Experimental Study of Light Wave Propagation for Underwater Optical Wireless Communication (UOWC)

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Abstract—Underwater Optical Wireless Communication (UOWC) is identified as a promising technology because it offers higher bandwidth than acoustics and radio frequency techniques. This paper investigates the performance of light wave propagation for UOWC through experimental approach. An experimental set-up is developed consists of a transmitter, receiver and a glass chamber to emulate the water channel. Three types of water including clear, sea and cloudy are used to investigate their interaction with the light emitted by light emitting diode (LED) and laser diode. The geometrical loss (GL) analysis shows the white LED suffered a severe GL (GL<<1) as the transmission link increases due to the wide viewing angle while green and yellow LED obtained an equal GL due to the same size of viewing angle. However, red laser does not experience any GL. Therefore, the received power by red laser is 35% higher than by green LED. The analysis deduces that the estimated attenuation coefficient *c* had an increase of 15% and 55% for green LED and red laser respectively when the UOWC medium changed from clear water to sea water. This study contributes to identify the potential and limitations of different parameter design in order to optimize UOWC performance.

Index Terms—UOWC, attenuation constant, LED, laser, light intensity, normalized received power, geometrical loss

I. INTRODUCTION

Water covers approximately 71% of the earth's surface and 96.5% of the earth’s water is contained within the ocean as salt water. Over the decades, ocean exploration has attracted significant interest due to the climate change and resource depletion of land. Recently in 2021, the whole world was in shocked with the sinking of Indonesian submarine KRI Nanggala and prior to that in 2014 with the disappearance of civilian aircraft MH370 which is yet to be found till now. These incidents left a huge impact and served as a wake-up call on the plethora of issues that is yet to be explored in underwater environment [1]. In view of this issue, a reliable underwater wireless communication (UWC) link is one of the important needs as a medium for the mankind to elucidate underwater environment especially for military, industry and scientific community. UWC refers to data transmission in unguided water environment through wireless carriers namely acoustic waves, Radio Frequency (RF) waves and optical waves.

However, each carrier has its own limitation and constraint. The propagation of RF waves in water is constraint by signal attenuation due to high water electrical conductivity at high frequency. Acoustic waves seem to be the most reliable because it can send data at a longer distance up to several tens of kilometres but at the cost of limited bandwidth with the highest it can support is only several hundred kHz, insufficient for video transmission. Acoustics carriers encounter a large propagation delay due to the slow speed of sound and also suffer from multipath propagation due to reflection from the sea floor and refraction from varying sound speed [2]. Relative to RF and acoustic counterparts, optical waves offer higher transmission bandwidth, thus supporting much higher data rate up to 1 Gbps over ranges up to several tens of meters with low power and mass requirement. However, the optical signal propagation underwater is affected by three major degrading phenomena, namely absorption, scattering, and turbulence-induced fading. These phenomena are caused by the wide range of physical processes in various types of underwater environment ranging from shallow coastal water to deep sea [3]-[8]. Underwater optical wireless communication (UOWC) is prone to severe absorption and scattering due to the nature of visible light wave when it propagates in underwater environment. The interactions between an inevitable photon with the water molecules and other particulate matters (i.e., chlorophyll and other coloured dissolved organic material (CDOM)) may increase the water turbidity and consequently reduce the light propagation distance. On the other hand, optical turbulence occurs as a result of random variations of refractive index due to the fluctuations of the water temperature, pressure and salinity [9], [10]. Thus, the transmitted light signal is severely attenuated and directly degraded the quality of the transmitted data.

In short, it is important to correctly characterize the underwater optical channel as a mean to establish a high-quality optical link. Therefore, this paper works on the

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experimental study of light wave propagation for underwater optical wireless communication. The remaining of the paper is organized as follows: Section II reviews on the theories pertaining to UOWC namely the optical properties and the geometrical loss; Section III describes the experimental set-up; Section IV discusses the obtained results and finally Section V concludes the paper.

II. THEORY

A. *Optical Properties of UOWC*

Light wave propagation in water is complex due to the unique optical characteristics of underwater environment. Absorption, $a(\lambda)$ and scattering, $b(\lambda)$ coefficients are the two main optical properties that determine the underwater light attenuation coefficient, c(λ) which is given by:

$$c(\lambda) = a(\lambda) + b(\lambda) \tag{1}$$

Absorption is an energy transfer process in which photons lose their energy and convert it into other forms such as heat and chemical (photosynthesis). The process caused the total light propagation to continuously decrease and consequently reduce the link limit of UOWC. According to [11] there are four main factors that contribute to the overall absorption namely pure water, fulvic acid, humic acid and chlorophyll concentrations.

On the other hand, scattering is the deflection of light beam from the original path. It is caused by the interaction of light with the molecules and atoms of the transmission medium. Considering the fact that the size of optical aperture is finite, the scattering process caused the light beam to spread and eventually, the number photons collected at the UOWC receiver is reduced [12], [13]. In comparison to the absorption, the scattering is independent of wavelength (for visible wavelength) but relies on density changes in aquatic medium, specifically the shape, size and concentration of particles [14]. In general, the scattering spectra is mainly affected by two biological factors, including particulate matter and pure water. The former is isolated into small and large particles, each with a different scattering strength and distribution.

It has been shown in [15] that absorption and scattering have their minimum effects at the wavelength interval 400 nm $< \lambda <$ 530 nm. Hence, UOWC systems apply the blue/green region of the visible light spectrum to actualize data communication. In this paper an experimental approach is used to determine the attenuation coefficients of light wave in varying experimental scenarios

B. *Geometrical Loss*

Geometric loss (GL) is defined as the ratio of the surface area of the receiver aperture to the surface area of the transmitter beam at the receiver [16], [17]. Fig. 1 illustrates three possible scenarios on the setup of UOWC transmission link. Figs. 1(a) and 1(b) should not experience any loss because the surface area of the receiver aperture is at least equal to the size of received light spot. However, Fig. 1(c) demonstrates the scenario when the GL is severely encountered where the surface area size of the receiver aperture is too small to receive the transmitted light spot and consequently caused the signal loss The geometrical losses are determined by parameters of the system design including the viewing angle of the light source (θ_{tx}) diameter of the receiver aperture (d_{rx}) and link distance (L) between light source and receiver plane. In this paper, we mathematically established the geometric loss ratio as follows:

$$GL = \frac{4\pi(d_{rx}/2)^2}{\pi(L\tan\frac{\theta_{tx}}{2})^2} \tag{2}$$

The analysis of geometrical loss is carried out in the Section III based on the experimental parameters used in this work.

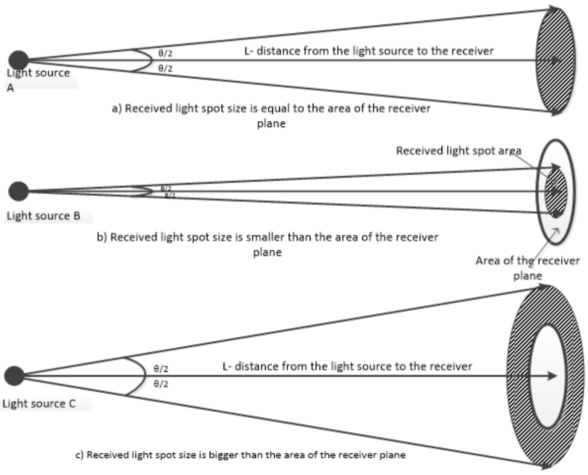

Fig. 1. Three possible scenarios on the setup of UOWC transmission links.

III. METHODOLOGY

A. *Experimental Set-up*

The intensity of the received light emitted by different light sources is measured in three types of water (as the UOWC medium) with varying distance of the transmitting link. A rectangular glass tank of dimension 0.6 m x 0.3 m x 0.3 m is used to emulate the water channel. Table I summarizes the experimental set-up parameters. The intensity of the received light emitted by different light sources is measured in three types of water (as the UOWC medium) with varying distance of the transmitting link. A rectangular glass tank of dimension 0.6 m x 0.3 m x 0.15 m is used to emulate the water channel. Table I summarizes the experimental set-up parameters.

The aperture diameter and viewing angle sizes of the light sources are shown in Fig. 2 to illustrate how these two parameters are related and measured. In this experiment four types of light sources (Table I) are used to emit light in three types of water namely clear water, sea water and cloudy water. The clear water is the water collected directly from the water tap and the sea water is freshly collected from Mengabang Telipot beach in Kuala Terengganu.

TABLE I: LIST OF EXPERIMENTAL SET UP PARAMETERS

Components	Parameters		
Transmitter/light source	Aparture diameter (mm)	Wavelength (nm)	Viewing angle θ_{tx} (rad)
white LED	8	620 (peak)	2.44
green LED	5	568	0.79
yellow LED	5	587	0.79
red laser	6	650	0.001
Receiver	Aparture diameter d_{rx} (mm)	Spectral range of detection (nm)	
Spherical underwater quantum sensor	61	400-700	

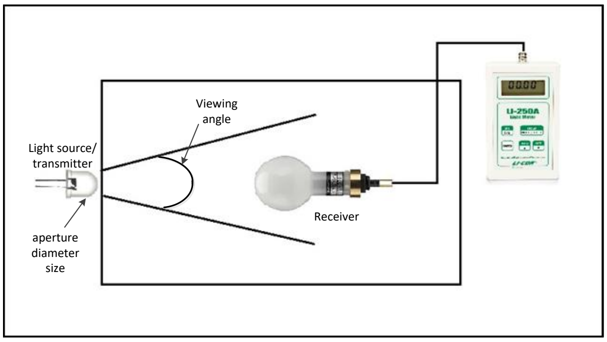

Fig. 2. Relationship between viewing angle and the aperture diameter

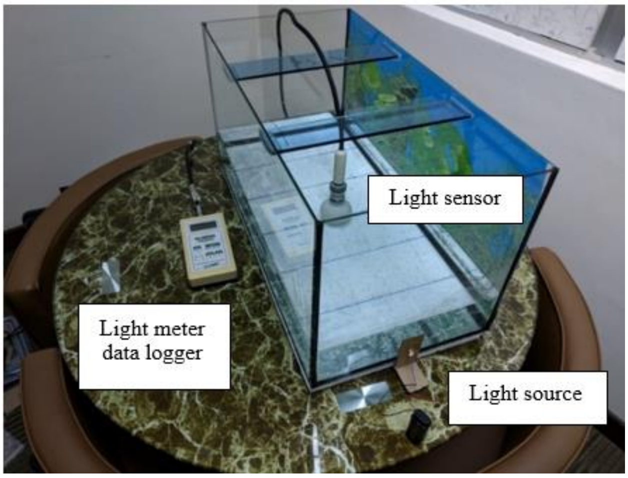

Fig. 3. The experimental set-up of the experiment

However, for the cloudy water, sodium bicarbonate powder is used as the artificial cloudy matter and being mixed with the tap water to imitate the original cloudy water. The transmitted light which is propagated over the varying distance is detected by LI-COR LI-193R Spherical Underwater Quantum Sensor and its intensity is measured using LI-COR LI-250A Light meter. Fig. 3 shows the experimental set-up of the experiment.

B. Determination of Attenuation Coefficient

Beer-Lambert's law is used to express the light attenuation effects in UOWC due to its simplicity and commonly used scenario. From the attenuation coefficient, $c(\lambda)$, that has been introduced in (1), the received intensity of light is defined as in [13]:

$$I = I_0 e^{-c(\lambda)d} \tag{3}$$

where *I* is the intensity of light after the light pass through the media, I_o is the initial light intensity of incident light, *c* is the attenuation coefficient of the light in media and *d* is the distance of light travel in media. In order to estimate the value of *c* from the *I* measured in the experiments, a natural logarithmic is applied to (3). Then, the value of *c* is obtained through curve fitting method as illustrated in Fig. 4.

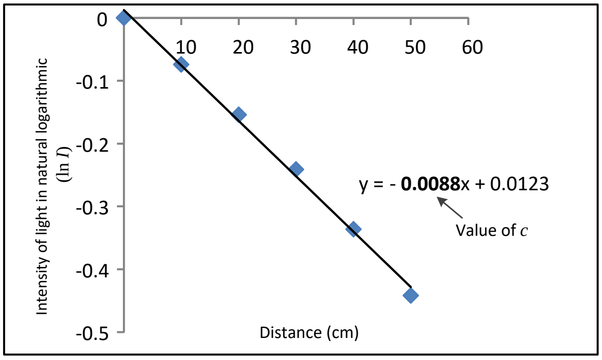

Fig. 4. Curve fitting technique to estimate c in clear water at wavelength of 650 nm using red laser diode.

C. Analysis of Geometrical Loss

This section analyses the effect of experimental parameters specified in Table I to the GL. The ratio of GL is calculated based on the equation established in (2). Note that the surface area of the receiver aperture is the sphere surface area because the receiver used in this experiment is a spherical shape of Underwater Quantum Sensor as shown in Fig. 2.

Table II tabulates the obtained GL ratio for each type of light sources used in this experiment. It is observed that laser diode gained a GL ratio of more than 1 indicating that it does not encounter any loss. This advantage is due to the relatively small size of viewing angle possessed by laser diode.

TABLE II: GEOMETRIC LOSS BETWEEN 3 LED LIGHT SOURCES.

	Geometric loss ratio			
Distance (cm)	White LED	Green LED	Yellow LED	Red Laser
0	1.000	1.000	1.000	1.00
10	0.050	2.141	2.141	148839999.800
20	0.012	0.535	0.535	37209999.940
30	0.006	0.238	0.238	16537777.750
40	0.003	0.134	0.134	9302499.984
50	0.002	0.086	0.086	5953599.990

However, it is noted that as the transmission link increase, the GL ratio decreases. It is expected that laser will eventually experience a GL at extremely long transmission link but that situation will never happen due to constraint of optical communication itself.

In contrast, white LED suffered a severe GL (GL<<1) as the transmission link increases due to the wide viewing angle (140 degree). Green and yellow LED resulted in equal GL due to their similarity size of viewing angle. Both light sources start to encounter GL at a transmission link of 20 cm and getting worse as the transmission links go further. The obtained GL ratio remained constant irrespective types of water used as the UOWC medium because all internal design parameters remain unchanged [16].

In summary, GL can be minimized by selecting a narrower viewing angle type of the light source and a larger side diameter of receiver aperture size to ensure all the information transmitted through optical carrier is received. However, larger receiver aperture results in noise from the ambient light [16]. Therefore, a proper selection of system design parameters is crucial in order to optimize the overall performance.

IV. RESULTS AND DISCUSSION

A. Light Intensity from Different Light Sources

Fig. 5 shows the normalized received optical power in clear water using four types of light sources. The normalized received power is plotted against the underwater link length from 0 cm up to 50 cm with a gap scale of 10 cm. In common, it is observed that the received power of the optical signal emitted by all the light sources decreased as the underwater link length increased. In comparison to LED, laser diode produced at least 41% higher intensity of received light normalized power. Laser diode produced higher power than LED due to fact the light beam generated from laser diode is directional and highly collimated [18], [19]. Therefore, laser does not encounter any geometric loss because the surface area of the receiver aperture is much larger than the surface area of the transmitter beam at the receiver [17]. The resultant small surface area of the transmitter beam at the receiver is due to a very small viewing angle of the laser light source which for this experiment is only 1 mrad.

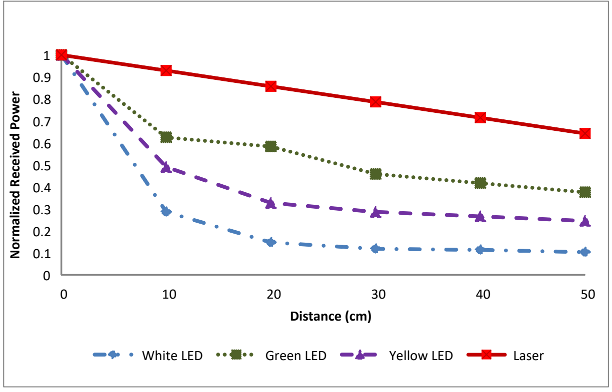

Fig. 5. Normalized received power in still clear water using different light sources.

Fig. 6 further validates the received light intensity emitted by laser does not suffer any geometric loss as the measured output intensity is almost identical to the calculated value using (3). In contrast, the LED sources have wider viewing angle as specified in Table I, resulted in a significant GL because the surface area of the transmitter beam at the receiver is larger than the surface area of the receiver aperture. Among three LED light sources, white LED suffered the most GL (Table II) caused by wide viewing angle (140 degree) of the transmitter aperture.

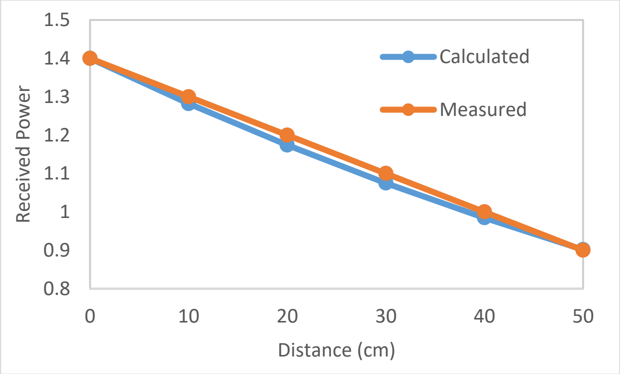

Fig. 6. Comparison between calculated and measured value of the received intensity using red laser diode as the light source.

As a result, the received light power emitted by white LED is heavily attenuated as shown in Fig. 5. Green LED gained the highest output power followed by yellow and white LED. The obtained result is consistent with the fact that green (relative to yellow and white) spectrum is less affected by absorption and scattering losses in underwater environment [20]-[21]. The same trend of results is also observed when the sea and cloudy water are used as the UWOC medium.

B. Overall Performance Evaluation

This section compares the received power from the calculated values with the measurement values obtained from the experiments. The calculated values are obtained by using (3) and the attenuation coefficient is estimated accordingly. Based on the GL analysis presented in Section III, the effect of GL is significantly degraded the LED performance. Therefore, the value of *c* cannot be estimated using curve fitting approach. Instead, the value of *c* for green and yellow LED is estimated from the measurement value at L = 10 cm. Noted that at L = 10 cm (Table II), both green and yellow LED having a GL ratio >> 1, indicating that there is no GL. Hence, the value of *c* can be estimated using (3) by having *I* from the measured value at L = 10 cm. The estimated value of *c* for each light source in 3 types of water is summarized in Table III.

The estimated value of *c* for white LED is assumed equal to the value of *c* from red laser due to the fact that white spectrum contains all wavelengths and its peak wavelength is close to the red wavelength. Comparing the estimated *c* in three types of water, the value of *c* in cloudy water is almost close to the one in clear water for all types of light sources. This observation is inconsistent with the typical value of *c* found in literature where *c* in cloudy water is much higher than in clear water [3]. The estimated value of *c* in cloudy water is considered unrealistic most probably because an artificial ingredient (i.e. sodium bicarbonate) is used to emulate the cloudy water condition. Thus, the cloudiness of the water is not as significant as in real underwater environment. Hence, the results for cloudy water is disregarded and the following discussion will only focus on clear and sea water. The plots in Fig. 7 compare the normalized received power between measured and calculated values from the yellow LED in clear water. The calculated power is computed using (3) and the calculated power with loss is obtained by multiplying the GL ratio obtained in Table II with the calculated power. Fig. 7 shows the trend of the plots is against our hypothesis, at which the measured power is higher than the calculated power. The same trend of plots is also observed using green LED irrespective of water type. The calculated power is supposed to be higher than the measured power considering the fact that the calculated power only considers the attenuation loss as in (3). In contrast to the measured power which should have additional losses due to environmental effect such as ambient temperature (scintillation effects) and system design parameters particularly the geometric loss [16]. It is anticipated that the higher measured power is obtained due to reflection phenomena. Some of the transmitted light in the experiment is reflected back from all sides of the glass made water tank.

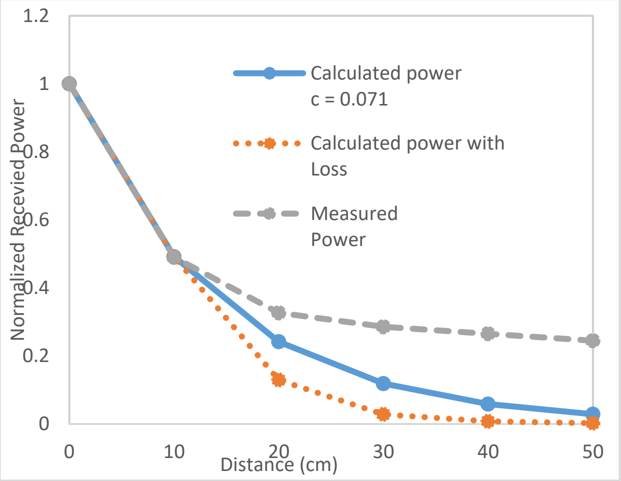

Fig. 7. Comparison between measured and calculated values of normalized received power from yellow LED in clear water.

As a result, the reflected signals are being carried all the way along to the end and received by the receiver together with the original transmitted light. Therefore, the total received power is much higher and even the additional losses mentioned earlier is not able to compensate the received reflected signal. This unwanted phenomenon is also encountered by other work in [22]. It can be resolved by transforming all sides of the glass tank into black colour to absorb the light.

In comparison to yellow and green LED, different trend of plots is observed in white LED. Fig. 8 compares the measured and calculated values of normalized received power from white LED in sea water. The calculated power without considering loss is much higher than the measured and calculated power with loss. This finding indicates that the GL in white LED severely attenuates the received signal to the extend it overweighs the reflection effect and results in a significant lower power than the calculated power without loss. A huge difference between calculated power with and without loss validates that the effect of geometrical loss (Table III) is severe in white LED. The same trend of plots is also observed when white LED is used in clear water as the GL ratio is constant irrespective of types of water.

TABLE III: THE ESTIMATED ATTENUATION COEFFICIENT OF LIGHT INTENSITY FROM DIFFERENT LIGHT SOURCES IN 3 TYPES OF WATER

Type of water	Attenuation coefficient of the light intensity (cm^{-1})			
	Green LED λ = 568 nm	Yellow LED λ = 587nm	White LED λ = 620 nm (peak)	Red Laser λ = 650 λnm
Clear	0.047	0.071	0.0088	0.0088
Cloudy	0.047	0.08	0.0091	0.0091
Sea	0.054	0.089	0.0136	0.0136

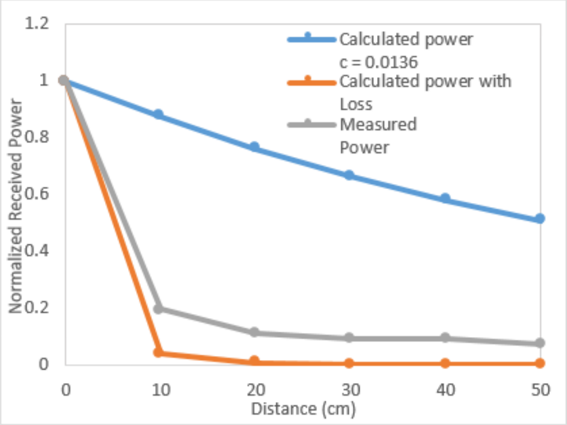

Fig. 8. Comparison between measured and calculated values of normalized received power from white LED in sea water.

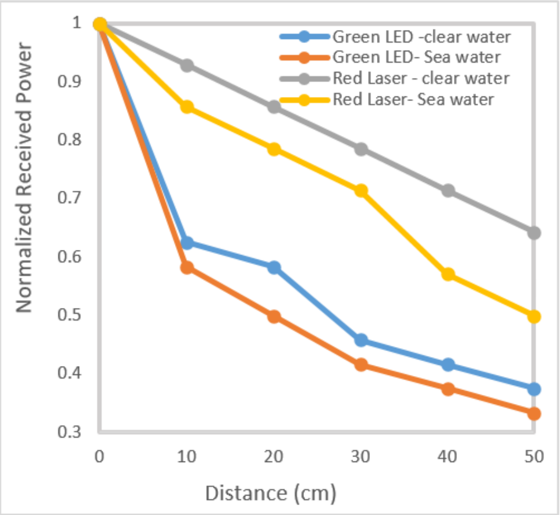

Fig. 9. Normalized received power in clear water and sea water using green LED and red laser as light sources.

Fig. 9 compares the received power between the light emitted by green LED and red laser in sea and clear water environment. Both sources show similar characteristics as the received power in clear water is higher than in sea water. This observation is justified by the fact that the visible light attenuates lesser in clear water than in sea water. The estimated attenuation coefficient, *c* tabulated in Table III, shows a significant increase of 15% and 55% for green LED and red laser respectively when the UOWC medium change from clear water to sea water. This trend is consistent with other UOWC studies in [22]-[23] which have shown the received power gradually reduced as the salinity in water channel was increased. Hence, it can be concluded that the salt concentration in the sea water is the main factor that degrades the UOWC performance.

From the light source perspective, the received power from light emitted by red laser is about 35% higher than power emitted by green LED. This outcome is expected as the laser does not incur any GL as we have discussed in Section 3.1. Therefore, it is apparent that laser source performs better than LED but at the price of higher cost, higher input power and power hazard to eye safety [19].

V. CONCLUSION

This paper presents an experimental work to study the performance of light wave propagation for underwater optical wireless communication (UOWC). The analysis shows that the received power of the optical signal emitted by all light sources decreases as the underwater link length increases. This is due to the effect of signal attenuation and the geometrical loss caused by internal parameter design. Relative to laser, GL is more significant when LED sources are used and the most severe is when white LED is used due to wide viewing angle. As a result, the received power from light emitted by red laser is about 35% higher than power emitted by green LED. Further, the received power in clear water is higher than in sea water because the visible light attenuates lessen in the clear water than in the sea water. Our experimental analysis resulted in the estimated attenuation coefficient c has a significant increase of 15% and 55% for green LED and red laser respectively when the UOWC medium changes from clear water to sea water Therefore, a proper selection of system design parameters is crucial in order to optimize the overall performance. For future work, it is suggested to modify the water tank by covering all sides with black color to minimize the reflection effect when conducting the experiment. Besides, original cloudy water should replace the use of artificial cloudy matter to imitate the cloudy water in order to ensure a reliable result is obtained.

CONFLICT OF INTEREST

The authors declare no conflict of interest to disclose.

AUTHOR CONTRIBUTIONS

Our research team jointly conducted the presented study, performed the experimental work and analyzed the results. All authors discussed the results and contributed to the final manuscript.

REFERENCES

[1] L. J. Johnson, "Optical property variability in the underwater optical wireless channel," Ph.D. dissertation, University of Warwick, UK, 2015.

[2] F. Jasman, "Modelling and characterization of short range underwater optical wireless communication channels," Ph. D. dissertation, University of Warwick, 2016.

[3] H. Kaushal and G. Kaddoum, "Underwater optical wireless communication," *IEEE Access*, vol. 4, pp. 1518-1547, 2016.

[4] Z, Zeng, S. Fu, H. Zhang, Y. Dong, and J. Cheng, "A survey of underwater optical wireless communications," *IEEE Communications Surveys & Tutorials*, vol. 19, pp. 204 - 238, 2017.

[5] C. Gabriel, M. Khalighi, S. Bourennane, P. Léon, and V. Rigaud, "Monte-Carlo-based channel characterization for underwater optical communication systems," *IEEE/OSA Journal of Optical Communications and Networking*, vol. 5, no. 1, pp. 1-12, 2013.

[6] S. Tang, S, Y. Dong, and X. Zhang, "Impulse response modeling for underwater wireless optical communication links," *IEEE Trans. Commun*., vol. 62, pp. 226–234, 2014.

[7] N. B. Mehta, J. Wu, A. F. Molisch, and J. Zhang, "Approximating a sum of random variables with a lognormal," *IEEE Trans. Wireless Communications*, vol. 6, pp. 2690–2699, 2007.

[8] W. Cox and J. Muth, "Simulating channel losses in an underwater optical communication system," *J. Opt. Soc. Am. A*, vol. 31, no. 5, pp. 920–934, 2014.

[9] S. Tang, X. Zhang, and Y. Dong, "Temporal statistics of irradiance in moving turbulent ocean," *MTS/IEEE Oceans*, Bergen, 2013, pp. 1–4.

[10] M. Sharifzadeh and M. Ahmadirad, "Performance analysis of underwater wireless optical communication systems over a wide range of optical turbulence," *Optics Communications*, vol. 427, pp. 609-616, 2018.

[11] N. G. Jerlov, *Marine optics*, 2nd ed., Elsevier, 1976.

[12] W. C. Jr. Cox, "A 1 Mbps underwater communication system using a 405 nm laser diode and photomultiplier tube," M.S. dissertation. Dept. Elect. Eng., North Carolina State Univ., Raleigh, NC, USA, 2008.

[13] Z. Zeng, S. Fu, H. Zhang, Y. Dong, and J. Cheng, "A survey of underwater optical wireless communications," *IEEE Communications Surveys & Tutorials*, vol. 19, pp. 204-238, 2017.

[14] Y. X. Yap, F. Jasman, and T. C. E. Marcus, "Impact of chlorophyll concentration on underwater optical wireless communications," in *Proc. 7th International Conference on Computer and Communication Engineering (ICCCE)*, Kuala Lumpur, Malaysia, 2018, pp. 1-6.

[15] C. F. Bohren and D. R. Huffman, *Absorption and Scattering of Light by Small Particles*, Hoboken, NJ, USA, Wiley, 2008

[16] M. T. Mushtaq, S. M. Yasir, M. S. Khan, A. Wahid, and M. S. Iqbal, "Analysis of internal design parameters to minimize geometrical losses in free-space optical

communication link," *Acta Physica Polonica, A.*, vol. 134, no. 1, pp. 275-277, 2018.

[17] A. G. Alkholidi and K. S. Altowij, *Free Space Optical Communications - Theory and Practices*, INTECH, 2014.

[18] C. Shen, *et al*, "20-meter underwater wireless optical communication link with 1.5 Gbps data rate," *Optics Express*, vol. 24, no. 22, pp. 25502-25509, 2016.

[19] Z. Ghassemlooy, W. Popoola, and S. Rajbhandari, *Optical Wireless Communications: System and Channel Modelling with Matlab®*, CRC Press, 2013.

[20] H. B. Mangrio, A. Baqai, F. A. Umrani, and R. Hussain, "Effects of modulation scheme on experimental setup of RGB LEDs based underwater optical communication," *Wireless Personal Communications*, vol. 106, no. 4, pp. 1827-1839, 2019.

[21] M. A. A. Ali, "Characteristics of optical channel for underwater optical wireless communication system," *IOSR Journal of Electrical and Electronics Engineering*, vol. 10, no. 2, pp. 1-9, 2015.

[22] Z. Ahmad, "Underwater optical wireless sensor network," Ph.D. dissertation, University of Warwick, UK, 2013.

[23] S. Kumar, S. Prince, S. J. V. Aravind, and G. S. Kumar, "Analysis on the effect of salinity in underwater wireless optical communication," *Marine Georesources & Geotechnology*, pp. 1-11, 2019.

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