Implementation of a Two-Way Communication Link on Optical Fiber-Free Space Photonics System used in Beam Bridge

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Abstract: In this paper, a two-way communication link is implemented on optical fiber (OF) cable and free-space photonics (FSP) for the outdoor applications like beam bridge. Beam Bridge's condition is monitored using a uniform fiber-Bragg-grating. In case the beam bridge is damaged, the signal propagation will be diverted from OF link to FSP link to restore the communication. A BER (Bit Error Rate) of value 0 (close to an ideal system) and a Quality (Q) factor of value 239.581 has been achieved.

Keywords: Outdoor environment, Optical line terminal (OLT), Free Space Photonics (FSP), Optical network unit (ONU), FBG (Fiber Bragg Grating).

Introduction

Free Space Photonics (FSP) is basically the transmission of the modulated visible beam through the vacumn or air to achieve broadband communication [1]. FSP theory is same as that of optical transmission. The only difference lies in the channel of communication. The beam is collimated and sent through the atmosphere from the transmitter to the receiver in the case of FSP, while in the fiber optics the beam is transmitted via a guided channel. At the transmitter side, the beam is modulated with the data which is to be transmitted, while at the receiver side, the received signal is picked off by the photodetector, demodulated and then amplified. One of the merits of FSP includes low power per transmitted bit [2]. Other important features of FSP are the elimination of the optical fiber cable and the need of the frequency coordination between the users, as required in radio systems [3]. In wide area networks, FSP can provide high speed data services for the users of mobile phones [4]. FSP can be used as an alternate link in the case of transmission failure through the optical fiber cable. Apart from this, when the optical fiber is being deployed during that time, FSP technology provides fast and instant services to the mobile users[5]. In this paper, a two-way communication link is proposed for outdoor enviornment, which includes FSP link which is to be used as a backup when the optical transmission fails. In order to detect any abnormal behavior of the beam bridge, a uniform fiber bragg grating is used so that if such abnormailty occurs, the transmission path is diverted in no time from optical fiber to FSP link. Performance of the system is evaluated in the terms of BER, eye-diagram and Q-facor using OptiSystem 14.1.0 version simulation tool.

Experimental Setup

The proposed system (shown with dotted lines) a uniform FBG connected to a beam bridge, two optical switches and a FSP system. FBG is used to monitor the OF cable, which is embedded in the beam bridge and in case of any damage to the optical fiber, the diverting of the transmission path from OF to FSP link will take place. The FSP link comprises two transmitters and receivers.

For bi-directional long distance systems, the proposed system will be used as shown in Fig. 1. Overall system comprises Multiplexer, optical circulator (OC), pump laser, OLT, Optical Fiber; Erbium doped fiber (EDF), ONU, Demultiplexer and FBG detector. The data rate and power used for transmission are 10 Gbps 12dB respectively. Any number of channels can be used in OLT and ONU. In this paper, the upstream channels used are 1551.03 nm and 1554.07 nm and for the downstream channels are 1549.14 nm and 1552.38 nm. At the receiver side, ONU is further connected to BER Spectrum Analyzer. FBG operates a 1538.25 nm frequency. The FBG detector comprises a rectangular optical filter, optical spectrum analyzer and a power meter. The FBG detector is used for the monitor the beam bridge by analyzing the signal reflected from the FBG.

Total length of fiber used is 40.025 km. To couple the power from the fiber output and the laser, pump coupler is used. This is in turn used by the Erbium doped fiber.

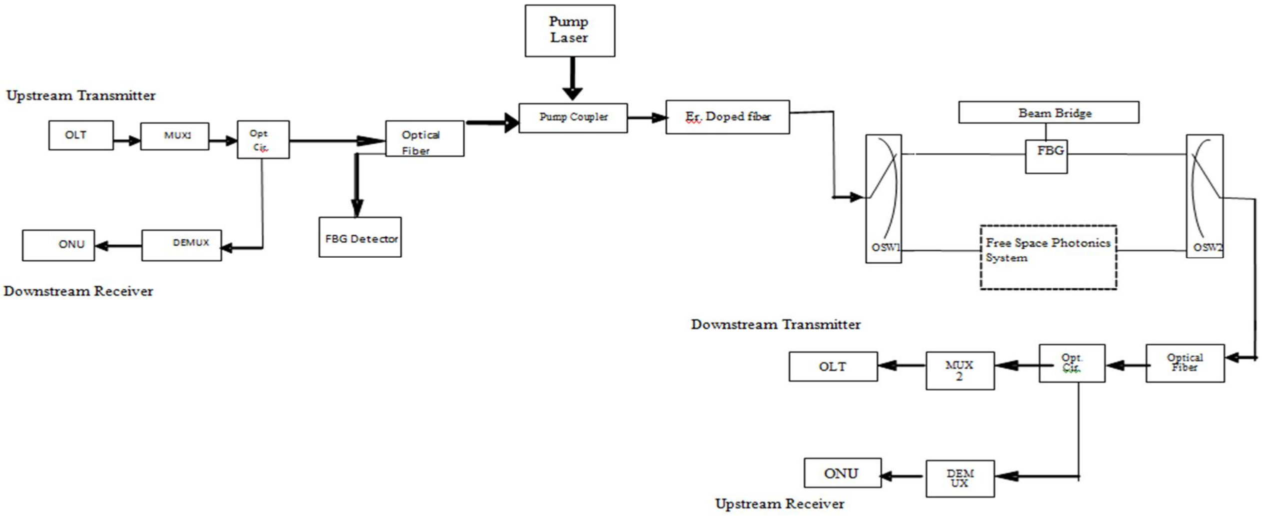

Figure1. Two-way long distance network using OF-FSP system

Related Work or Literature Studies

Rana et al. (2012) designed a FSO system in which FSO link in which a length of 10 km is established between the transmitter and the receiver, at a data rate of 2.50 Gbps with BER~10^{-6} and transmitted power of 3 dBm. Performance analysis was done by plotting a graph between Q^2 value and BER versus the transmission distance at different transmission power. It was observed that there is significant decrease in the value of Q factor, which lies within {27, 25 & 23} and {21, 18 & 16} for transmission distance of 10 km in case of transmission power 1, 2 and 3 dBm respectively. Further, it was observed that there was significant increase in the value of BER, which lies within {10^{-9}, 10^{-15} & 10^{-26}} and {10^{-105}, 10^{-104} & 10^{-103}} for transmission distance of 10,000 m in case of transmission power 1, 2 and 3 dBm respectively.

Hsu et al. (2013) discussed that very high capacity wireless optical link (OWL) using two-way dense wavelength division multiplexing (DWDM) can be achieved through wavelength reuse to show multiple user access. Wavelength reuse is done in order to increase bandwidth efficiency of OWL. Free space channel of 10m is used between two terminals. EDFAs are used to compensate for the link losses and to boost the WDM signals. The proposed scheme would be very attractive for building to building communication.

Singh et al. (2014) investigated different modulation formats like RZ, CRZ, CSRZ and NRZ on free space optical communication system. It was observed that external modulation gave better performance in comparison to direct modulation because direct NRZ spectrum has a strong carrier component compared to external modulated NRZ. Simulation results showed that RZ modulation format is best for long distance whereas NRZ is used for short distance and it is less complex and cheaper in comparison to RZ.

Shahpari et al. (2014) demonstrated a hybrid fiber–free-space passive optical network that enables high spectral density, aggregated capacity, and total throughput through ultra-dense wavelength-division multiplexing (UDWDM) baseband and radio over-fiber channels. Ultra-dense wavelength-division multiplexing 10-Gb/s Nyquist shaped 16-ary quadrature amplitude modulation(QAM), 10-Gb/s radio-over-fiber(RoF) orthogonal frequency-division multiplexing(OFDM), and 8.75-Gb/s baseband orthogonal frequency division multiplexing signals per user were transmitted through a maximum 40-km passive optical network, which includes a 6-m free-space optics link with acceptable performance.

Yu et al. (2015) designed a system comprising optical fiber (OF) and Free Space Optics (FSO) used in long-haul OF transmission for application in outdoor environments such as bridges. System was operated at 10 Gbps. A fiber-Bragg-grating (FBG) sensor head was used for monitor the condition of a bridge, and in the case of the bridge being damaged, the transmission path was changed over from OF to the FSP link to ensure link connectivity. An Erbium-doped fiber amplifier (EDFA) was used to compensate for losses due to the fiber cable and the free-space channel. At a bit error rate (BER) of 10e-9, the power penalty between the OF and FSO paths was < 1 dB.

Test Results

First of all, the spectrum of the multiplexed signal is obtained. Fig. 2 shows the output of MUX 1 and for the downstream transmission, Fig. 3 shows the output of MUX2. It is followed by the performance analysis of FBG.

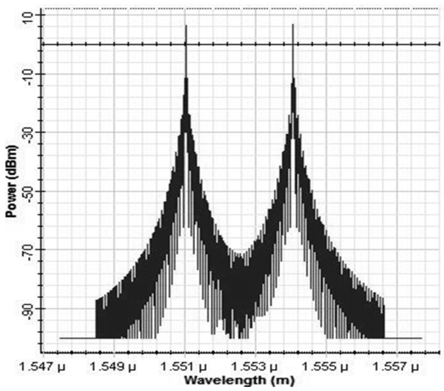

Figure2. Optical spectrum of multiplexed upstream traffic

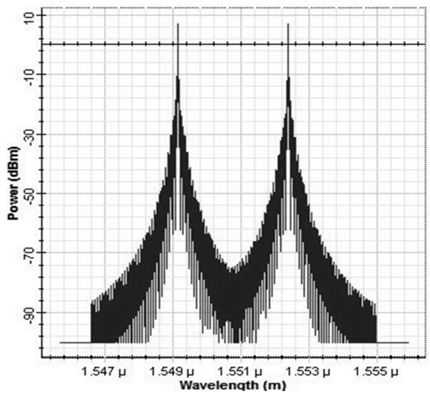

Figure3. Optical spectrum of multiplexed downstream traffic

Performance Analysis of FBG

FBG is mainly used to detect the strain in the beam bridge via optical fiber cable. The placement of FBG is such that it is placed along the optical fiber, which is in turn embedded in the beam bridge. The FBG used is coated with the layer of Silicon to increase reflectivity. The signal which will be reflected from the FBG, that signal will be transmitted to FBG detector which is used to assess the bridge condition. Fig.4 shows the measured transmitted spectrum of FBG. The spectrum of the light reflected from the FBG and transmission spectrum of the Rectangular Filter is as shown in Fig. 5 and Fig. 6 respectively.

Depending upon strain, the wavelength shift of FBG can be used to determine the condition of the optical fiber (embedded in the beam bridge) according to the following relation.

$$\frac{\Delta\lambda}{\lambda} = -k_{\epsilon}(1-2\upsilon)\frac{\Delta P}{E}$$

Where, $\Delta\lambda$ is wavelength shift of FBG, v is Poisson ratio of silicon (equal to 0.27), E is Young modulus of silicon (equal to 0.001), ΔP is applied force. It can be inferred from the above equation that ΔP has a linear relation with $\Delta\lambda$. So in case, when the high value of strain is detected indicating that the beam bridge is damaged, which can be inferred by comparing the transmission spectrum, reflected spectrum of FBG and the transmission spectrum of FBG Detector, the transmission path will be diverted from OF to FSP link to sustain communication.

Performance of the system is assessed with the help of BER, Q-factor and the eye-diagram. Fig. 7 and Fig. 8 shows the eye-diagram and Q-factor obtained at one of the upstream receivers (ONU) for the signal propagation through OF link and FSP link.

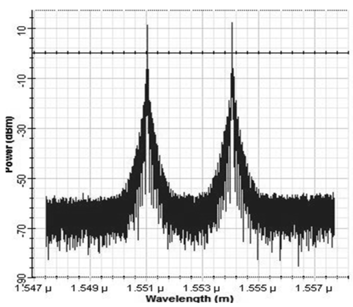

Figure4. Measured transmission spectrum of FBG

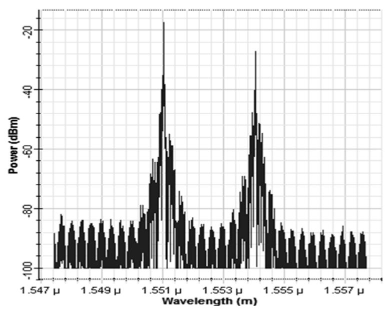

Figure5. Spectrum of light reflected from FBG

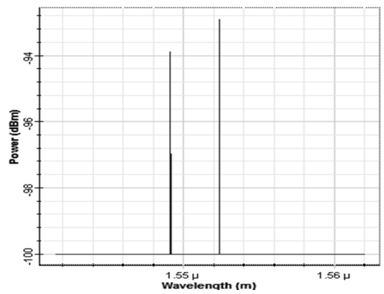

Figure6. Transmission spectrum of Rectangular filter

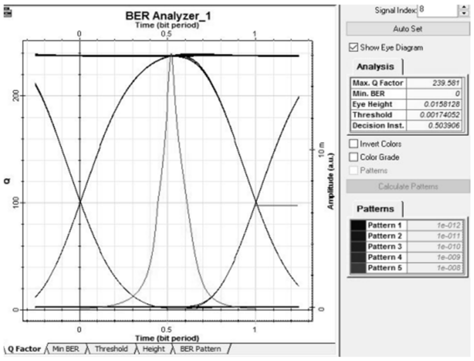

Figure7. Measured Eye-diagram and Q-factor obtained at upstream ONU for signal propagation through OF link

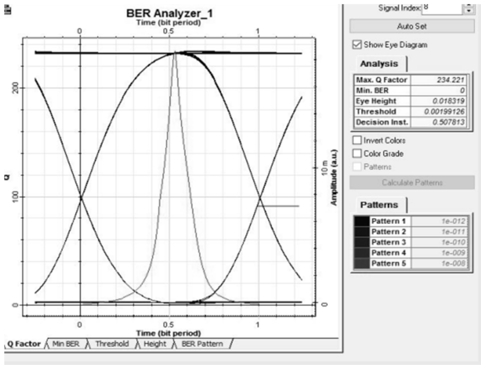

Figure8. Measured Eye-diagram and Q-factor obtained at upstream ONU for the signal propagation through FSP link

Comparison

The comparison between the reported and the proposed system is carried out as shown in Table 1 for different parameters. The proposed system provides an excellent result especially in terms of BER which is 0(close to ideal system) as compared to the reported work in which BER is 10^{-9}.

Table 1 Comparative Analysis of the reported work and the proposed work

S.No	Parameters		Reported Work [9]	Proposed Work
1	Wavelengths used for upstream		1547.35-1557.05 nm	1551.03-1554.07 nm
2	Wavelengths used for downstream		1545.50-1555.48 nm	1549.14-1552.38 nm
3	Power		4 dBm	12 dBm
4	Fiber Cable	Type	Single Mode Fiber	Two-way optical fiber
		Length	80 Km	40.025 Km
5	Obtained BER		10^{-9}	0
6	Obtained Q-factor		__	239.581

Conclusion

The ever increasing expectations and demands of subscribers for high speed, license free, cost-effective and seamless communication has prompted the researchers to make some improvements in the existing optical networks. OF-FSP system is one such system that caters to the need of the increasing expectations and demands and also provides a backup in case of optical fiber communication failure. The work in this project is aimed at obtaining the low bit error rate and high Q-factor.

- Two-way communication link for long distance communication using OF-FSP system operating at 10 Gbps is designed using Optisystem.
- FSP link has been introduced in this system which acts as an alternative for the emergency situations when the communication through OF is disrupted. This results in sustained communication.
- From the values of BER and Q-factor obtained, which are 0 and 239.581 respectively, it can be concluded that a high quality signal has been received at the receiver side.

Future Scope

Hybrid OF-FSP system has shown promising results, yet there is a scope of improvement so that the system can provide in terms of the following.

- **Number of users –** The work has been done for two users. By making use of higher order splitters, the system can be designed to support more number of users thereby increasing the capacity.

- **Use of Dispersion compensating techniques-** With the use of more pump power and dispersion compensating techniques like DCF (Dispersion Compensating Fiber), the transmission distance can be increased up to 100 Km.

References

[1] Free Space Photonics, “http://whatis.techtarget.com/definition/free-space-optics-FSP".

[2] A. K. Rahman, M. S. Anuar, S. A. Aljunid, and M. N. Junita, “Study of rain attenuation consequence in free space optic transmission,” in Proceedings of the 2nd Malaysia Conference on Photonics Telecommunication Technologies (NCTT-MCP '08), IEEE, Putrajaya, Malaysia, 2008, pp. 64–70.

[3] S. Vigneshwaran, I. Muthumani, and A. S. Raja, “Investigations on free space optics communication system,” in Proceedings of the International Conference on Information Communication & Embedded Systems (ICICES '13), , IEEE, Chennai, India, 2013. pp. 819–824.

[4] V. Sharma and G. Kaur, “High speed, long reach OFDM-FSO transmission link incorporating OSSB and OTSB schemes,” Optik, vol. 124, no. 23, pp. 6111–6114, 2013.

[5] H. A. Willebrand and B. S. Ghuman, “Fiber optics without fiber,” IEEE Spectrum, vol. 38, no. 8, 2001, pp. 40–45.

[6] A. Shahparia, A. Abdallaa, R. Ferreiraa, G. Parcaa, J. D. Reisab, M. Limaa, V. Carrozzoc, G. T. Beleffid, A. Teixeira, “Ultra-high-capacity passive optical nework systems with free-space optical communications,” Fiber Integr. Opt., vol. 33, no. 3, 2014, pp. 149-162.

[7] J. Singh and N. Kumar, “Performance Analysis of Different Modulation Format on Free Space Optical Communication System,” Optik International Journal for Light and Electron Optics, vol. 124, no. 20, 2014, pp. 4651-4654.

[8] H. Y. Hsu, W. C. Lu,1 H. L. Minh, Z. Ghassemlooy, Y. L.Yu,1 and S. K. Liaw, “2 x 80 Gbit/s dense wavelength division multiplexing (DWDM) two-way wavelength reuse optical wireless transmission,” IEEE Photon. J., vol. 5, no. 4, 2013.

[9] Y. L. Yu, S. K. Liaw, H. H. Chou, H. L. Minh, and Z. Ghassemlooy, “A hybrid optical fiber and FSP system for two-way communications used in bridges,” IEEE Photonics Journal, vol. 7, no. 6, 2015.