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Study the effect of Iraqi weather parameter in FSO communication using different wavelength (650, 532) nm

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Abstract

Light has already becomes a popular means of communication, and the high-bandwidth data into free space without the use of wires. A great idea took us to design a new system for transmitting sound through free space at (650, 532) nm wavelengths using reflective mirrors under different atmospheric conditions. The study showed us the effect of various weather factors (temperature, wind speed and humidity) on these wavelengths for different distances. As well as studying the attenuation caused by long-distance laser and beam divergence, A reflective dish was used to focus the spot of the laser beam on the photocell. Results were discussed under the effect of these factors and the attenuation resulting from the beam divergence. Thus, the system performance can be improved for range and the quantity transfer data by increasing transmitted power and reducing the divergence of the laser beam.

Key words
Free space optics, laser communication, optical wireless, attenuation, weather attenuation.

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دراسة تأثير معلمات الطقس العراقي في الأتصالات البصرية عبر الفضاء الحر بأستخدام أطوال موجية مختلفة (650، 532) نانومتر

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الخلاصة

أصبح الضوء بالفعل وسيلة شعبية للأتصال، وللبيانات ذات النطاق الترددي العالي في الفضاء الحر دون استخدام الأسلاك. وقد أخذنا فكرة عظية لتصميم نظام جديد لنقل الصوت عبر الفضاء الحر عند أطوال موجية في منطقة المرئية من الطيف (650، 532) نانومتر بأستخدام مرايا عاكسة في ظل ظروف جوية مختلفة. وأظهرت الدراسة لنا تأثير عوامل الطقس المختلفة (درجة الحرارة وسرعة الرياح والرطوبة) على هذه الأطوال الموجية لمسافات مختلفة. فضلاً عن دراسة التوهين الناجم عن أنفراجية شعاع الليزر لمسافات طويلة، حيث تم أستخدام صحن عاكس لتركيز بقعة شعاع الليزر على الخلية الضوئية. ونوقشت النتائج تحت تأثير هذه العوامل والتوهين الناجم عن أنفراجية الحزمة. وبالتالي، يمكن تحسين أداء النظام للمدى وسرعة نقل البيانات عن طريق زيادة القدرة المرسلة والحد من زاوية أنفراجية شعاع الليزر.

Introduction

The Free Space Optical (FSO) communication is too known as wireless optical communication, or laser communication. FSO communication is one of the different types of wireless communication which witnesses a vast growth these days. FSO provides a wide service where it requires a point-to-point connection between the transmitter and receiving device in clear weather conditions. FSO is basically the same idea of transport in fiber optic but the difference is to direct the laser beam through the free space atmospheric in the FSO instead of directing it through optical fibers to transmit the data. [1-4]. Although the advantages of FSO system on optical fiber system and microwave system, weather condition seem to have more effect over FSO comparison to other medium of communication system. The domestic weather condition plays a substantial role on the availability and reliability of free space optical system [5].

The execution of FSO link is primarily dependent upon the climatology and the physical characteristics of its synthesis location**.** In general, weather and synthesis characteristics that weaken or reduce visibility also effect FSO link execution. A model FSO system is eligible of operating at a range of two to three times that of the abstract eye in any special ecological condition. The primary factors affecting performance include atmospheric attenuation, Turbulence, scintillation, geometric attenuation, solar interference [6].

This work proposes the design of a short-range FSO system using a visible beam of light (650, 532) nm of red and green laser as a means of communication. Communication in visible region is a technology for the transmission of information using the visible light of available components at low cost and high modulation efficiency [7-9]. The system is built point-to-point via optical link (laser diode) up to 200 meters and can provide open space for wireless transmission of voice or data signal.

System parameters

The parameters can be split to two categories which are predictable attenuations and unpredictable attenuations. Predictable attenuations are geometrical attenuation. While unpredictable attenuations are atmospheric attenuation (rain, fog and scintillation).

A. Atmospheric attenuation

Atmospheric attenuation is defined as the procedure whereby some or whole of the electromagnetic wave energy is lost when cross the atmosphere. So, atmosphere cause signal dissolution and attenuation in a FSO system link in various ways, including (scattering, absorption, and scintillation). All these effects are time-varying and will depend on the current local conditions and weather [10]. In general, attenuation is the relation between received and transmitted signal powers as follows [11]:

$$\text{Attenuation} = 10 \log \frac{Prece.}{Ptrans.} \quad (\text{dB}) \quad (1)$$

where:

Prece.: the received power.

Ptrans.: the transmitted power.

Atmosphere attenuation is given by Lambert Beer's law as follows Eq. (1) [7, 12]:

$$\tau = \exp(-\alpha.\text{L}) \quad (2)$$

where:

τ: the atmospheric attenuation.

L: the atmospheric transmission path length.

α: the attenuation coefficient, which is equal to sum of the absorption coefficient (α_{abs}) and scattering coefficient (α_{sca}) given as:

$$\alpha = \alpha_{abs} + \alpha_{sca} \quad (3)$$

scattering in the atmosphere is due to small particles suspended in the atmosphere such as rain, fog, snow, smog and gaseous molecules as well as the shimmer, refraction and scintillation can diffract or scatter the light beam [13]. Absorption in the atmosphere is due to gaseous molecules spread in the atmosphere like water carbon, dioxide vapor, and ozone. The measurements of the atmospheric transmittance as a function of wavelength consider both absorption and scattering as shown in Fig.1.

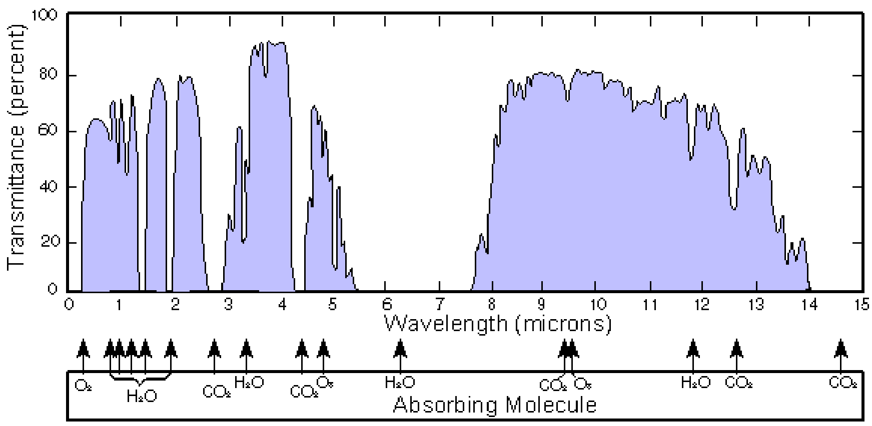

Fig.1: Atmospheric transmittance window with absorption contribution.

Both (α_{abs}) and (α_{sca}) can be predictable to vary with wavelength. where strong absorption occurs around wavelengths (0.94 µm, 1.13 µm, 1.9 µm, 4.3 µm, and 6.0µm) between those values lay the so-called atmospheric window [14]. Then the wavelengths of the free space optical system are between 0.78-0.92 µm [15].

B. Turbulence

Clear atmospheric disturbances affect the propagation of the optical beam through the spatial and temporal fluctuations of the refractive index due to changes in pressure, temperature and wind along the optical propagation channel [16, 17]. Initial shifts in air turbulence cause changes in the visual signals that cause distortions in the front of the wave. These distortions, referred to as visual anomalies, also cause deformation of intensity, referred to as scintillation. Moisture, aerosols, pressure and temperature changes produce refractive index differences in the air by causing random differences in density [18]. These differences are referred to as eddies and have a lens effect on light passing through them. When a plane wave thread cross these eddies, parts of it are refracted at random causing a deformed wave front with the joint effects of variation of intensity across the wave front and warping of the isophase surface [19].

C. Scintillation

Scintillation may be the most prominent one for FSO systems [20]. Light traveling through scintillation will suffer experimental intensity fluctuations, even over comparatively short propagation paths [21]. Scintillation can be defined as the shift of light intensity in time and space at the plane of a receiver that is detecting a signal from a transmitter existing at a distance. The received signal at the detector turn as an outcome of the thermally induced changes in the index of refraction of the weather along the transmit channel. The change of these indicators makes the atmosphere work like a series of small lenses that deviate part of the light into and out of the transmitter path. Scintillation can alter at by more than an order of size during the course of a day, being the worst, or most scintillated, through midday when the temperature is high [6].

D. Geometrical attenuation

Knowing geometrical attenuation then it is a potential to evaluate received power level and link margin in request to evaluate the execution of FSO links. Geometrical attenuation is a constant value for a specified FSO system ago it does not vary with time. Geometrical attenuation happen when the light beam laser is diverged as it moves throughout its spread course. As a result not the whole light beam hits the receiver [22].

Beam divergence intentionally allows the beam to diverge or propagation. The advantage using light beam in FSO system produce a lot higher data rates and raise the security. Laser beam to produce with utmost cramped light can be easily modulated with voice and data information. The beam propagation is dependent on the beam divergence angle and transmission extent. Usually, 1 mrad to 8 mrad beam divergence propagation 1 to 8 m at distance of 1 km. To avert Proliferation of a large beam, it is better to use tight beam divergence like 1 mrad [23].

The geometric attenuation of the optical system can be calculated through the free space of the transmitted beam, divergence, and distance between the two nodes, range and the diameter of the laser beam reaching in receiver optics (d) as follows [13]:

$$P_{geom.} = 20\log(Div\,.\tfrac{L}{d})\ \ (dB) \qquad (4)$$

$$d_1 = Div\ \times L + d_2 \qquad (5)$$

where:

$P_{geom.}$: the geometric loss.

div: the divergence of laser beam.

L: the distance between transmitter and receiver.

d_1: the diameter of the laser beam at the optical receiver.

d_2: the laser beam diameter at output aperture of the device of the transmitter.

The divergence angle of the transmitted beam and the beam angle received are shown in Fig. 2.

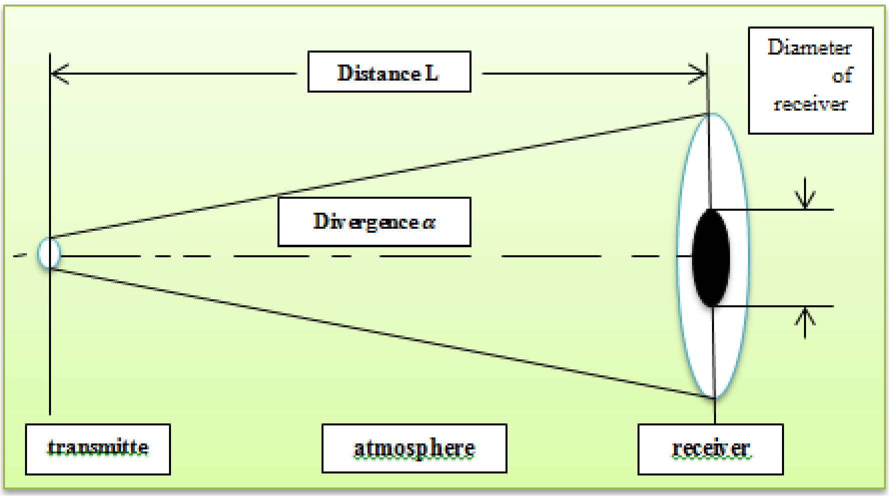

Fig. 2: Geometric system.

Therefore, Eqs. (1, 2, 4) represent the total energy of the signal received through the earth's atmosphere can be calculated by:

$$P_{rece.} = P_{trans.}\cdot\frac{A_{rece.}}{(Div.L)^2}\cdot\tau \qquad (6)$$

$$A_{rece.} = \pi\,(D^2/_4) \qquad (7)$$

where:

$A_{rece.}$: receiver optics area.

D: detector diameter.

E. Solar interference

A FSO system uses a highly sensitive receiver in set with a large-slot lens and as a result, natural setting light can potentially interfere with FSO signal receiver. This is chiefly the case with the high levels of setting radiation associated with intensive sunlight. In some state of affairs, direct sunlight may reason link outages for term of several minutes when the sun is within the receiver's field of view (FOV). However, the times when the receiver is more exposed to the effects of direct solar light can be easily predicted. When direct exposure of the equipment cannot be avert, narrowing the receiver FOV and/or using a narrow-bandwidth light filter can progress system execution. It is substantial to remember that interference by sunlight reflected off a glass surface is potential as well [6].

Experimental set-up

In this section, we will explain how to design the FSO system using two different wavelengths (650, 532) nm for voice transmission by reflection across the atmosphere. Fig. 3 shows the general description of the system.

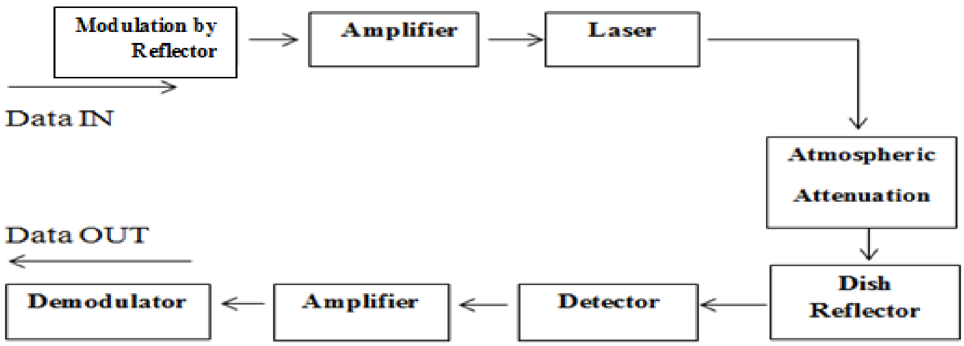

Fig.3: General Description.

In this work compared two different wavelengths of lasers, Table 1 constructs the parameters of these lasers.

Table 1: Equipment parameters.

TYPE LASER	WAVELENTHS nm	OUTPUT PWOR mW	DIVERGENCE mrad
RED (diode)	650	100	**2**
GREEN (diode)	532	1000	**2.5**

To get rid of the laser beam divergence angle problem we encountered in this work, we use a reflective dish to focus the divergent laser beam into a small spot.

The efficiency of each wavelength was measured for specific distances during the day and night then we analyze the results obtained under different climatic conditions. Fig. 6 showing the transmitter and receiver parts, to study the effect of the more important weather factors on laser light in free space and to discuss them. Also to compare the efficiency of each laser under these circumstances to determine the best one to use in this area.

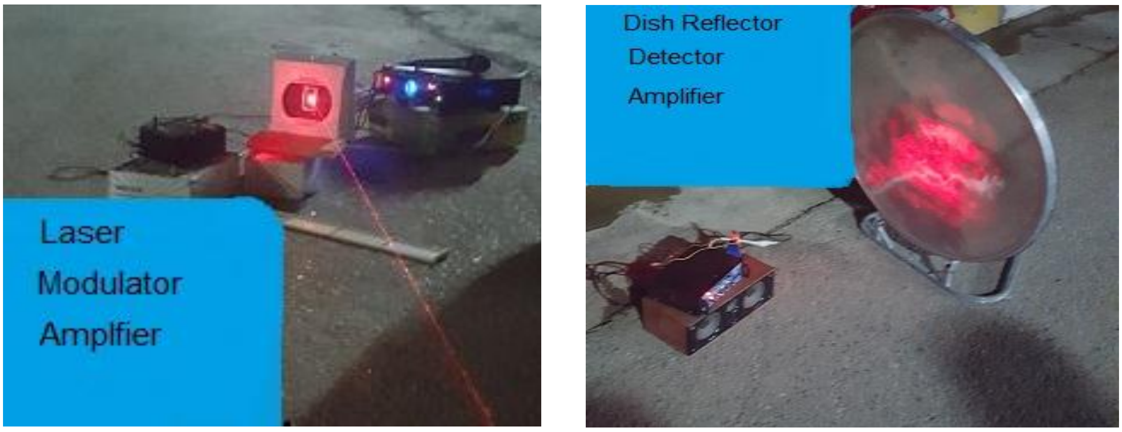

Fig.6: The parts of the transmitter and receiver.

Experimental results

The FSO system uses the laser beam to transmit data through the atmosphere. Bad conditions in the atmosphere as well as engineering attenuation caused by the laser beam divergence angle affect the performance of the transmitted signal were studied. In this part we will discuss the performance of the FSO system for sound modulation by reflectors and its transmission in free space under different weather conditions (temperature, wind speed, humidity).

Fig. 7, shows the efficiency of each wavelength which measured during the day at 20 °C, wind speed 15 km/h and 61% humidity. From the figure, the wavelength of 650 nm is slightly higher in efficiency under these conditions.

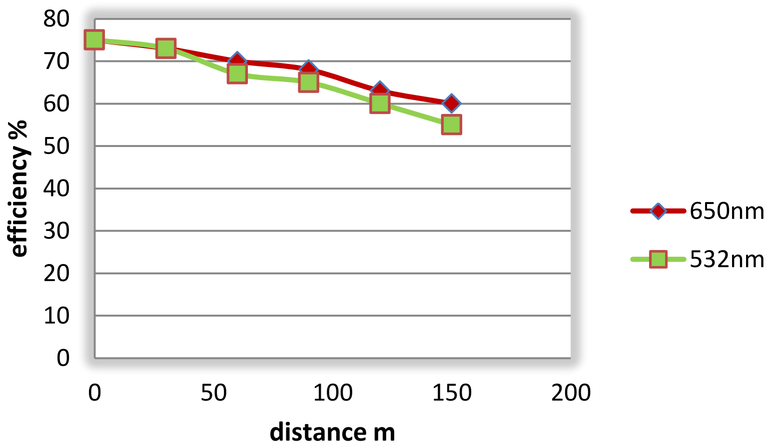

Fig. 7: Efficiency % for (650, 532) nm versus distance (m) which measured during the day at 20 °C, wind speed 15 km/h and 61% humidity.

In Fig. 8, the efficiency of each wavelength was measured in a rainy night at 17 °C, wind velocity 12 km/h and 71 % humidity. From the shape we observe that the 650 nm wavelength is more affected by precipitation at a distance of 180 m as a result of the absorption due to rain drops where the intensity of precipitation increased at the last two readings of the wavelength 650 nm.

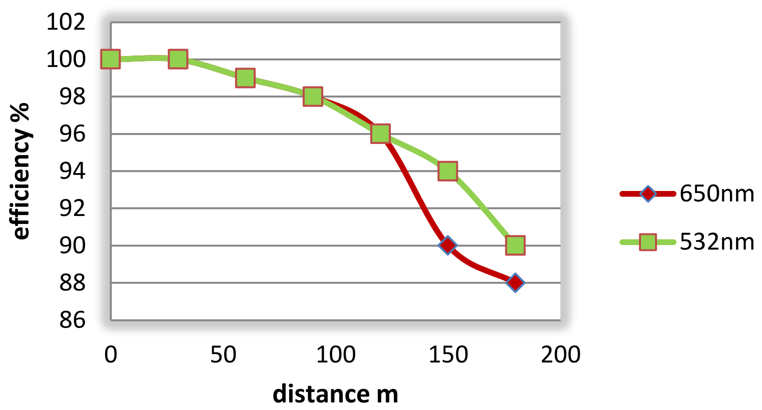

Fig. 8: Efficiency % for (650, 532) nm versus distance (m) was measured in a rainy night at 17 ℃, wind velocity 12 km/h and 71 % humidity.

In Fig. 9, the efficiency of each wavelength was measured in a partially cloudy climate during the day at 25 °C, wind velocity 11 km/h and 29 % humidity. We noticed the wavelength superiority of 650 nm under these conditions. The reason for this is that short wavelengths are more affected by the scattering caused by air dust minutes as well as by the effect of solar interference with lasers beam, resulting in lower efficiency.

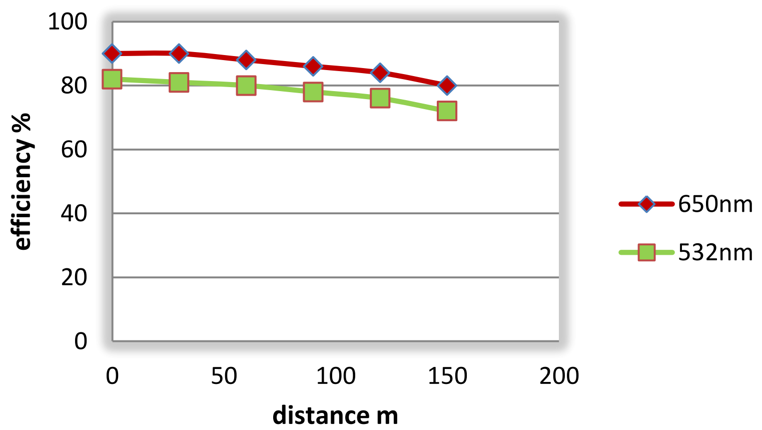

Fig.9: Efficiency % for (650, 532) nm versus distance (m) was measured in a partially cloudy climate during the day at 25 ℃, wind velocity 11 km/h and 29% humidity.

In Fig.10, the efficiency of each wavelength was measured during the day in sunny weather at 43 °C, 19 km/h winds and 13 % humidity. We observe how each wavelength has been affected by temperature rise. Reach efficiency at 150 meters for each wavelength is approximately 40 %. In addition to the effect of dispersion caused by the dust minutes in the air and because of the solar interference caused by the interference of the laser beam with the sunlight destructive interference due to phase difference between them at the receiver, which cause a decrease in efficiency.

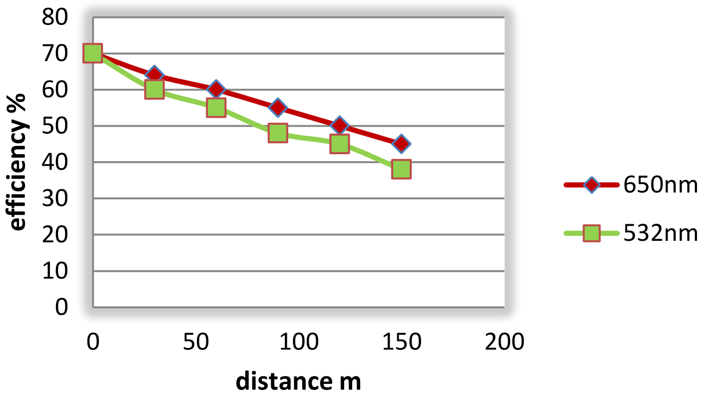

Fig.10: Efficiency % for (650, 532) nm versus distance (m) was measured during the day in sunny weather at 43 ℃, 19 km/h winds and 13 % humidity.

In Fig. 11, the efficiency of each wavelength at night was measured at 38 °C, the wind speed was 17 km/h and the humidity was 14 %. Note that the wavelength 650 nm exceeds the wavelength 532 nm under these conditions because the short wavelength is affected by the scattering caused by the dust minutes in the air.

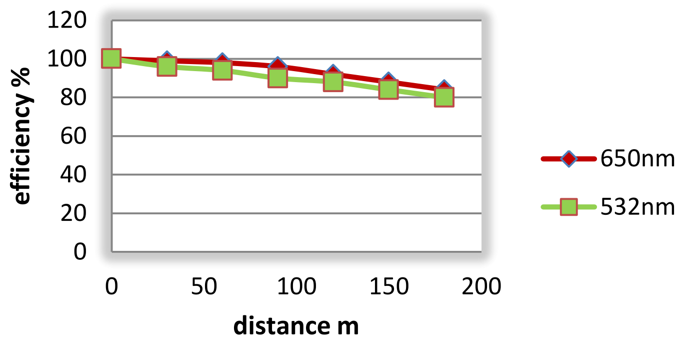

Fig. 11: Efficiency % for (650, 532) nm versus distance (m) was measured at 38 ℃, the wind speed was 17 km/h and the humidity was 14 %.

From previous drawings we see that the efficiency of each wavelength at night is better than its efficiency during the day under the same conditions and the reason for the impact of ambient light during the day where the solar conjunction occurs when the sun light emitted by the sun inter for with the laser light with different phase cause intensity damping. The power of the sun becomes pervasive within the recipient than the power received from the transmitter. Solar interference is usually limited to the order of the receiver so that the sun always deviates from the axis.

Conclusions

In this study, we designed an optical system for transmitting the sound by the laser beam modulation by reflection using two of wavelength (650, 532) nm in the free space for short range up to 180 m, under the influence of different weather conditions. This type of modulation is characterized by low cost and high efficiency of transmitted power. This is due to the use of mirrors for laser beam modulator based on the Doppler phenomenon and the reflective dish used to focus the laser beam divergence instead telescope system which absorb such amount of light. Finally, the efficiency of the system can be increased by increasing the transmitted power and reducing the laser beam divergence angle.

References

[1] H. Weichel, "Laser Beam Propagation in the Atmosphere", SPIE, Optical Engineering Press, Vol. TT-3, 1990.
[2] R. Srinivasan, D. Sridharan, IEEE International Conference on Computational Intelligence and Computing Research, Parameters, 2, (2010) 3.
[3] A. Alkholidi, K. Altowij, In Optical Communications Systems, In Tech, 2012.
[4] M. S. Khan, M. R. Naqvi, M. A. Khan, M. Latif, K. Ullah, R. D. Khan, R. Wali, E. Leitgeb, In Network and Optical Communications (NOC), 2013 18th European Conference on and Optical Cabling and Infrastructure (OC&i), IEEE (2013) 203-208.
[5] A. Husagic, W. Al-Khateeb, Proceedings of the International Conference on Computer and Communication Engineering (2008) 1206-1120.
[6] S. Bloom, E. Korevaar, J. Schuster, H. Willebrand, J. of Optical Networking 2, 6 (2003) 178-200.
[7] G. Pang, 2004 IEEE Region 10 Conference: Analog and Digital Techniques in Electrical Engineering, (2004) B395-B398.
[8] G. Pang, T. Kwan, H. Liu, C.H. Chan, Proceedings of the 1999 IEEE Industry Applications Conference, (1999) 1693-1699.
[9] G. Pang, T. Kwan, H. Liu, C.H. Chan, "LED wireless". IEEE Industry Applications Magazine, 8, 1 (2002) 21-28.
[10] Willebrand, A. Heinz, B.S. Ghuman, "Fiber Optic without Fiber Light Pointe Communications", 2001.
[11] F. Halsal, "Data communications, Computer Networks and Open System", McGraw Hill, Inc., U.S.A, 1996.
[12]A. Mazin, M. Abdulatteef, J. Al-Nahrain Univ., 16, 3 (2013) 133-140.
[13] R. Freeman, "Telecommunication Transmission handbook", John Wiely & Sons,Inc.,2^{nd} Edition, U.S.A, 1975.
[14] R. Hudson, "Infrared system Engineering", Wiley-Interscience Inc., 2^{nd} Ed., U.K, 1969.
[15] E. Douglas, "Computer Networks and Internets", Prentice-Hall Inc., Purdue University,2^{nd} Edition, 1999.
[16] I. Kim, R. Stieger, J. A. Koontz, C. Moursund, M. Barclay, P. Adhikari, J. Schuster, E. Korevaar, R. Ruigrok, C. DeCusatis, Optical Engineering, 37, 12 (1998) 3143-3155.
[17] J. Li and M. Uysal, Global Telecommunications Conference, 5, (2003) 2654-2658.
[18] Wilkins, D. Gary, "The diffraction limited aperture of the atmosphere and its effects on free space laser communications." In Aerospace and Electronics Conference, NAECON 1992, Proceedings of the IEEE 1992 National, (1992) 1158-1163.
[19] I. I. Kim, E. Korevaar, In Proc. SPIE, 4530, 84 (2001) 84-95.
[20] Nadia B. M. Nawawi, "Wireless Local Area Network System Employing Free Space Optic Communication Link", A Bachelor Degree thesis, May 2009.
[21] H. Hemmati, "Near-Earth Laser Communications", California, Taylor & Francis Group, Book, LLC, 2008.
[22] O. Bouchet, H. Sizun, F. Boisrobert, F. De Fornel, P. Favennec, Free-Space Optics: Propagation and Communication. UK: ISTE, Ltd, 2006.
[23] I. I. Kim, B. McArthur, E. Korevaar, In proc. SPIE, 4214 (2001) 26-37.