ISSN 2229-5518

Design of a Rectangular Plate Optical Pressure Sensor Waveguide with Integrated Bragg Grating

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Abstract-- This paper presents the design and simulation of a rectangular plate optical pressure sensor waveguide. The waveguide has a nano-scale Bragg grating introduced on the upper half area. The Bragg grating shows a considerable deformation, when it is subjected to tangential strain, which forms the basic sensing principal for the design. The free space wavelength of 1.55µm and Bragg spacing of 0.5µm is used. The performance of the Bragg sensor for different types of grating is also observed and compared. The maximum sensitivity counted for a pressure of 300bar was about 2.436dBm/µm. After analyzing the simulation results of types of grating, it is found that chirped fiber grating gives the better reflectivity, with maximum suppressed side lobes. The design is simulated using COMSOL Multiphysics 3.2a**.**

Keywords- Wave guide, Reflectivity, Bragg Grating, Chirped Grating, Tilted Grating**.**

1 INTRODUCTION

Recent studies in the field of optical communication show a considerable improvement in the use of Fiber Bragg sensors for the measurement of pressure. This may be characterized by their immunity to electromagnetic interference, high sensitivity, small size, and multiplexing advantages. A Bragg sensor basically finds an essential application in areas where distributed sensing is the primary goal [1]. Gratings can be photo-inscribed into a silica fiber, and can have all the basic advantages essential for a fiber optic sensor.

The basic principle behind Bragg sensing is periodic variation in the refractive index of the core material causes a change in the reflected wave from the Bragg grating It has been demonstrated that strain and temperature can be simultaneously measured on a single fiber Bragg sensor, by measuring the shift in the Bragg wavelength[2]. Also some other works show that the basic fiber Bragg sensor can be used for measurement of saccharinity and salinity, using polymeric coating materials[3]. In [4], properties of silicon material are identified for which it can be used for higher sensitivities.

This paper shows a frequency modulated Bragg grating sensor, inscribed on a rectangular waveguide, for high pressure sensing.

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The measure of sensitivity shows the benefit of using this waveguide in harsh environments. The detailed mathematical analysis for pressure measurement and sensitivity can be found in [5].A comparative study among uniform, chirped and tilted bragg grating is done in this paper. The modules used are Electromagnetics module, to set the free space wavelength, and the stress strain module, to observe the pressure effect.

2 DESIGN OF PRESSURE SENSOR

The basic principal of operation commonly used in the FBG based sensor system is to observe a shift in the Bragg wavelength with the changes in the applied parameters. The relationship between bragg wavelength and grating width is given by (1).

$$\lambda_B = 2n_{eff}\Lambda \quad (1)$$

Where, Λ is the grating width and $n_{eff}$is the effective mode refractive index.Using (1), the grating width is determined for a bragg wavelength of 1.55µm and n_{eff}=1.430015, which is found to be 0.5µm.

The sensor (figure 1) consists of a silicon membrane of refractive index 3.48, which has an optical waveguide on the top. On this waveguide, the above grating is formed. The core of the waveguide is formed of SiONhaving a refractive index 1.478, and SiO_2 forms the upper and the lower cladding layers having a refractive index of 1.436. The total thickness of the resultant waveguide is 120µm.

The grating is located on the upper half area of the waveguide because this way we can easily convert the applied pressure into longitudinal strain. Another advantage is that the grating reflectivity is increased and reflection bandwidth is reduced. This sensor also has grooves to facilitate the coupling of the waveguide to the optical fiber.

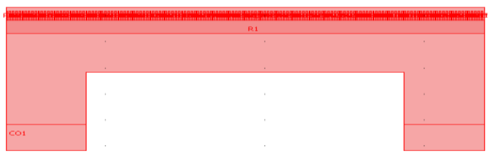

Figure 1. Waveguide with uniform Bragg grating

The reflected signal bandwidth is mainly dependent on the grating length. To get maximum reflectivity, it is important to reduce the bandwidth of the reflection peak. Any deformation in the wavelength of the fiber on applying tangential strain will cause a change in the grating period. The boundary conditions are fixed and a uniform tangential pressure is applied on the upper surface.

All the above simulations are also repeated for different grating structures like chirped and tilted, and compared for maximum reflectivity with minimum side lobes. The measured reflectivity with varying wavelengths is also shown.

3 RESULTS AND DISCUSSION

A pressure of 300 bar is applied to the upper area of the waveguide sensor Figure 1. The simulated result is shown in figure 2.From the figure, it is seen that the reflection peak of the waveguide sensor at 1.55μm, with a uniform bragg grating..

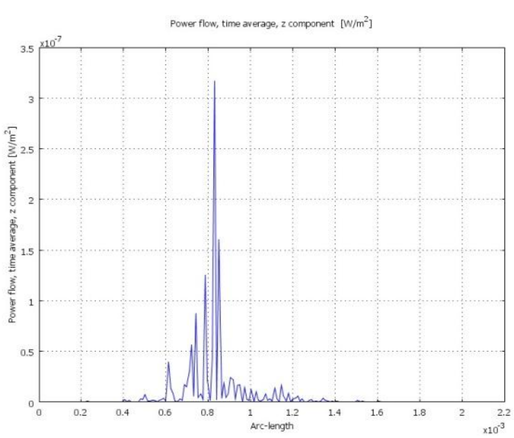

Figure 2. Reflection spectra for uniform bragg grating with an applied pressure of 300 bar

For the same wavelength, the sensitivity of the device was measured to be 2.436dBm/μm

A considerable amount of side lobes are visible in the above power spectra of uniform grating. This can have an adverse effect on the reflectivity of the bragg grating, which in turn affects the sensitivity of the waveguide sensor. These side lobes are considerably reduced in chirped bragg grating structure as seen in figure 3.

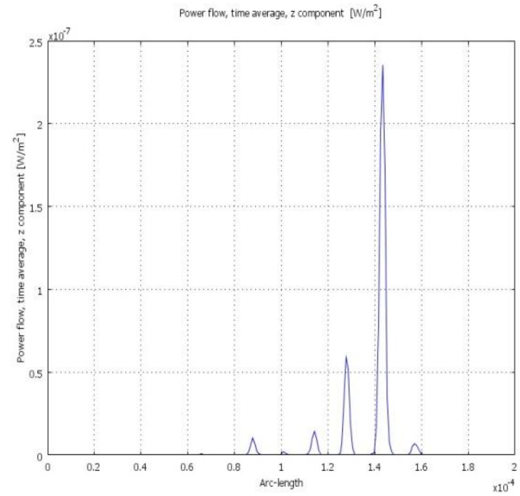

Figure 3.Reflection spectra for chirped bragg grating with applied pressure of 300 bar.

Figure 4 shows the reflection spectra with tilted bragg grating. It can be seen that as we increase the angle of tilt, the reflectivity reduces. More the tilt angle increases, the coupling to cladding layers also increases, hence giving a lower reflection peak.

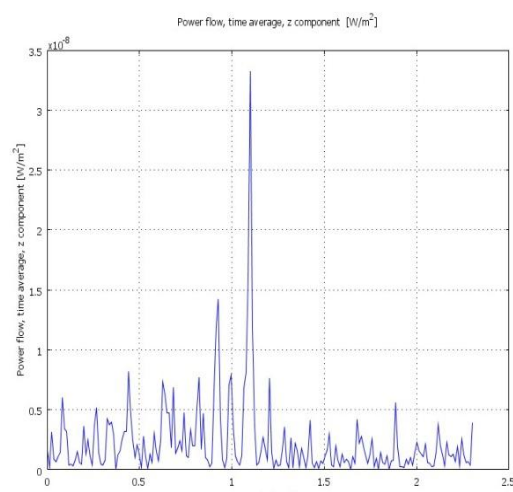

Figure 4. Reflection spectra with tilt angle θ=4˚

Figure 5 is the reflection spectra with tilt angle θ=8˚, and pressure applied is 300 bar.

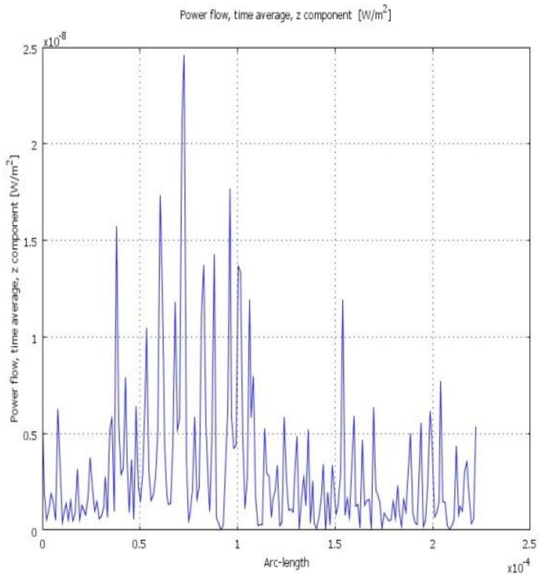

Figure 5.Reflection spectra with tilt angle θ=8˚

Figure 6 shows measured reflection spectra for uniform bragg grating sensor with applied pressure of 250bar, 300bar and 350bar. It shows that at a wavelength of 1.55µm, the sensor has the highest power .the sensitivity calculated for the pressure of 300bar is 2.436dBm/µm.

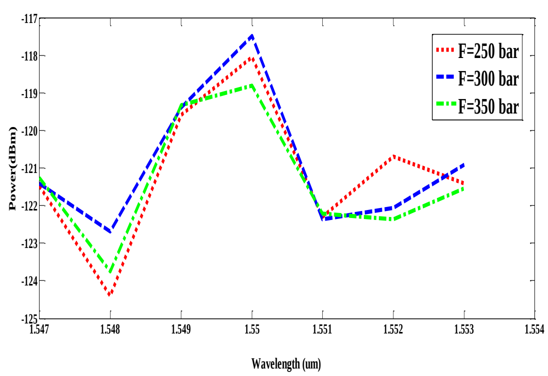

Figure 6. Measured reflection spectra for uniform fiber bragg grating with different pressure values.

Figure 7 shows the measured reflection spectra for reflectivity at different wavelengths. The graph shows the maximum reflectivity occurs at a wavelength of 1.55µm, whereas it decreases beyond this value. The reflectivity is calculated for wavelengths varying from 1.1µm to 1.56µm.

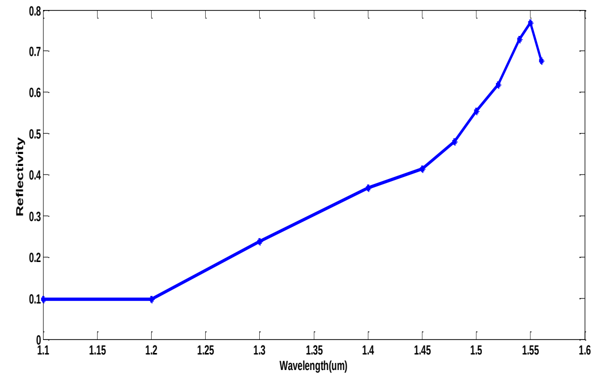

Figure 7. Reflectivity vs Wavelength for uniform grating

Figure 8 shows the reflectivity variation with different wavelengths for chirped bragg grating ranging from 1.1µm to 1.56µm.

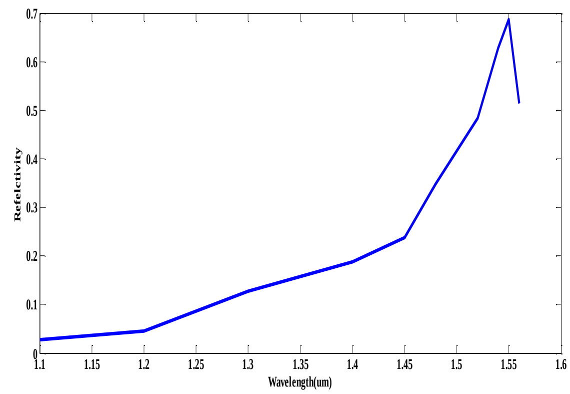

Figure 8. Reflectivity vs Wavelength for chirpedgrating

Figure 9 shows the reflectivity variation with different wavelengths for tilted bragg grating ranging from 1.1µm to 1.56µm.

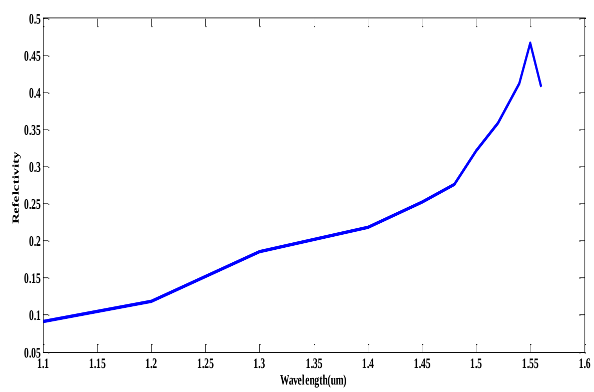

Figure 9. Reflectivity vs Wavelength for tilted grating

4 CONCLUSION

In this paper, a rectangular plate optical pressure sensor waveguide with different grating, uniform, chirped and tilted, is analyzed. Simulated results show that the maximum sensitivity of 2.436dBm/µm is achieved for an applied pressure of 300 bars. The same is also tested for chirped and tilted grating structures, from which we can see that the chirped grating fiber bragg structure give us better results in terms of reflectivity and side band reduction. The wavelength with different reflectivity is also considered in this.

ACKNOWLEDGMENT

The authors want to express their profound thanks to the Chancellor Vellore Institute of Technology for his support, providing best infrastructure and lab facilities. We would also like to thank Dr. Elizabeth Rufus, Director, School of Electronics Engineering for her valuable encouragement. Also we are thankful to all the teaching and non-teaching staff of the college for their technical assistance. Last but not the least, thanks to all friends and family members who have been with us throughout the completion of project.

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