Optical Fiber Bragg Grating Filter for Wavelength Division Multiplexing (WDM) Applications

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Abstract— A Fiber Bragg grating is an aperiodic or periodic disorder of the effective index of refraction in the optical fiber core, having nanometres range period. For short periods of the index modulation, the disorder in index of refraction perturbation induces the light reflection in a limited wavelength range, for which condition of Bragg is satisfied. Incidence of a broad-spectrum light onto one fiber end containing a fiber Bragg grating, induces reflection of the portion of the light corresponding to wavelength of the Bragg grating to the input end, while the remaining light reaches the other end. Optical wavelength division multiplexing (WDM) networks employed in long distance and metro areas; several nodes are present to distribute the signal. The optical add-drop multiplexer (OADM) is the significant equipment which is responsible for separation of distinct wavelengths and redirection of the linked signals across the network to the corresponding users. The operating principle of the optical add-drop multiplexer deems an accurate filtering operation, provided by Bragg gratings. In this paper, optical fiber Bragg grating filter is designed and analysed for Wavelength Division Multiplexing (WDM) application.

Keywords- Bragg grating, Bragg wavelength, optical filter, wavelength division multiplexing.

I. INTRODUCTION

Fiber Bragg grating (FBG) based photonic filters find their applications in a wide assortment of areas; sensor [1], laser [2], systems of optical communication [3,4]. Additionally, Bragg filters possessing narrow bandwidth are employed in astronomy to suppress the background of the night sky [5].

FBGs are components of passive nature possessing enhanced performances, cheap and easily producible. FBGs are installed as indispensable components in the systems of optical sensors and optical communications [6,7]. Fiber Bragg grating find their applications as photonic filters [8,9], filters for flattening of gain [10], fiber lasers' feedback mirrors [11] and compensator for dispersion [12,13].

Enhancement of traffic of information has posed increased constraints on the present system of fiber optic communication leading to its fast improvement. Advanced and recent technologies are required to entails the transition of the links with higher bit rate and enhanced efficiency of spectrum smoothly. This is being limited by the difficulty in developing cheap devices which processes in all optical domain. Fiber Bragg gratings with tiny dimensions and probability of customed design of transfer function, presents to be the most striking passive component amongst the different techniques available. Massive applications in systems of telecommunication include compensation of dispersion, optical filtering and shaping of pulse. Most importantly, FBGs play a key role in splitting and combining channels of different wavelengths as a part of communication links in wavelength division multiplexing optical networks.

FBG is a periodic perturbation of the index of refraction laterally through the length of the fiber length. This disorder is instilled through the exposing of the core of the fiber to photonic interference pattern of great strength. Hill et al. verified forming of the perpetual gratings inside the optical fiber in 1978 at the CRC, Ottawa, Canada, [14,15]. This was achieved by launching of high-power radiation of argon-ion laser to the fiber doped with germanium whereby, light instensity of the reflected light enhance after several minutes till almost all the incident light got reflected back from the fiber. Confirmation of formation of Bragg grating filter of narrow bandwidth over the whole length of the fiber was achieved through spectral measurements.

For communication systems employing dense wavelength division multiplexing (DWDM), gratings engraved fibers having perfect box spectra are quickly fetching to be indispensable device. Numerous approaches are existing to attain the maximum possible utilization of bandwidth. Ibsen et al. [16] presented gratings with several channels having equal spacing and indistinguishable wavelengths with the help of a periodic modulation of profile of index of refraction in Bragg gratings engraved fibers. Carballar et al. [17] reported the achievement of perfect box spectrum through the adoption of function of apodization in the designing of modulation of period of grating. Zhang [18] enhanced the performance periods as filetrs with multi-channel and compensators for dispersion by hosting Sinusoidal chirps of periods of grating.

Optical wavelength division multiplexing (WDM) networks employed in long distance and metro areas, several nodes are present to distribute the signal. The optical add-drop multiplexer (OADM) is the significant equipment which is responsible for separation of distinct wavelengths and redirection of the linked signals across the network to the corresponding users.

The operating principle of the optical add-drop multiplexer deems a accurate filtering operation, provided by Bragg gratings. In this paper, optical fiber Bragg grating filter is designed and

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analysed for Wavelength Division Multiplexing (WDM) application.

II. THEORETICAL ANALYSIS

The optical filtering function of a fiber Bragg grating owes to the presence of a stop band which is the band of frequency where back reflection of almost all the light incident occurs. It is characterised by the existence of periodic refractive index modulation inside an optical fiber core operating in single mode. Gratings engraved fibers of uniform period with normal phase fonts to the longitudinal axis of the fiber and the planes of grating having a fixed period, are considered as the indispensable structural components for the mainstream Bragg grating structures. Under certain conditions, coupling of beam of light occurs strongly through the mode which is passing on the direction opposite to it. The condition is the so called Bragg condition where the spatial frequency of the grating's equals the difference of the propagation constants of the two modes which are coupled.

The Bragg's equation is given by:

$$\lambda_{bragg} = 2\Lambda \, n_{eff} \quad (1)$$

with λ_{bragg} as the Bragg's wavelength, n_{eff} is the effective refractive index of the grating and Λ is the period of the structure.

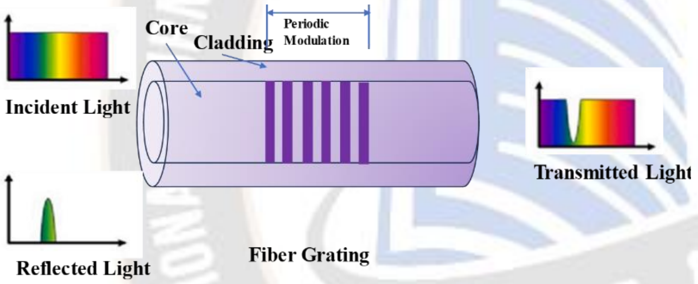

Figure 1. Schematic Representation of fiber Bragg grating filter.

Equation (1) stipulates the wavelength of occurrence reflection of great strength. Physically, reflection of some light occurs at each change in index of refraction. Addition of multiple reflections in phase takes place leading to the formation of stronger reflection when the reflections from points parted by a spatial period are in phase. This occurs when equation (1) is satisfied. Figure 1 shows the schematic representation of fiber Bragg grating filter.

III. PROPOSED DESIGN

In this work, fibre Bragg grating based Optical Grating Filter will be designed and analysed for Wavelength Division Multiplexing (WDM) application using OptiFDTD software. Two filters are designed to operate at the wavelengths of the normal Wavelength Division Multiplexing. The wavelengths are 1330 nm and 1550 nm. Figure 2 depicts a schematic representation of the proposed filters.

Figure 2. Schematic representation of proposed Bragg grating.

IV. RESULTS AND DISCUSSION

A. *1330 nm Optical Bragg Grating Filter*

The optical Bragg Grating Filter to operate at the wavelength of 1330 nm of the normal wavelength division multiplexing (WDM) has been designed with the refractive indices $n_1 = 1.5$ and $n_2 = 3.5$ giving an effective refractive index of 2.5. Using the Bragg's equation, the period of the grating is calculated to be 0.262 micrometre.

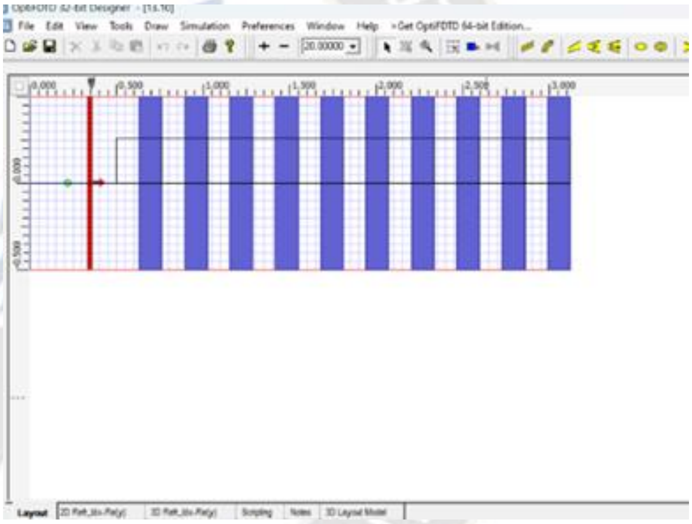

Figure 3. Optical Bragg Grating Filter at 1330 nm.

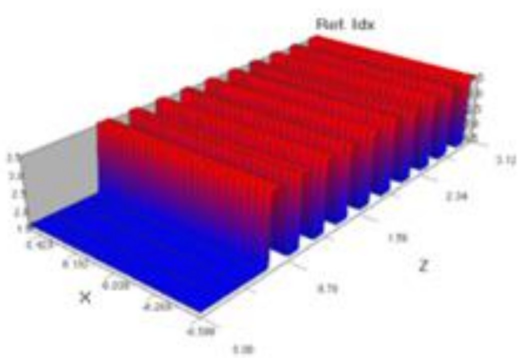

Figure 4. Refractive index profile of Optical Bragg Grating Filter at 1330 nm.

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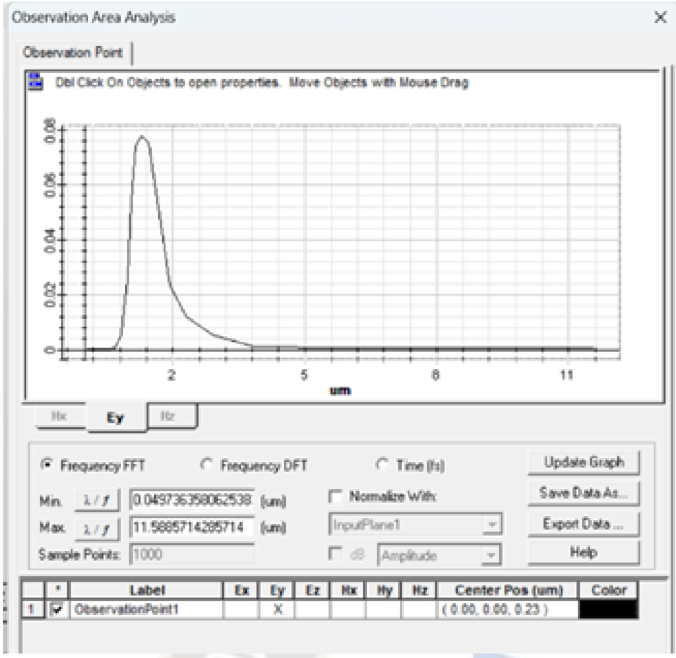

Figure 5. Reflection propertied of Optical Bragg Grating Filter at 1330 nm.

Figure 3 shows the proposed filter to operate at 1330 nm. Figure 4 shows the refractive index profile of the proposed filter. Figure 5 shows the reflection properties of the Optical Bragg Grating Filter at 1330 nm. From the simulation results, the peak of the reflection properties is observed to be around 1300 nm which verifies our proposed filter to be operating at the desired normal WDM wavelength of 1330 nm.

B. 1550 nm Optical Bragg Grating Filter

The optical Bragg Grating Filter to function at the 1550 nm wavelength of the normal wavelength division multiplexing (WDM) has been designed with the refractive indices n_1 = 1.5 and n_2 = 3.5 giving an effective refractive index of 2.5. Using the Bragg's equation, the period of the grating is calculated to be 0.31 micrometre.

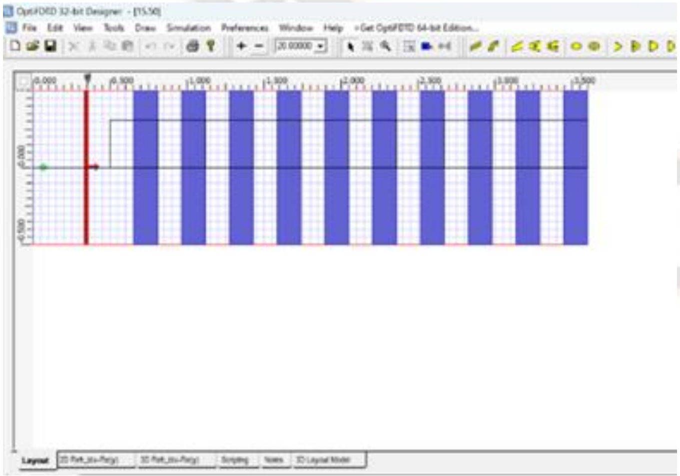

Figure 6. Optical Bragg Grating Filter at 1550 nm

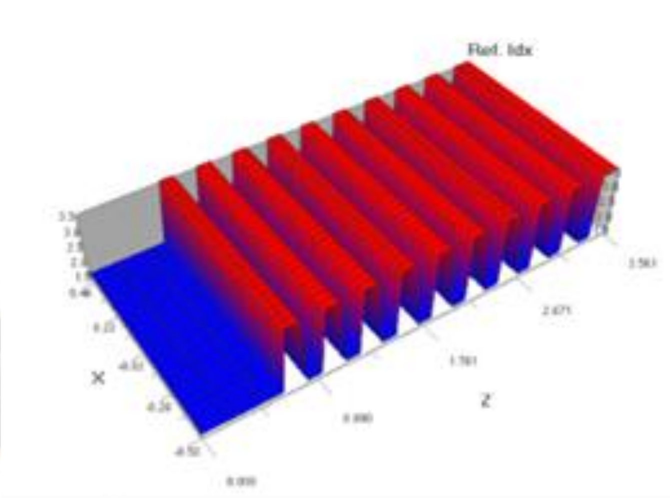

Figure 7. Refractive index profile of Optical Bragg Grating Filter at 1550 nm.

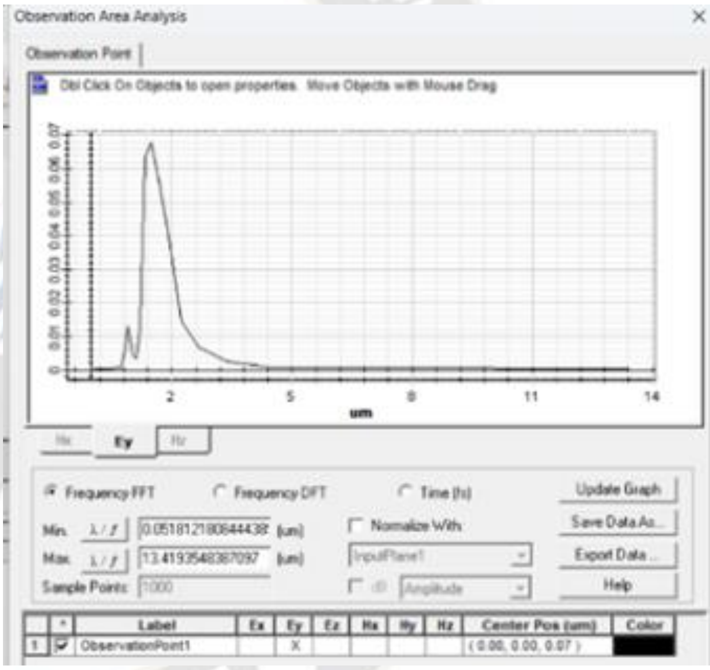

Figure 8. Reflection properties of Optical Bragg Grating Filter at 1550 nm.

Figure 6 shows the proposed filter to operate at 1550 nm. Figure 7 shows the index of refraction profile of the proposed filter. The figure 8 depicts the Optical Bragg Grating Filter reflection properties operating at 1550 nm. From the simulation results, the peak of the reflection properties is observed to be around 1500 nm which verifies our proposed filter to be operating at the desired normal WDM wavelength of 1550 nm.

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