

# Light Fidelity (LI-FI) - The Future of Visible Light Communication

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**Abstract--** In the present world, Wireless communication has become a utility like electricity, food and water. We use it every day and everywhere, in our business life, private life, social life and so on. Whether we are using internet at our home or office or simply in a coffee shop, we usually get irritated at the slow speeds and pray to almighty for a faster internet speed. To tackle this issue, a German Physicist- Harald Haas has introduced a solution which he calls “data through illumination”-transmission of data through LED lights which vary in intensities faster than the human eye can follow. According to him, the heart of this technology lies in the intensity and potential of the light emitting diode. This paper focuses on construction and working of Li-Fi based system and compares its performance with the existing technologies.

**Keywords--** Li-Fi, Wi-Fi, visible light communications (VLC), RF (Radio Frequency), LED (Light Emitting Diode), electromagnetic spectrum, lamp driver.

## INTRODUCTION

Li-Fi, is a bidirectional, high speed and fully networked wireless communications, using visible light and can be a very good complement to RF communication (Wi-Fi or Cellular network), or can even serve as a replacement in contexts of data broadcasting.

Li-Fi basically known as “light fidelity” is an outcome of twenty first century research. It is a [5G visible light communication](#) system that uses light from [light-emitting diodes](#) (LEDs) as a medium to deliver networked, mobile, high-speed communication in a similar manner as [Wi-Fi](#).

Li-Fi could lead to the [Internet of Things](#), which is everything electronic being connected to the internet, with the LED lights on the electronics being used as Li-Fi internet access points. Visible light communications (VLC) works by switching bulbs on and off within [nanoseconds](#), which is too quickly to be noticed by the human eye. This can be obtained by fitting a Li-Fi chip, to turn the light bulb into a high speed broadband communication device. Although Li-Fi bulbs would have to be kept ON to transmit data, the bulbs could be dimmed to the point that they were not visible to humans and yet still functional. Li-Fi has an amazing feature to think about i.e. - one light bulb of 1 watt can produce internet streaming of media in nearly 5 laptops.



Fig. 1. Example of Li-Fi application

The wireless technology’s huge success has led to an imminent shortage of radio frequency (RF) spectrum. The amount of data sent through wireless networks is expected to increase 10 fold during the next 4 years. However, there isn’t enough new RF spectrums to

allocate. In addition, the spectral efficiency (the number of bits successfully transmitted per hertz bandwidth) of wireless networks has become saturated. The U.S. Federal Communications Commission has therefore warned of a potential spectrum crisis.

The solution to this problem is the Li-Fi technology. It has been designed in such a way that it overcomes the disadvantages that occurs during the usage of Wi-Fi. The demonstration took place using two Casio smart phones. The data was made to exchange between the phones using light. Even though the distance was nominal, it is sure that there would be a rapid increase in the distance of transmission. The German Physicist believes that a speed of 10 Gbps can be achieved in no time. If this would be possible then a high clarity image would take about 30 seconds to download!!

If we consider this technology 10 years from now, it certainly will be very useful to us. Consider malls, roads, shops-we have light everywhere we go, so we can think of internet almost everywhere.

## WHY ONLY VLC

Radio-waves	Infrared	Visible	Ultra-violet	X-rays	Gamma rays
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Fig. 2. Electromagnetic Spectrum

- Gamma rays cannot be used as they can be dangerous.
- X-Rays have similar health issues.
- Ultra-violet rays are good for places without people, otherwise dangerous for human beings.
- Infrared due to eye safety regulation should be used with low power.
- Visible light on the other hand is everywhere, and also has a wide spectrum.

## HOW Li-Fi WORKS

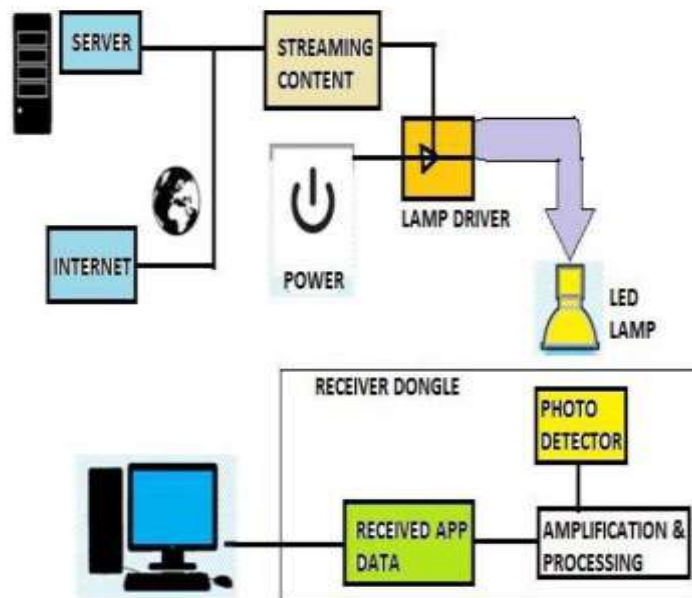


Fig. 3. Block Representation of Li-Fi

This figure describes the major functionality of Li-Fi where all light sources will have small LED lamps with lamp driver circuitry fitted inside the arrangement to make the LEDs turn ON and OFF according to the digital data being transmitted. On the receiver side a photo-detector will decode the received light signals, which is further amplified, processed and sent to the device you are using. Li-Fi can give you speed up to 1 Gbps in your home network. Also this speed is variable and can be adjusted by varying the properties of light source.

A. Stage 1 - Server

A server is a system ([software](#) and suitable [computer hardware](#)) that responds to requests across a [computer network](#) to provide, or help to provide, a [network service](#).

Internet and server run parallelly. When we type a site for example-google.com, it sends request to various servers and finally sending request to the server of google in USA. Finally after analysing the request google server sends us the required information in various packets. All this happens in a few seconds.

### B. Stage 2 - Lamp Driver

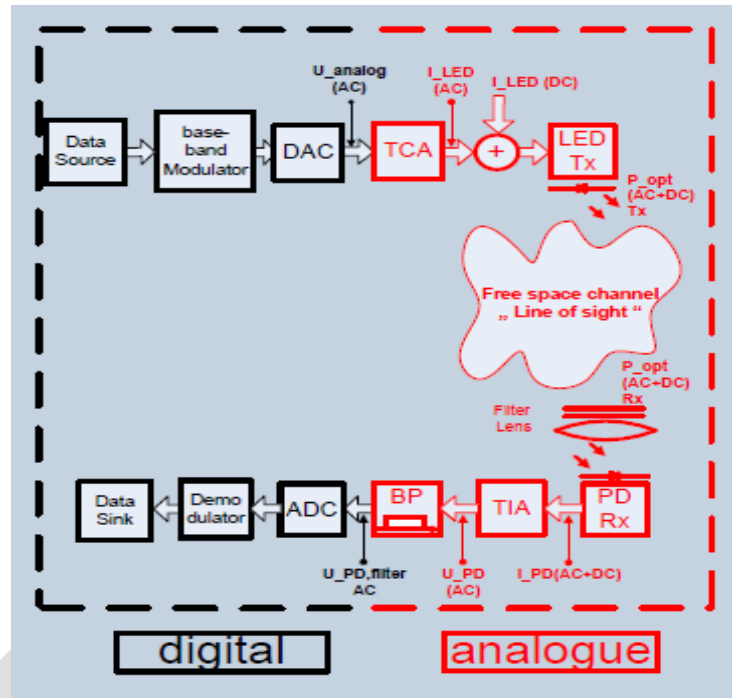


Fig. 4. Block Diagram of Lamp Driver <sup>[3]</sup>

### Components of Light driver -

1. **Baseband modulator:** Baseband modulation and demodulation techniques are fundamental to communication systems. Baseband is actual frequency band of signal (e.g voice, video). If we consider the voice signal then voice signal band is approximately 4 kHz. That means voice signal contains frequencies ranging from 0-4kHz. Modulation is basically increasing signal frequency. This means voice base band of 4 kHz can be uplifted to let's say, 1900 kHz

2. **DAC:** In [electronics](#), a digital-to-analog converter (DAC, D/A, D2A or D-to-A) is a function that converts digital data (usually binary) into [analog signal](#) ([current](#), [voltage](#), or [electric charge](#)) <sup>[12]</sup>.

3. **TCA:** A trans-conductance amplifier (gm amplifier) puts out a current proportional to its input voltage. In [network analysis](#), the trans-conductance amplifier is defined as a voltage controlled current source (VCCS). It is common to see these amplifiers installed in a [cascade](#) configuration, which improves the frequency response.

4. **ADDER:** It simply adds a dc current to the TCA output.

### C. Stage 3

An overhead lamp fitted with an LED with signal processing technology streams data embedded in its beam at ultra-high speeds to the photo-detector.

### D. Stage 4

A receiver dongle then converts the tiny changes in amplitude into an electrical signal, which is then converted back into a data stream and transmitted to a computer or mobile device.

## ADVANTAGES OF Li-Fi

- *Capacity:* Visible light spectrum is 10000 times bigger than RF spectrum. It is predicted that we will run out of the RF spectrum by 2020.
- *Security:* Light cannot penetrate walls, but radio waves can, thus security is higher in using Li-Fi.
- *Efficiency:* The 1 million radio masts base stations consume a lot of energy, which indeed is used to cool the base stations and not to transmit radio waves. These base stations have poor efficiency upto only 5%. Whereas Li-Fi uses the 2.4 billion led lamps which offers a much higher efficiency.
- *Transmission of data:* Wi-Fi transmits data serially and Li-Fi transmits thousands of data streams parallelly thus offering higher speed <sup>[6]</sup>.
- *Infrastructure:* It is already existing. Inexpensive devices, mostly powered by LED, so it is cost effective, compared to base stations.

## APPLICATIONS OF Li-Fi

1. *Intelligent Transport System:* LED equipped headlight and backlights, where the cars can talk to each other and react faster when they are Li-Fi enabled. Traffic lights and street lights can talk to each other and also to the cars which can indeed reduce the number of accidents <sup>[9]</sup>.
2. *Underwater Awesomeness:* The RF cannot penetrate in the water while the visible light can. Divers can use their torches enabled with Li-Fi technology to communicate with each other <sup>[8]</sup>. Also, the submarines can transmit and receive information from the ships that are above it, through transmission and reception of light.
3. *Indoor Navigation:* Li-Fi can be used to navigate through any hospital or office building that has Li-Fi enabled LED lighting, through the user's smart phones.
4. *Oil and gas wells:* Testing and maintaining of gas wells can be performed with greater ease and efficiency. This can be obtained by placing the Li-Fi transmitter at the bottom of the well and the receiver at the surface, for real-time continuous monitoring.
5. *Intrinsically safe environments:* This can be used in petroleum and chemical industries and other environments where the usage of radio waves or other transmission frequencies can be hazardous.
6. *Boon for Hospitals:* Operating rooms in hospitals do not allow Wi-Fi over radiation concerns, and also there is lack of dedicated spectrum. Wi-Fi is in place in many hospitals, but interference from cell phones and computers can block signals from the monitoring equipment. Li-Fi solves both problems: lights are not only allowed in operating rooms, but tend to be the most glaring fixtures in the room. It can also be used for advanced medical instruments.
7. *Enjoy your Flight:* 'Kindly switch off your Mobile Phones', is the primary instruction of flights globally, during takeoff and landing. The reason being the electromagnetic interference caused to the aircraft systems by the radio waves emitted from mobile phones, thus hindering our online operations. Li-Fi provides a solution to this as it can use the light present in the aircraft lobby for data transmission.

## CONCLUSION

Li-Fi technology thus holds the solution to various shortcomings of radio based wireless communication systems. It has a wide range of applications. It also supports green environment, as it uses Visible Light Communication for transmission of data, which is harmless and available everywhere. Thus if the idea and technology of Harald Hass are put to practical use, every LED bulb can be used as a Li-Fi hotspot for transmitting and receiving wireless data.

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## WIND ENERGY CONSERVATION WITH GRID LEVELING FOR TRANSIENT LOADS

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**Abstract:** The paper discusses the maximum power point tracking in a grid connected PMSG based WECS. To the variable-speed wind turbine, if the rotor speed can always be adjusted to make the turbine operate under optimum tip speed ratio then it means that the turbine realises the MPPT operation. For this purpose the P & O tracking algorithm is adopted. In addition to fully recognise the wind energy it is necessary to integrate it to the grid and hence grid parameters are regulated as well using PI controller. The proposed system is developed in Matlab environment.

**Keywords:** Wind Energy Systems, HAWT, PMSG, MPPT, PI Controller, Voltage, Current regulation, Grid Integration.

**INTRODUCTION:** The potential of renewable energy sources is enormous as they can in principle meet many times the world's energy demand. The depletion of fossil fuels and concomitant global climate change has compelled nations to seek new non-polluting ways to produce energy. Among various kinds of renewable energy, wind energy is treated as the most challenging one because of its free availability, policies fostering, and the maturity of turbine techniques. Renewable energy especially wind energy conversion systems have drawn an increasing interest in the past years since they could be considered as confirmed alternatives for sustaining the continuous growing energy needs. The growth of Renewable Energy in India is enormous and Wind Energy proves to be the most effective solution to the problem of depleting fossil fuels, importing of coal, greenhouse gas emission, environmental pollution etc. Thus, wind energy conversion technology has become the research focus of researchers all over the world.

In modern wind energy conversion system two turbine structures are preferred: DFIG and PMSG. Although both of these structures feature improved efficiency, reduced aerodynamic loads, and ease of active and reactive power regulation, latter is much more reliable than the former, considering the possibility of cancellation of gearbox. Therefore, a direct-drive-PMSG based WECS is considered in this paper. To harvest more energy from the variation winds, MPPT control should be included in the power control system. The different methods of MPPT system are defined in [9]. However till date, there is no conclusive evidence is available as to which MPPT system is likely to provide a more efficient and less expensive in literatures.

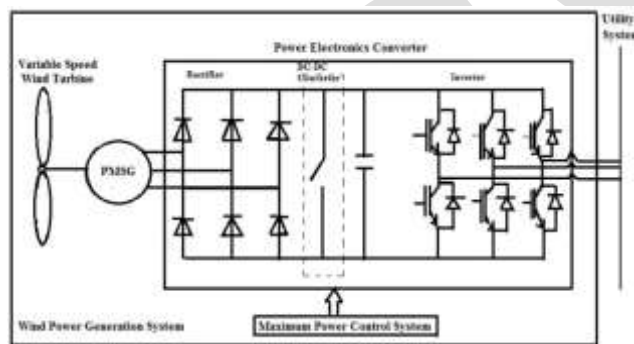
### WIND ENERGY CONVERSION SYSTEM TECHNOLOGY

A WECS is a structure that transforms the kinetic energy of the incoming air stream into electrical energy. Modern Wind Energy Conversion System (WECS) is shown in Figure 1

The energy conversion chain is organised into four subsystems:

- **Aerodynamic subsystem**, consisting mainly of the turbine rotor, which is composed of blades, and turbine hub, which is the support for blades;
- **Drive train**, generally composed of: low-speed shaft – coupled with the turbine, hub, speed multiplier and high-speed shaft – driving the electrical generator;
- **Electro Magnetic subsystem**, consisting mainly of the electric generator.
- **Electric subsystem**, including the elements for grid connection and local grid.

The circuit diagram of the proposed system as in figure 3.1 includes Variable speed wind turbine, Permanent Magnet Synchronous Generator, power electronic components which includes rectifier, inverter, boost converter and the control system which is a PI controller. The de description of the circuit diagram parameters are described in the following sections.



**Figure 1:** Circuit Diagram of the proposed system

The tip speed ratio of a wind turbine is a variable expressing the ratio between the peripheral blade speed and the wind speed. It is denoted by  $\lambda$  and computed as below,

$$\text{TSR} = \frac{(\text{Blade length} * \text{rotor speed})}{\text{wind speed}} \quad (1)$$

Where, the blade length is denoted as  $R$ , the rotor speed as  $\omega$ , the wind speed is  $v$  and the power extracted by a wind turbine whose blade length is  $R$  is expressed as,

$$P_T = \frac{1}{2} \rho \pi R^2 C_p(\lambda) v^3 \quad (2)$$

$$\text{Therefore, } C_p = 4a(1 - a)^2 \quad (3)$$

The maximum value of  $C_p$  occurs for  $a = 1/3$  and hence  $C_{pmax} = 0.59$  known as the Betz limit and represents the maximum power extraction efficiency of a wind turbine.

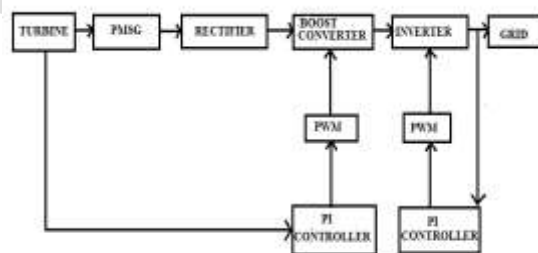


### **Working:**

- (a) When wind speed is below cut-in speed the machine does not produce power. If the rotor has a sufficient torque to start, it may start rotating below this wind speed. However, no power is extracted and the rotor rotates freely. In many modern designs the aerodynamic torque produced at the standstill condition is quite low and the rotor has to be started (by working the generator in the motor mode) at the cut-in wind speed.
- (b) At normal wind speeds, maximum power is extracted from wind. The maximum power point is achieved at a specific (constant) value of the TSR. Therefore, to track the maximum power limit point, the rotational speed has to be changed continuously in proportion to the wind speed.
- (c) At high winds, the rotor speed is limited to maximum value depending on the design limit of the mechanical components that are the turbine blades and hub. In this region, the power co-efficient is lower than the maximum and the power output is not proportional to the cube of the wind speed.
- (d) At even higher wind speeds, the power output is kept constant at the maximum value allowed by the electrical components.
- (e) At a certain cut-out wind speed or otherwise known as furling wind speed, the rotation of turbine blades are stalled and hence no power generation is done in order to protect the system components.

The output power evolves according to Equation (2), proportionally with the wind speed cubed, until it reaches the wind turbine rated power. This output power from turbine is fed into the PMSG. PMSG is favoured more and more in developing new designs because of its higher efficiency, high power density, availability of high-energy permanent magnet material at reasonable price, and the possibility of providing smaller turbine diameter in direct drive applications.

Then power conversion for wind energy systems occurs in two stages. The first stage is rectification, where the alternating current (AC) is transformed into direct current (DC). The boost converter steps up the input DC voltage. The second stage is inversion where the direct current is transformed back into alternating current. PI controller is adopted in this system as this will optimize the conversion coefficient to maintain maximum power output. The inputs to the controller are the wind speed and voltage, current that are to be fed into the grid. The PI controller regulates the inputs and feeds the error signal to PWM. The PWM scheme is most commonly used because of the possibility of voltage regulation, but it will also cancel out multiples of the third harmonic to help improve output power quality. The inverter receives the switching signals from the PWM which in turn regulates the incoming DC link voltage and current and feeds it into the grid. The wind speed tracking is also shown.



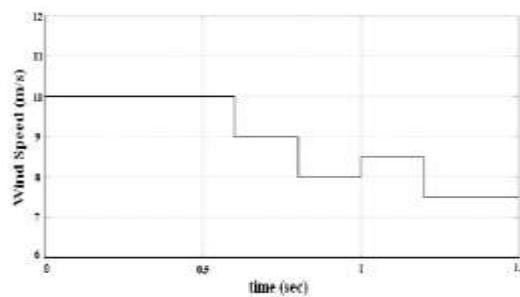
**Figure 2:** Block Diagram of the Proposed Grid-Connected WECS



The basic device in the wind energy conversion system is the wind turbine which transfers the kinetic energy into a mechanical energy. The wind turbine is connected to the electrical generator through a coupling device gear train or a direct drive system. The output of the generator is given to the electrical grid by employing a proper controller to avoid the disturbances and to protect the system or network. The detailed description of various blocks are already discussed in the above sections

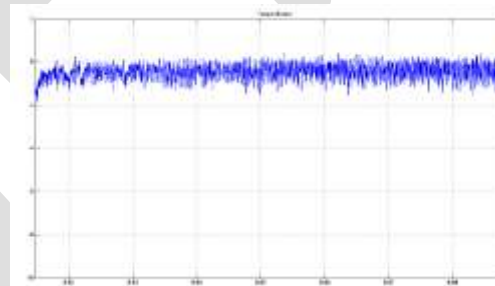
## SIMULATION RESULTS

This chapter presents the results of the proposed wind energy conservation system with grid levelling for transient loads. Simulation results are shown below in the following sections.



**Figure 3:** Tracking of wind speeds with varying time

The intended contribution of this paper is to find out a relation between the MPPT speed and the transient loads (torque ripples). Hence a graph showing the waveform of the tracking of wind speed with time is shown in figure 3 generated torques is shown in figure 4



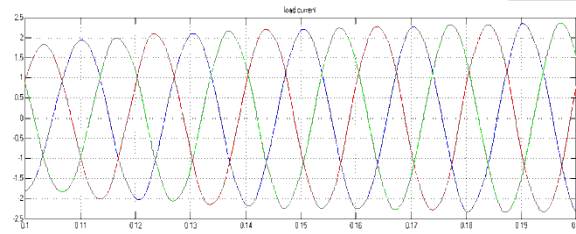
**Figure 4:**Generated Torque

The WTS controller outputs a torque command which contains the turbine dynamic information to the inverter, which is working in torque control mode. Because the PMSG is driven by this inverter, it will generate a torque that is equal to that of a real wind turbine. The validity of the wind turbine emulator has already been verified in the previous work. As mentioned earlier the output from the wind energy system is integrated with the grid in order to fully utilise its potential.



**Figure 5: Input Voltage to Grid**

The voltage fed into the grid from the inverter. The current waveforms that are free from ripples which are obtained as outputs from the inverter are also given to the grid are shown in figure 6.



**Figure 6 : Input current to grid**

The first plot is the output voltage, as can be seen, without the harmonic filters; the output is essentially a square wave due to the switching nature of the inverter. The second plot is of the output current, it is not in phase with the output voltage. Both the unclean output voltage and current lead to an unstable output active power (P), and a large, also unstable, reactive power (Q) output

## CONCLUSION

The main focus of this paper is on proposing a systematic study on the MPPT system to get a good compromise between the MPPT speed and the transient load. Furthermore, to confirm that the WECS can operate at the designed system bandwidth, P and O control method is proposed. The MPPT controller helps in tracking wind speeds varying with time. In addition, the system includes a PI controller to control the turbine speed and the grid voltage on the generator side and the grid side respectively. The controller further inputs pulses to the PWM inverter, the output of which are fed to grid

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# Negative Role of Atmosphere On Free Space Light Communication

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**Abstract**— When every a communication system is to be designed whether wireless or wired, the first and the most important issue which is to be considered is about the features possess by the medium through which communication will take place and whether those features will induce a negative role on it or not. In free space light communication technique, it is clear by the name that the atmosphere is being used as a medium for carrying or transferring data using infrared carrier. Various atmospheric phenomena do play a negative role on light communication and what we term them as attenuation phenomenal. This paper deals with such various phenomena and its negative role on free space light communication technique. Also why IR wave is preferred for free space light communication is also explained.

**Keywords**— Free space light communication (FSLC), Infrared wave (IR), penetration depth (Dp), signal to noise ratio (SNR), bit error rate (BER).

## INTRODUCTION

At one time, connecting all of the people at all time around the world was a nice idea but completely impractical. Even communication using light was never imagined that some day it would take a real face. Today's commercially available FSLC systems operate in the near IR spectral windows located around 850 nm and 1550 nm. Even a clean, clear atmosphere is composed of oxygen and nitrogen molecules. The weather can contribute large amounts of water vapor. Other constituents can exist, as well, especially in polluted regions. These particles can scatter or absorb infrared photons propagating in the atmosphere.

## ADVANTAGES OF USING LIGHT OVER RADIO WAVE

### Free space light communication versus radio communication

Advantage of FSLC over radio communication is its no interference with external fields (magnetic and electric) as well as they do not cause EMI themselves. No problem jamming. Another advantage is that it can carry data over a very long distance than radio waves without using repeaters frequently. Below Fig.1 and Fig.2 shows the difference between them.

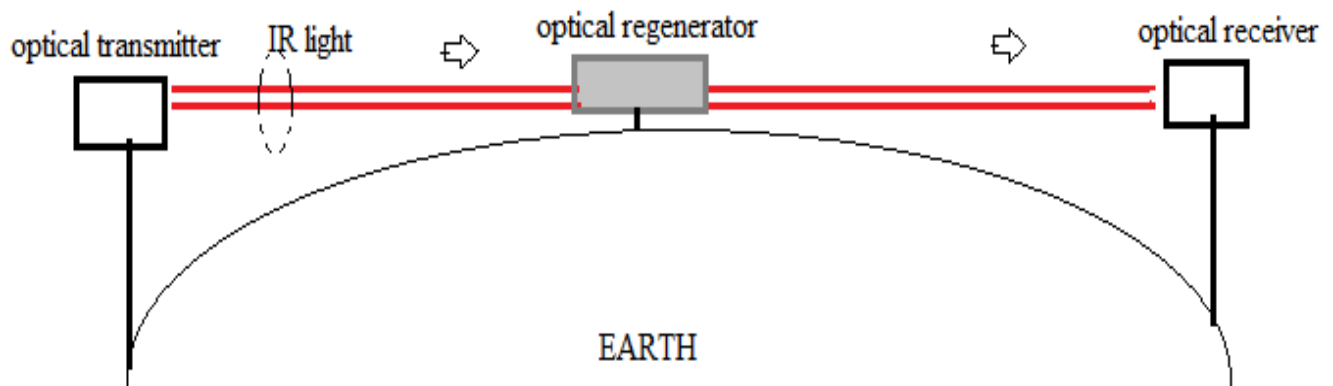


Fig.1: FSLC using IR wave