MJFAS
Malaysian Journal of Fundamental and Applied Sciences

Fakhruldeen *et al.* | Malaysian Journal of Fundamental and Applied Sciences, Vol. 19 (2023) 399-405

RESEARCH ARTICLE

Design and Performance Analysis of Simple WDM Optical Fiber Communication System

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Abstract WDM (wavelength division multiplexing) is used in this project to simultaneously send data over several channels at high speed. Single mode fiber is favored over Multimode fiber for long-distance communication. As data rate and optical fiber length grow, the quality factor falls. Dispersion effects on an 8-channel dense WDM system at a high data rate will be examined using the Optisystem 10 simulator. A dispersion compensation fiber (DCF) and an Erbium doped fiber amplifier (EDFA) are used to compensate for the dispersion and attenuation in the transmitted optical signal, respectively. Bit error rate (BER) and eye diagram analyzers were used to evaluate the optical communication system's performance.

Keywords: Wavelength division multiplexing, dense wavelength division multiplexing, dispersion compensation fiber, erbium doped fiber amplifie.

Introduction

With the advent of high-speed internet, low bit error rate optical fiber networks are becoming increasingly common, allowing for high-capacity communication between transmitter and receiver. Dense wave length division multiplexing (DWDM) is being used to expand the number of channels available in optical fiber. The DWDM technology allows the transmission of optical signals with varying wavelengths, and there are a vast number of channels available in WDM [1]. Both an Intrinsic and an Extrinsic Method are used to flatten the Gain of EDFA. Intrinsic approach is favored for systems with small bandwidth requirements, while extrinsic method is preferred for systems with big bandwidth requirements. WDM channels has the channel spacing of 1 nm. When dealing with high input laser power, RZ modulation is favored over NRZ modulation in most cases. Attenuation and chromatic dispersion lower the performance of the system as a result of the pulse broadening, and the peak amplitude decreases as a result of the pulse Broadening [2]. When communicating over vast distances, EDFA is employed. A single EDFA is capable of amplification of many wavelength signals at the same time. Because of the interaction with Erbium ions, signals are magnified [3-5]. It is possible to equalize the Gain of EDFA with the use of several Pumping methods; nevertheless, these methods are chosen because of their characteristics such as high gain, low noise, and wide bandwidth [6]. With a 10 Gbps data throughput per channel and a 1 nm wavelength separation, the primary goal of this study is to develop an 8-channel WDM system. Dispersion compensation fiber is used to correct for the dispersion caused by single mode fiber in the system [7]. Results: The dispersion limits the system's performance. Dispersion compensation fiber has been utilized to address this issue. Dispersion compensation fiber with a negative chromatic dispersion is used between amplifier spans, whereas conventional single-mode fiber is used at each amplifier position. A WDM system with 8 channels has been designed using this methods [8-10]. This study can be expanded to include more channels, such as 100 or more, with much narrower wavelength separation. It transmits user data over a variety of frequencies. In addition to DCF's, EDFA's

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Received: 8 Nov. 2022
Accepted: 11 April 2023

10.11113/mjfas.v19n3.2990

are utilized to enhance and regenerate the optical signal [10]. The EDFA (Erbium-Doped Fiber Amplifier) is the recommended long-distance amplifier [11]. The term "pre compensation" refers to EDFA being used before SMF, and "post compensation" refers to EDFA being used after SMF [12]. Both of these methods can be utilized in conjunction with one another to generate and deliver an optical signal of high quality to the transmitter [13]. An EDFA's noise figure and gain are affected by fiber length [14-18]. The following table lists the various transmitter-side parameters that were derived through simulation using the optisystem software.

System Design and Simulation

Figure 1 depicts an 8-channel WDM system without dispersion compensation and an optical amplifier. This system is being used to investigate and compare the functionalities of the dispersion compensation fiber (DCF) and the optical amplifier before and after adding the compensation components. According to the proposed design, the transmitter of the system is composed of electrical information signals that are generated by a (Pseudo Random Bit Sequence NRZ Generator), while the optical carrier signals are generated by CW Lasers of various wavelengths. Both information and carrier signals are inserted into the Mach Zehnder modulator (MZM) and modulated into optical signals that are coupled to the WDM multiplexer and then to the optical fiber channel. The demultiplexer is used on the receiver side to separate the received signal into its constituent parts, after which the photodetector converts the received optical signal to an electrical signal in order to recover the information signal, and finally the low pass filter is used to separate the high frequency carrier signal from the lower frequency information signal.

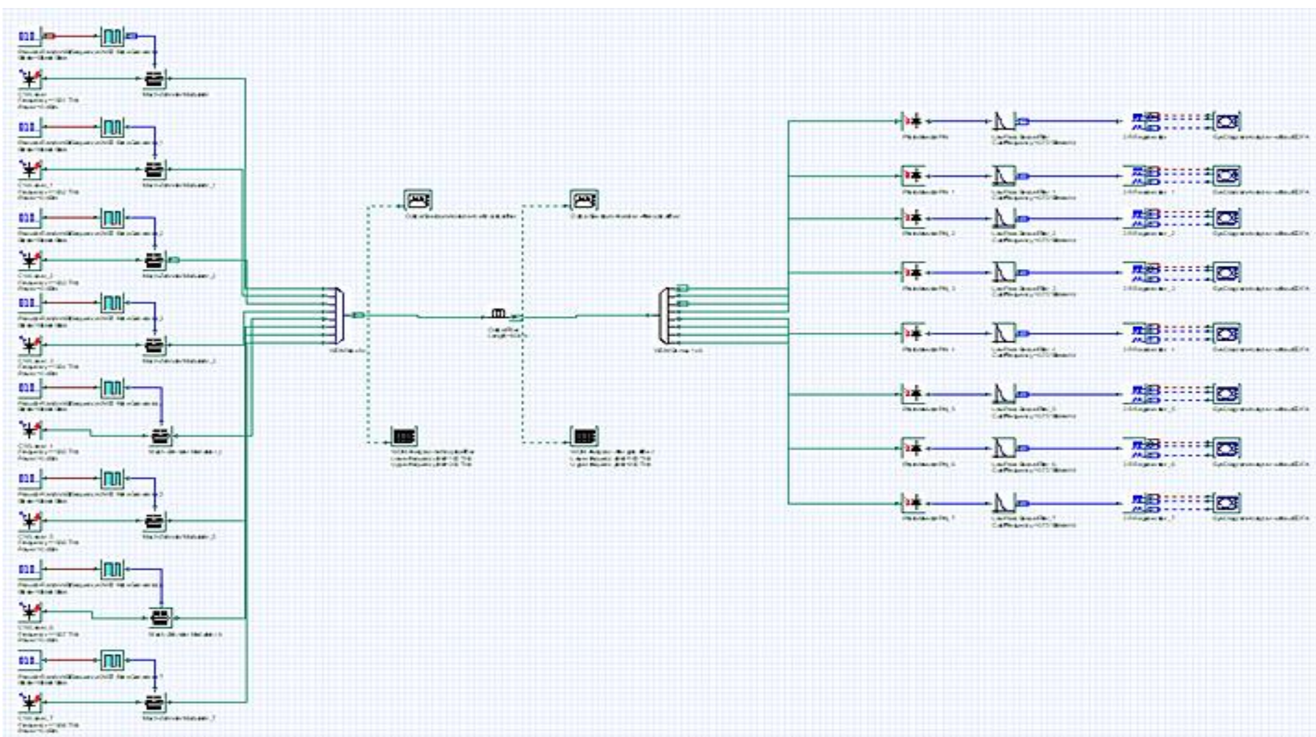

Figure 1. The 8 channels system without EDFA and DCF

Figure 2 shows that the dispersion and attenuation are considerable in an 8-channel system without an EDFA or DCF; as a result, the signal-to-noise ratio (SNR) is low.

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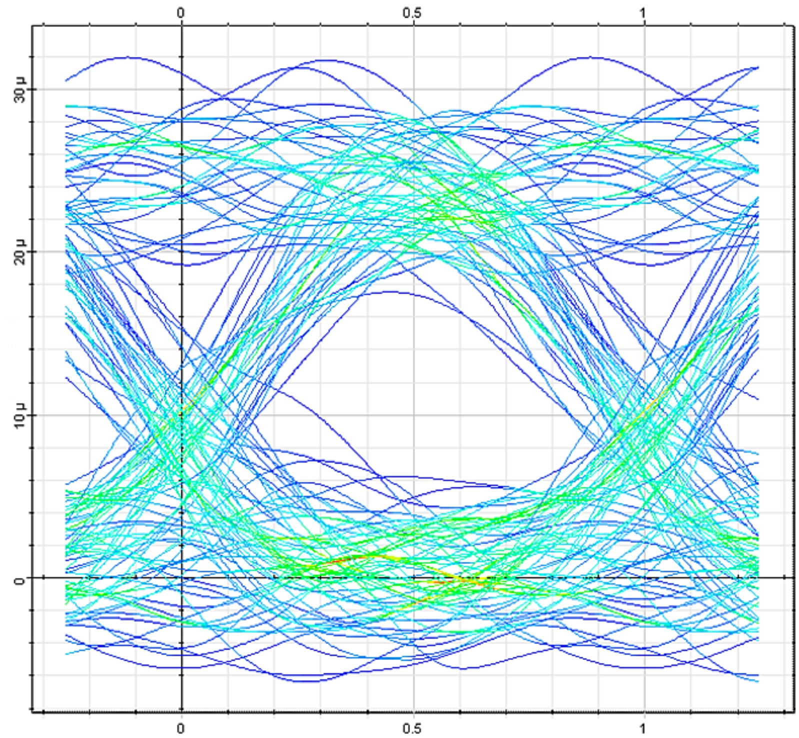

Figure 2. The eye diagram of the 8 channels system without EDFA and DCF

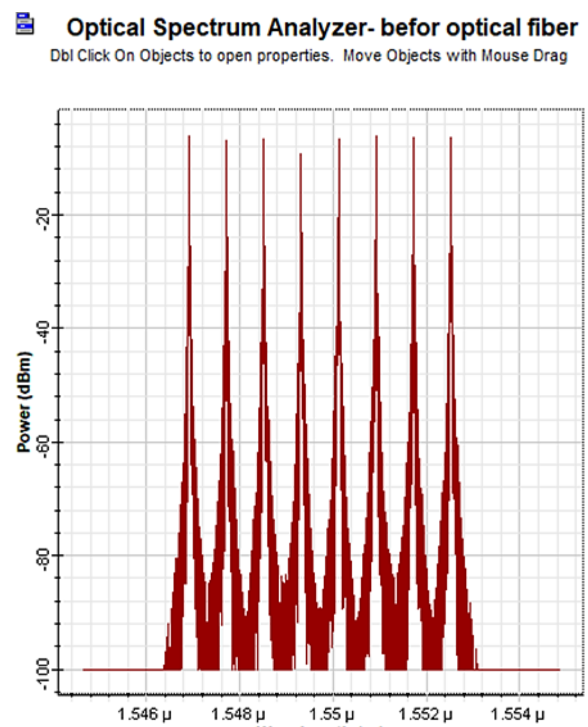

Figure 3. (a) The optical spectrum analyzer (OSA) of the 8 channels system without EDFA and DCF before launching into the optical fiber

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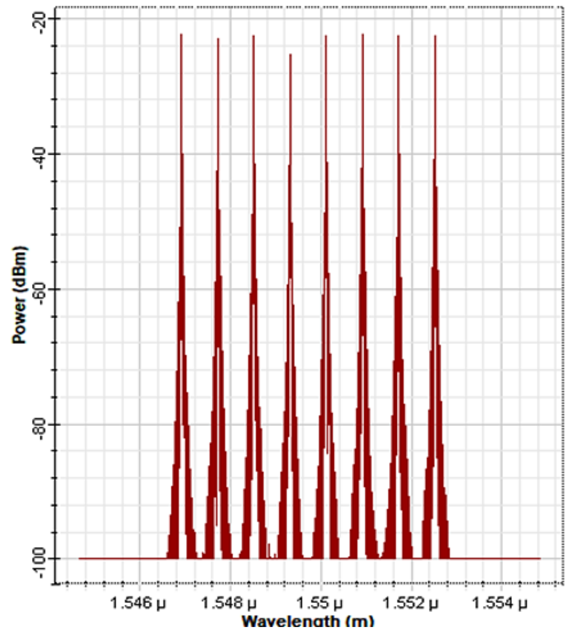

Figure 3 (b) The optical spectrum analyzer (OSA) of the 8 channels system without EDFA and DCF after launching into the optical fiber

The optical spectrum analyzer window is shown in Figure 3 (a) and (b) before and after the signal is sent through the optical fiber channel, respectively. It's obvious that channel dispersion and attenuation have an impact on transmitted signals, especially for long-distance communications.

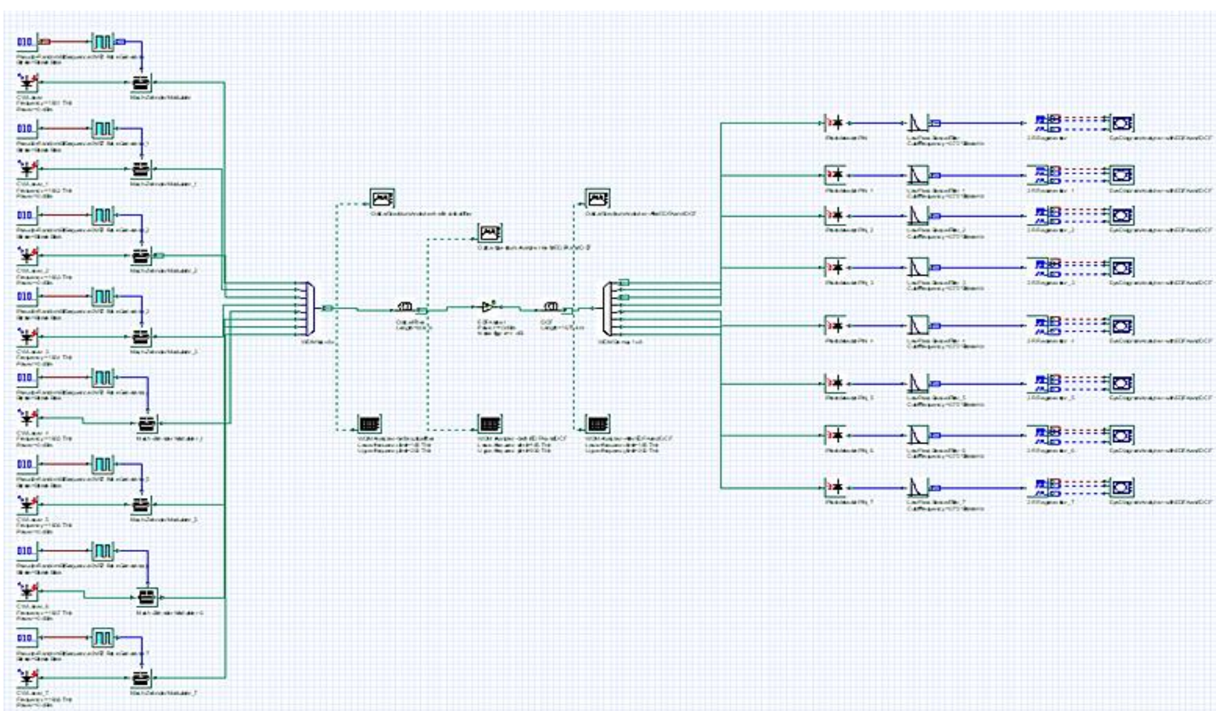

Figure 4. The 8 channels system with EDFA and DCF

The suggested 8 channel system is shown in Figure 4 after the optical amplifier and dispersion compensation fiber are added to overcome dispersion and attenuation caused by channel considerations. It is easy to see that the additional components improve the system's performance, as illustrated in Figures 5 and 6.

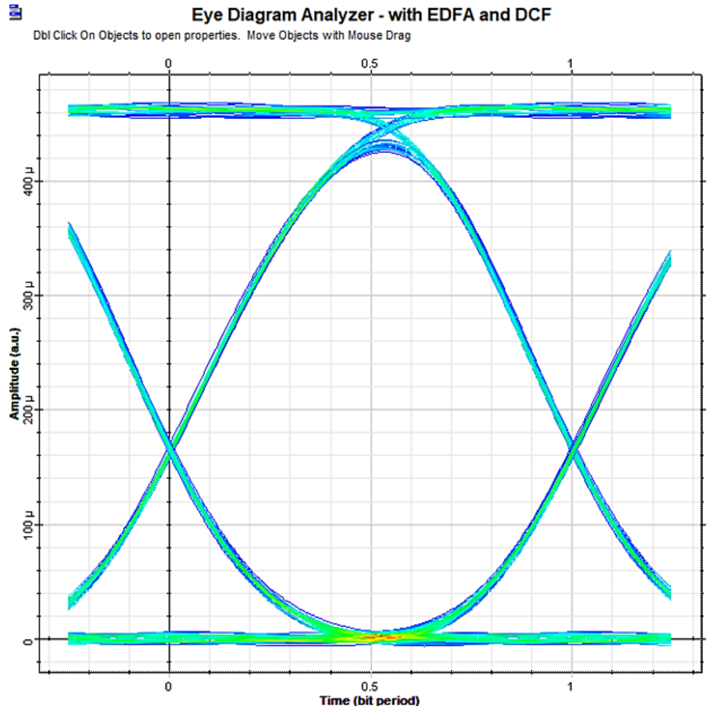

Figure 5. The eye diagram of the 8 channels system with EDFA and DCF

The eye diagram is improved over Figure 2 as a result of the optical amplifier and dispersion compensation fiber being added. The dispersion and attenuation generated by the channel are compensated as shown in Figure 6 (a, and b), and hence the optical spectrum analyzer window after the fiber is similar to that before the fiber.

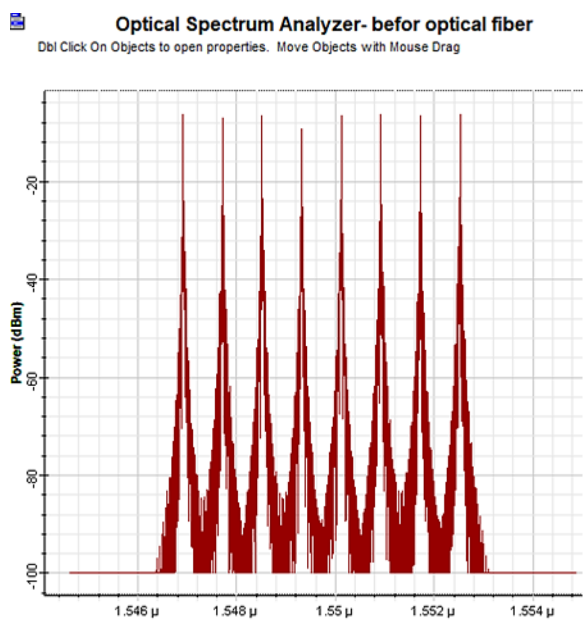

Figure 6 (a) The optical spectrum analyzer (OSA) of the 8 channels system with EDFA and DCF before launching into the optical fiber

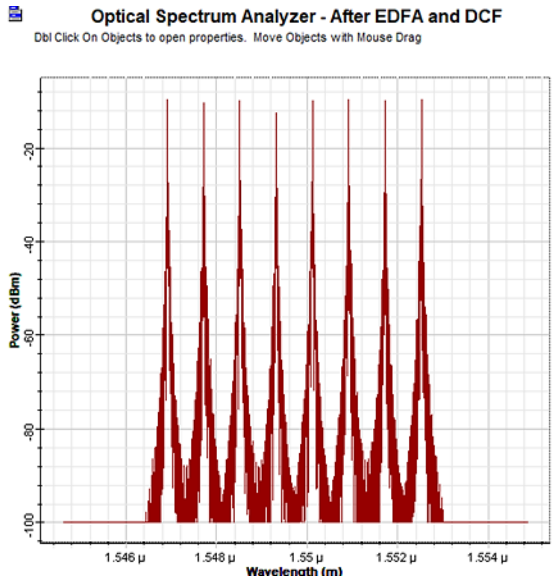

Figure 6 (b) The optical spectrum analyzer (OSA) of the 8 channels system with EDFA and DCF before launching into the optical fiber.

Table 1 shows a comparison between the system performance before and after adding the dispersion compensation fiber (DCF) and optical amplifier EDFA as a function of bit error rate (BER) with respect to optical fiber length.

Table 1. BER as a function of optical fiber length under different conditions

Optical Fiber length (km)	BER without (EDFA and DCF)	BER with (EDFA and DCF)
5	0	0
10	0	0
15	0	0
20	0	0
25	0	0
30	4.85 *10^- 261	0
35	5.37 *10^- 174	0
40	1.51 *10^- 118	0
45	2.29 *10^- 082	0
50	4.60 *10^- 057	0
55	8.07 *10^- 040	0
60	7.22 *10^- 028	0
65	1.92 *10^- 019	0
70	1.26 *10^- 013	0
75	1.14 *10^- 009	0
80	5.80 *10^- 007	0
85	4.01 *10^- 005	0
90	0.0007	0
95	0.005	0
100	1	0

Without DCF and EDFA, the BER increased as the channel length increased, however with DCF and EDFA, the BER of the system is fixed due to dispersion and noise cancellation.

Conclusions

The proposed work presents an optimized WDM link with dispersion compensation and attenuation cancellation using DCF and EDFA. The performance of the system is constrained by dispersion and

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attenuation. To compensate for this, we employed a dispersion compensation fiber. Between the amplifier spans, ordinary single-mode fiber is used, but a dispersion compensating fiber with a negative chromatic dispersion is introduced at the amplifier position. We have successfully developed a WDM system with 8 channels using this technique. Additionally, a variety of EDFA's can be used to amplify and regenerate the signals. Additionally, this work can be extended to 16, 32, and 64 channels in the future.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

Acknowledgment

This work is part of a research project, supported by the Imam Ja'afar Al-Sadiq University, Baghdad, Iraq.

References

[1] Kareem, F. Q., Zeebaree, S. R., Dino, H. I., Sadeeq, M. A., Rashid, Z. N., Hasan, D. A., & Sharif, K. H. (2021). A survey of optical fiber communications: challenges and processing time influences. *Asian Journal of Research in Computer Science,* 48-58.

[2] Wang, K. J., & Zou, B. R. (2021). On new abundant solutions of the complex nonlinear Fokas–Lenells equation in optical fiber. *Mathematical Methods in the Applied Sciences*, *44*(18), 13881-13893.

[3] Fakhruldeen, H. F., Al-Asady, H. A. J., Mahinroosta, T., Sohrabi, F., & Hamidi, S. M. (2021). Novel add-drop filter based on serial and parallel photonic crystal ring resonators (PCRR). *Journal of Optical Communications.*

[4] Salim, A. A., Ghoshal, S. K., Shamsudin, M. S., Rosli, M. I., Aziz, M. S., Harun, S. W., ... & Bakhtiar, H. (2021). Absorption, fluorescence and sensing quality of Rose Bengal dye-encapsulated cinnamon nanoparticles. *Sensors and Actuators A: Physical, 332*, 113055.

[5] Salim, A. A., Bidin, N., Bakhtiar, H., Ghoshal, S. K., Al Azawi, M., & Krishnan, G. (2018, May). Optical and structure characterization of cinnamon nanoparticles synthesized by pulse laser ablation in liquid (PLAL). *Journal of Physics: Conference Series*, *1027*(1), 012002. IOP Publishing.

[6] Wang, Y., Huang, X., Tao, L., Shi, J., & Chi, N. (2015). 4.5-Gb/s RGB-LED based WDM visible light communication system employing CAP modulation and RLS based adaptive equalization. *Optics Express, 23*(10), 13626-13633.

[7] Sewaiwar, A., Tiwari, S. V., & Chung, Y. H. (2015). Smart LED allocation scheme for efficient multiuser visible light communication networks. *Optics Express*, *23*(10), 13015-13024.

[8] Al-Asady, H. A. J., Fakhruldeen, H. F., & Alsudani, M. Q. (2021). Channel estimation of OFDM in c-band communication systems under different distribution conditions. *Indonesian Journal of Electrical Engineering and Computer Science*, *23*(3), 1778-1782.

[9] Kottke, C., Hilt, J., Habel, K., Vučić, J., & Langer, K. D. (2012, September). 1.25 Gbit/s visible light WDM link based on DMT modulation of a single RGB LED luminary. *European Conference and Exhibition on Optical Communication* (pp. We-3). Optica Publishing Group.

[10] Cossu, G., Khalid, A. M., Choudhury, P., Corsini, R., & Ciaramella, E. (2012, September). 2.1 Gbit/s visible optical wireless transmission. *European Conference and Exhibition on Optical Communication* (pp. P4-16). Optica Publishing Group.

[11] Fakhruldeen, H. F., & Mansour, T. S. (2020). Design of plasmonic NOT logic gate based on insulator–metal–insulator (IMI) waveguides. *Advanced Electromagnetics*, *9*(1), 91-94.

[12] Waheed, S. R., Rahim, M. S. M., Suaib, N. M., & Salim, A. A. (2023). CNN deep learning-based image to vector depiction. *Multimedia Tools and Applications*, 1-20.

[13] Andri, C., Alkawaz, M. H., & Waheed, S. R. (2019, June). Examining effectiveness and user experiences in 3d mobile based augmented reality for msu virtual tour*. 2019 IEEE International Conference on Automatic Control and Intelligent Systems* (I2CACIS) (pp. 161-167). IEEE.

[14] Fakhruldeen, T. S. M. H. F., & Mansour, T. S. A. (2018). All-optical NOT gate based on nanoring silver-air plasmonic waveguide. *Int. J. Eng. Technol. 7,* 2818-2821.

[15] Alsunbuli, B. N., Fakhruldeen, H. F., Ismail, W., & Mahyuddin, N. M. (2022). Hybrid beamforming with relay and dual-base stations blockage mitigation in millimetre-wave 5G communication applied in (VIOT). *Computers and Electrical Engineering*, *100*, 107953.

[16] Waheed, S. R., Suaib, N. M., Rahim, M. S. M., Adnan, M. M., & Salim, A. A. (2021, April). Deep Learning Algorithms-based Object Detection and Localization Revisited. *Journal of Physics: Conference Series*, *1892*(1), 012001. IOP Publishing.

[17] Amana, M. S., Aldhuhaibat, M. J. R., & Salim, A. A. (2021). Evaluation of the absorption, scattering and overall probability of gamma rays in lead and concrete interactions. *SCIOL Biomed*, *4*, 191-199.

[18] Salim, A. A., Ghoshal, S. K., & Bakhtiar, H. (2022). Prominent absorption and luminescence characteristics of novel silver-cinnamon core-shell nanoparticles prepared in ethanol using PLAL method. *Radiation Physics and Chemistry, 190*, 109794.