Indian Journal of Science and Technology, *Vol 9(36), DOI: 10.17485/ijst/2016/v9i36/93953, September 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Exemplary Advancement of EPON Communication by FBG based Splitters

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Abstract

Objectives: In the last few years, researchers in the field of optical fibre communication have focused on designing optical filter for blocking certain wavelength using Fiber Bragg Grating (FBG). In this paper inculcates the study and research on FBG base splitters with alteration of grating length for Ethernet Passive Optical Network (EPON) is carried out. **Methods/Analysis:** The simulation is incorporated on simulation Software MATLAB 7.2 of Mathworks. The simulation model is constructed by varying design parameters such as grating length, which in turn attains the maximum reflectivity for the wavelengths required for EPON. We fix the values of the effective refractive index of grating and radius of the core. Here the grating length and centre wavelengths are fixed 35 mm and 1550 nm respectively and findings obtained. **Findings:** FBG is one of the renowned distributed Bragg reflector manoeuvred in an optical fiber of small segment and it possesses the stupendous attribute of reflecting particular wavelengths of light whilst traversing all other wavelengths. As per observations the reflectivity of the grating or the effectiveness of the grating in extracting the wavelength has a tremendous value of 100%. This filter has various applications which improve the quality and reduce the cost of an optical network.

Keywords: Ethernet Passive Optical Network (EPON), Fiber Bragg Grating (FBG), Grating Length, Reflectivity, Wavelength

1. Introduction

One of the renowned point-to-multipoint fiber for the arena of peculiar network architecture envisages unpowered optical splitters with incorporation of Brewster's angle principles for the Passive Optical Network (PON). As a result of this multiple premise typically around 32-128 are served by a single optical fiber. The PON configuration relative to the point to point architectures reduces the requisite amount of fiber and central office equipment. Furthermore Ethernet Passive Optical Network (EPON) is an IEEE/EFM standard incorporating Ethernet for packet data. It conveniently supports packetized traffic and time-sensitive voice and video traffic too and in addition to this it facilitates an incredible data rate of 1.25Gbps for either of the upstream and downstream[1-3].

A Wavelength Division Multiplexing (WDM) is utilized in PON, in which one wavelength is used for downstream traffic and another is used for upstream traffic on a single optical fiber link[4]. Broadband Passive Optical Networks (BPON), EPON, Gigabit Passive Optical Network (GPON) and Gigabit Ethernet Passive Optical Network (GEPON) have the similar elementary wavelength plan employing wavelength of 1490 nanometre (nm) for downstream traffic and upstream wavelength of 1310 nm. One can reserve 1550 nm for optional overlay services, typically radio frequency video.

The several nodes which enumerate in a PON are central office node, referred to as Optical Line Terminal (OLT), one or more user nodes, referred to as the Optical Network Units (ONUs) or Optical Network Terminals (ONTs), the combination of fibers and splitters used between OLT and ONUs is known as the Optical

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Distribution Network (ODN). The ONT are bridged to the customer premise device in multiple tenant units within the individual dwelling unit and the incorporating technologies for making this possible are Ethernet over twisted pair or Digital Subscriber Line (DSL). This is the equipment, which terminates the PON thus manifesting customer service interfaces to the user. Furthermore ONUs maneuver are utilized to separate subscriber unit for providing services and these exemplary services have the ingredients of voice or voice over IP, data, video and/or telemetry[1, 5].

The interface between the PON and the service provider's network services are exhibited by OLT. These typically include:

- 10G or 100 Mbps Ethernet of internet protocol traffic
- SONET and SDH which are the Standard Time Division Multiplexed (TDM) interfaces.
- ATM UNI at 155-622 Mbit/s[6].

Optical Splitters which are passive in nature are an important component of EPON.

1.1 Fiber Bragg Grating

Fiber Bragg Grating (FBG) has been enumerated by Hill KO and Meltz G[7]. An FBG behaves like a distributed bragg reflector maneuvered in exemplary ways in an optical fiber having small segment, which reflects particular wavelengths of light and transmits all other wavelengths[8]. The fiber core having a stepped variation to the refractive index is added in order to attain the same. Furthermore it facilitates the generation of a wavelength specific dielectric mirror. FBG is thus implicated as an inline optical filter restricting certain wavelengths, or as an explicit wavelength-specific reflector. The FBGs originally were developed for optical telecommunication[9]. As depicted in Figure 1, FBG acts as a vast wavelength selective reflection filter with the wave length of peak reflectivity. FBG is also utilized as the passive splitter as the passive nature of this device is supportive and feasible for it.

The gratings were fabricated in the beginning by utilizing a visible laser traversing along the fiber core. The emergence of FBG is due to the precision techniques such as inscribing the systematized alteration into the core refractive index of a unique optical fiber incorporating magnanimously extreme Ultra-Violet (UV) source like a UV radiation are incorporated. Furthermore the two techniques prevalent for this are the interference and masking. A germanium-doped silica fiber supports the manufacturing of FBGs, as the germanium-doped fiber is photosensitive, and consequently there is variation in the core refractive index alters in contact with UV light. Furthermore the proportion of alteration is proportional to the period of the exposure and intensity, as it is a function of these[10, 11].

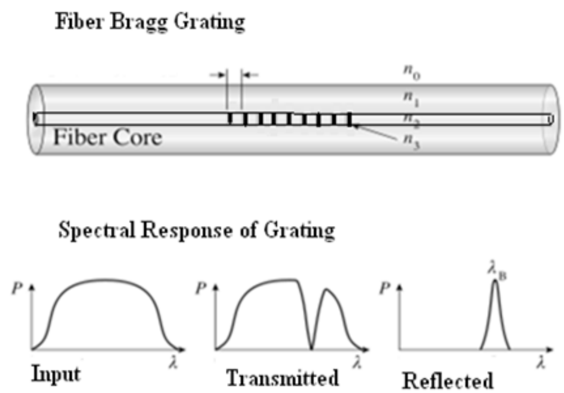

Figure 1. FBG structure and spectral response of grating.

Interference method: In this method there is the ramification of the UV laser into two parts interfering mutually, which results into distribution of periodic intensity along the interference pattern. Photosensitive fiber's refractive index varies in accordance with the intensity of light[7]. It enables for quick and easy alteration to the Bragg's wavelength, as it is explicitly proportional to the interference duration, having angle of incidence of the laser light as its function.

Masking method: In masking method the positioning of the photomask is exactly midway of photosensitive fiber and UV light source. The grating structure is speculated here from the shadow of the photomask and subsequently determined from the intensity of the transmitted light striking the fiber. Furthermore a single UV laser beam is also possible to be implicated for writing of the grating into the fiber, point-by-point. Here the narrow beam of the laser is equivalent to the grating period[7]. This technology is peculiarly appropriate for the production of fiber gratings for long duration and there is also an implication of the effective point-by-point technique in the fabrication of tilted gratings. The Bragg's wavelength of an FBG is deduced by the pitch of phase mask and the wavelength of the UV laser is insignificant in relation to it[12].

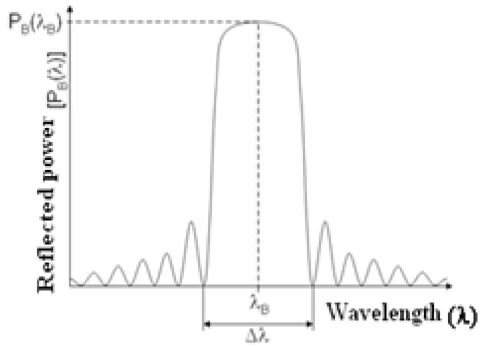

Figure 2. FBGs reflected power as a function of wavelength.

The basic principle enunciated for operation of FBG given by Fresnel's reflection is the light traversing through the medium of separate refractive indices which can reflect and refract at the interface. Thus the reflected wavelength (λ_B) known as Bragg Wavelength is described by the relationship exhibited in the Equation (1)[12]. Figure 2 shows a variation of reflected power measured as wavelength's function.

$$\lambda_B = 2n\Lambda \tag{1}$$

In Equation (1) n' denotes the grating's effective refractive index in the core of fiber and Λ' represents the period of grating. Equation (2) represents the wavelength spacing between bandwidth and the first minima. Where δn_0 denotes the variations in refractive index and η is the parameter to control fraction of power in the fiber core.

$$\Delta\lambda = \left[\frac{2\delta n_0 \eta}{\pi}\right]\lambda_B \tag{2}$$

Equation (3) gives the approximate value of peak reflection $P_B(\lambda_B)$ and N denotes the value of periodic variations.

$$P_B(\lambda)_B \approx \tanh^2\left[\frac{N\eta(V)\delta n_0}{n}\right] \tag{3}$$

The reflected power $P_B(\lambda)$ is calculated by the full equation (4).

$$P_{B(\lambda)} = \frac{\sinh^2\left[\eta(V)\delta n_0\sqrt{1-\Gamma^2}\frac{N\Lambda}{\lambda}\right]}{\cosh^2\left[\eta(V)\delta n_0\sqrt{1-\Gamma^2}\frac{N\Lambda}{\lambda}\right]-\Gamma^2} \tag{4}$$

Where $\Gamma(\lambda)$ is given by Equation (5),

$$\Gamma(\lambda) = \frac{1}{\eta(V)\delta n_0}\left[\frac{\lambda}{\lambda_b}-1\right] \tag{5}$$

1.2 Applications of FBG:

- The Fiber Bragg's Grating is peculiarly incorporated as notch filters.
- These can also be utilized in optical multiplexers and de-multiplexers with an Optical Add-Drop Multiplexer (OADM) or optical circulator. An OADM is a key ingredient in wavelength-division-multiplexing communication system[13]. De-multiplexing is attained by placing multiple drop sections of the OADM in cascade, in which each individual drop element utilizes FBG which is adjoined to the wavelength that is to undergo de-multiplexing operations. Also, a multiplexer may be maneuvered as the multiple add sections of the OAD are cascaded. Furthermore FBG de-multiplexers and OADMs can also be tunable. Figure 3 represents the Optical add-drop multiplexer.
- FBG can also be used as sensors.

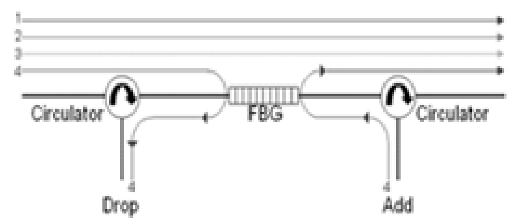

Figure 3. Optical add-drop multiplexer.

The literature on the subject was reviewed. The system proposed by Pan et al.[14], monitored the centre wavelength of a FBG with a resolution of 0.01 nm by compression or extension alternately to the FBG. Fu et al.[15] concluded that the sensitivity of the wavelength measurement has been in continuity with the RF modulation frequency applied to the optical signal. Gong et al.[16] proposed a methodology for the incorporation and optimization of Multi-channel Fiber Bragg Grating Filters (MCFBGFs). These different methodology consisted of two steps, i.e., the discrete layer peeling algorithm which was used for the origination of appropriate initial guess values and subsequently for the reconstruction and optimization of the Fiber Bragg Grating parameters the nonlinear least squares method was implemented from the different speculations in the previous step. It has been concluded that their proposed methods have optimized the reflectivity and dispersion of MCFBGFs. Moreover, to improve performance their index modulation is decremented effectively. Hanawa[17] professed the Sampled Fiber Bragg Grating (SFBG) which was a cascade of FBGs with partial reflectivity. Xing-hua et al.[18], professed a high channel-count comb filters specifically for the wavelength-division-multiplexing (WDM) in wireless communication system. Furthermore the 26-channel comb filter with channel spacing of 50 GHz was then manufactured. Along with investigation Weiwei et al.[19] scrutinized the effect of several grating positions in the coupling region and grating dimensions on the filtering spectra. They further observed that the coupling region on the left of the grating severely impacts the drop channel characteristic. In addition to this the length of the grating is also profoundly impacted by the drop efficiency; and the transmission characteristic is highly appropriate and suitable with the entire length of the coupling region. Wong et al.[20] scrutinized and concluded that by altering the angle of tilt and grating length in different combinations and manipulate the different attributes of cladding mode such as grating and resonance dip bandwidth characteristics are advantageous in the designing of optical filters with controlled pass-band and stop-band features.

It is observed and concluded that for implementation and exemplary advancement of EPONS, the wavelength splitters is an extremely vital component. A lot of work has been done for the designing of the prominent wavelength splitters relying and based on FBG via choosing optimal parameter such as grating dimensions. This paper is organized with the introduction of the EPON and FBG first. After introducing EPON and FBG and its primary details an illustrated literature review has been enfolded in section-1 and the furthermore the simulation results are enlisted in the section 2. At the end, conclusions are elaborated in section 3.

2. Simulation, Results and Discussion

The simulation is incorporated on simulation Software MATLAB 7.2 of Mathworks. There is a tremendous improvement in the simulation model, constructed by varying design parameters such as Grating length thereby attaining the maximum reflectivity for the wavelengths required for EPON. We have fixed the values of the effective refractive index of grating $n_{eff} = 1.45$ and radius of the core is '$a = 4.5\mu m$ '.

The results of the simulation are exhibited in the form of traces of spectrum of the WDM wavelength extracted for EPON system. The values of centre wavelength have been fixed i.e. 1550 nm and length of the grating (mm) is varied. The results are depicted in Figure 4 – 6. In Figure 4, the reflectivity of the grating or the effectiveness of the grating was computed as 20.43% for 3mm grating length. There was an augmentation to 32.65% as the grating length was augmented to 4mm and subsequently augmented to 44.98% with 5mm grating length. In Figure 5 the reflectivity of the grating was computed to be 65.99% for the grating length of 7mm as it was augmented to 80.62% and 89.36%, when the grating length was still further augmented to 9mm and 11mm respectively. As the minor manipulations in the grating length are made, there was a tremendous change in the reflectivity.

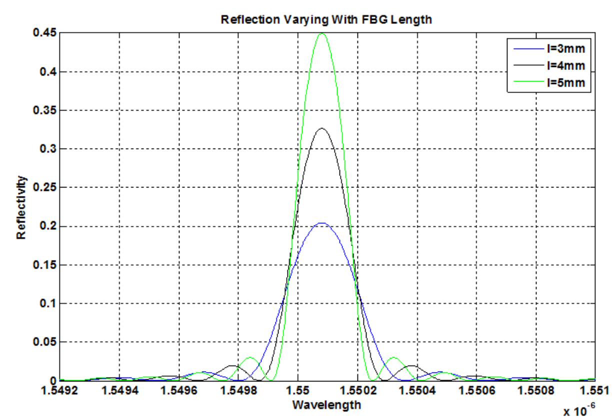

Figure 4. Reflection varying with FBG Length for = 3 mm, 4 mm and 5 mm.

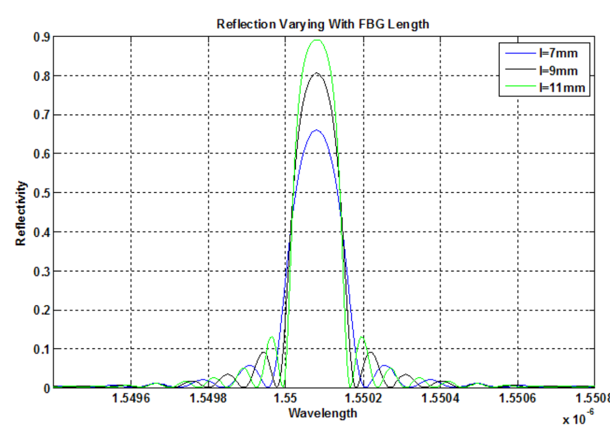

Figure 5. Reflection varying with FBG Length for =7 mm, 9 mm and 11 mm.

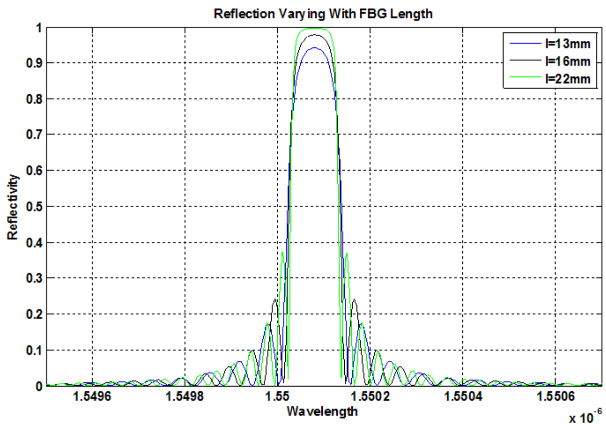

Figure 6. Reflection varying with FBG Length for = 13 mm, 16 mm and 22 mm.

In Figure 6 the effectiveness of the grating was computed 94.30% for 13mm grating length. It was augmented to 97.81% and 99.68% when the grating length was simultaneously augmented to 16mm and 22mm. When the grating length was still further augmented, subsequently a very minor increment in the reflectivity is there. This small increase in the reflectivity is shown in Table 1.

Table 1. Reflectivity varying with the length of grating

Length of Grating(mm)	Reflectivity (%)	Bragg Wavelength(nm)
23	99.77	1550
26	99.91	1550
27	99.94	1550
31	99.98	1550
33	99.99	1550
35	100	1550

In our work we have made the observation of reflectivity of Fiber Bragg Grating having centre wavelength 1550 nm and for altering grating lengths. Reflectivity is insufficient for the extraction of wavelength for the effective grating length of 3mm to 11mm. At grating length of 13mm the reflectivity is greater than 94% and this value augments as the length of grating is simultaneously augmented. When the grating length is kept 20 mm, the reflectivity raises up to 99.40% and after that with a minor manipulation in grating the augmentation in reflectivity is observed to be extremely meager. Hence from these simulation results it is explicitly deduced that for a grating length of 35mm, it is possible to extract the wavelength effectively as it is achievable from the reflectivity.

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