THE PERFORMANCE OF A MODULATION PASSIVELY Q-SWITCHED SOLID – STATE LASER PUMPED BY LASER DIODE, FOR FREE – SPACE LASER COMMUNICATIONS

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Abstract

The aim of this project is to demonstrate a simple method of a multiple-frequency operation of passively Q- switched Nd: YAG optically pumped by an RF modulation Injection Laser Diode (ILD) at (808 nm wavelength), and controllable repletion rate (100 Hz – 4 KHz). A stable gain –switched pulse train of (1.064 nm) wavelength is obtained with a maximum repletion rate of 4 KHz and (17 ns) pulse duration.

Key words: Modulation, free-space communication, Q- switch

1. INTRODUCTION

Free-space optical communication (FSO) systems (in space and inside the atmosphere) have developed in response to a growing need for high-speed and tap-proof communication systems. Links involving satellites, deep-space probes, ground stations, unmanned aerial vehicles, high altitude platforms, aircraft, and other nomadic communication partners are of practical interest. Moreover, all links can be used in both military and civilian contexts. FSO is the next frontier for net-centric connectivity, as bandwidth, spectrum and security issues favor its adoption as an adjunct to radio frequency (RF) communications [1]. The optical carrier can be modulated in its frequency analog or digital. Analog modulation simply means that waveform is continuously varying in amplitude. A sine wave is a perfect example. Digital modulation, on the other hand, implies a discontinuous change in amplitude. A Square wave is the prime example of digital modulation [2]. Communication system consists of three main units, a transmitter, propagation medium and receiver [3]. Today, diode-pumped solid-state lasers it's used as transmitter, they offer significant advantages in terms of efficiency, compactness, lifetime and high beam quality. So satisfy requirements (FSO) [4].

2. OPTICAL SIGNAL LINK ANALYSIS

The overall system performance of a lasercom is quantified using a link budget derived from the range equation, which combines attenuation and geometrical aspects to calculate the received power. The process of finding the link margin through the system link calculation transmitter power, propagation losses, receiver sensitivity. The receiver's sensitivity determines the amount of received optical power needed to achieve the required signal-to-noise ratio (SNR) for a given expected communication performance [6]. The purpose of this section is to develop the parameters necessary to calculate the performance of an optical communication link. We shall consider the situation of optical propagation between points in free-space. Consider a laser transmitter antenna with gain GT transmitting a total power PT at the wavelength. The signal power received (PR) at the communications detector can be expressed (from the range equation) [7].

$$P_R = P_T\, T_{ATM}\, G_T\, G_R\, (\lambda/4\pi L)^2$$

where P_T is the power transmitted, T_{ATM} is the value of the atmospheric transmission at the laser transmitter wavelength (λ), G_T is the transmitter antenna gain

$$GT = 16/(\theta T)^2$$

where θ_T is the full transmitting divergence angle, GR is the receiver antenna gain

$$GR = (\pi\, DR/\lambda)^2$$

where D_R is the receiver diameter, and where L is the link range. Normally an optical link typically consists of two transceivers, each made up of one (or more) transmitting laser and receiving photo detector. Transmitting optics (telescope, lenses, mirrors) shape the transmitted laser beam which is collected by the receiver optics so that the received signal is focused onto the photo detector. The parameters of the communications are chosen so that sufficient signal from the lasers on one transceiver reaches the photo detector on the other transceiver through the atmosphere to differentiate ones (signal) and zeros (no signal) with negligible error [8].If Given a laser transmitter power $\boldsymbol{P_T}$, with transmitter divergence of θT, receiver telescope area ***A***, transmit and receive optical efficiency $\boldsymbol{T_{opt}}$, the achievable data rate R can be obtained from [9].

$$R = \frac{P_T T_{opt} T_{ATM} A}{\pi (\theta_t / 2)^2 L^2 E_P N_b}$$

where E_p = hc/λ is the photon energy and N_b is the receiver sensitivity in photons/bit.

3. EXPERIMENTAL SETUP

Fig. 1 shows a schematic of our experimental Setup. A (0.1 %) doped, Nd:YAG crystal with diameter of 5 mm and length of 5 mm, was utilized as laser medium. Both ends of the crystal were parallel, which created a flat-flat cavity. A coating a highly reflective at the laser wavelength of 1064 nm, has been vapour deposited onto one end of the rod that also forms the left resonator mirror. The vapour deposited system of layers is designed such that the maximum pump-light radiation can penetrate the highly reflective layer with only 20% losses. The other end of the rod has a vapour deposited, high-quality antireflex layer for 1064 nm in order to keep the internal resonator losses as low as possible. The pump source (ILD) at 808 nm, which operates in either CW mode or pulsed mode. A Peltier's cooling element for the control of the diode temperature and a thermistor for the measurement of the temperature are all located inside the laser diode. The (ILD) output beam was collimated and focusing onto the Nd:YAG crystal by sequence of three lens system it consists of a three-lens system with a short focal length (f=6 mm) in addition to a focal length of 60 mm lens. The Nd- YAG output beam was filtered by a narrow band pass interference filter to reject the (ILD) wavelength (808 nm) and allow the (1.064 nm) only. Which is then detected by a PIN Photo diode and displayed by a storage oscilloscope.

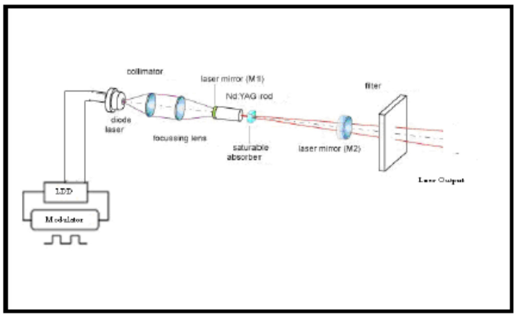

Fig. 1. Schematic of experimental Setup

4. RESULTS

4.1. Modulation Laser Diode

Light output of a laser diode can be directly modulated. The laser output is either amplitude or pulse modulated by controlling the current flow through the device. In figure 2 a,b shows the potodetector output of laser pulse modulated at low frequency (100 Hz) and high frequency (4 KHz) channel 2 (yellow trace). Channel 1 (red trace) is the input modulation signal.

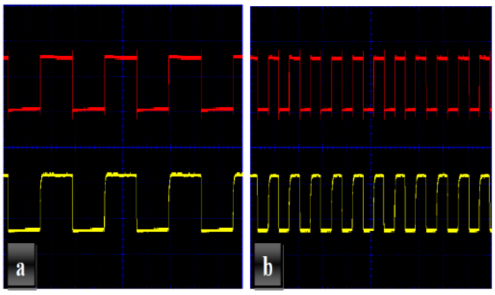

Fig. 2. Digital modulation signals of laser diode, (a) at low frequency, (b) at high frequency.

4.2. Pulse Repetition Rate (PRR)

The life time of the upper state of the active medium is very important parameter to limited the PRR of DPSSLT. Increased the life time decrease the PRR. The life time for active medium (Nd:YAG) used in this system is measured about (230 μs) as shown in figure (3), which mean that the DPSSLT can controlled about (4.3 KHz).

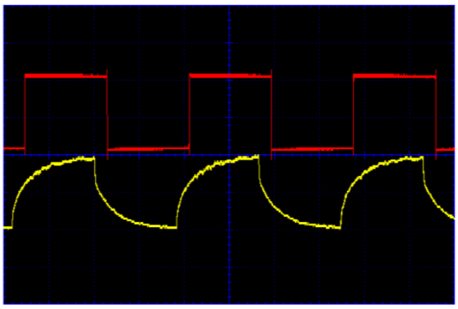

Fig. 3. Signals of the fluorescence life time level for Nd: YAG laser

4.3. Modulation DPSSLT

Fig. 4a shows the photodetector output of a laser modulated by alow frequency (100 Hz) digital signal Channel 2 (yellow trace). Hence at free – running mode, the pulse duration of laser is in microsecond. Channel 1 (red trace) represents the input modulation signal (ILD) pumping source. Fig 4b shows the high frequency (4 KHz) modulation case.

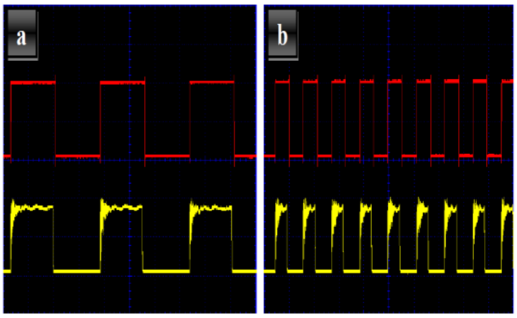

Fig. 4. Digital modulation signals free -running Nd:YAG laser, (a) at low frequency, (b) at high frequency

Fig. 5 show the output gain –switched pulse train with stable peak values, narrow pulse duration at the low frequency (100 Hz), channel 2 (yellow trace) in fig. (5a) and high frequency (4 KHz) channel 2 (yellow trace) modulation case in fig. (5b). Correspondingly the diode laser output is a rectangle pulses, channel 1(red trace).

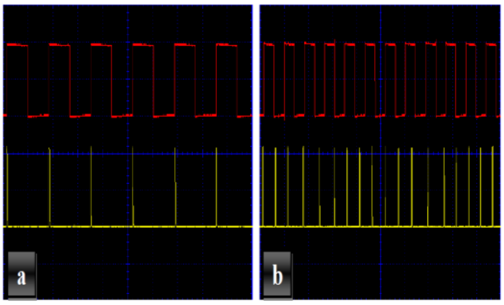

Fig. 5. Digital modulation signals, gain switched, (a) at low frequency, (b) at high frequency.

4.4. Optical signal link and data rate calculations

At the system parameters such as laser power, gain receiver, gain transmitter operation wavelength and visibility conditions, which are calculated the received power with versus link range atmosphere transmitter. As shown in the fig. 6, T_{ATM}= 0.9 is available for clear condition for the system operation over a (2Km) span, for T_{ATM}= 0.6 over a (1.5 Km) span, for T_{ATM}= 0.4 just under a (1 Km) span.

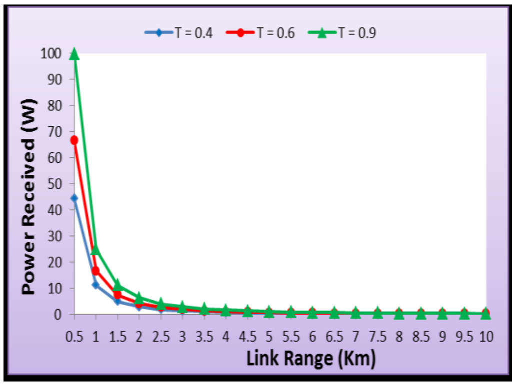

Fig. 6. Power received as a function of link range for three atmospheric conditions

Fig. 7 illustrates available optical data rate versus link range for the same system parameters. As shown in this figure, the link is available for very clear condition for the system operating over a 3.5-km span, for clear weather over a 3 km span, and for bad weather just under a 2.5-km span. The curve shows how system operation, parameters defining channel capacity can be varied to accommodate link availability under varying atmospheric conditions.

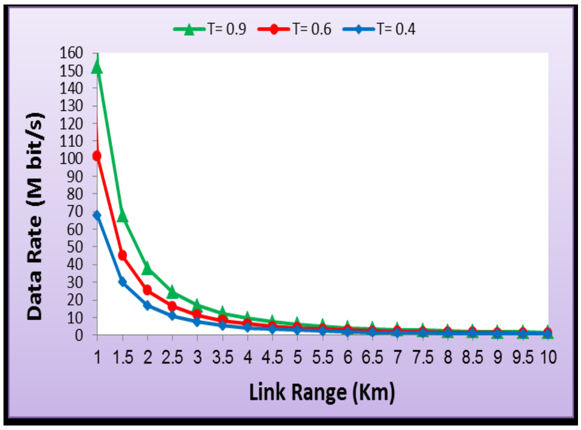

Fig. 7. Data rate as a function of link range for three atmospheric conditions

5. CONCLUSION

The Passively Q-switched Nd:YAG laser (1.064 nm) pumped by an RF modulated (ILD) demonstrated as stable pulse repletion rate of (100 Hz-10 KHz) and a pulse width of (17 ns). The pulse width and the modulation frequency dependence of the passively Q-switched, repetitively modulated laser output vs. the diode pump power for Nd:YAG crystals. Choosing the proper pumping current & pulse width makes system usable in a (FSOC) system.

References

[1] E. Kozachenko ,and M. Anderson, "A Free Space Optical Communications System", IEEE Journal, Vol. 1, No. 3, (2011), PP. 195- 201.

[2] H. G. yong, C. C. ying, and C. Z. qiang, "Free-Space Optical communication using visible light", Journal of Zhejiang University, Vol.8, No.2, (2007),PP.186-191.

[3] H. HENNIGER , "An Introduction to Free-space Optical Communications", Radio engineering, VOL. 19, NO. 2, (2010).

[4] K. Morrison and M. Sosa, "Application of COTS High Speed 980 nm Pump Laser Diode and Driver for Free Space Laser Communication Terminal", SPIE, Vol. 3708, April (1999).

[5] V. Chan, "Free-Space Optical Communications", Journal of Lightwave Technology, Vol. 24, No. 12, (2006), PP.4750-4762.

[6] G. Gilbreath and W. Rabinovich, "Research in Free Space Optical Data Transfer at the U. S. Naval Research Laboratory", Journal SPIE, Vol. 5160, No.4, (2004), PP.225-233.

[7] A. Komaee, P. Krishna, and P. Narayan, "Active Pointing Control for Short Range Free-Space Optical Communication", Communications in Information and Systems Journal, Vol.7, No. 2, (2007) , PP. 177-194.

[8] D. Aviv, "Laser Space Communications", ARTECH HOUSE, USA, (2006).

[9] R. E. Ziemer and W. H. Tranter, "Principle of communications, systems, modulation, and noise", Wiley, New York, (1995).