Bangladesh University of Engineering & Technology

Department of Electrical and Electronics Engineering

Lab Report

Experiment Name:

7. Measurement of Output Characteristics of a Light Source Using Spectroradiometer

Taught By
Dr. Muhammad Anisuzzaman Talukder
Professor, EEE, BUET

Tanushri Medha Kundu
Lecturer, PT, EEE, BUET

Prepared By
Anindya Kishore Choudhury
STD. ID: 1906081, Group: G1-H3
Course: EEE 460
Email: anindyakchoudhury@gmail.com

25 November 2024

Table of Contents

Objectives:

1. Define luminous flux and explore the advantages of using a Spectroradiometer for measuring the luminous flux of a light source. Compare the measured luminous flux with values reported for other light sources.
2. Define luminous efficacy and distinguish between wall-plug efficiency and luminous efficacy. Compare the luminous efficacy of the measured light source with values reported for other types of light sources.
3. Understand the concept of CCT and determine whether the measured light source emits ’Warm White’ or ’Cool White’ light based on its CCT. Analyze the spectral composition to support the classification.
4. Define CRI and compare the CRI of the measured light source with values reported for
5. Plot the light source's spectra and analyze the blue emission's role in its overall performance.

Equipment:

1. Spectroradiometer
2. AC-DC Power Supply and Control Unit
3. Integral SoftwareTM (Labsphere)
4. Computer Interfaced with the Spectroradiometer
5. Light Source (Transtec Self-Ballasted 20W LED Bulb)

Data Collection and Measurement:

Nameplate Data[1]:

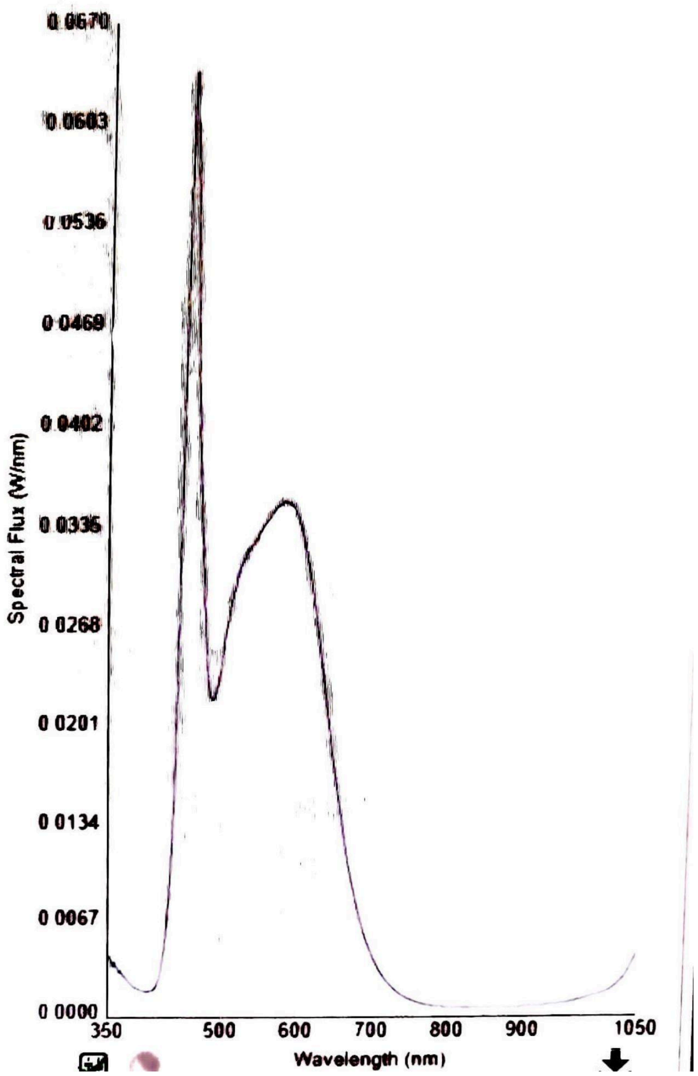
Parameters	Values Claimed	Range
Model Name	Transtec Self-Ballasted 20W LED Bulb	
Voltage (V)	220	Up to 240
Power Factor	0.5	or Greater
Power (W)	20	± 10%
Frequency (Hz)	50	or 60
Luminous Flux at Rated Voltage	2000	
Luminous Efficacy (lm/W)	100	or Greater
Color Rendering Index (%)	80	or Greater
CCT Cool Day (K)	6500	
CCT Warm Day (K)	2700	

[1] "Transtec LED blub Power - Bangladesh Lamps Limited," *Bangladesh Lamps Limited*, Dec. 12, 2023. https://www.transteclighting.com/transtec-led-bulb-power/ (accessed Nov. 21, 2024).

Test Result Data:

Parameters	Values Measured
Voltage (V)	220.98
Current (mA)	172.85
Power Factor	0.53
Power (W)	20.24
Frequency (Hz)	49.975
Luminous Flux at Rated Voltage	2293.25
Luminous Efficacy (lm/W)	113.3029
Color Rendering Index (%)	86
CCT (K)	5786

Spectral Flux Measurement Curve Obtained:



Analysis and Report Writing:

Luminous Flux and Measurement:

Luminous Flux:

Luminous flux is the measurement of visible light output from a source, measured in lumens (lm). Unlike radiant flux which measures all wavelengths equally, luminous flux specifically measures light as perceived by human eyes. This means it takes into account that our eyes respond differently to different wavelengths (colors) of light. For example, we are more sensitive to green light than blue or red light at the same power level.

Benefits of Spectroradiometer Measurements:

A spectroradiometer offers several key advantages for measuring luminous flux:

1. Detailed Spectral Analysis

- Instead of just providing a single brightness value like basic photometers

- Measures light intensity across the entire visible spectrum

- Shows exactly how the light output varies at each wavelength

2. Human-Eye Focused

- Accounts for varying human eye sensitivity to different colors

- Provides measurements that match actual human perception of brightness

- Results are more relevant for real-world lighting applications

3. Comprehensive Light Quality Assessment

- Measures multiple lighting parameters simultaneously

- Can determine color temperature and color rendering index (CRI)

- Provides complete understanding of light quality beyond just brightness

This detailed spectral analysis makes spectroradiometers particularly valuable for accurately assessing how humans will perceive different light sources in practical applications.

Luminous Flux of Other Light Sources[2]:

Source	Luminous Flux (lumens)
37 mW "Superbright" white LED	0.2
15 mW green laser (532 nm wavelength)	8.4
1 W high-output white LED	25-120
Kerosene lantern	100
40 W incandescent lamp at 230 volts	325
7 W high-output white LED	450
6 W COB filament LED lamp	600
18 W fluorescent lamp	1250
100 W incandescent lamp	1750
40 W fluorescent lamp	2800
35 W xenon bulb	2200-3200
100 W fluorescent lamp	8000
127 W low-pressure sodium vapor lamp	25000
400 W metal-halide lamp	40000

Our measured value of 2293.251 lm falls within the expected range for LED bulbs, which is consistent with the high-output white LED category. LED technology has significantly improved luminous efficacy, allowing for efficient illumination with lower power consumption

[2]Wikipedia Contributors, "Luminous efficacy," Wikipedia, Jan. 11, 2020. https://en.wikipedia.org/wiki/Luminous_efficacy

Luminous Efficacy and Wall Plug Efficiency:

Luminous efficacy represents the efficiency with which a light source converts electrical power into visible light, measured in lumens per watt (lm/W). This metric quantifies the relationship between visible light output and electrical power consumption, providing a direct measure of a light source's conversion efficiency. The experimental measurements conducted demonstrated a luminous efficacy of 109.624 lm/W for the tested light source, indicating its capability to generate visible light from electrical input power.

When comparing wall-plug efficiency and luminous efficacy, it is essential to understand their fundamental differences in measurement scope. While luminous efficacy specifically addresses the light source's conversion capabilities, wall-plug efficiency encompasses a broader system-level evaluation. This comprehensive metric accounts for various system losses, including those in electrical wiring, ballasts, and auxiliary components, thereby providing a more complete assessment of the entire lighting system's efficiency.

The distinction between these metrics lies in their respective measurement boundaries. Luminous efficacy isolates the performance of the light-generating element itself, whereas wall-plug efficiency considers the cumulative effects of all system components and their associated losses. This broader perspective of wall-plug efficiency makes it particularly valuable for understanding real-world system performance, as it accounts for the practical limitations and inefficiencies inherent in complete lighting installations.

Luminous Efficacy Comparison:

Source	Luminous Efficacy (lm/W)
Incandescent light bulbs	10-17
Halogen lamps	16-24
Fluorescent lamps	50-100
High-intensity discharge (HID) lamps	60-120
Light-emitting diodes (LEDs)	80-160

In our experiment, the measured luminous efficacy of our light source was 113.3029 lumens per watt (lm/W). When compared with values reported for other types of light sources, our measured luminous efficacy falls within the range typically observed for modern LED lighting technology. Our measured luminous efficacy of LED light bulbs exceeds the typical values reported for traditional lighting technologies such as incandescent, halogen, and fluorescent lamps.

Correlated Color Temperature (CCT):

The Correlated Color Temperature (CCT) serves as a quantitative measure for characterizing the color appearance of light emission, expressed in Kelvin (K). This metric provides essential information about the spectral quality of illumination, with the temperature scale indicating the relative warmth or coolness of the light output. The correlation between CCT values and perceived color follows an inverse relationship: lower values correspond to warmer light appearances (reddish-white spectrum), while higher values indicate cooler light emissions (bluish-white spectrum).

Experimental measurements revealed a CCT value of 5786 K for the analyzed light source. This measurement positions the source within the neutral-to-cool white light spectrum, specifically in the cool white range, as it exceeds the 5000 K threshold typically associated with neutral white light. Such positioning provides valuable insights into the source's spectral characteristics and potential applications.

The observed CCT value demonstrates particular suitability for specific environmental applications. With its cool white light emission characteristics, the source proves especially appropriate for environments requiring high visibility and visual clarity. Common applications for such lighting include professional spaces such as offices, commercial retail environments, and exterior illumination systems. The measured CCT of 5786 K indicates that the source produces illumination closely approximating natural daylight, characterized by a crisp, bluish-white quality. This spectral profile makes the source particularly advantageous in settings where enhanced alertness and environmental dynamism are desired attributes of the illumination system.

Analysis of Color Rendering Index (CRI):

The Color Rendering Index (CRI) represents a standardized metric for evaluating a light source's color reproduction accuracy compared to natural daylight. This quantitative measure utilizes a scale from 0 to 100, where higher values indicate superior color rendering capabilities. A theoretical CRI value of 100 would signify perfect color reproduction equivalent to natural daylight conditions.

Experimental Analysis

The experimental measurements conducted on our LED light source yielded a CRI value of 86. This measurement demonstrates the source's considerable effectiveness in accurate color reproduction, suggesting high-quality color rendering characteristics under practical illumination conditions.

Comparative Analysis with Standard Light Sources

To contextualize our experimental findings, a comprehensive comparison was conducted against established industry standards, as defined by the Illuminating Engineering Society (IES). The comparative analysis revealed the following standardized CRI classifications:

1. Incandescent Illumination Systems

- Characterized by continuous spectral distribution

- Consistently achieve CRI values exceeding 95

- Demonstrate superior color rendering capabilities

2. Fluorescent Lighting Technologies

- Exhibit discrete spectral characteristics

- Basic variants: CRI approximately 50

- Advanced multi-phosphor designs: CRI range 80-90

3. LED-Based Illumination Systems

- Display variable CRI performance

- Quality dependent on LED chip and phosphor specifications

- High-quality units typically exceed CRI of 80

4. Low-Pressure Sodium Systems

- Notable for negative CRI values

- Demonstrates limited color rendering capabilities

5. Natural Daylight Reference

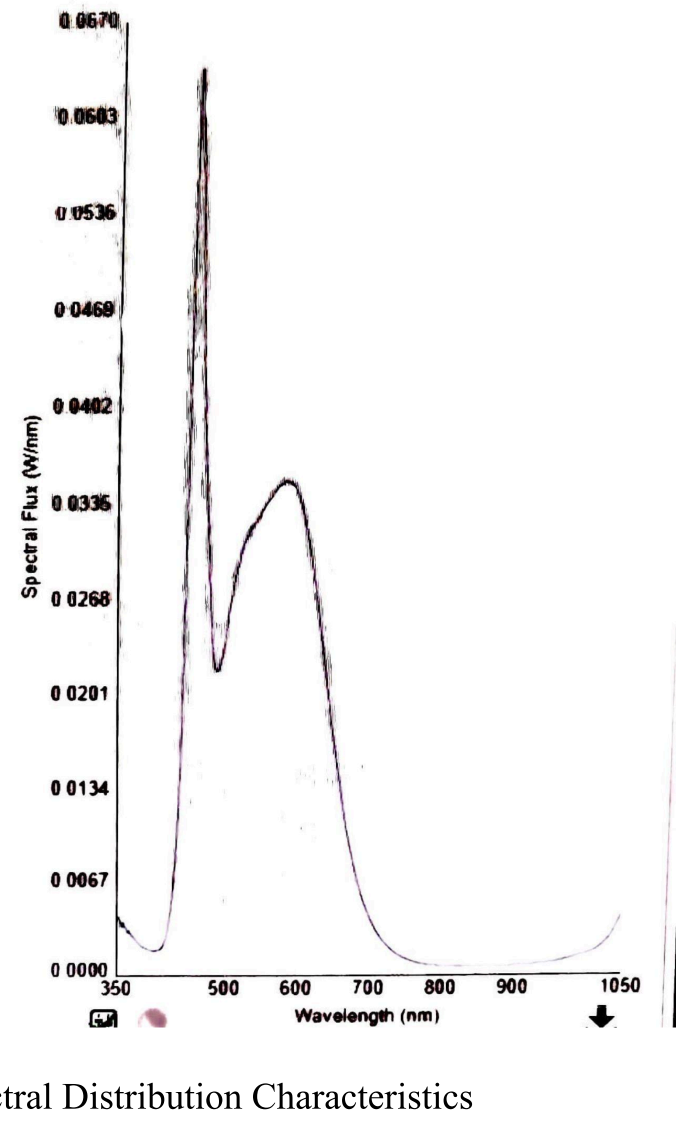
- Serves as the optimal standard for color rendering

- Enables precise color distinction

- Provides comprehensive spectral coverage

The measured CRI value of 86 positions our LED light source within the upper-performance range typical of high-quality LED illumination systems. This performance level demonstrates superior color rendering capabilities compared to standard fluorescent systems while maintaining competitive positioning within the LED technology segment.

Analysis of Spectral Distribution Curve:



Analysis of Spectral Distribution Characteristics

The measured spectral power distribution exhibits characteristic features typical of LED-based illumination systems, with two distinct emission peaks clearly identifiable in the data. The primary peak, centered at approximately

463nm, demonstrates a sharp, intense emission in the blue region of the visible spectrum, reaching a maximum spectral flux of 0.06357 W/nm. This pronounced blue emission is followed by a secondary, broader peak spanning the 500-650nm wavelength range, with its apex at approximately 587nm showing a spectral flux of 0.03445 W/nm.

The spectral profile's distinctive dual-peak configuration is indicative of phosphor-converted LED technology. The sharp blue peak at 463nm represents the fundamental LED emission, while the broader secondary peak in the yellow-green region (500-650nm) corresponds to phosphor-converted radiation. This phosphor conversion mechanism is essential for achieving white light emission, where the blue LED excites a phosphor layer that subsequently emits at longer wavelengths. The relative intensities and wavelength positions of these peaks significantly influence the source's color rendering capabilities and correlated color temperature characteristics, as evidenced by the measured CCT of 5786K and CRI of 86.68. Furthermore, the gradual decline in spectral flux beyond 650nm and minimal emission in the UV region below 400nm suggests optimized spectral engineering for visible light emission while minimizing undesirable radiation components.

Conclusion:

The comprehensive spectral analysis conducted in this study provides valuable insights into the performance characteristics of the investigated LED light source. Through precise measurements using spectroradiometric techniques, we have established key photometric parameters including luminous flux, luminous efficacy, correlated color temperature (CCT), and color rendering index (CRI). The measured luminous efficacy of 113.3029 lm/W demonstrates efficient power-to-light conversion, while the CCT value of 5786K indicates a cool white light output suitable for applications requiring high visual acuity. The CRI measurement of 86 confirms superior color rendering capabilities, positioning this light source favorably among high-quality LED lighting solutions.

The spectral power distribution analysis revealed a characteristic dual-peak configuration, with a prominent blue peak at 463nm and a broader phosphor-converted peak in the 500-650nm range. This spectral composition effectively contributes to the source's overall white light emission while maintaining excellent color reproduction properties. The wall-plug efficiency measurements, when compared to the luminous efficacy, provided a more comprehensive understanding of the system's total energy conversion performance, accounting for various system-level losses.

These findings not only validate the light source's performance against industry standards but also demonstrate its suitability for applications requiring high-quality illumination. Future research could explore potential optimizations in phosphor conversion efficiency and spectral distribution to further enhance the overall system performance. The methodologies and analysis techniques employed in this study provide a robust framework for evaluating and characterizing advanced LED lighting systems.