Fiber Interferometer

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Abstract

In this report, a Fiber Loop Mirror (FML) with a polarization controler attached and a Coupler 50:50 are used for the study of the interference phases of a ligh signal emitted by a LASER source.

1 Introduction

1.1 Objective

The objective of this experiment is to use a strain sensor based on an optical fiber loop mirror in order to measure the magnitude of deformation when two laser beams are in a state of quadrature phase-shift.

1.2 Theory

1.2.1 Fiber Loop Mirror (FLM)

In the FLM, two counter-propagating light beams travel through the Hi-Bi fiber with different velocities. This difference of velocities is due to the individual polarization directions of the beams, making them interfere with each other in the output port.

The phase difference between the fast and the slow beams in the Hi-Bi fiver is:

$$\Delta\phi = \frac{2\pi\beta L}{\lambda}$$

where β, L and λ are the birrefrigerence, lenght of the Hi-Bi fiber and the wavelenght at which one is working, respectively.

The transmission spectrum of the loop, approximately periodic with the wavelenght, is determined by:

$$T = [\sin(\frac{\beta L}{\lambda}) \cdot \cos(\theta_1 + \theta_2)]^2$$

where $\theta_1$and θ_2 are the angles between the light at the both end of the Hi-Bi fiber and the fast or slow axis of the Hi-Bi fiber, respectively. His reflectivity response (R) is

$$R = 1 - T$$

The wavelenght spacing $\Delta\lambda$ (spacing of the fringes of the resulting interferometer) is determined by

$$\Delta\lambda = \frac{\lambda^2}{\beta L}$$

where small wavelenght spacing requires a larger birefrigerence or a longer lenght of the fiber. $\Delta\lambda$ is also independent of the polarization state of the input light.

For the interferometer, the phase change can be determined with the relation:

$$\phi = \arctan(\frac{V_1 - G_1}{V_2 - G_2})$$

where $V_1$and V_2 are the voltage of the signals.G_1 and $G_2$are the respective gains. We can obtain the relation between the phase shift and the microstrain.

2 Proceadure

The experimental setup used is represented in Figure 1, where two lasers (1 and 2) are connected to a 3dB coupler (3). The circulator (4) distributes the signal to the respective device,. If the signal exits the coupler, it will enter the FLM system. On the other hand, the signal will serve as the input of the OSA (Optical Spectrum Analyser) if it exits from the FLM .

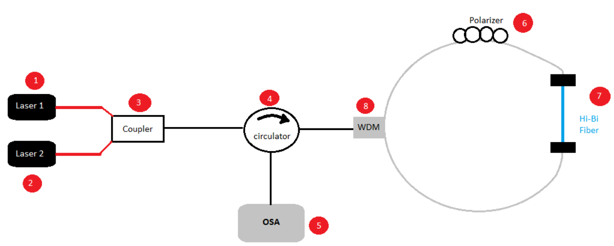

Figure 1: Experimental Setup

Figure 2: Real Setup

Once the lasers (1 and 2) are turned on, the beams go through a 3dB coupler (3), exiting as a single beam, and goes to the circulator (4). In the circulator, if the beam comes from the coupler, the output beam will go to de WDM (8), which controls the light that enters the FLM. If the beam comes from the WDM, it will exit to the OSA (5).

The FLM is composed of a Hi-Bi fiber (7) connected to a polarizer (6) and both conneted to a WDM (Wavelenght Division Multiplexer). In the FLM, the input light interferes. This action varies with the stretch of the Hi-Bi fiber (which we vary). Through this process we can see the power of the laser that is leaving the fiber. This power is proportional to the strain applied, which we vary it in order to see the balance changes of the power of both lasers.

3 Results

The wavelenghts used for the beams were $\lambda_1 = 1573.920$ nm and $\lambda_2 = 1579.300$ nm. Figure. corresponds to the phase shift of the beams.

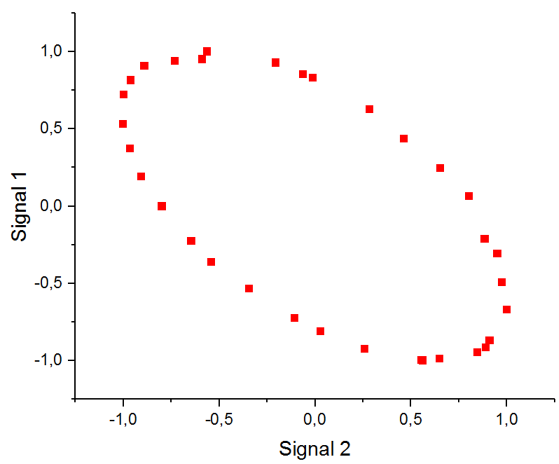

Figure 3: x-y realtion between both signals

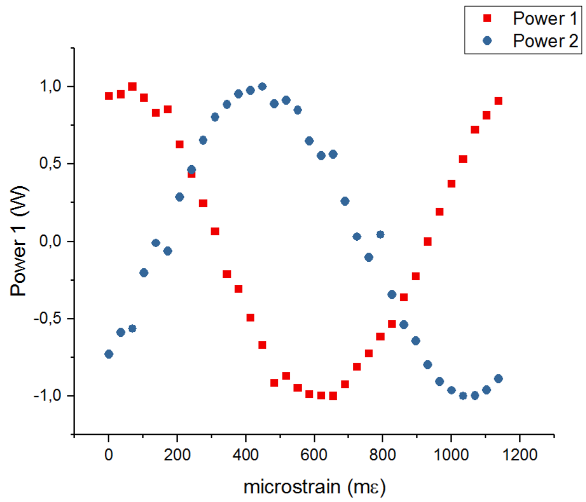

Figure 4: Detected signals versus strain

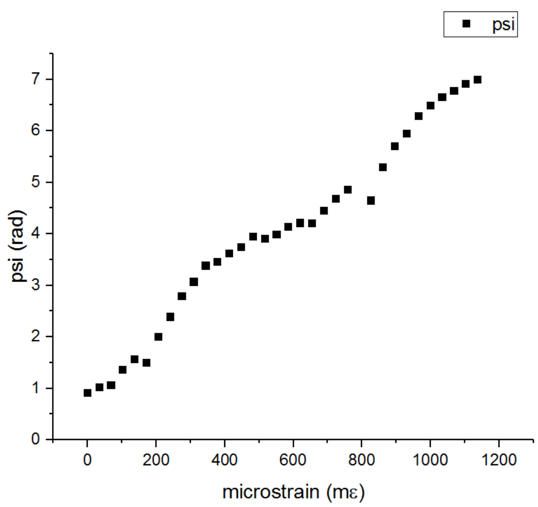

Figure 5: Interferometric phase change versus strain using the obtained values.

The normalized output voltages obtained from both detectors in this situation are represented in Figure 3.

From the graphics constructed using the values obtained, we can see that:

- The phase-shift between signal 1 and 2 is diferent of $\frac{\pi}{4}$, due to the fact that Figure 2 is aproximated into an ellipse (if this wasn't the case, it would look like a circle). Figure 4 supports this observation;

- The relation between the strain and the interferometric phase change isn't linear, making it very difficult to determine the sensitivity of the strain sensor.

If the values are shifted by 3, then we get the expected shape of the graphics:

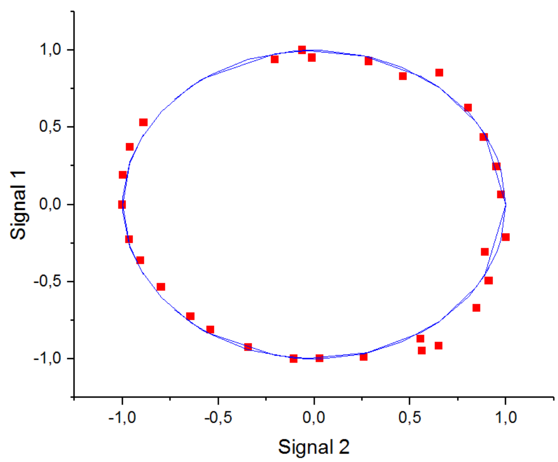

Figure 6: x-y signal representing the quadrature condition

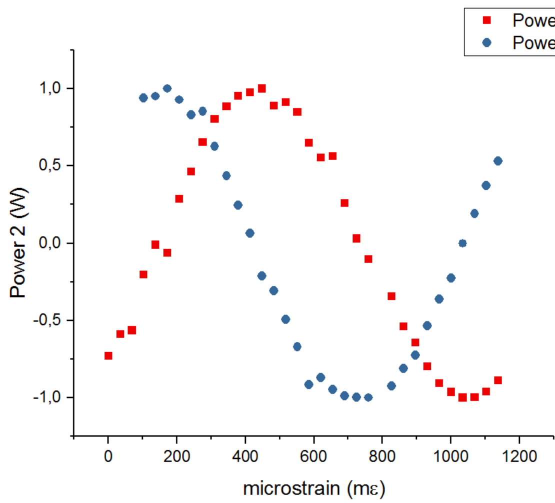

Figure 7: Detected signals versus strain expected.

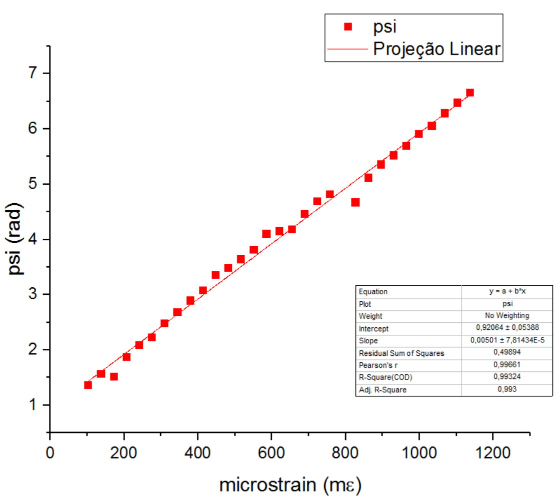

Figure 8: Interferometric phase change versus strain after the shift of values.

We can se that, in this case, the signals would be in quadrature phase-shift, shown in Figure 6. Still in this case, the normalized output voltage is represented in Figure 7, which itself confirms the quadrature phase-shift between the two signals.

Figure 8 shows the shift in the interferometric phase as a function of the strain. It has been normalized due to the phase jumps every 90 degrees. Because it's a linear relation, we can determine the sensitivity by making a linear projection of the graphic and determine the value of the slope, which in this case is 5.01 rad/nε (nanostrain).

4 Conclusion

It can be concluded that, despite our initial results not being what would have been expected, a strain sensor based on an optical fiber loop mirror with an unbalanced Mach-Zehnder interferometer can be demonstrated by shifting the obtained values. This indicates the error of the experiment as being a missreading of the values obtained or a bad recolection of them.

Nevertheless, using this aproximation, a strain sensor with sensitivity 5.01rad/nε can be obtained.

5 References

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