EFFECT OF GRATING LENGTH ON PEARAMETERS OF UFBG USEFUL IN OPTICAL COMMUNICATION

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Abstract: In this paper peak reflectivity and the bandwidth of the reflection spectra of uniform fiber Bragg grating (UFBG) are studied at different grating lengths along with different index amplitude values of 1×10^{-4}, 5×10^{-4}, $10\times10^{-4}$and 14×10^{-4}. The UFBG is modeled on the datasheet of SG682 single mode optical fiber. The numerical integration of the coupled mode equation was used to solve the properties of FBG. The paper discusses the variation of both quantities and their usefulness in the area of communication.

Keywords: Bandwidth, grating length, index amplitude, reflectivity, uniform Fiber Bragg Grating (UFBG).

Introduction: Uniform fiber Bragg gratings (UFBGs) are based on contradirectional modes coupling [1]. In today's optical communication technology need for all optical components has been aroused. According to International Telecommunication Union – Telecommunication (ITU-T) recommendation on the inter channel spacing in dense wavelength division multiplexing optical system is 100 *GHz* (0.8 *nm*) [2] ,[3]. In this the bandwidth becomes the prominent issue as the inter channel spacing is decreasing with the new technologies which may lead to accommodate more number of channels through the single fiber. FBGs fulfills the need of wavelength selective of applications such as filtering, wavelength multiplexing, demultiplexing and signal add/drop applications to combine or separate wavelength channels in dense wavelength division multiplexing (DWDM) optical communication systems [3]. As in case of EDFA & semiconductor laser to maintain a reasonable amount of population inversion in the gain medium, a counter-propagating amplifier configuration is used for optimum power conversion efficiency. There the use of a broad, highly reflecting FBG is needed to double pass the pump light in the amplifier. Hence in optical instrument having FBGs the bandwidth estimation and reflectivity are very sensitive issue [3], [4].

Photosensitivity is the main characteristic of an optical fiber which leads to the formation of FBG on it. By inscribing the periodical intensity of UV lights onto the photo-sensitive fiber core induces to have permanent periodical refractive index change throughout grating length FBGs are usually fabricated [5].

So in this paper an analytic method is used to model a uniform FBG in SG682 single mode fiber. The dispersion parameters of core, cladding and surrounding material are ignored by assuming them negligible. Attenuation and absorption losses of the fiber are also not considered here. We have simulated the grating spectra of UFBG, its reflectivity and bandwidth by varying its grating length and index amplitude.

Theory of FBG: By Uniform FBG it is meant that the grating's spatial periodicity (Λ) & index amplitude (Δn) of the grating remains constant throughout the grating length. Basically uniform FBG works on the mechanism of coupling the light coming from core mode to a counter-propagating mode. Because of this coupling it modifies the phase or intensity of the reflected Bragg's wavelength i.e. the wavelength coupled to the counter-propagating mode. But this mechanism is only possible in FBG if the reflected wavelength is equal to Bragg's resonant wavelength. So it becomes important to calculate the resonant wavelength. The resonant Bragg's wavelength can be described by the equation [5], [6],

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

Where, λ_B is the Bragg's wavelength that will be reflected back from the Bragg grating, n_{eff} is the effective refractive index of the fiber core at Bragg's grating wavelength and Λ is the grating period [6]. A typical diagram showing the mechanism of FBG is in Fig. (1).

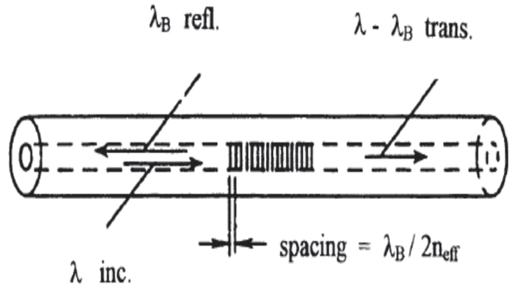

Fig.1. Uniform Fiber Bragg Grating [6].

Structural Modeling of UFBG: For the simulation we have used the specifications of a practically available SG682 single mode fiber. The specifications given for this fiber are core diameter 1.8 μm, core refractive index 1.47 and cladding refractive index 1.457. Hence all of the simulations done here are

based on these values [7].
From equation (1), we comes to know that the Bragg's resonant wavelength (λ_B) varies with the periodicity (Λ) and effective refractive index (n_{eff}) of the mode, and the effective mode refractive index depends upon the propagation constant (β), and on the vacuum wave number ($k_0 = \frac{2\pi}{\lambda}$), where λ is the wavelength,

$$n_{eff} = (\beta / k_0) \qquad (2)$$

If we consider a uniform Bragg grating formed within the core of an optical fiber having an refractive index (n_{co}). Then the sinusoidally modulated index of refractive profile n(x) through the fiber core can be expressed as,

$$n(x) = n_{co} + \Delta n \left[1 + \cos(\tfrac{2\pi x}{\Lambda})\right] \qquad (3)$$

Where, Δn is the refractive-index perturbation typically 10^{-5} -10^{-3} [8]; 'x' is the distance along the fiber longitudinal axis. Using the coupled-mode theory analytical description of the reflection properties of Bragg gratings may be obtained [8], [9]. The reflectivity of a grating with constant modulation amplitude and period is given by the following expression [9], [10],

$$R(l,\lambda) = \frac{\delta^2 sinh^2(fl)}{\Delta s^2 sinh^2(fl) + f^2 cosh^2(fl)} \qquad (4)$$

Where, R(l, λ) is the reflectivity, which is a function of the grating length (l) and wavelength λ, δ is the coupling coefficient, $\Delta s = k - \pi/\lambda$ is the differential propagation constant; $k = 2\pi n_{eff}/\lambda$ is the propagation constant and $f = \sqrt{\delta^2 - \Delta s^2}$. For contra-directional coupling between two LP_{01} modes having modal field profile ψ_1 and ψ_2 propagating in opposite directions to each other, and if $\psi_1 = \psi_2$, coupling coefficient can be written as [9], [10],

$$\delta = \frac{\omega \varepsilon_0}{8} \iint \Delta n^2(x,y) |\psi|^2 dxdy \qquad (5)$$

Where, ω is the frequency component and ε_0 is the free space permittivity. At the Bragg grating resonant wavelength there is no wave vector detuning and differential propagation constant is zero (i.e. $\Delta s = 0$) at Bragg grating center wavelength; therefore, the expression for the reflectivity becomes,

$$R(l,\lambda) = tanh^2(\delta l) \qquad (6)$$

From the equation (5) it is clear that the reflectivity increases as the induced index of refraction change increases. Similarly, as the length of the grating increases so does the resultant reflectivity [9], [10]. The three main parameters grating length, effective refractive index and bandwidth of the reflection spectra are related to each other as approximated in equation below [10],

$$\Delta\lambda_{BG} \cong \frac{\lambda_B^2}{n_{eff}\pi L} [(\delta L)^2 + \pi^2]^{1/2} \qquad (7)$$

Equation defines that effective refractive index is inversely proportional to bandwidth of the FBG spectra. So if n_{eff} is large the bandwidth will be narrow.

Results: A FBG reflection spectra as a function of the wavelength tuning is shown in fig. 2. Multiple reflections to and from opposite ends of the grating region are shown by the side lobes of the resonance peak in the figure. We have done simulation in MATLAB 7.6 (2008a).
In this simulation the center wavelength (Bragg's wavelength) is 1550 nm, core radius = 1.8 μm, cladding radius = 62.5 μm, grating period = 0.529 μm and effective refractive index is 1.4644.
Fig. 2 shows the reflection spectra of 7mm grating length of FBG for different index amplitudes (Δn) values. It has been observed that reflectivity of the grating is 37.57% and 94.7% for Δn = 2×10^{-4} and 3×10^{-4} respectively.

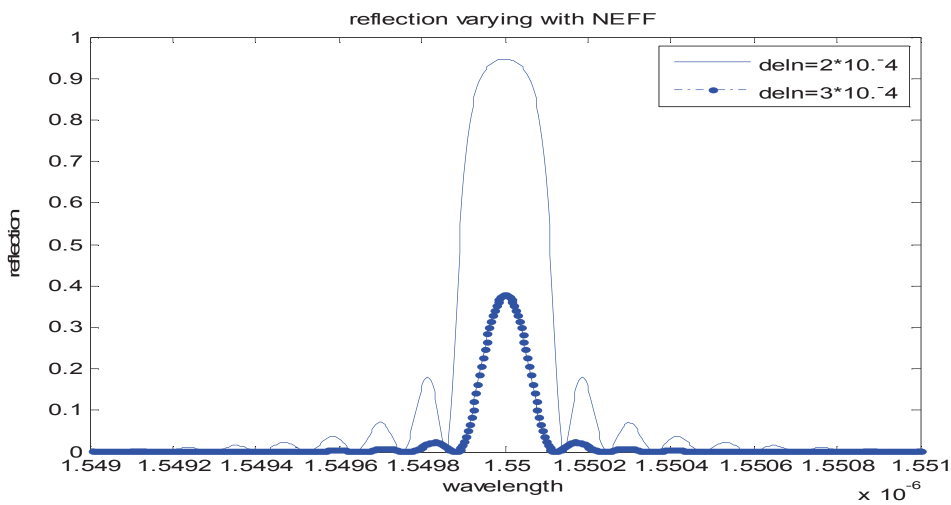

Fig.2. Reflectivity versus wavelength at 7mm FBG length.

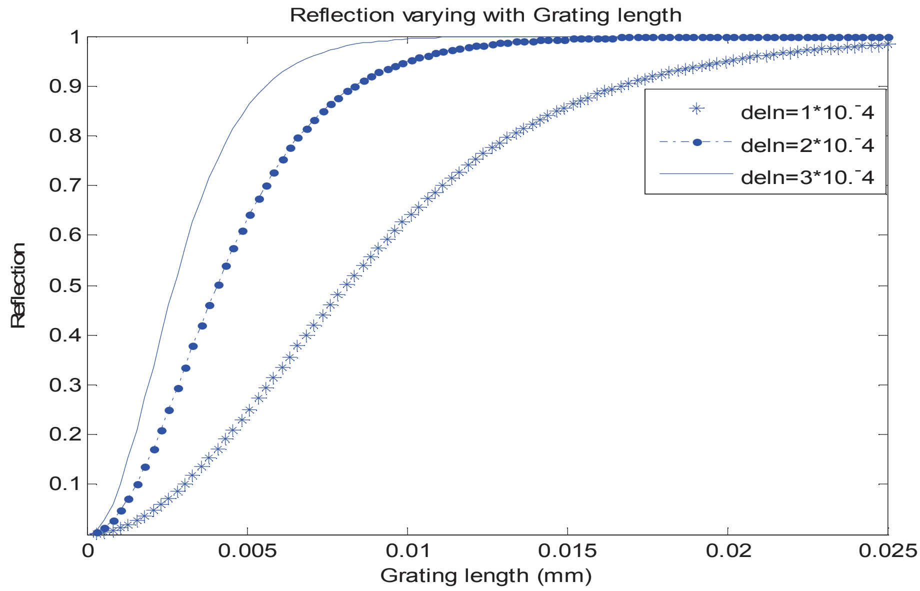

Fig.3. Reflectivity plot with varying grating length.

Fig. 3 shows the peak reflectivity values of the Bragg's resonance occurring for different grating lengths at constant refractive-index perturbation values. Some tabulated values of reflectivity obtained at resonant Bragg's wavelength are given in the table 1.

TABLE 1			
Grating Length (mm)	R at ($\Delta n=1\times10^{-4}$)	R at ($\Delta n=2\times10^{-4}$)	R at ($\Delta n=2\times10^{-4}$)
25	98.3%	99.9%	100%
19.9	94.98%	99.93%	100%
14.9	85.64%	99.4%	99.98%
12.4	76.4%	98.21%	99.88%
9.8	62.59%	94.71%	99.37%
7.3	44.02%	84.89%	96.74%
4.8	23.08%	60.94%	84.11%
2.3	5.98%	21.06%	39.88%

Here in Fig.4 we have seen the behavior of bandwidth at different grating lengths at different values of index amplitudes 0.5×10^{-4}, 7×10^{-4}, 11×10^{-4} and 15×10^{-4} respectively.

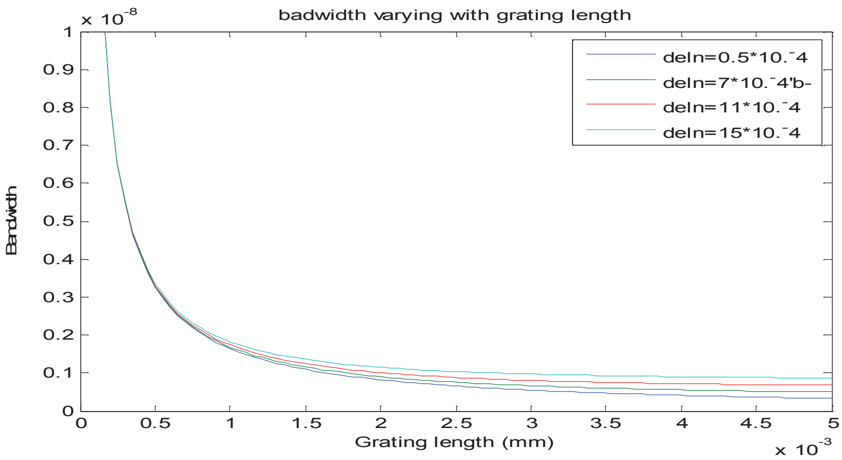

Fig.4. Bandwidth of FBG spectra Versus Grating length

From Fig. 4 it is clear that at shorter grating lengths i.e. up to 1mm the variation and bandwidth value is large but remains approximately same at all index amplitudes. At larger grating length up to 5mm there is no large variation in the bandwidth value but a contrast in the bandwidth at different index amplitudes is seen. Bandwidth shows a linear behavior with refractive index rather at large grating lengths.

Conclusion: It is observed from the results that with the increase in the value of refractive-index perturbation the reflectivity of the FBG is decreasing. So the reflectivity can also be varied if it is possible to vary index perturbation values, but this is possible in chirped FBG's which has varying index perturbation values. Calculated results are for uniform FBG, so from the table 1, it is seen that for shorter grating lengths the reflectivity value is low & for longer grating lengths reflectivity is higher. So these higher values of reflectivity are useful in the applications such as EDFA where population inversion has to be maintained at certain level by using high value of reflectivity at the ends and the lower values are helpful in semiconductor lasers.

The dependence of bandwidth, refractive index & grating length shows that at large grating lengths narrow bandwidth and at small grating lengths wide bandwidth is available. So these cases can be implemented to have narrow band filter and wide band filter in the optical communication system.

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