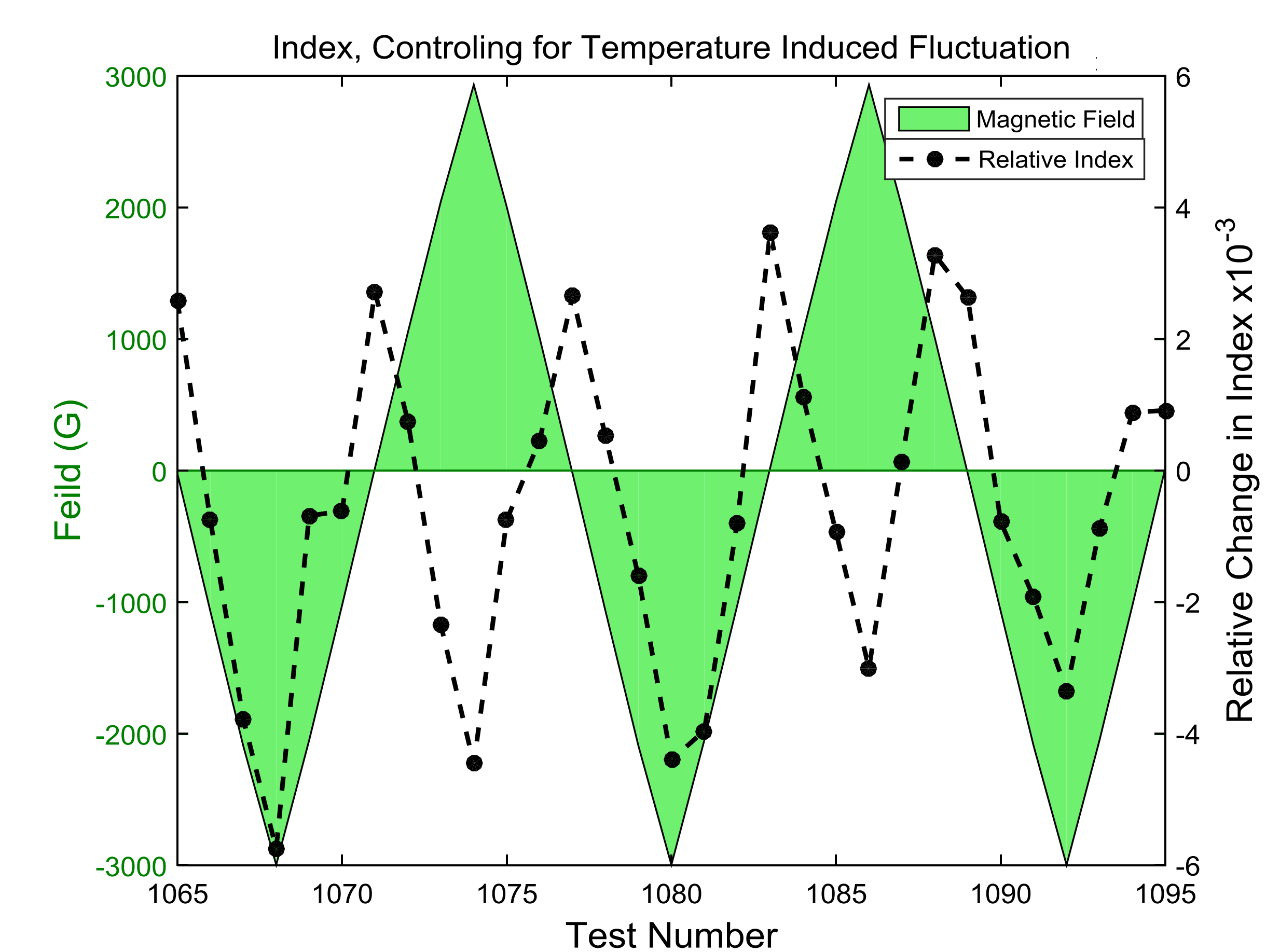
Magnetic Field
Relative Index

Test Number

Figure 5. Magnetic field over time, and relative change in index after controlling for index of refraction changes.

Summary of Results

After removing erroneous points, the peak effect is at 290K, with -3 x10^{-6} RIU/G.

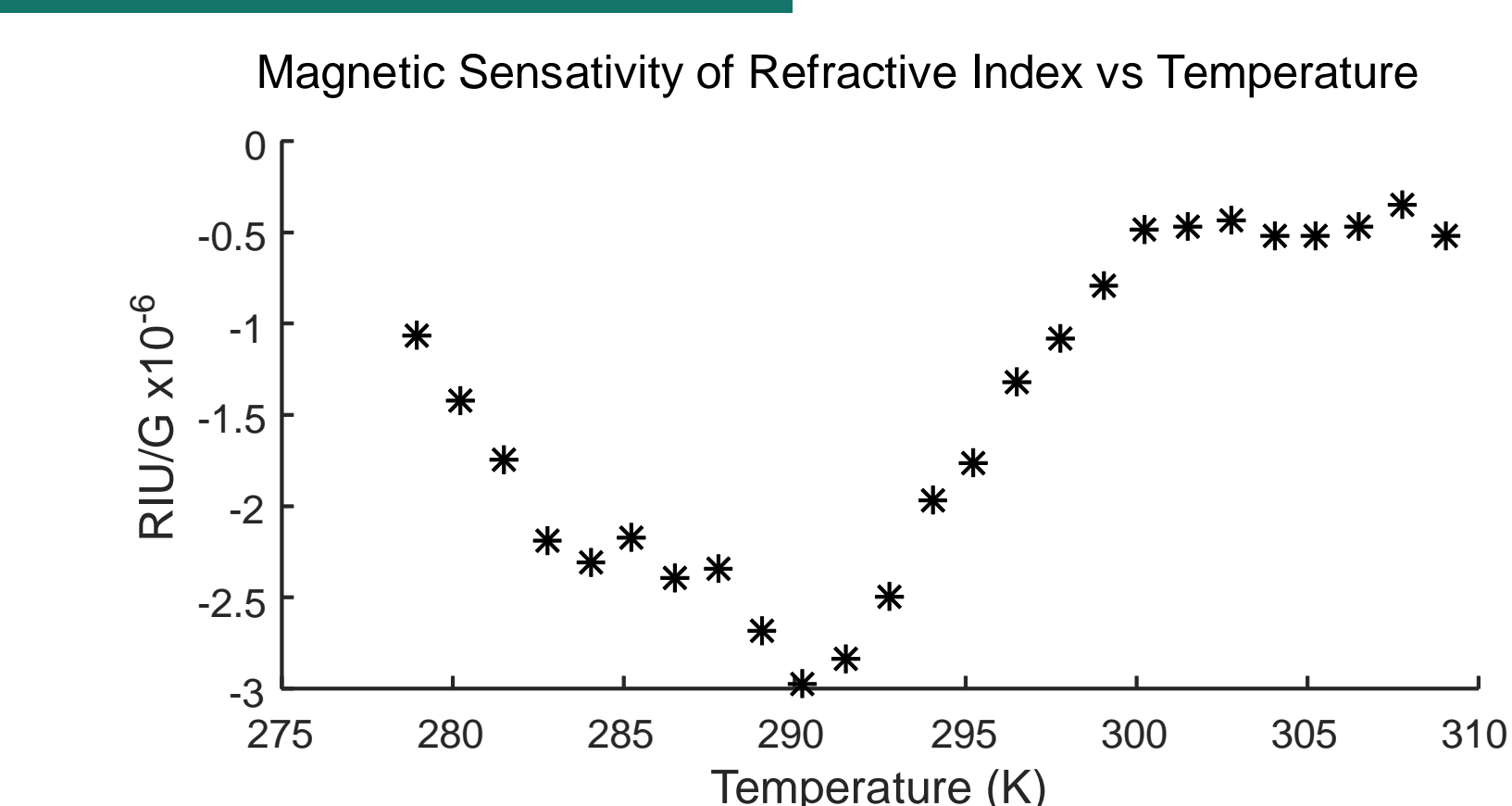After correcting for thin film effects, -2 x10^{-6} RIU/G.

Magnetic Sensativity of Refractive Index vs Temperature

Figure 6. Sensitivity of index of refraction to magnetic field, vs. temperature

Future Work

Use a Mach-Zehnder interferometer to create the first device using magnetorefractive effect

Buy
250 nm of Si₃N₄
2um of SiO₂
Silicon
Hard step!

2nm etch
2/3/2015

Deposit
2μm of SiO₂
2/12/2015

Etch SiO₂
2/26/2015

Au
Hard step!
3/24/2015

Etch Grating
4/14/2015

500 µm