# Dependence of emission spectrum of RGB LEDs on ambient temperatures and driving current

**Research Project**

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا ۖ إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ

(سورة اِلبقرة- الآيه 32)

# CHAPTER ONE
## Introduction

### 1.1 Introduction:

In the simplest terms, a light-emitting diode (LED) is a semiconductor device that emits light when an electric current is passed through it. Light is produced when the particles that carry the current (known as electrons and holes) combine together within the semiconductor material.

Inside the semiconductor material of the LED, the electrons and holes are contained within energy bands. The separation of the bands (i.e. the bandgap) $E_g$ determines the energy of the photons (light particles) that are emitted by the LED.

LEDs are comprised of compound semiconductor materials, which are made up of elements from group III and group V of the periodic table (these are known as III-V materials). Examples of III-V materials commonly used to make LEDs are gallium arsenide (GaAs) and gallium phosphide (GaP). Until the mid-90s LEDs had a limited range of colors, and in particular commercial blue and white LEDs did not exist. The development of LEDs based on the gallium nitride (GaN) material system completed the palette of colors and opened up many new applications.

The photon energy determines the wavelength $\lambda$ of the emitted light, and hence its color. Different semiconductor materials with different bandgaps produce different colors of light. The precise wavelength (color) can be tuned by altering the composition of the light-emitting, or active, region.

LED Characteristics such as I-V, junction resistance, and emission spectrum change when it is operated at a high current density that leads to self-heating or/and when operating in an environment with variable temperatures that requires adjustment of the operating point. The high temperature greatly weakens the luminescent material and causes the luminescent coating to deteriorate as its transparency is reduced. Avoiding the high temperatures of the LED extends the lifespan and ensures the quality of the light. Therefore, the p-n junction temperatures must be measured and controlled by the LED driver. In many LED, about 15% of the energy is converted into visible light [1]. The related issue is not only about energy efficiency, higher temperatures can shorten the life of the LED and also affect operational features such as emitting color.

LEDs are supplied using LED drivers which often ensure constant current flow; Therefore, it is obvious that thermal management is incorporated into the LED driver. LED drivers that support thermal management, use an external temperature-sensitive resistor to roughly sense LED temperatures [3], it is necessary to develop a more accurate method for temperature estimation that can be integrated within the LED package.

The forward current in the diode is based on the exp term $(qV/nkT)$. Device constant (n) varies between 1 to 3 and is a function of carrier generation and recombination process in the space charging area of the intersection [4].

The diode equation has two terms temperature depend. One is explicit which express in the term exponent $(qV/nkT)$ and the other is implicit which is related to the reverse saturation current $I_0$ of the diode is directly proportional to the temperature

$(T^{\frac{5}{2}})$ and is exponentially related to (-$qEg/nkT$) [4]

Considering the dominance of the exponential term, $I_0$ can be approximated as,

$$I_0 = Ke^{(-\frac{qE_g}{nkT})} \qquad (1)$$

where K is a constant that is almost independent of temperature. Since the bandgap $E_g$ also varies with temperature [5], it cannot be considered a constant.

Substituting the value of Boltzmann's constant k and the charge q we obtain

$$I_0 = Ke^{(-\frac{1000}{T}\times 11.59\times\frac{E_g}{n})} \qquad (2)$$

By measuring the current-voltage characteristics of the diode at different temperatures, n and I0 can be estimated at different temperatures. The reverse saturation current is related to temperature as given in Eq. (1). A temperature-dependent relationship of the device constant (n) is shown based on experimental observations.

In this work, we present improved spectral models for RGB LEDs based on a simple but still powerful LED temperature measurement principle that enables LED temperature control by calculating the constant (n). The spectral emission of RGB LEDs is calculated at different ambient temperatures using a modified visible spectrometer and temperature in the range 283-353K.

# CHAPTER TWO
## Theory

### 2.1 Theory of Temperature effects on LED

(LEDs) are becoming common in lighting applications, both commercial and residential. Many of these applications, such as automotive lighting or street lighting, are outdoors and subject to great temperature variations. In such applications, it is advantageous for LEDs to have stable performance characterized by the weak temperature dependence of light output as well as forward voltage.

Light-emitting diodes based on the (Al, In, Ga)N material system show a strong dependency of the emission wavelength λ on the carrier concentration n in the quantum well (QW) active region and hence on the injected current I [A]. This behavior is undesired since this means a dependency of spectral characteristics on the light output power, which is unacceptable for many applications such as lighting, sensing, and Currently, LEDs suffer from decreasing light-output power as the temperature increases. This is due to both increased Shockley-Read-Hall recombination, as well as increased electron leakage out of the active region. Such characteristics are undesired but can be mitigated by reducing the concentration of non-radiative recombination centers in the active region of the LED, or by an LED structure that is designed to limit electron overflow out of the active region. Furthermore, in many applications, LEDs are operated at high current densities, leading to self-heating. If an LED heats up, the peak wavelength shifts to a longer wavelength, and its forward-voltage-vs.-current characteristic changes, thereby requiring adjustment of the LED’s electrical operating point.

# CHAPTER THREE
## Materials and Methods

### 3.1 Methodology:

In this work, an integrated system has been built for emission measurement system using ***Shimazu UV 100-01*** spectrometer, the temperature-controlled by ***STC1000*** system, regulated DC power supplies are used as sources for LEDs and heater chamber. see (Fig1):

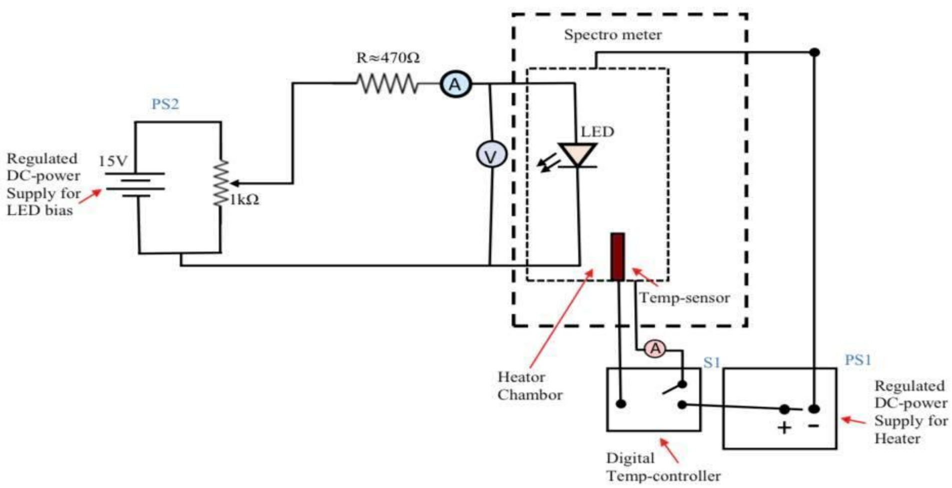



Fig.1: Diagram of apparatus to measure the emission spectrum of an LED at ambient temperature.

The spectrometer is a device for measuring wavelengths and transmission of LED, and both power supplies (PS1 and PS2) are used to convert electrical power to the diode (Light Emitting Diode) and heater chamber, this resistance ($R \approx 470\Omega$) is used to protect LED, Also, using a voltmeter and ammeter to read the current and voltage on the diode and digital temperature controller. And mini heater chamber to put LED in and then heated, digital temperature controller used to control the temperature in the chamber.

### 3.2 Working:

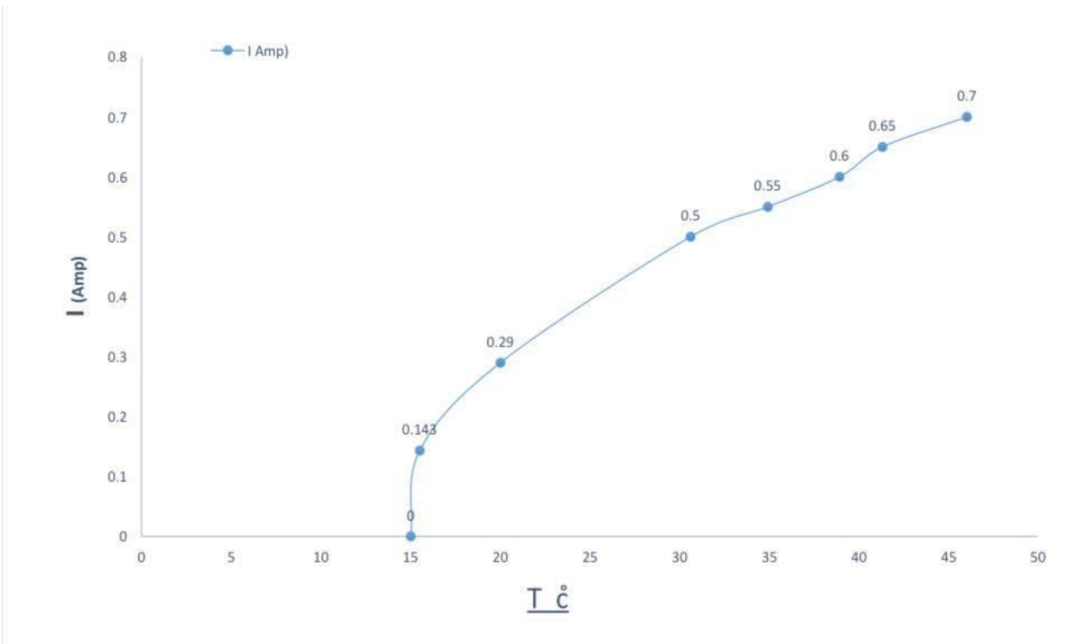
In this experiment, that device (Digital Temp- controller), which we use is continuing. It means it keeps warming, only if we choose the temperature in the settings of the device, for example: ($T=30\ ^oC$), that the heating heater that reaches ($30\ ^oC$) only the device (Digital Temp- controller) that stops will not prevent the heat of the heater more. To save us from these problems. Before we start taking data, we will do the work of ( Double controller ). And that by receiving data between the temperature and current. We were changing the current and reading the temperature. See Table(1):

Table (1): Double controller process Data, between current (Amper ) and temperature ( Celsius ).

| **I (Amp)** | **T ( $^oC$ )** |
|---|---|
| **0** | **15** |
| **0.143** | **15.5** |
| **0.290** | **20** |
| **0.5** | **30.6** |

| | |
|---|---|
| **0.55** | **34.9** |
| **0.6** | **38.9** |
| **0.65** | **41.3** |
| **0.70** | **46** |

Then because of the Matlab program, they created a graph between ( I (Amp) Vs T ( $^{o}$C ) ), see Fig(2). In order to fitting data and know the equation, when the equation went out to put a gives us a current in output, so when receiving data for any level of temperature because of the equation, we can give the necessary current to the heater.




Fig(2): Graph between current (Amp ) and temperature (Celsius).

At the beginning of the measurement of the peak wavelength for the three color LEDs (Red – Green – Blue), because of the peak wavelength, we can know what semi-conductor material the LEDs were made of, Because of using a spectrometer, measuring the intensity of LEDs. For this reason, we change the wavelength and read the intensity on the spectrometer. At the beginning of the room temperature and then we heat the heater because of the current, temperature between 289K-333K, to know how many shifts peak wavelength at any level of heat. This work will be done for all three colors of the LED (Green-Blue-Red). After the completion of the data between (λ and i), then we get data that we pass a very small amount of current through the diode in the temperature (289K-333K), we will read the voltage, for the third part, we will get data between voltage and current to all three of LEDs colors in the temperature between (289K-333K).