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Laser Based Underwater Communication

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Abstract: To revolutionise under water communication system with the use of narrow beam LASER as the wireless medium for transmission and reception of data. To provide a very high data rate of (1 gbps - 256 gbps) which is far greater than the data rate provided by acoustic communication(1kbps-50kbps). We also discuss the advantages of operating with single mode laser devices and matched filtering at the receiver in the context of applications with significant solar background.

Keywords: Visible lasers, frequency modulation, optical communication, oceanic optics, wavelength filtering devices.

I. INTRODUCTION

The combination of hardware and software components together constitute an embedded system. The processing unit of each and every embedded system is a microprocessor or microcontroller. In recent years embedded systems have played a vital role in the day to day life of human beings.

Free Space Optical Communications :After LIFI was first introduced in the year 2011 light based communication has been a revolution Since then LED's have been used for FSO communication Use of LASER is one of the most recent upgrades in the field of free space optical communication.

Under Water Optical Communications: Acoustic communication have a very long range but the major disadvantage is that they have very low data rate . LASER based optical communication has the ability to overcome this disadvantage of acoustic communication

*EMBEDDED SYSTEMS :*Microcontrollers are widely used in Embedded System products. An Embedded product uses the microprocessor (or microcontroller) to do one task & one task only. A printer is an example of embedded system since the processor inside it performs one task only namely getting the data and printing it. Contrast this with Pentium based PC. A PC can be used for any no. of applications such as word processor, print server, bank teller terminal, video game player, network server or internet terminal.

Software for variety of applications can be loaded and run. Of course the reason a PC can perform multiple task is that it has RAM memory and an operating system that loads the application software into RAM & lets the CPU run it. In and Embedded system there is only one application software that is typically burn into ROM. An x86PC Contain or its connected to various Embedded Products such as keyboard, printer, modem, Disc controller, Sound card, CD-Rom Driver, Mouse & so on. Each one of these peripherals as a microcontroller inside it that performs only one task. For example inside every mouse there is microcontroller to perform the task of finding the mouse position and sending it to PC.

II. RELATED WORK

A literature review in a project report is that section which shows the various analyses and research made in the field of interest and the results already published, taking into account the various parameters of the project and the extent of the project. It gives a direction in the area of research. It helps set a goal for analysis.

Ultrahigh-speed violet laser diode based free-space optical-Violet laser diode (VLD) based ultrahigh-speed free-space optical (FSO) system is demonstrated for point-to-point data transmission. By directly encoding the VLD with 64-quadrature amplitude modulation discrete multi-tone (64-QAM DMT) data stream for optical wireless communication through 0.5–10 m in free space, the point-to-point VLD-based FSO link allows delivering the 64-QAM DMT data at an ultrahigh bit rate of up to 26.4 Gbps. After receiving with a high-speed p-i-n photodiode, such a VLD-FSO link can provide clear constellation plot with error vector magnitude (EVM) of 8.57%, signalto-noise ratio (SNR) of 21.34 dB and bit error ratio (BER) of 3.17×10^{-3} under forward-error-correction criterion. The EVM increases from 8.8% to 9.4% and the SNR decreases from 21.1 to 20.6 dB to slightly degrade the reachable data rate from 25.8 to 24 Gbit/s with transmission distance lengthening from 3 to 10 m.

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10m/500Mbps WDM visible light communication systems - A wavelength-division-multiplexing (WDM) visible light communiction (VLC) system employing red and green laser pointer lasers (LPLs) with directly modulating data signals is proposed and experimentally demonstrated. With the assistance of preamplifier and adaptive filter at the receiving sites, low bit error rate (BER) at 10m/500Mbps operation is obtained for each wavelength. The use of preamplifier and adaptive filter offer significant improvements for freespace transmission performance. Improved performance of BER of <10−9, as well as better and clear eye diagram were achieved in our proposed WDM VLC systems. LPL features create a new category of good performance with high-speed data rate, long transmission length (>5m), as well as easy handling and installation. This proposed WDM VLC system reveals a prominent one to present its advancement in simplicity and convenience to be installed.

UHD Video Transmission Over Bidirectional Underwater Wireless Optical Communication - The links extend up to 4.5 m using QPSK, 16-QAM, and 64-QAM modulations. The system is built using software defined platforms connected to TO-9 packaged pigtailed 520 nm directly modulated green laser diode (LD) with 1.2 GHz bandwidth as the optical transmitter for video streaming on the downlink, and an avalanche photodiode (APD) module as the downlink receiver. The uplink channel is connected to another pigtailed 450 nm directly modulated blue LD with 1.2 GHz bandwidth as the optical uplink transmitter for the feedback channel, and to a second APD as the uplink receiver.

26 m/5.5 Gbps air-water optical wireless communication based on an OFDM-modulated 520-nm laser diode - We experimentally demonstrate a high-speed air-water optical wireless communication system with both downlink and uplink transmission employing 32-quadrature amplitude modulation (QAM) orthogonal frequency division multiplexing (OFDM) and a single-mode pigtailed green-light laser diode (LD). This work is an important step towards the future study on optical wireless communications between underwater platforms and airborne terminals. Over a 5-m air channel and a 21-m water channel, we achieve a 5.3-Gbps transmission without power loading (PL) and a 5.5-Gbps transmission with PL in the downlink. The corresponding bit error rates (BERs) are $2.64\times10^{-3}$and 2.47×10^{-3}, respectively, which are below the forward error correction (FEC) criterion. A data rate of 5.5 Gbps with PL at a BER of $2.92\times10^{-3}$is also achieved in the uplink.

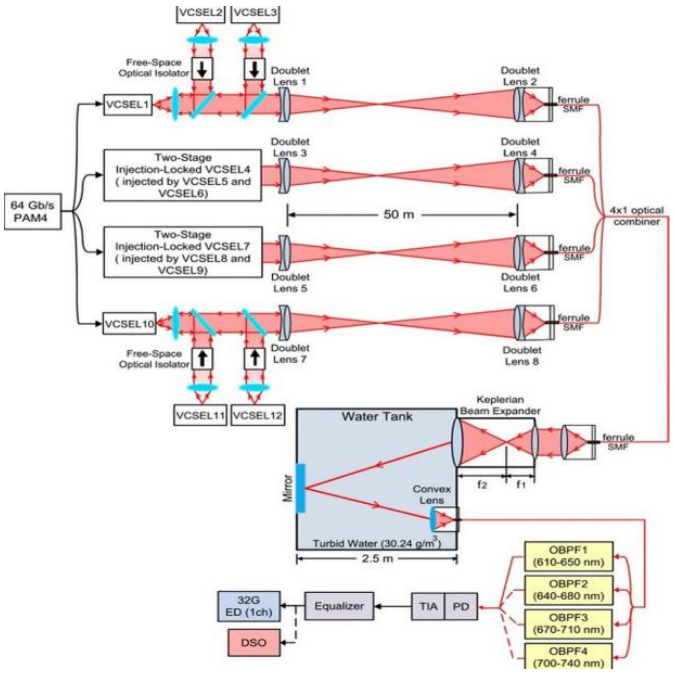

Fig:3.1Ray DiagramReperesentation from base paper

III. PROPOSED METHODOLOGY

The proposed system is designed and developed to accomplish the various tasks in an adverse environment of an industry.

To establish a under water communication system with the use of narrow beam LASER as the wireless medium for transmission and reception of dataTo provide a very high data rate of (1 gbps - 256 gbps) which is far greater than the data rate provided by acoustic communication(1kbps-50kbps)

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3.1 Laser Based UWOC/FSO

Familier Efficient Method of Communications.

- Acoustic communication like ultrasonic waves Use of very low frequency RF signals
- Very low data rate

UnfamilierEfficient Method of Communications

- Using narrow beam LASER Very high data rate
- Highly efficient

Efficiency of Laser based UWOC/FSO

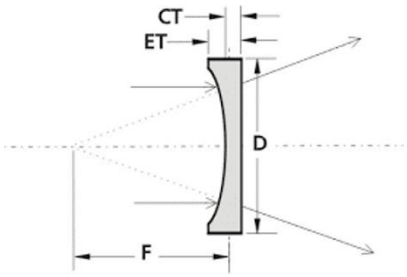
- Highly secure
- Since light cannot penentrate through solid objects the acess is limited only to the user.
- Long distance coverage
- With the help of proper optics laser can be used for very long distances
- LLCD-Lunar laser communication demonstration
- very high data rate
- With the help of laser very high data rate can be acheived
- Highly efficient
- Compared to all the other methods that are now available laser is efficient in many ways

3.2 Transmission and FSO

- Four individual channel with a bit rate of 64 Gb/s is used.
- Twelve VCSEL laser diodes are used with three for each channel.
- Each triple laser setup has two stage
- injection locking.
- Doublet lens and 4x1 optical combiner is used.

3.3 Brief overview of components used

1. Doublet lens (plano concave lens)



In optics, a doublet is a type of lens made up of two simple lenses paired together. Such an arrangement allows more optical surfaces, thicknesses, and formulations, especially as the space between lenses may be considered an "element". With additional degrees of freedom, optical designers have more latitude to correct more optical aberrations more thoroughly. Doublets can come in many forms, though most commercial doublets are achromats, which are optimized to reduce chromatic aberration while also reducing spherical aberration and other optical aberrations. The lenses are made from glasses with different refractive indices and different amounts of dispersion. Often one element is made from crown glass and the other from flint glass. This combination produces a better image than a simple lens. Some Trilobites, which are now extinct, had natural doublet lenses in their eyes. Apochromats can also be made as doublets.

2. 4x1 Optical combiner

For analytical purposes a portion can be separated from the incident beam or a selected wavelength can be extracted from or coupled into the optical path. The variety goes from simple plates to sophisticated beamsplitter assemblies. Used in the reverse direction, combiners converge two separate light beams into one beam while filtering a specific wavelength range from each incoming beam. At times a passive device in which the power from several output fibers is connected and then distributed among a smaller number (one or more) of input fibers or photoreceivers

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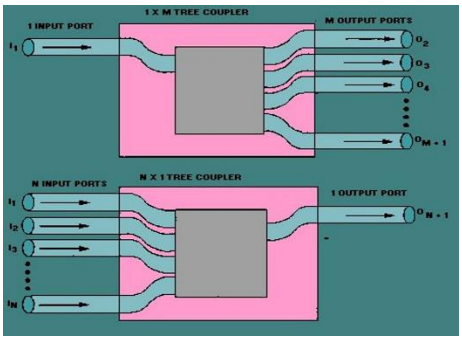
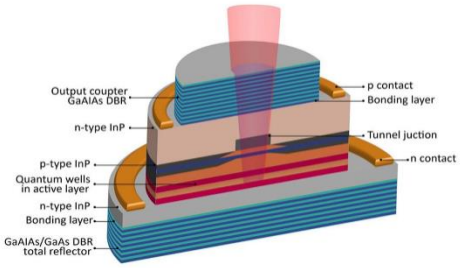


3 . VCSEL Laser

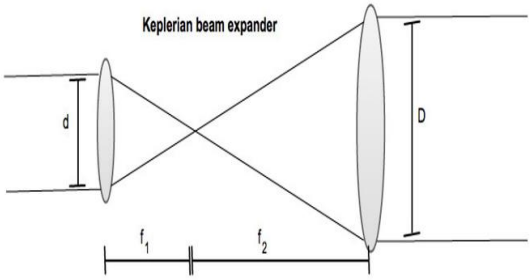


VCSELs are semiconductor lasers, more specifically laser diodes with a monolithic laser resonator, where the emitted light leaves the device in a direction perpendicular to the chip surface. The resonator (cavity) is realized with two semiconductor Bragg mirrors. Between those, there is an active region (gain structure) with (typically) several quantum wells and a total thickness of only a few micrometers. VCSELs can have a high beam quality only for fairly small mode areas (diameters of a few microns) and are thus limited in terms of output power. For larger mode areas, the excitation of higher-order transverse modes can not be avoided.

State / VCSEL	free-running	one-stage injection locking	two-stage injection locking
VCSEL1	5.3 GHz	12.2 GHz	26.3 GHz
VCSEL4	5.1 GHz	12 GHz	26 GHz
VCSEL7	5.2 GHz	12.1 GHz	26.1 GHz
VCSEL10	5.3 GHz	12.2 GHz	26.2 GHz

3.4 UWOC and Reception

Keplerian beamexpander



Beam expanders are optical devices that take a collimated beam of light and expand its size. In a laser beam expander, the placement of the objective and image lenses is reversed. Keplerian beam expanders are designed so that the collimated input beam focuses to a spot between the objective and image lenses, producing a point within the

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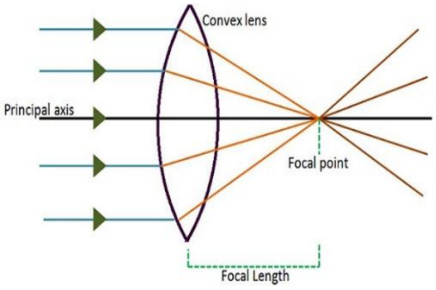
system where the laser's energy is concentrated. Thus beam expansion reduces the beam divergence and enables the emission of very narrow linewidths which is a desired feature for many analytical applications including laser communication.

Convex lens

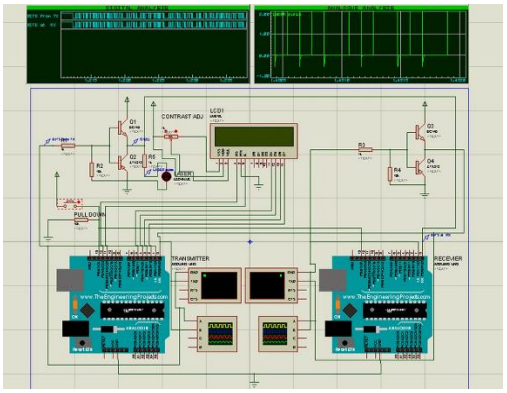


A convex lens is a converging lens. When parallel rays of light pass through a convex lens the refracted rays converge at one point called the principal focus. The distance between the principal focus and the centre of the lens is called the focal length. Lenses are classified by the curvature of the two optical surfaces. If the lens is biconvex or plano-convex, the lens is called positive or converging. Most convex lenses fall into this category.

A lens is biconvex (or double convex, or just convex) if both surfaces are convex. These types of lenses are used in the manufacture of magnifying glasses. If both surfaces have the same radius of curvature, the lens is known as an equiconvex biconvex. If one of the surfaces is flat, the lens is plano-convex (or plano-concave depending on the curvature of the other surface). A lens with one convex and one concave side is convex-concave or meniscus

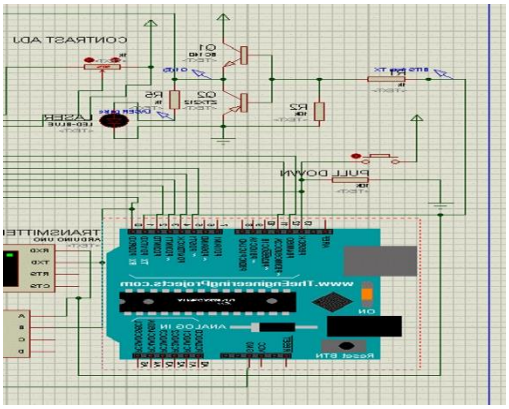
3.5 Working Design

3.5.1 Over all Design



The above image shows the overall circuit simulation done on Proteus which is a electronic design automation tool

3.5.2 Transmitter Section



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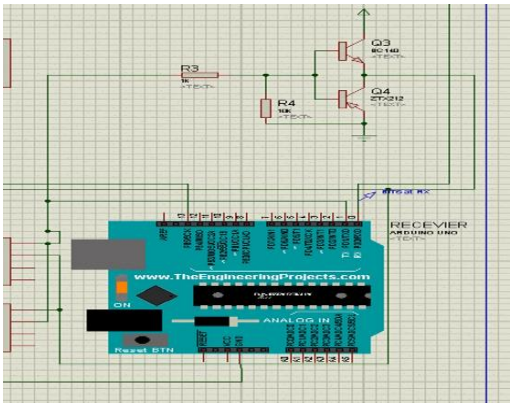
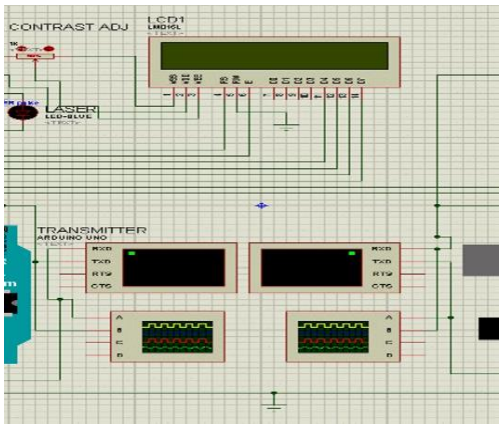
- The transmitter section of the section of the model consists of an arduino UNO microcontroller.
- ATmega 328p consists of a single transmitter and recevier for serial communication using UART protocol A liquid crystal display is interfaced with the transmitter to display the status of the process
- A SPST switch is provided for the purpose of initiating the transmission and the reception process

3.5.3 Receiver Section



- Similar to the transmitter the receiver also uses an arduino UNO board to receive the information
- Received info is in the form of one and zero and so the controller is used to convert the info to its original format
- A transistor switch is also used to transmit the data back to the transmitter
- During both transmission and reception a set of pnp and npn transistors are used in a switch like arrangement to simulate the delay caused by the time taken by a semiconductor laser to reach its active region.

3.5.4 User Interface Devices



Three user interface devices are used to view the status of the process

1. Liquid crystal display
2. Cathode ray oscilloscope
3. Virtual terminal

- A virtual terminal is a device used to view the transmitted and received information
- In arduino IDE the virtual terminal is called serial monitor.
- The information from the interface devices are shown in the next slide.

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IV. RESULTS AND DISCUSSION

4.1 Red Laser

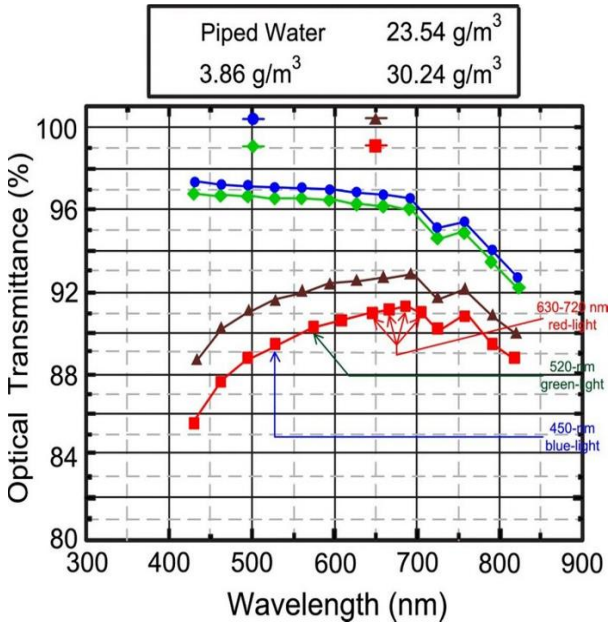

Fig:4.1Transmittance of different coloured laser

Fig 4.1 shows, That compared to all the other light in the visible spectrum only red color has the least transmittance.

4.2 Optical Band Pass Filter

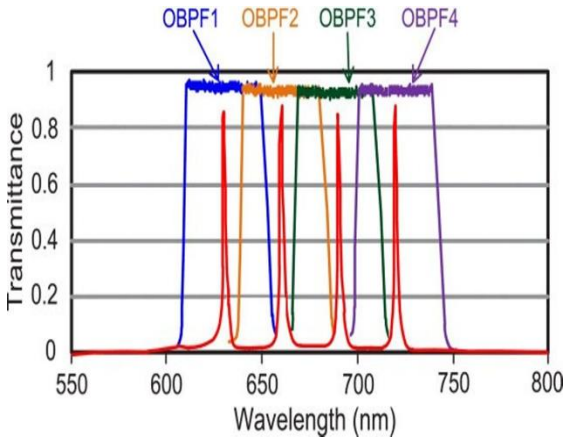

Fig 4.2 Optical Band Pass Filter

Fig 4.2 shows, The optical spectra of four separate OBPFs with passband windows of 610- 650 (OBPF1), 640–680 (OBPF2), 670–710 (OBPF3), and 700–740 (OBPF4) nm; and four filtered optical wavelengths with wavelengths of 631.27, 661.73, 691.56, and 720.58 nm.

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4.3 Analog analysis

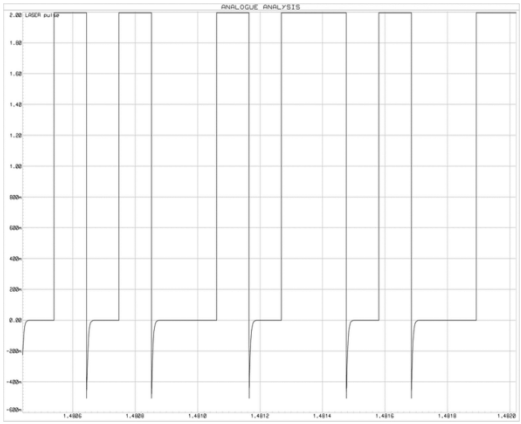

Fig 4.3 Analog analysis of the pulse provided to the LASER diode

4.4 Message transmitted

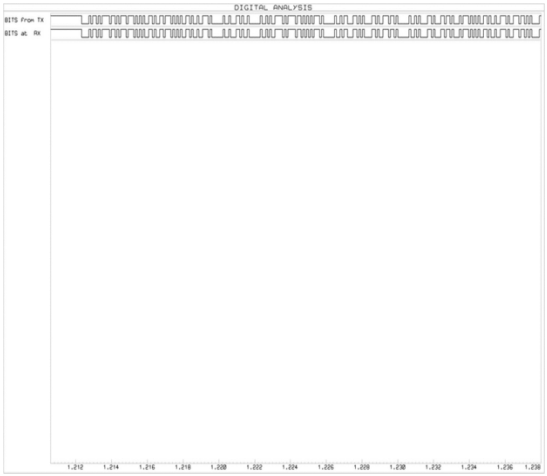

Fig 4.4 Message transmitted from the transmitter to the receiver

The first array of pulses shows the date from the transmitter arduino. The second array of pulses show the data that is received at the receiver end.

Thus from the above analysis it is clear that the data from the transmitter is successfully transmitted through the communicstion link to the receiver without any losses during the process.

V. CONCLUSION

A simulation of a LASER based communication was achevied with the help of a EDA(Electronic Design Automation) software called proteus Two microcontroller (ATmega 328p) was used .One of the controller is used to transmit and the other one is used to receive the transmitted signal A PNP and NPN transistor is used as a high speed switching circuit to turn the LASER diode ON and OFF A LCD display ,virtual terminal and a cathode ray oscilloscope are used for user interface.

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