Fiber Bragg Grating (FBG) is used as modeling and simulation for temperature sensor

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ABSTRACT

This paper deals with mathematical modeling, design and application of Fiber Bragg Grating as temperature sensor. In this paper we used the MATLAB and filter characteristics simulation software as a tool for simulation results. The fabrication of Fiber Bragg Grating, their characteristics and fundamental properties are described. The reflectivity of FBG is described using simulation results. This paper also presents the simulation results of FBG as temperature and gas sensor. From the plotting analysis it can be concluded that for reduce the width of reflection spectrum we can take long grating.

Keywords: Fiber Bragg Grating, Grating Sensor, WDM, MATLAB, strain, Temperature, Runge Kutta algorithm.

INTRODUCTION

The refractive index and grating period are the important properties of Fiber Bragg Grating, so we will study the effect of refractive index of FBG and grating period in sensor application. A FBG is a periodic perturbation of refractive index along the fiber length which is formed by exposure of the core to an ultraviolet light. The first FBG demonstrated by Hill et al in 1978 the Canadian communication Research center. FBG have the advantage of low insertion loss, low cross talk, low light return loss, compact size, a periodically low cost.

The linear effect of FBG like dispersive and wavelength selective properties has been studied. It also have successfully implemented in optical signal processing devices in WDM network such as dispersion compensator, and filter. There have been many studies to develop technique to obtain the desired spectrum response of FBG by altering physical parameter such as induced index change, length, apodized period chirp and fringe tell. FBG are now commercial available and they have found key application in routing, filtering, control and application of optical signal and sensor technology.

In this paper an introduction of FBG is given which focus on the mathematical modeling of FBG by the help of simulation results we will able to provide the properties of FBG.

Mathematical Modeling Of Fbg

The Bragg scattering of waves in a waveguide occur when the refractive index vary in z direction given as

\[ n(z) = n_0 + \Delta n(z) \cos \left( \frac{2\pi}{\Lambda} z + \theta(z) \right) \]

where \( \Delta n(z) \) and \( \theta(z) \) vary with grating period. If fiber is in a single mode operation, it support only fundamental mode. Which has two component propagating in opposite direction. These are \( v_1 \) for
forward propagating wave and v2 for backward propagating wave then compact mode equation

\[ \frac{dv_1(z, \delta)}{dz} = i \delta v_2 + q(z)v_i \]

Where \( v_1 \) and \( v_2 \) are complex amplitude envelopes of waves and obtained by removal of the spatial dependence \( \exp(\pm i\pi z / \Lambda) \) and \( q(z) \) defined as is complex coupling coefficient

Where \( \delta \) the phase shift per unit length compared to the Bragg wavelength is is given as

\[ \Delta \lambda_B = 2(\lambda \partial n / \partial T + \partial n / \partial l)\Delta T + 2(\lambda \partial n / \partial l + n \partial T / \partial l)\Delta l \]

Where \( T \) is the temperature and \( l \) is the length of strain effect, the second term of equation show the effect of temperature on FBG. The shift in Bragg wavelength due to thermal expansion and change in the index of refraction

\[ \Delta \lambda_B = \Delta \lambda_B(\rho - \bar{\rho}) \Delta T \]

Simulation Results of Uniform Grating

The below given graph are of uniform Fiber Bragg Grating. These plots are drown at grating length at 5 mm & 10 mm and different transmission loss 1 dB, 2dB, 3dB. These plots show the different reflectivity at different loss and Bragg wavelength. At the Bragg wavelength the reflection is highest, and before and after the reflection decrease in the form of sinc function and similar the transmission is highest at other than Bragg wavelength. At Bragg wavelength the transmission loss is highest.

Result on Temperature

As we increase the temperature the Bragg wavelength shift to left or right depend on the value of temperature if the temperature is less than 0°C than shift to the right and if temperature is greater
Fig. 1: Reflvl=1.0db, span=2, scale =2db/div, length =5mm, loss=3db

Fig. 2: Reflvl=1.0db, span=2, scale=2db/div, length =10mm, loss=3db

Fig. 3: Reflvl=1.0db, span=2, scale =2db/div, div, length =5mm, loss=2db

Fig. 4: Reflvl=1.0db, span=2, scale =2db/div, length =10mm, Loss 2db

Fig. 5: Reflvl=1.0db, span=2, scale =2db/div, =2db/div, length =5mm, loss =1db

Fig. 6: Reflvl=1.0db, span=2, scale length=10mm, loss 1db
Fiber Bragg grating based sensor can be used to measure the temperature 73K to 350K and this sensor have higher resolution, high accuracy and easy to use. The given plots are showing the spectrum of reflection and transmission. According to the figure, the reflection is highest at Bragg wavelength and at that point the transmission loss is high. These plots are drawn for 5 mm/10 mm length of grating. As we increase the length of grating, the width of the spectrum decreases, which means for low reflection, we should use long grating.

**CONCLUSION**

Simulation results are taken for uniform grating, different length (5mm and 10mm), and different reflection loss (1db, 2db and 3db). Simulation results give spectral properties of grating for uniform grating and temperature-effected grating. This paper gives description based on modeling of FBG. From results we can conclude that for low loss and less reflection, we must try to use long grating and FBG is suitable for using in temperature sensor. From the plots, we can see that the transmission loss is high at Bragg wavelength and its shift to right when we use grating as a temperature sensor.

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