International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 10, December- 2012

Optic based Wireless Power Transmission for Wireless Sensor Networks

Shreyas Srinath
Dept. of Information Science & Engineering
Dayanada Sagar College of Engineering
Bangalore, INDIA.

Sahana S Bhandari
Dept of Information Science Engineering
Dayananda Sagar College of Engineering
Bangalore, INDIA.

***Abstract*— Led and laser technology not only used as a communications channel but also it can be used as a means to transfer energy without wires. In the present paper a different application of optics are discussed.. Different concepts and applications of wireless power transmission via laser are discussed, including terrestrial and space-based applications. Optics is already one of the most utilized in the field's physics, chemistry, and mathematics, electrical engineering up to architecture, psychology and medicine. This paper intends to describe the application of optics and light in an area where it can be to charge batteries without conducting wires (power cords) and powering/charging of wireless sensor networks.**

***Keywords*—Phototransistors, Wireless sensors, semiconductors, photons.**

I. INTRODUCTION

Light is a form of energy. it is made up of many tiny particle-like packets that have energy and momentum but no mass. These particles, are called photons, are the most basic units of light. Photons are released as a result of moving electrons. in an atom, electrons move in orbital's around the nucleus. Electrons in different orbitals have different amounts of energy. Generally speaking, electrons with greater energy move in orbital's farther away from the nucleus. For an electron to jump from a lower orbital to a higher orbital, some energy has to given. Conversely, an electron releases energy when it drops from a higher orbital to a lower one. This concept is in accordance with principle of water. When water has to transfer from lower potential to higher potential energy has to be spent. but the converse of it i.e., when water flows from higher potential to lower potential it develops some energy (kinetic and potential)which can be harnessed. on similar lines when an electron jumps from higher orbital to a lower one energy is released in the form of a photon.

LED's are relatively simple devices and are basically consists of positive and negative junction with a semiconductor 'chip' doped with various metals (and fluorescent phosphors in the case of many of the LEDs producing 'white' light). An electrical current passing across the semiconductor chip within the reflector 'excites' its coating resulting in nearly monochromatic light. The reflector can be of different shapes and determines the dispersion angle of the emitted light. The most important part of a light emitting diode (LED) is the semi-conductor chip located in the center of the bulb as shown in figure 1. The chip has two regions separated by a junction. The p region is dominated by positive electric charges, and the n region is dominated by negative electric charges. The junction acts as a barrier to the flow of electrons between the p and the n regions. Only when sufficient voltage is applied to the semi-conductor chip, can make the current flow, and the electrons cross the junction into the p region. The electric energy is proportional to the voltage required to cause electrons to flow across the p-n junction. The different colored LED's emit predominantly light of a single color. The energy (E) of the light emitted by an LED is related to the electric charge (q) of an electron and the voltage (V) required to light the LED by the expression: E = qV Joules. This expression simply says that the voltage is proportional to the electric energy, and is a general statement which applies to any circuit, as well as to LED's. The constant q is the electric charge of a single electron , -1.6 x 10^-19 Coulomb.

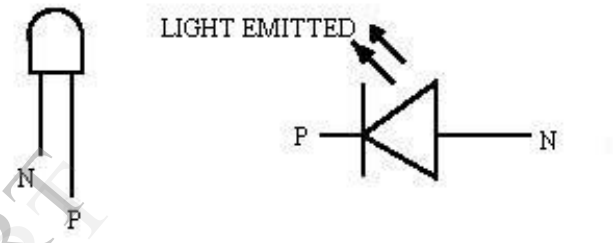

Figure 1: Parts of a typical Light Emitting Diode

Free electrons moving across a diode can fall into empty holes from the P-type layer. This involves a drop from the conduction band to a lower orbital, so the electrons release energy in the form of photons. This happens in any diode, but you can only see the photons when the diode is composed of certain material. The atoms in a standard silicon diode, for example, are arranged in such a way that the electron drops a relatively short distance. As a result, the photon's frequency is so low that it is invisible to the human eye it is in the infrared portion of the light spectrum.

PRINCIPLE OF OPERATION OF PHOTO TRANSISTOR

The actual operation of a phototransistor depends on the biasing arrangement and light frequency. For instance, if a PN junction is forward biased, the increased current through the junctions due to incident light will be relatively insignificant. On the other hand, if the same junction is reverse biased, the increase in current flow will be considerable and is a function of the light intensity. Therefore, reverse bias is the normal mode of operation.

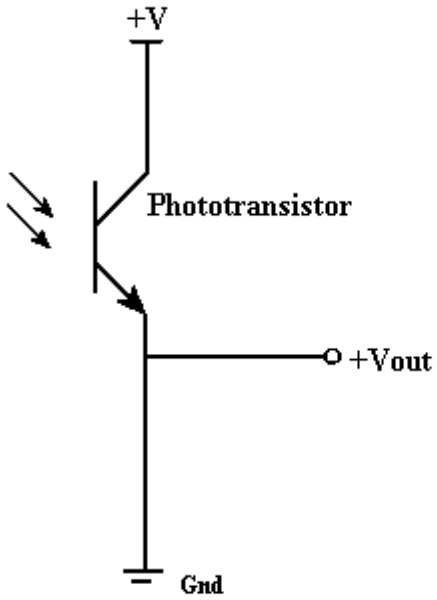

Figure 2: Circuit of photo transistor

Now, if the PN junction is the collector-base diode of a bipolar transistor, the light-induced current effectively replaces the base current. The physical base lead of the transistor can be left as an open terminal, or it can be used to bias up to a steady state level. It is the nature of transistors that a change in base current can cause a significant change (increase) in collector current figure2. Thus, light stimulation causes a change in base current, which in turn causes a bigger increase in collector current. The output of photo transistor is taken out from emitter terminal.

WORKING OF LASER

Lasers are devices that produce intense beams of light which are monochromatic, coherent, and highly collimated. The wavelength (color) of laser light is extremely pure (monochromatic) when compared to other sources of light, and all of the photons (energy) that make up the laser beam have a fixed phase relationship (coherence) with respect to one another. Light from a laser typically has very low divergence. It can travel over great distances or can be focused to a very small spot with a brightness which exceeds that of the sun. Because of these properties, lasers are used widely.

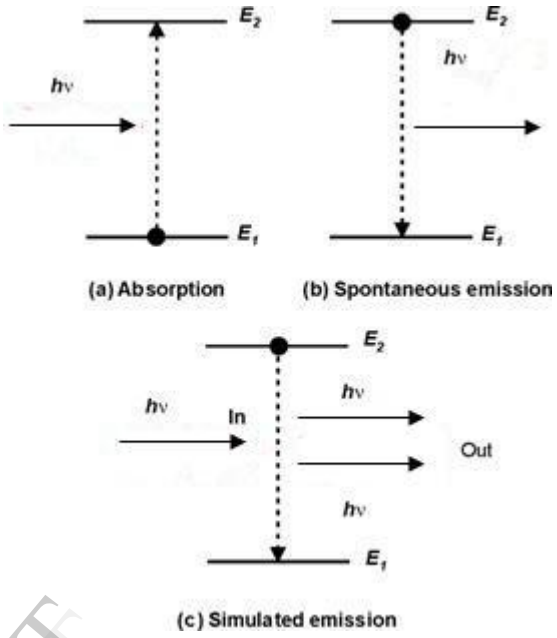

Figure 3: Working of three state energy level laser

Figure 3 (a) shows that the when an light energy (right energy)falls on electron, electron jumps from lower energy(E1} to the higher energy (E2),it does not stay for longer time as it is not stable at higher energy to attain stability it jumps down to lower energy state(E1)as shown in figure 3(b).Laser action is based on stimulated emission where right energy is given to the electron in the higher state and made to fall down to lower energy state through a intermediate state(metastable state)as shown in figure 3(c).A laser usually comprises an optical resonator (laser resonator, laser cavity) in which light can circulate (e.g. between two mirrors), and within this resonator a gain medium (e.g. a laser crystal), which serves to amplify the light. Without the gain medium, the circulating light would become weaker and weaker in each resonator round trip, because it experiences some losses, e.g. upon reflection at mirrors. However, the gain medium can amplify the circulating light, thus compensating the losses if the gain is high enough. The gain medium requires some external supply of energy – it needs to be "pumped", e.g. by injecting light (optical pumping) or an electric current (electrical pumping → semiconductor lasers). The principle of laser amplification is stimulated emission as shown in figure 3.

II. RELATED WORKS

Wireless Power Transmission (WPT) is not a new concept, it is developing from ages. Transferring power through electromagnetic radiation was first theorized by James Maxwell in 1873. Thirty years later Nikola Tesla proved Maxwell's

theory by transporting energy using electromagnetic waves through vacuum. Soon after, in 1918, Heinrich Hertz also validated the findings in principle. [1] It was not until the Klystrom and Magnetron were developed that the next step in WPT took place. William Brown used microwave energy to power a small tethered helicopter. In 1968, Peter Glaser proposed the first solar powered satellite based systems on work done by Tsickovski, Oberth, and Brown. Following in 1979, a study by the Department of Energy (DoE) and NASA about the potential of creating a solar power plant in space and beaming the energy down to earth. The "Solar Power System" report created by NASA and the DoE concluded that while the technology was feasible, the size and cost of such a system was too high to pursue [1].

This system consists of a number of IR lasers on the transmitter side, and a PV cell detector on the receiving end. The laser operates at apprx1400 nm with a collimated beam. This allows the beam to traverse relatively large distances (1 m to 100 m) with minimal loss in power or efficiency. While most of Laser Motives work was concentrated on winning the space elevator competition over the past few years, they recognize the importance of what they developed. Laser Motive released a white paper in March of 2010 about how WPT laser systems could be used to power or recharge small UAV's [2] as shown in figure4.

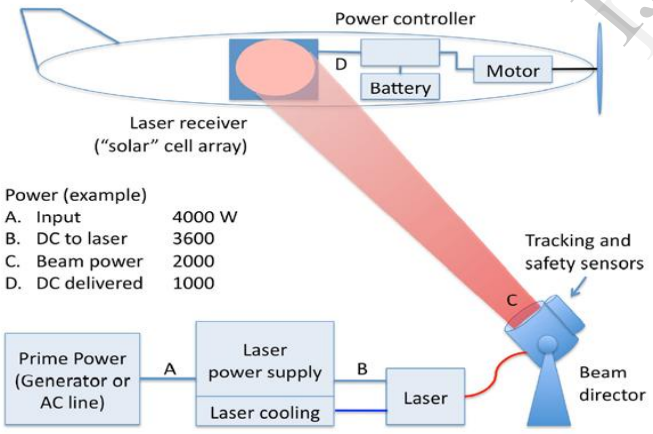

Figure 4: Schematic diagram of power beaming to UAV

Powering of Unmanned Systems

In Kawashima and Takeda's work, students developed a laser based WPT [wireless power transmission] system to power small vehicles .Three systems were designed and tested at an indoor atmosphere. The first was laser powering a rover.

A 60 W laser diode was driven through a 400 μm fiber, transmitting to a 70 cm diameter solar panel receiver. The transmission was done at a distance of 1 km and produced a 20% overall efficiency.The second setup used a small kite plane. This system used a 200 W, 808 nm laser diodes driven through a 400 μm fiber to a 30 cm diameter receiving GaAs solar panel. GaAs provides 40% conversion efficiency per cell, to result in an overall panel efficiency of 25%. The average power measured on board was about 40 W [10].

In 2002 and 2003, Steinsiek and Schoafer demon started round to ground wireless power transmission via laser to a small, otherwise fully independent rover vehicle equipped with photovoltaic cells as a first step towards the use of this technology for powering airships and further in the future lunar surface rovers. The experiment was based on a green, frequency-doubled Nd: YAG [8] laser at only a few Watts. It included the initiation and supply of the rover including a micro-camera as payload as well as the pointing and tracking of the moving rover over a distance up to 280 m by applying active control loops.

.

III. PROPOSED METHOD FOR POWERING SMALL VICINITY DEVICES USING LED'S

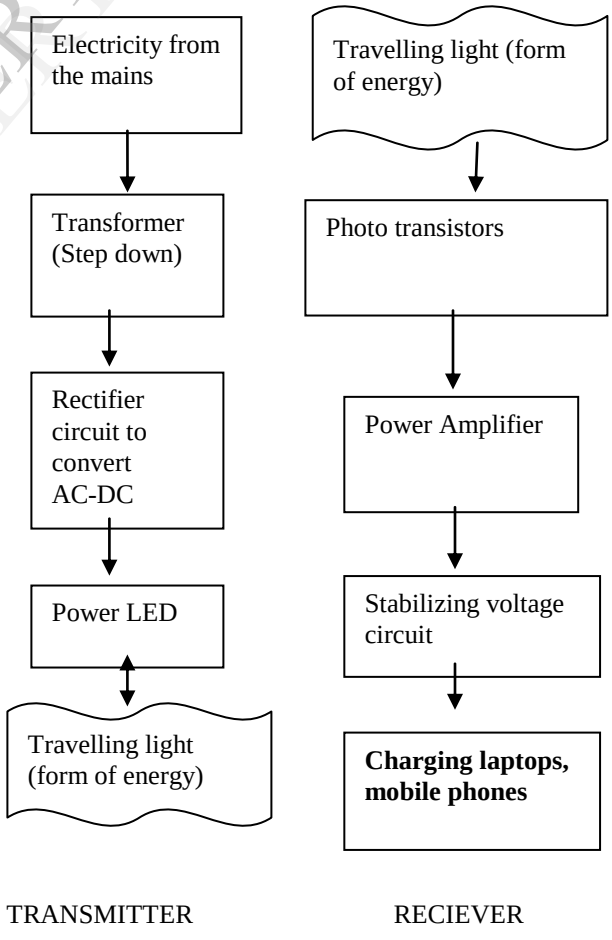

Figure 5: Wireless power transmission using LED for Wireless sensor networks.

Electricity from the mains (220v AC in INDIA) is stepped down to with the help of transformer circuit. Rectifier circuit is used to convert ac voltage to dc voltage. This voltage is applied to power LED'S. Led will emit light which is intern energy and is transmitted to a small distance of around 2 feet(60cm).This above unit is called transmitter end as it transmits energy. This energy in the form of light can be converted back to power using photo transistor at the receiving end which is kept at a distance of around 2 feet as shown in figure5 (RECEIVER). The led's beam should be kept linearly to the photo transistor for maximum output. Power amplifier is used to enhance the power generated by photo transistor and a voltage stabilizer and controller circuit is used to control the voltage at the receiving end. The controlled power is fed to wireless sensor network, laptop or mobile phone depending on the power amplifier used and power generated. In this way without connecting the conductors i.e., wires power is transmitted to devices using led's.PROPOSED METHOD FOR POWERING WIRELESS SENSOR NETWORKS USING LASER

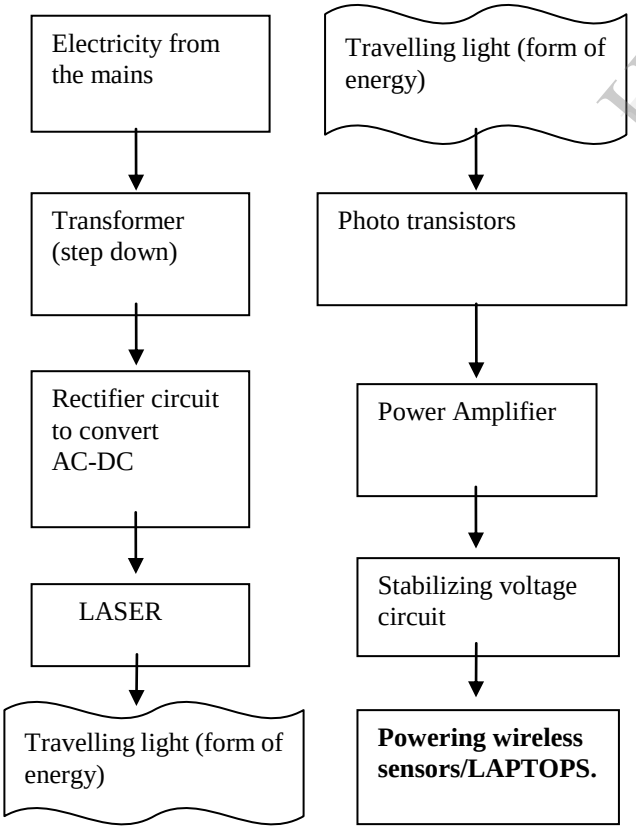

Figure 6: Wireless power transmission using LASER to wireless sensor networks.

The changes made in figure6 are that instead of LED, LASER is used. Because Laser light is coherent and it can travel very long distances without scattering. Hence for larger distance power transmission laser can be used. Using laser power can be transmitter >2km efficiently without much loss in power, also the power transmitted by the laser is greater than ordinary led's. Hence efficiently power from the socket can be transferred to charge the batteries of mobile or laptops with the help of laser.

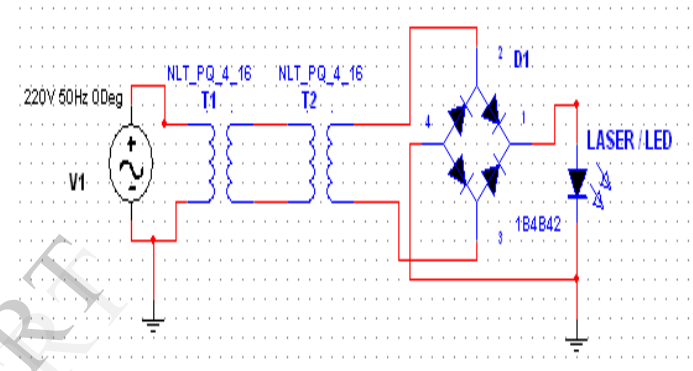

Figure 7: Transmitter circuit diagram

A 220v 50 Hz from the power from the socket is stepped down using two TRANSFORMERS (T1 and T2) shown in figure 7 with the bridge wave type rectifier the ac voltage from the output of transformer 2 is fed as a input to rectifier and the output of rectifier is given to the laser or led, which converts electric energy into light energy and transmits in air as visible light, the above circuit is simulated using multisim software.

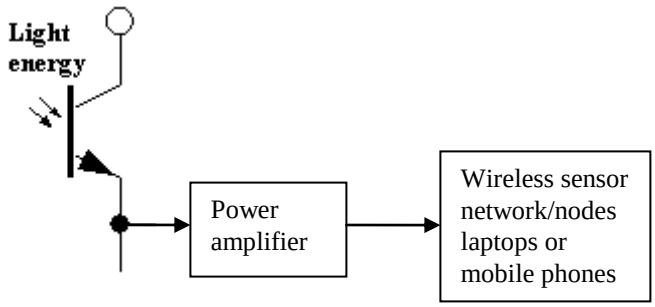

Figure 8: Receiver circuit diagram

Phototransistor convert the light energy (given by the transmitter in figure 7) into corresponding voltage as shown in figure 8, this voltage and current is amplified using power amplifier circuit, depending on the application used accordingly the amplifier circuit used i.e., for mobile phones the amplifier should produce 5V and 350mA and for laptops the output of amplifier should be 18.5V and 3.5A.

An experiment conducted at room temperature for red colour LED (5mm, wavelength 640 nm~ 645 nm) .Red led is illuminated,the voltage across the led is 2.98v.and the voltage response of phototransistor with respect to different distances of receiver is tabulated in table 1 ,the same experiment is conducted with laser as the transmitter and voltage response is tabulated in the table1.

TABLE 1: Response of phototransistor with distance

DISTANCE	OUTPUT OF LED(red)	OUTPUT OF LASER(red)
1cm	82.6mV	0.874V
5cm	64.3mV	0.866V
10cm	20mV	0.806V
20cm	6.6mV	0.781V
30cm(1Ft)	5.0mV	0.76V
60cm(2ft)	1.8mV	0.721V
150cm(5ft)	-	0.714V
300cm(10ft)	-	0.699V
600cm(20ft)	-	0.629

The above experiment is conducted (both the proposed method's) in darkness where there is no response for the other light sources other than the transmitter, and with small variation in the linearity between transmitter and receiver. The output of phototransistor is fed to the appropriate power amplifier for the amplification needed for the desired application.
There is no response of the phototransistor at a distance of 5ft and >5ft when led is made as transmitter, hence a high output laser can be used as the transmitter since voltage with respect variation is small as there is no divergence of laser light.

IV. MERITS, DEMERITS OF WIRELESS POWER TRANSMISSION

Wireless power transmission is consider as one of the most effective power transmission technique and has following merits of using it.
An electrical distribution system, based on this method would eliminate the need for an inefficient, costly, and capital intensive grid of copper wires, cables, towers, and substations. The system would reduce the cost of electrical energy used by the consumer and rid the landscape of wires, cables, and transmission towers.
There are areas of the world where the need for electrical power exists, yet there is no method for delivering electricity. Africa is in need of power to run pumps to tap into the vast resources of water under the Sahara Desert. Rural areas, remote areas ,such as those in China, require the electrical power necessary to bring them into the 20th century and to equal standing with western nations. The wireless transmission will solve many of these problems. Electrical energy can be economically transmitted without wires to any terrestrial distance, so there will be no transmission and distribution loss [8].
More efficient energy distribution systems and sources are needed by both developed and under developed nations. In regards to the new systems, the market for wireless power transmission is enormous. It has the potential to become a multi-billion dollar per year market [9].
Every discovery or invention is accompanied by advantages and also the disadvantages. Same story continue over here that means wireless power transmission method is accompanied with some disadvantages. The major demerit of this method is a biological impact on wireless power transmission. One common criticism of the Tesla wireless power system is regarding its possible biological effects. While calculating the circulating reactive power, it was found that the frequency is very small and such a frequency is very biologically compatible
Also when it comes to laser based wireless power transmission the transmitter and receiver should be liner for maximum power output .it should be accurately liner since laser is a coherent source, small variation leads to variation in the output power [10].

CONCLUSION

The transmission of power without wires is not a theory or a mere possibility, it is now a reality. The ability to power an electronic device without the use of wires provides a convenient solution for the users of portable devices and also gives designers the ability to develop more creative answers to problems. The advantages of LEDs are many – low power consumption. Relatively large-distance laser power

transmissions are also considered to avoid the complexity and mass of cables for planetary or lunar installations in combination with a surface power plant. When we are transmitting power using led based transmitter instead of using photo transistors solar cell can also be used as the working is same up to certain extent. By this method charging of devices can be done efficiently for more than 2km.

V. ACKNOWLEDGMENT

This Technical paper could not have been written without my parents **SRINATH S** (who shared his own experience) and **GAYATHRI DC**, who encouraged and challenged me through my academic program. A special thanks to the **SATEESH H BHANDARI** and **SAVITA G ADPEKAR** who helped me to bring out this technical paper and authors mentioned in the reference. Without you, this Technical paper would have taken years off my life .I would like to acknowledge and Most especially to my family, friends, cannot express what I owe them for their encouragement and whose patient love enabled me to complete task. And especially to God, who made all things possible.

REFERENCES

[1] Summerer, Leopold; Purcell, Oisin;, "Concepts for Wireless Energy tyransmission," Europeans Space Agency (ESA) - Advanced Concepts Team, 2009

[2] Nobuki Kawashima and Kazuya Takeda (2008). "Laser Energy Transmission for a Wireless Energy Supply to Robots," Robotics and Automation in Construction, Carlos Balaguer and Mohamed Abderrahim (Ed.), ISBN: 978-953-7619-13-8, InTech.

[3] Nikola Tesla, ―The Transmission of Electrical Energy Without Wires as a Means for Furthering Peace,‖ Electrical World and Engineer. Jan. 7, p. 21, 1905

[4] WiTricity Corp. — Applications of WiTricity Technology‖ , www.witricity.com/pages/application.htm

[5] Goodbye wires" MIT News, 2007-06-07, http://web.mit.edu/newsoffice/2007/wireless-0607.html.

[6] Thomas F. Valone, ―Tesla's Wireless Energy... For the 21st Century!!! One Step Beyond Direct TV!!!‖ Extra Ordinary Technology, 1, no. 4, Oct / Nov / Dec 2003.

[7] B. A. Warneke, M. D. Scott, B. S. Zhou, and K. S. J. Pister, "An Autonomous 16 Mm3 Solar-Powered Node for Distributed Wireless Sensor Networks,"

[8] "High Altitude Long Endurance UAV – Zephyr." QinetiQ. Web. 10 Oct. 2010.

[9] "Technology – How Power Beam Works." PowerBeam Wireless Electricity Inc. Web. 15 Sept. 2010.

[10] B. A. Warneke, M. D. Scott, B. S. Zhou, and K. S. J. Pister, "An Autonomous 16 Mm3 Solar-Powered Node for Distributed Wireless Sensor Networks,"