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Application of LED as an Ecological Safe Source for Optical Sensors

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Abstract

Visualization of optical communication had started many years ago but with its continuous development for better performance, it had become more effectual to the communication industry and also to the environment. This paper mainly focuses on eco-friendly behavior of light emitting diode as an optical source. Due to the ecological characteristics, these different color LEDs find applications in both urban and rural sectors, in the field of agriculture for testing the soil pH values and other controlling operations.

Keywords: *Electroluminescence, Edge Emitting LED (ELED), Optical Source, Surface Emitting LED (SLED)*

1. Introduction

Optical communication has revolutionized the whole world and has become a vast area for research. The researchers have found its application in various field as it supports long-distance transmission with high bit rates. Optical fibre acts as the medium in this communication, helps in reliable signal propagation with less attenuation. This technology has evolved as the cheapest way for transmitting signal in the form of light, as the principle material used in its fabrication is sand (SiO_2) which is found in abundance. Senior (2010) stated that the information transmitting technique in optical communication is based on the simple phenomenon of Total Internal Reflection (TIR).

The whole communication system in fiber optics is divided into three sections i.e. transmitter, channel and receiver. Figure 1 shows the detailed block diagram of optical fiber communication which demonstrates how the message from the information source given to an electrical transmitter reaches the destination through an optical channel. This non electrical form of the message is first converted to an electrical form with the help of transducer. This electrical signal is provided to the optical source that converts electrical energy into optical energy in the form of current. It basically turns on the optical source. The main optical sources currently used are lasers and light emitting diodes (LEDs). The optical current from the optical source is transmitted to the optical detector using fiber optic cable as the medium, Senior (2010). It is a path between the transmitter and receiver section which carries information in form of light.

The receiver section consists of three elements. The first element is the optical detector which is directly connected to the fiber optic cable so that the output in optical form can be fed to these detectors. The principle of optical detectors, such as photodiode, phototransistor and avalanche photodiode, is to separate the information superimposed with the light so that original data can be recovered and is converted into electrical signal, Keiser (2008). After the conversion into electrical form, the output from optical detectors is then given to the second element of this section i.e. electrical receiver. From the electrical receiver, the electrical signal is converted into the desired non-electrical form before reaching the destination. This paper focuses mainly on only one type of optical source, i.e. LED, from all the elements of an optical communication system.

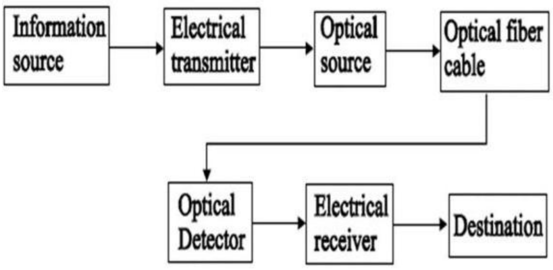

Fig. 1: Block Diagram of Optical Fiber Communication

2. Materials and Methods

2.1 LED as Optical Source

The optical source is the heart of the optical system. The main optical sources are the low price light emitting diodes, which are more practically utilized than other optical sources. They are also used for shorter distances due to low bandwidth and low power consumption. Light emitting diode (LED) is a special type of pn junction diode which is made of a semiconductor material other than silicon and germanium semiconductors. This diode emits the visible range light or infrared region of the spectrum when forward biased. LED is made up of three semiconductor layers deposited on the substrate. The light is emitted from the active layer in between p and n layer, in all directions. This emission can be focused to a desired direction by placing the basic three-layered structure inside a small reflective cup. The principle of LED operation is based on the process electroluminescence. In this process, when LED is forward biased, the electrons residing in higher energy conduction band cross the junction and recombines with the holes in the valence band at the lower energy level. While recombining process, the electrons give away their excess energy in the form of light.

Edge Emitting LED (ELED) and Surface Emitting LED (SLED) are the two common LED types used in optical communication systems as shown in Figure 2 and Figure 3 respectively. Both of these structures are having Double Hetero-junction layers. The Edge Emitting LED type is having a narrow primary active region, Keiser (2008). The rear face of this semiconductor structure is polished which makes it highly reflective but the front face is coated with anti-reflective so that no light is emitted from this face. Edge emitters have high output power as the emitting spot area is typically between 30 µm to 50 µm, which is very small. These also have narrow emission spectra of about 7% of the central wavelength.

The second type of LED structure is the surface emitters, which have a comparatively simple structure and emit light in all directions. These are good indicators as the emitting area is large and offers low to moderate power output levels. In a surface light emitting diode, the primary active region is a small circular area located below the surface of the semiconductor substrate. In this direct coupling of emitted light with the fiber is allowed due to a well type structure etched in its substrate and the emission area of the substrate is perpendicular to the axis of the optical fiber. Comparing both the ELED and SLED structures, the edge emitting LED has better coupling efficiency as the light is emitted at a narrower angle.

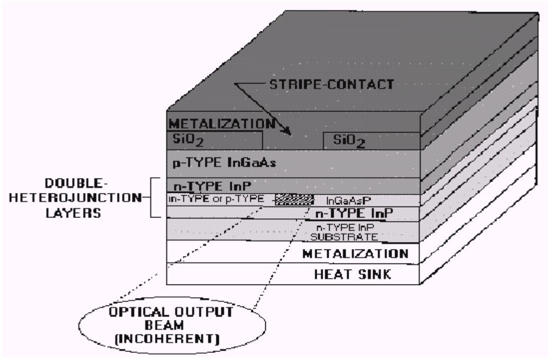

Fig. 2. Structure of an ELED

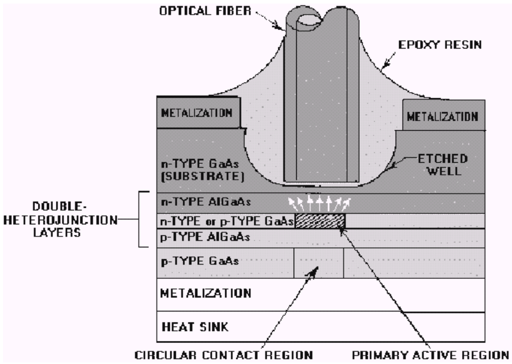

Fig. 3. Structure of a SLED

2.2 Eco-friendliness of LED

Available in different colors, LED bulbs are more durable and offer good quality for distribution of light in one direction. LEDs are environment friendly and also are energy efficient devices. Around 90 to 95 percent of LED energy is converted to optical light and very less amount of energy is liberated in the form of heat. Schubert (2006) stated that the LEDs protect the surrounding and prove to be advantageous as no toxic elements are contained in them, when compared with the fluorescent street lamps. The greatest environmental impact after energy-in-use for the LED sources comes from manufacturing the aluminum heat sink, which would be reduced in size as the ability to get the desired result increases and more of the input wattage is converted to useful light instead of wasted heat. The heat sink is the main reason the LED currently exceeds the others in the category of precarious waste to landfill. Recycling efforts could further reduce this adverse impact.

Table 1. Various Parameters of LED Types

Emitted Color in LED	Intensity of Light	Manufacturing Material (Semiconductor)	Peak Wavelength in nm	Dissipated Power in mW	Luminous Intensity in mcd
Red	Low	Gallium arsenide phosphide	626	105	150
Yellow	Low	Gallium arsenide phosphide	591	105	50
Green	Low	Gallium(III) phosphide	526	105	50
Blue	Low	Gallium(III) nitride	431	140	400
Red	High	Aluminium gallium indium phosphide	645	125	6000
Yellow	High	Aluminium gallium indium phosphide	592	125	9750
Green	High	Gallium(III) nitride	566	120	5000
Blue	High	Gallium(III) nitride	476	120	900
White	-	Indium gallium nitride	-	100	10000

3. Results and Discussion

LEDs are not fabricated from silicon and germanium as these semiconductors are heat producing materials and also are very poor in producing light. Light emitting diodes are made from a combination of different semiconductor materials like Gallium (Ga), Arsenic (As), Phosphide (P) etc. The commonly available LEDs emit green, red, yellow, blue colors. Emitted colors depend on the light wavelength and the forbidden energy gap of semiconductor materials used. So, to get the desired emitted color, various impurities are added in the semiconductor material during the doping process, Schubert (2006).

Table 1 shows the parameters of various LED types based on the color of the emitted light with its associated intensity. Along with the emitted colors and its intensity, peak emission wavelength in nanometer, dissipation power in milli-Watt and luminous intensity in milli-candela are also provided in this Table. The power dissipated ranged from 100mW to 140mW which has no negative impact on human health and the environment. The LEDs having luminous intensity ranging from 50mcd to 400mcd are used as indicators in various electronic instruments, Schubert (2006). The range for high luminous intensity in different color LEDs varies from 900 mcd to 9750 mcd, hence are useful in decorating purposes in festive occasions. As the power dissipation of white LED is minimum i.e. 100mW as compared with other colored LEDs, these highly luminous LEDs are suitable for application such as backlighting of LCDs and other vehicles.

Eco-friendly LEDs, connected together with the embedded unit, are applicable for various parts of rural and urban sectors, Kar and Shukla (2017). As these optical sources are not harmful to the environment and with their low power consumption feature, these are also used for sensing the soil parameters such as humidity, pH value, etc. in the agricultural sector, Kar et al. (2019). Hence, these optical pH sensor using LEDs, when connected to an automated scientific unit, powered by harnessing renewable energy i.e. solar energy will become an economical and portable unit in future, Kar and Dwivedi (2017).

4. Conclusions

In the optical communication, the research on LED as optical sources has headway the early efforts due to its various advantages. These LEDs are more economically environment-friendly when compared with the other lighting technologies used in many houses of this developing nation. Stojanovic and Karadaglic (2007) studied that the ELED and SLED types of optical source are used in the manufacture of an optical sensor and hence can be used as both emitter and detector. Thus, LED's ecological nature finds its application in both the rural and urban sectors.

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