EFFECT OF GRATING PARAMETERS OF FIBER BRAGG GRATING ON ITS REFLECTION SPECTRUM

1ASHWIN SURESH NIJAPKAR, 2MANISHA CHATTOPADHYAY

1ME in Electronics & Telecommunication Engg, VESIT, Chembur, Mumbai, 2Prof. in Electronics & Telecommunication Engg, VESIT, Chembur, Mumbai
E-mail: 1ashwin.nijapkar@ves.ac.in, 2manisha.chattopadhyay@ves.ac.in

Abstract—This paper presents the effect of grating parameters on reflectivity, bandwidth and bragg wavelength of Fiber Bragg Grating. Length of the fiber, index modulation and grating period are the grating parameters. Couple mode theory is used for analysis of Fiber Bragg Grating spectrum which is solved by transfer matrix method to analyse the Spectral reflectivity with changes in the grating parameters. Simulation is carried out using Opti-grating software.

Index Terms—Couple Mode Theory (CMT), Fiber Bragg Grating (FBG), Reflectivity, Transfer Matrix Method.

I. INTRODUCTION

The Fiber Bragg Grating (FBG) is a passive optical device with a periodic variation of the refractive index along the fiber length in the core of the fiber. [1] Bragg gratings are formed by periodically changing the refractive index in the core of the fiber. Refractive index changes are made by exposing the core of the optical fiber to an interference pattern of ultraviolet light.

Several techniques used for the fabrication of FBG which are transverse holographic, phase mask and point by point technique. [2] When the core of the optical fiber is exposed to ultraviolet light, the refractive index is changed. This is known as ‘photosensitivity’. Germanium is a dopant used in fiber core which is photosensitive to ultraviolet light. Amount of change in the refractive index depends on the intensity and duration of the ultraviolet light exposure. Photosensitivity of the fiber allows the fabrication of phase structures into fiber core. [3] FBG has advantages of simple structure, small size, light weight, high sensitivity, electrically passive device and immune to electromagnetic interference. [4] FBGs have many applications in dense wavelength division multiplexing, dispersion compensation and in different types of sensing applications. [5]

Fiber bragg grating is a type of filter. FBG reflects light in shorter range of wavelength and transmit other wavelengths. [6] In this paper, the effect of grating parameters on FBG reflectivity is analyzed. Section II presents the fundamentals of Fiber Bragg Grating. Results and analysis are presented in section III.

II. FUNDAMENTAL THEORY OF FBG

A. Fiber Bragg Grating

Bragg grating consists of periodic modulation of refractive index in the core of single mode fiber. In uniform fiber gratings, phase fronts are perpendicular to longitudinal axis of the fiber & grating planes have a constant grating period $\Lambda$.

$$\lambda_B = 2n_{\text{eff}} \Lambda$$

where $\lambda_B$ is the central wavelength of FBG, wavelength that satisfies bragg condition. $n_{\text{eff}}$ is the grating period or pitch. [7]

![Fig.1. Basic concept of Fiber Bragg Grating][1]

When the light is incident in the fiber, it propagates through the periodic variation. Forward propagating light will undergo strong reflection, leading to propagate light in backward direction through the fiber. Wavelength corresponding to bragg wavelength will get strongly reflected i.e. when the bragg condition is satisfied. [8] Typical layout of Fiber Bragg Gratings with transmitted and reflected spectrum is shown in Fig.1.

B. Couple Mode Theory (CMT)

The couple mode theory is a method to analyze the light propagation in perturbed or weakly coupled waveguides. In this method unperturbed and uncoupled structures are defined and solved. Then a linear combination of these modes is used as a
solution to Maxwell’s equation for complicated structures. [9]

For a single mode fiber, the simplified couple mode equations are given by, [10]

\[
\frac{dR}{dz} = i \sigma R(z) + ik S(z)
\]

(2)

\[
\frac{dS}{dz} = -i \sigma S(z) - ik R(z)
\]

(3)

Where \( R \) and \( S \) are the transmitted and reflected fields respectively, \( R(z) \) is the amplitude of forward and \( S(z) \) is the amplitude of backward propagating mode. \( k, \sigma \) are “ac” & “dc” coupling coefficients respectively and are given for single mode bragg reflection grating as:

\[
k = k^* = \frac{\pi}{\lambda}
\]

(4)

\[
\sigma = \frac{2 \pi}{\lambda} \frac{d \phi}{dz}
\]

(5)

Here, \( \delta \) is a detuning parameter.

\[
\delta = \beta - \frac{2 \pi}{\lambda} = 2 \pi \left( 1 - \frac{1}{\lambda_B} \right)
\]

(6)

\[
\sigma = \frac{2 \pi}{\lambda} \frac{d \phi}{dz}
\]

(7)

In uniform Fiber Bragg Grating, \( \beta \) is propagation constant, \( \lambda_B \) is a designed bragg wavelength, \( n_{ef} \) is a constant and grating chirp \( \frac{d \phi}{dz} \) is 0. With appropriate boundary conditions the analytical expression of reflectivity is given by,

\[
r = \frac{\sinh^2 \left( \sqrt{k^2 - \sigma^2 L} \right)}{\cosh \left( \sqrt{k^2 - \sigma^2 L} \right) - \frac{\sigma^2}{k^2}}
\]

(8)

C. Transfer Matrix Method

Transfer Matrix Method is used to solve the couple mode equations of the FBG. Grating structure is divided into a number of uniform grating sections, which have analytic transfer matrix. Transfer matrix for entire structure can be obtained by multiplying individual transfer matrices. [9]

\[\text{III. RESULTS AND ANALYSIS}\]

The spectral response of Fiber Bragg Grating is obtained; the simulation is carried out using opti-grating. FBG parameters are listed in Table1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Symbols</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bragg wavelength</td>
<td>( \lambda_B )</td>
<td>1550 nm</td>
</tr>
<tr>
<td>Index modulation</td>
<td>( \Delta n )</td>
<td>0.0001</td>
</tr>
<tr>
<td>Grating period</td>
<td>( \Lambda )</td>
<td>533.81 nm</td>
</tr>
<tr>
<td>Effective index</td>
<td>( n_{ef} )</td>
<td>1.47</td>
</tr>
<tr>
<td>Grating length</td>
<td>( L )</td>
<td>10000 µm</td>
</tr>
</tbody>
</table>

A. Effect of grating length on reflection spectrum

Effect of grating length on spectral reflectivity is observed by varying the grating length from 10000 to 40000 µm. Fig. 2-5 shows that the reflectivity of the FBG increases with increase in the grating length. For the grating length \( L=10000\mu m, 20000\mu m, 30000\mu m, 40000\mu m \) the maximum reflectivity is 57.51%, 94.76%, 99.48%, 99.99% respectively. Reflectivity remains constant after 40000 µm. Bandwidth becomes narrow with increase in grating length.

B. Effect of index modulation on reflection spectrum

Effect of index modulation on spectral reflectivity is observed by varying index modulation from 0.0001 to 0.0004. Fig.6-9 shows that the reflectivity of the FBG increases with increase in the index modulation. For the index modulation \( \Delta n =0.0001, 0.0002, 0.0003, 0.0004 \) the maximum reflectivity is 56.38%, 94.86%, 99.56%, 99.98% respectively. Reflectivity remains constant after 0.0004. Bandwidth becomes wider with increase in index modulation.

C. Effect of grating period on reflection spectrum

Fig.10-13 shows the Bragg wavelength shift with increase in the grating period. For the grating period \( = 0.53381599, 0.53391599, 0.53401599, 0.53411599 \) Bragg wavelength is shifted from 1550 nm to 1550.002, 1550.29, 1550.586, 1550.872 nm respectively. Reflectivity and bandwidth remains unaffected by the changes in the grating period.

A. Reflectivity spectrum at different grating lengths

![Fig.2. Spectral reflectivity of FBG for grating length 10000µm](image)
Effect of Grating Parameters of Fiber Bragg Grating on its Reflective Spectrum

B. Reflectivity spectrum at different index modulations

C. Reflectivity spectrum at different grating period
Effect of Grating Parameters of Fiber Bragg Grating on its Reflection Spectrum

CONCLUSION

Reflectivity of fiber bragg grating increases with increase in grating length and index modulation. The Bandwidth of the fiber bragg grating is narrower for longer grating length and is wider for larger index modulation. For narrow bandwidth we have to select longer gratings with smaller index change. When index modulation is a constant in a grating over some length and drops to zero outside the range there are number of sidelobes are present with increase in grating length and refractive index modulation, which can be suppressed by using apodization technique to eliminate the crosstalk between information channels. Apodization is a grading of refractive index at the end of the grating to approach zero. With increase in grating period, bragg wavelength shifts from the central wavelength. This wavelength shift can be used for strain and temperature sensing.

REFERENCES