International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 5, Issue 09 (Oct 2016) PP: 11-17

Influence of Electrical Current Variation on Spectral Mismatch Factor and Uncertainty Estimation For Incandescent Lamps

Dr. Manal A. Haridy[1,2]
1 Physics Department, College of Science, University of Hail (UOH), Hail, Kingdom of Saudi Arabia (KSA).
2 Photometry and Radiometry Division, National Institute of Standards (NIS), Giza, Egypt

Abstract:- The human eye exhibits a characteristic variation in spectral response over the 380-780nm band, referred to as the photopic response. Photometry is the science of measuring light scaled to how the human eye would see it. In order to calculate photometric quantity precisely, the relative spectral responsivity of the photometer head and the relative spectral power distribution (RSPD) of the light source should be known. An error occurs when a photometer head measures a light source having the RSPD different from the calibrated source. In the present research, calculations made to determine the spectral mismatch correction factor and uncertainties for two groups of incandescent lamps at different electrical current values. A set up based on NIS Spectroradiometer Ocean optics HR 2000with uncertainty and photometric bench to measure the spectral power distribution of two groups of incandescent lamps at different electrical operating current. Also, NIS-standard lamps calibrated at National Physical Laboratory in England (NPL) have been used in measurements. It was found that there is change in the spectral mismatch factor due to the changing in the spectral power distribution of the lamps which is influenced by changing in the electrical current values of these lamps. Uncertainty estimated to these two groups of incandescent lamps at different electrical current values.

Keywords: *Spectral mismatch correction factor, Spectral Power Distribution, Uncertainty, Spectroradiometer, Incandescent Lamp, Electrical Current*.

I. INTRODUCTION

The eye's photopic response is the reason why we see one unit of green light as being much brighter than one unit of blue or red light. The eye is most sensitive to yellow-green light (specifically 555nm),a color which corresponds to the peak wavelength of sunlight that reaches the earth's surface. The daylight-adapted relative spectral response of the eye is called the spectral luminous efficiency function for photopic vision, V(λ) (V-lambda), as shown in Figure. 1. In photometry, we use light meters ("photometers") which have a spectral responsivity that should ideally match the standard photopic observer. Photometers generally use silicon or selenium photodetectors to convert the optical radiation into an electrical current; the magnitude of the electrical signal is proportional to the amount of light received onto the photodetector. However, the spectral responsivity of these photodetectors does not match that of the human eye [1].

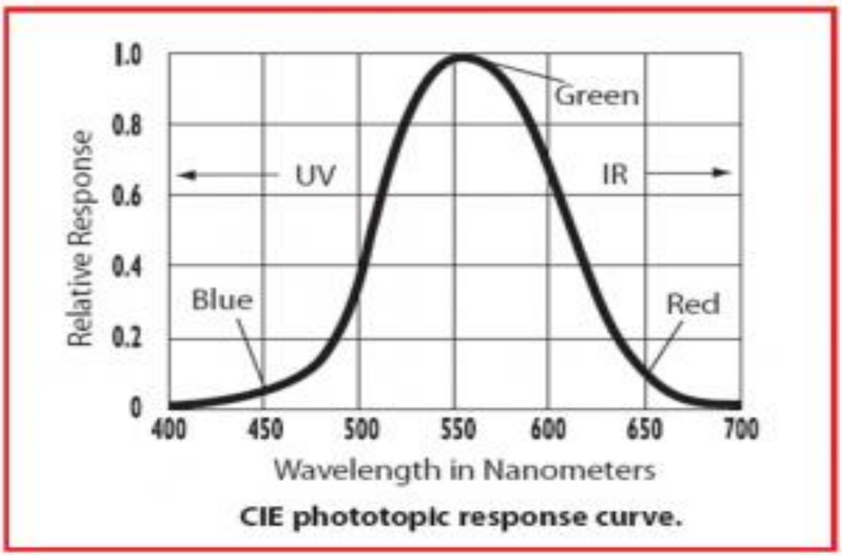

Figure. 1: CIE Photopic Response - Standard Observer Function for Photopic Vision

Spectral integration provides the link between radiometry and photometry and is an essential tool in optical radiation measurement. Often this integration involves an experimentally determined source spectrum and a defined spectral weighting function, for example the photopic spectral luminous efficiency function, $V(\lambda)$ [2].

Traditionally the 'integration' has been performed optically using a detector (such as a photometer) with a spectral responsivity approximating the spectral weighting curve. It is now common to perform the integration by measuring the source output spectrally, especially with the availability of rapid spectral measurements using hand-held array spectrometers, and calculating the integral numerically [3, 4]. Although determining the spectral mismatch does involve some knowledge of the relative spectral distribution of the test source, this generally does not have to be known with as much accuracy as would be needed if the lamp illuminance were calculated from the spectrum. If the test source and the reference source are very similar, and spectrally broad, then this correction factor is very close to unity, even when the photometer has a poor match to the defined spectrum. When there is some difference between the sources, it is often sufficient to use a 'typical lamp irradiance' for the specific type of test source, rather than measuring the irradiance of the actual lamp. Thus relatively poor spectral data can be combined with accurate, sensitive, and fast broadband measurements to obtain an accurate result[3]. Spectroradiometer may be used to measure the spectral power distribution (RSPD) of the lamps [5].

In order to measure photometric quantities with a photometer head, its illuminance responsivity should be precisely calibrated. The matching of the spectral response of photometer heads to $V(\lambda)$ function is the most important criterion, and photometer heads are characterized for spectral mismatch to the $V(\lambda)$ function by calculation error factor of f_1' [6,7]. In order to calculate photometric quantity precisely, the relative spectral responsivity of the photometer head and the relative spectral power distribution (RSPD) of the light source should be known. Standard photometer heads are generally calibrated against CIE Illuminant A (2856 K Plankian radiation). An error occurs when a photometer head measures a light source having the RSPD different from the calibrated source. If the photometer's relative spectral responsivity and the RSPDs of the test and standard light sources are known, the spectral error can be corrected by the spectral mismatch correction factor as given by[8].

$$SCF = \frac{\int_{360}^{830\ nm} P_e^T(\lambda)\times V(\lambda)\,d\lambda \int_{all-wavelengths} P_e^S(\lambda)\times R(\lambda)\,d\lambda}{\int_{all-wavelengths} P_e^T(\lambda)\times R(\lambda)\,d\lambda \int_{360}^{830\ nm} P_e^S(\lambda)\times V(\lambda)\,d\lambda} \qquad (1)$$

where

$P_e^T(\lambda)$: is the relative spectral output of the test source.

$P_e^S(\lambda)$: is the relative spectral output of the standard source.

$R(\lambda)$: is the relative spectral responsivity of the photometer.

$V(\lambda)$: is the spectral luminous efficiency function, which defines a photometric measurement.

Uncertainty of the spectral mismatch correction factor u(SCF) which can be determined regarding to Equation (1) and according to reference [9, 10] by the following equation:

$$u^2(SCF) = \delta^2 P_{iS}\left(\frac{\partial SCF}{\partial P_{iS}}\right)^2 + \delta^2 P_{it}\left(\frac{\partial SCF}{\partial P_{it}}\right)^2 + \delta^2 R_i\left(\frac{\partial SCF}{\partial R_i}\right)^2 \qquad (2)$$

Where

P_{iS} **:** the summation of $P_e^S(\lambda)$ within the visible wavelengths range.

P_{it} **:** the summation of $P_e^T(\lambda)$ within the visible wavelengths range.

R_i **:**the summation of $R(\lambda)$ within the visible wavelengths range.

In present research, calculations made to determine the spectral mismatch correction factor and uncertainties for the lamps at these different electrical current values. It was found that there is change in the spectral mismatch factor and the uncertainty depending on the changing in the spectral power distribution of the lamps which is influenced by changing in the correlated color temperatures of these lamps [11].

II. METHODS

2.1Measurementset up of the spectral power distribution of the lamps.

The Set up of measuring the spectral power distribution lamps [7] is in Figure. 2. It measured directly using the photometric bench and the Spectroradiometer ocean optics HR 2000at NIS with uncertainty 4.7% [4].

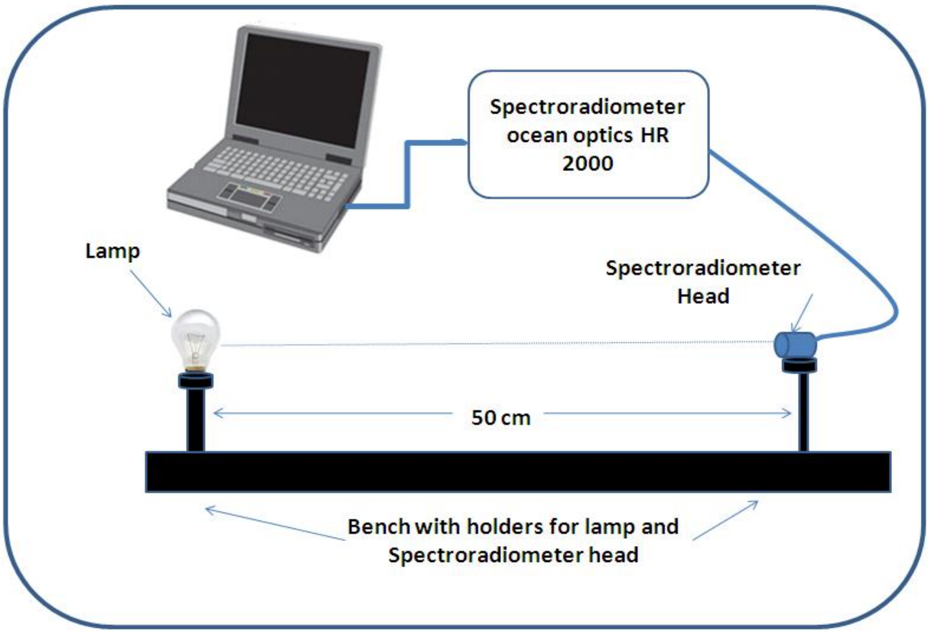

Figure.2. Set up of measuring the spectral power distribution of the lamps.

2.2 Measurement Set-up of the Integrating Sphere Photometer Spectral Responsivity

The sphere-photometer spectral responsivity was determined as the product of the relative spectral throughput of the sphere and the relative spectral responsivity of the photometer head.

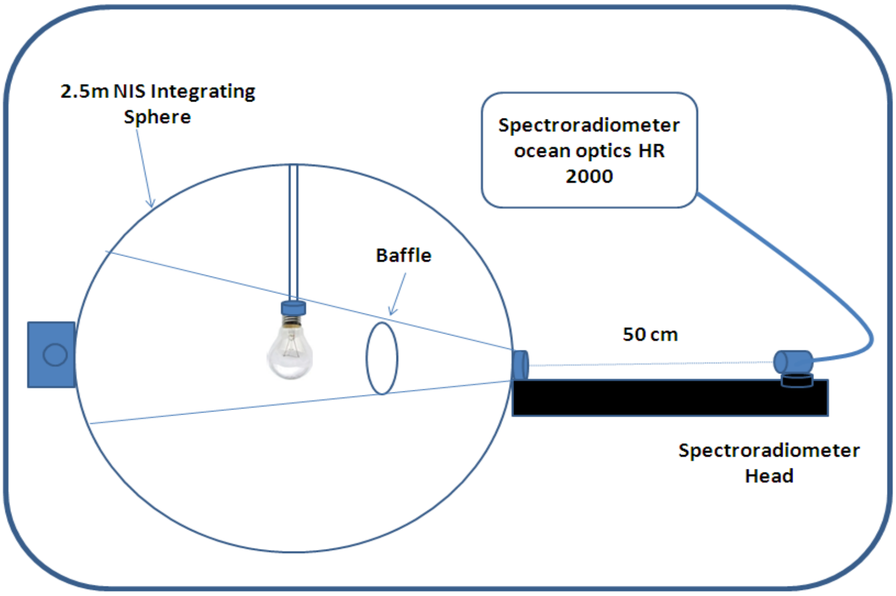

Figure.3. Set up of measurements the spectral responsivity of NIS Integrating Sphere Photometer system with NIS total luminous flux workingstandard lamps.

The spectral responsivity of the integrating sphere is determined by rationing the spectral distribution measured at the photometer port of one of the total flux working standard lamps to that measured directly of the working standard lamp using the photometric bench and the Spectroradiometer ocean optics HR 2000at NIS with uncertainty 4.7% [7]. A set up of measuring used to determine the sphere photometer spectral responsivity as shown in Figure. (2) and Figure. (3). Tables (1) and (2) contains the electrical control results of NIS standard lamps were calibrated at National Laboratory in England (NPL) with uncertainty 0.8% and the electrical control results of eight incandescent lamps which are used to calculate the spectral mismatch correction factor and uncertainties.

Table 1. The Electrical Control Results of NIS standard Lamps

NIS Standard Lamps	***SET Current***	***Voltage***	***Colour temperature***	***Total luminous flux***
	(amperes)	***(Volts)***	***(Kelvin)***	***(lumen)***
NIS-E31	0.20482	91.9	2400	131.5
NIS-E32	0.20315	92.0	2400	130.8
NIS-E33	0.20382	92.4	2400	132.4

Table 2. The Electrical Control Results of Incandescent Lamps.

Incandescent Lamps	***SET Current***	***Voltage***	***Colour temperature***	***Total luminous flux***
	(amperes)	***(Volts)***	***(Kelvin)***	***(lumen)***
NIS-M1-200	0.6050	116.7	2095	232
NIS-M2-200	0.6052	113.7	2070	225
NIS-M3-200	0.6051	117.0	2073	244
NIS-M1-150	0.4551	114.9	2074	150
NIS-M2-150	0.4551	116.7	2054	164
NIS-M3-150	0.4551	114.5	2084	152

III. RESULTS AND ANALYSIS

The spectral power distribution has been measured by using the system shows in Figure (2) at several electrical current values for eight incandescent lamps and presented in Figure (4). Tables (1) and (2) contains the electrical control results of NIS standard lamps were calibrated at National Laboratory in England (NPL) and the electrical control results of six incandescent lamps. Calculations have been made on these lamps measurements to determine the spectral mismatch correction factor and uncertainties for each lamp by using Equations (1) and (2). The results of the spectral mismatch correction factor are presented in Figures (5) and (6). The uncertainties are presented in Figures (7) and (8).

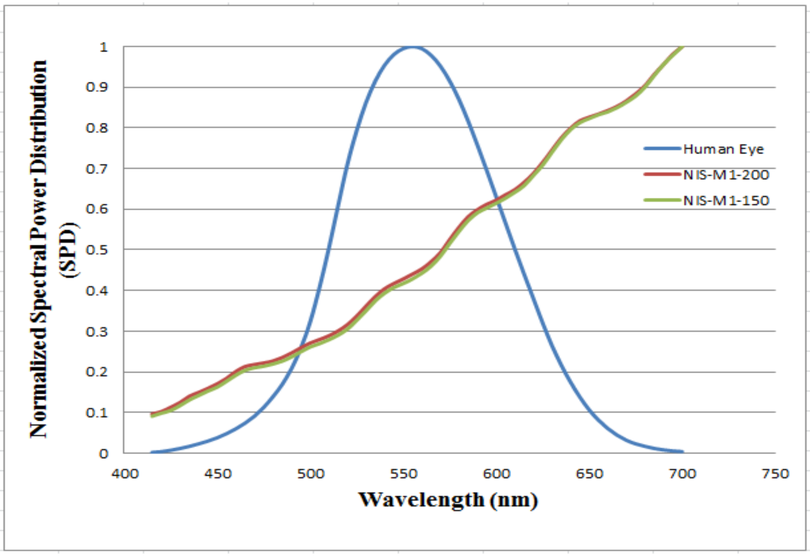

Figure 4. The spectral power distributions of the lamps NIS-M1-150 and NIS-M1-200 with the responsivity of human eye.

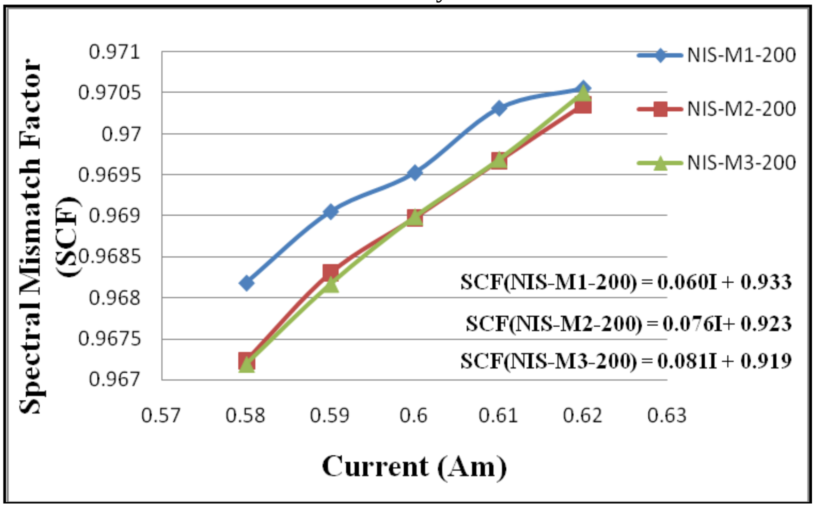

Figure5. Spectral Mismatch Factor of Lamps (200 Watt) at Different Electrical Current.

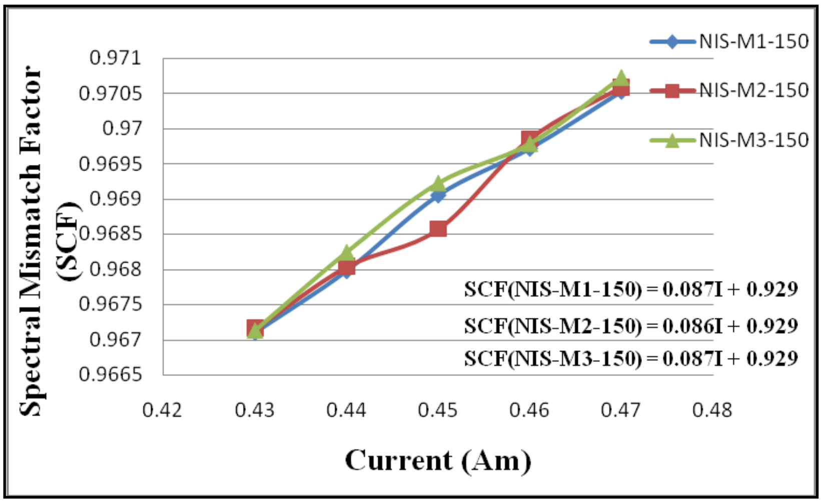

Figure 6. Spectral Mismatch Factor of Lamps (150 Watt) at Different Electrical Current.

IV. UNCERTAINTY ANALYSIS OF SPECTRAL MISMATCH FACTOR

It's important to recognize that measurements have inherent corresponding uncertainties. As the measurements reference a standard more and more removed from the original NIST or other national standard, the greater the associated uncertainty increases. A table of uncertainty components is typically referred to as an uncertainty budget. Total uncertainties are normally expressed as "expanded" uncertainty or % confidence. As might be expected, all uncertainty budgets should include the variation in results, scan-to-scan repeatability, realignments, drifts in samples or the measurement system. However, you must also include the conformance of the procedure and equipment to the specifications and requirements of measurement standard, the effects due to the differences between the standard lamp and tested lamp, environmental effects and the accuracy and stability of operating conditions [12].The measurement accuracy in the photometric quantity is determined by the value of the spectral mismatch correction factor, which is defined as a function of spectral power distribution of light sources besides illuminance responsivity of the photometer head used [13]. NIS Spectroradiometer with uncertainty 4.7% and NIS-standard lamps calibrated at National Physical Laboratory in England (NPL) with uncertainty 0.8% have been used in measurements.

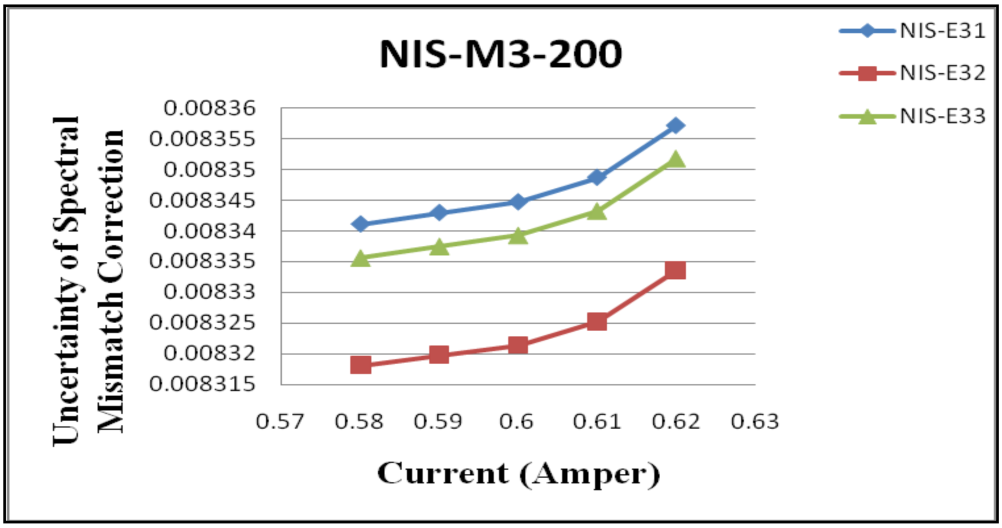

Figure 7. The Uncertainty of the Spectral Mismatch Correction of (200 Watt) Lamps.

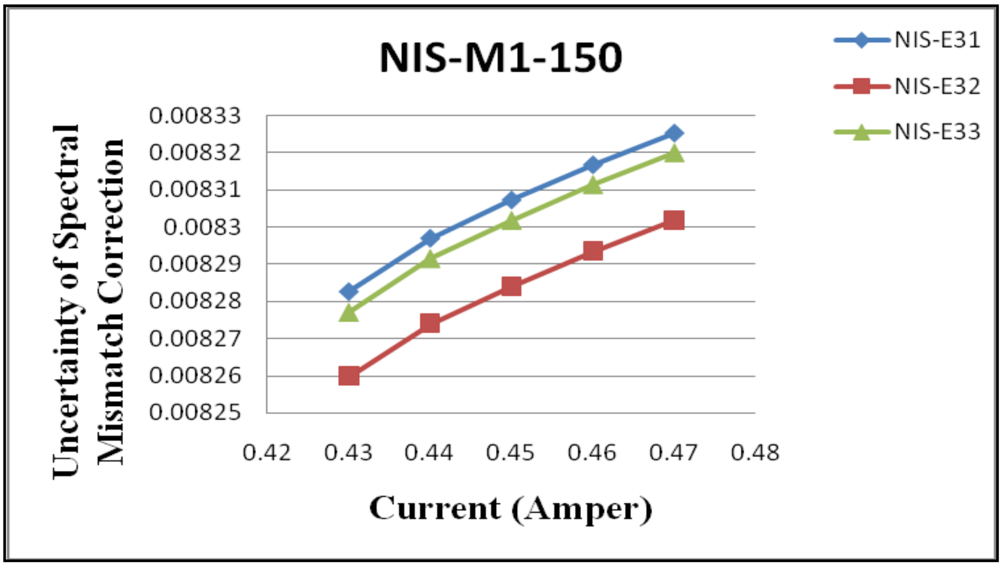

Figure 8. The Uncertainty of the Spectral Mismatch Correction of (150 Watt) Lamps.

V. CONCLUSION

This research demonstrates the spectral mismatch correction factor as a function of the electrical current applied to the lamp. This enables to determine change in the spectral mismatch correction factor of each lamp due to the change in the electrical operating current of the lamps by using the spectral mismatch factor curves and its fitting equations which are presented in Figures (5) and (6). Reduction of error in the spectral correction factor for the incandescent lamps can be achieved by minimizing the factor itself, such reduction can be achieved by choosing standard lamp spectra similar to the test lamp spectra. The Figures (7) and (8) are the uncertainties for each lamp with NIS standard lamps. They are very useful in the total luminous flux measurements and uncertainty budget.

REFERENCES

[1] Pro-lite Technology, “Photometer or Spectroradiometer? An Estimation of Errors When Using Filter-Based Photometers to Measure the Illuminance of LED Sources” , Technical Note – LED Measurements, August, 2009.

[2] IESNA LM-45, “Method for Electrical and Photometric Measurements of General Service Incandescent filament Lamps”, 2000.

[3] Emma R. Woolliams, “Determining the uncertainty associated with integrals of spectral quantities”, EMRP-ENG05-1.3.1, April 2013.

[4] Manal A. Haridy, 2015, “Uncertainty Estimation of Spectral Mismatch Correction Factor for Incandescent Lamps”, Int. J. Curr. Res. Aca. Rev; 3(7), pp. 262-273.

[5] Subcommittee On photometry of light sources of the IESNA Testing procedures Committee, IESNA” Guide to Spectroradiometric Measurements”, LM-58-94, New York: Illuminating Engineering Society of North America, 1994.

[6] ComissionInternationale de l0Eclairage. Methods of characterizing illuminance meters and luminance meters: performance, characteristics and specifications, CIE 69, 1987.

[7] Manal A. Haridy, 2015, “Improvement uncertainty of total luminous flux measurements by determining some correction factors”, Int. J. Curr. Res. Aca. Rev; 3(6), pp. 264-274.

[8] A.A. Gaertner, “LED Measurement Issues”, Photometry, Radiometry AndColorimetry Course NRC, Ottawa, Canada, 2007.

[9] Guide to the Expression of Uncertainty in Measurement, First Edition, International Organization for Standardization (ISO), 1995.

[10] Manal. A. Haridy, “The Realization of Luminous Flux Scale and Its Application in Preparing Calibrated and Tested Lamps”, Doctoral thesis, college of Women, Ein Shams University, Egypt and NRC Canada, 2008.

[11] Manal A. Haridy, “Correlated Color Temperature and Total Luminous Flux Influenced by Electrical Current Variation of Incandescent Lamps.”, Int. *Journal of Engineering Research and Applications*; *Vol. 5, Issue 8, (Part - 4) August 2015, pp.70-84*.

[12] Richard Young, Alexandre Y. Fong,” Reducing Uncertainty in Precision High-Brightness LED Measurements”, issue of Photonics Spectra December 2005.

[13] FerhatSametoglu, “Influence of the spectral power distribution of a LED on the illuminance responsivity of a photometer”, Optics and Lasers in Engineering, 46, pp. 643– 647, 2008.