Optical Fiber Temperature Sensor – Work in Progress

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Abstract-Research has shown that optical fiber is a popular choice in sensing applications, due to the advantages associated with it. An optical sensing system with the right demodulation scheme can allow parameters such as temperature and pressure to be measured accurately at a single point. There is also a possibility of multiplexing of sensors to allow for multiple point measurements and changing of sensitivity by varying certain parameters in an optical sensing system. In this paper we present work in progress on a multiplexed optical fiber temperature sensor.

Index Terms— Fiber Temperature Sensor, Multiplexing system.

I. Introduction

The use of optical fiber has increased substantially over the last few decades. Optical Fiber is most commonly used in telecommunications and has been welcomed into other disciplines such as medicine and sensing.

In industry two of the most important parameters that require measurement are temperature and pressure. Thermocouples are commonly used for temperature measurement, but at higher temperatures tend to give inaccurate readings. Optical fiber sensor have become a common choice for sensing purposes, as it offers a number of advantages that is absent in traditional sensing devices. These advantages include light weight, low loss, small size, low maintenance and immunity to EMI.

II. Background

A. *Optical Fiber Sensor*

The characteristics of optical fiber change when it is subjected to mechanical perturbations. This change in characteristics can be used to determine the change that the fiber is subjected to. Temperature is a mechanical perturbation that can cause a change to these properties – and can therefore be determined in this way.

Optical sensors can be used as single point sensors as for instance in medical application where used to monitor temperature and blood pressure of a patient, or multiple point sensors, as in sensors monitoring the structural health of a bridge.

An interferometer can be used as an optical sensor. Interferometers are used as it is more sensitive than using only a piece of fiber. A change in temperature in the interferometer will cause a change in the optical path that is followed by the light in the interferometer and the change is thus easily detectable.

III. Proposed Solution

An optical fiber sensor commonly consists of an optical pump source (which supplies optical power to the system); a sensor and a detector. The sensor can be formed by using a Fabry-Perot cavity, which can consists of twin Fiber Bragg Gratings, as will be used in this project. The proposed technique to use with the optical fiber sensor is the saw tooth frequency modulation continuous technique (FMCW).

Intrinsically, the following explanation can be used to describe the functioning of the sensor by using the technique as mentioned: the source is frequency modulated with a saw tooth wave (due to the simplicity of the mathematics associated with the waveform); the wave travels along the fiber to the sensor - a Fabry-Perot cavity is used to form the sensor - the wave will split at the sensor and different optical paths will be followed by the resulting waves. Interference will occur, due to the recombination of the waves. An interference wave will be detectable, oscillating at a frequency known as the beat frequency. Parameters influencing the beat frequency include the cavity length, modulation frequency and optical tuning range. The output will be detected by a photo detector. The output can be processed by applying a FFT technique to the interference wave. The FFT will produce a peak, of which the phase will change with a change in temperature at the sensor. Therefore, if the phase of the peak is tracked, a change in temperature can be calculated by using equation (1).

$$\frac{\Delta\phi_{b0}}{\Delta T} = \frac{4\pi l}{\lambda_0}\left[\frac{n_e \delta l}{l \delta T} + \frac{\delta n_e}{\delta T}\right] \qquad [1]$$

where l is the length of the cavity, λ_0 is the central wavelength, $\frac{\delta l}{l\delta T}$ is the thermal expansion coefficient, $\frac{\delta n_e}{\delta T}$ is the thermal dispersion coefficient and n_e is the effective refractive index.

The advantage of using the FMCW technique is the possibility of adding in additional cavities and multiplexing the sensor. If this is achieved, it will be possible to get multiple readings of temperature change from the same fiber cable – allowing for a heat profile to be determined.

Varying of parameters in the system also has the possibility of changing the sensitivity of the sensor. These variables include the cavity length, modulation frequency and tuning range.

IV. Proposed Experimental Setup

The proposed experimental setup is as shown in *figure 1*. The sensor is connected to the pump source via a circulator. The other output of the circulator is connected to a photo detector where results will be recorded to be analyzed. This setup will be used to test the change in resolution of the sensor too. For multiplexing, additional cavities will be spliced onto the existing setup to conduct the experimental procedures.

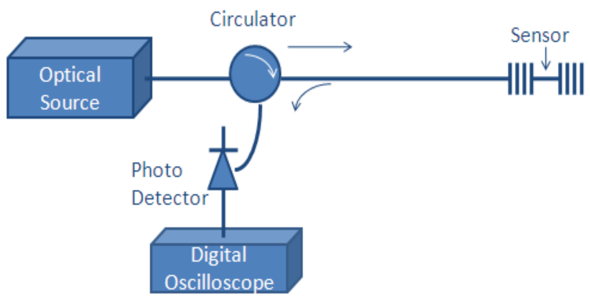

Figure 1 - Setup for experimental procedure

V. Expected Results

The expected results for the experimental procedure as explained in section three is as shown figure 2 below. For the multiplexing case, it is expected that the FFT produces a peak for each sensor, which can be tracked individually. The sensitivity changes expected is as shown in table I.

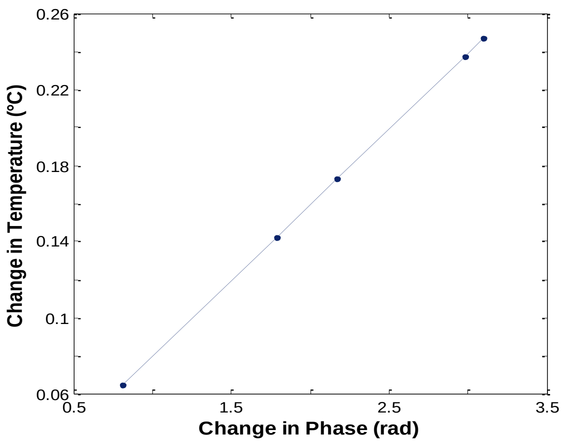

Table I - Expected Sensitivity Results

Wider Tuning range	More Sensitive
Longer Cavity Length	More Sensitive
Higher Modulation Frequency	More Sensitive

VI. Project Objectives

The objective of the project is to simulate and experimentally test the proposed solution to prove that accurate temperature measurements can be obtained using the optical frequency modulation continuous wave technique. Multiplexing of the system will also be simulated and tested experimentally as well as changing of the sensitivity by varying system parameters as mentioned in table I.

VII. Methodology

Simulation of the system has been completed and the following is to be done:

1. Complete setup as displayed in figure 1 and conduct experiments;
2. Simulate variation of sensitivity of sensor by varying system parameters;
3. Experimentally test sensitivity by varying system parameters on the system as displayed in figure 1;
4. Simulate multiplexing of system;
5. Test multiplexing of system experimentally by adding cavities to the system as in figure 1;
6. The simulated results will be compared to the experimental results obtained to verify satisfactory working of the sensor.

VIII. Conclusion

If the experimental procedure is followed according to the described method, the results should be as expected. The results obtained from the experimental procedure are expected to be a linear relationship. Multiplexing of the sensor should produce results that can be related into temperature measurements for each separate sensor as from the FFT a peak will be obtained for every additional cavity added. The sensitivity of the sensor is expected to increase as the cavity is lengthened, the modulation frequency is increased and the optical tuning range is widened.

IX. References

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