Distributed Bragg Reflector Fiber Laser Sensor for Temperature Sensing

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Abstract – A work in progress on a distributed Bragg Reflector (DBR) Fiber laser sensor for temperature measurement is presented. DBR Fiber Laser Sensor can be used in industry to monitor temperature in furnace, jet engines or power transformers. In telecommunication, they can be used to monitor temperature in Base Transceiver Stations where the equipments must be kept at controlled operating temperature. The goal of this project is to investigate, design, and develop a distributed Bragg Reflector Fiber Laser temperature sensor. DBR Fiber Laser Sensors are interesting for they allow higher resolution sensing due to their narrow line width as well as their higher signal-to-noise ratio as compared to fiber Bragg Grating or interferometric sensors.

Index Terms—Fiber Grating laser sensor, Distributed Bragg Reflector, Signal to noise Ratio.

I. INTRODUCTION

Since the first demonstration of fiber optic sensing capabilities, several sensing systems using fiber optics have been developed. Fiber optic sensors have crucial advantages over traditional electronic sensors such as compactness, low cost, and immunity to electromagnetic interference.

The working principle of a fiber optic sensor is the following: Light propagating in the fiber undergoes change of one or many of its parameters namely intensity, phase, wavelength or polarization as a consequence of its interaction with an external perturbation. The change of the parameter can be monitored via a detection system and therefore monitor the perturbation. [1]

One of the most popular fiber optics sensing scheme uses Fiber Bragg Grating. A Fiber Bragg Grating consists of a fiber segment whose index of refraction varies periodically along its length. Such structure has the property of reflecting a particular wavelength and transmitting all others. The reflected wavelength is called Bragg wavelength and is a function of the grating's period length and the effective refractive index of the fiber. Any physical parameter that modifies the grating length causes a shift of the Bragg wavelength. This property makes possible building sensors using Fiber Bragg Grating. The physical perturbation sensed is converted into wavelength variations, thus eliminating the problem of amplitude or intensity variations that plagues many other types of fiber sensors [2]. Numerous Fiber Bragg Grating sensors for strain, temperature, or pressure have been developed in the last years.

Another type of fiber optic sensor utilizes interferometers. The working principle of an interferometer is the following: An input beam is split into two separate beams. The two beams are recombined producing an interference pattern. An external perturbation shall alter the interference pattern, so that the perturbation can be sensed. Many interferometer configurations have been developed and used as sensors. Among the most popular can be named, the Michelson, Mach- Zender or Fabry Perot interferometers.

A Fabry-Perot interferometer consists of a cavity and a pair of mirrors. In a fiber optic Fabry-Perot interferometer Fiber Bragg Grating are used as mirrors. **A** Fabry Perot interferometer using a low reflectivity twin grating as mirrors has been developed and has proved good temperature sensing characteristics [3]

However such system suffers from low power efficiency. That is the signal reflected from the fiber Bragg grating is typically weak. Consequently, the Signal to Noise Ratio at the demodulation system is badly affected. Hence the accuracy of the sensor system is reduced in noisy environment.

For the above reason, Fiber Bragg grating sensor systems using fiber laser schemes is proposed.

Fiber Bragg Grating laser sensors can be classified into two types: Distributed Feedback (DFB) fiber laser sensors and Distributed Bragg Reflection fiber laser sensors (DBR). DFB fiber laser contains a π-phase-shifted Fiber Bragg Grating in an active medium and converts external perturbation into change in beat frequency between the two orthogonal polarizations from the fiber laser [4]. DBR fiber laser contains two wavelength-matched Fiber Bragg Gratings and a doped fiber in between forming a linear laser cavity. The cavity emits laser at the Bragg wavelength by pumping with a semiconductor laser diode. The DBR fiber laser responds to external perturbations in terms of shift in the operating wavelength of the fiber laser which is similar to that of a Fiber Bragg grating sensor. However the narrower linewidth permits higher resolution sensing. In this paper a DBR fiber laser sensor is presented.

II. PROPOSED EXPERIMENTAL SETUP

The proposed experimental setup is shown in figure 1. The DBR laser used in our experiment comprises two FBGs at the same wavelength (1550 nm) and separated by some distance of erbium-doped fiber, forming a linear laser cavity.

The pumping source is a laser diode emitting at 980 nm. Light from the source is launched in the fiber trough a 980/1550 nm WDM optical coupler. The signal from the laser is monitored at the signal processing system and gives a signal corresponding to the change in temperature.

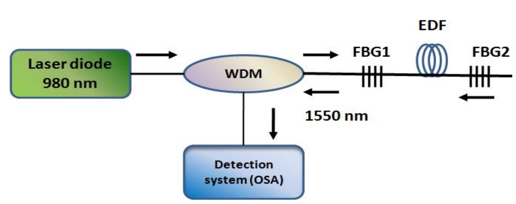

Figure 1. DBR fiber laser sensor proposed setup

The laser emits at Bragg wavelength by pumping with a semiconductor laser diode. The DBR laser cavity used in this experiment can be seen in figure (2)

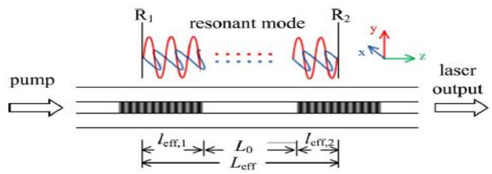

Figure 2. Schematic of the DBR fiber laser cavity

The resonant wavelength of the laser λ_{res} is expressed by the following equation:

$$\lambda_{res} = \frac{2n_{eff}.L_{eff}}{M} \quad , \qquad (1)$$

where L_{eff} is the effective cavity length, n_{eff} the effective refractive index of the Fiber Bragg Grating and M the order of the resonant mode of the laser.

$$L_{eff} = L_0 + L_{eff1} + L_{eff2} \qquad (2)$$

L_0 is the grating spacing; L_{eff1} and L_{eff2} are effective length of the two gratings respectively [4].

Typical DBR lasers are several centimeters long. As result, there are multiple longitudinal modes that satisfy the lasing condition. Our application requires a narrow linewidth from the laser. So the number of longitudinal modes having sufficient gain to oscillate has to be restricted to just a few numbers. This can be achieved by using a filter which selects the lasing mode around 1550 nm.

Due to the thermo optic effect and the thermal expansion, a change in temperature shall affect both n_{eff} and L_{eff} , as well as the fiber Bragg Grating pitch Λ , resulting in a change of the laser resonant wavelength, as it can easily be seen in equation (1).

The wavelength change of fiber Bragg Grating with temperature is expressed by:

$$\frac{\delta\lambda}{\lambda} = (\alpha + \beta)\delta T \quad , \qquad (3)$$

where $\beta = 8.5.10^{-6} K^{-1}$ represents the thermal expansion
And $\alpha = 5.10^{-7} K^{-1}$ denotes the thermo optic coefficient

A change in temperature will cause the shift of the Bragg wavelength of the grating; hence the lasing wavelength will shift. The measurement of the laser wavelength shift makes possible temperature monitoring.

III. OBJECTIVES

The Objectives of this project is to investigate, design, build and test a DBR fiber laser sensor for temperature measurement

IV. METHODOLOGY

To reach the objectives of the project the following methodology shall be followed.

- Literature study of a DBR fiber laser sensor for temperature measurement.
- Design and simulation of the DBR fiber laser sensor for temperature measurement.
- Implementation, measurement, and test of the sensor
- Characterization of the sensor of the DBR fiber laser sensor

V. CONCLUSION

In summary a DBR fiber laser sensor for temperature measurement has been described. Also the working principle, project objectives and methodology have been presented. The DBR fiber laser sensor can find application in industry whenever temperature monitoring is required like in Base Transceiver Stations. The crucial advantage of this sensor is the good signal to noise ratio as compared to other fiber optic laser sensors namely the fiber Bragg Grating sensors and the interferometric ones.

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Justice Sompo received his undergraduate degree at “Institut superieur pedagogique et technique de Likasi” DR CONGO and he is currently studying toward his Masters of Science degree at University of Johannesburg. His research interests include fiber sensors and fiber lasers.