Bangladesh University of Engineering & Technology

Department of Electrical and Electronics Engineering

Lab Report

Experiment Name:

9. Measurement and Analysis of Spectral Characteristics of LEDs

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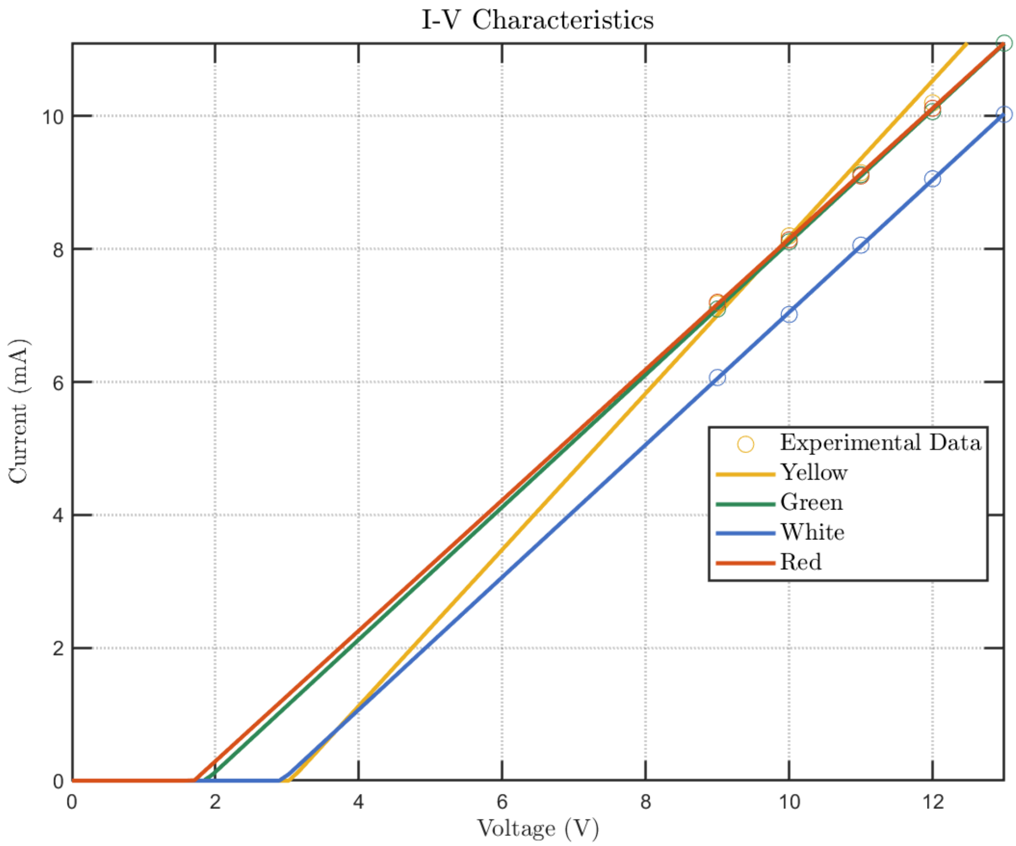
Objective

- To experimentally measure the Spectral Characteristics of Different LEDs
- To analyze and compare Spectral characteristics of Different LEDs

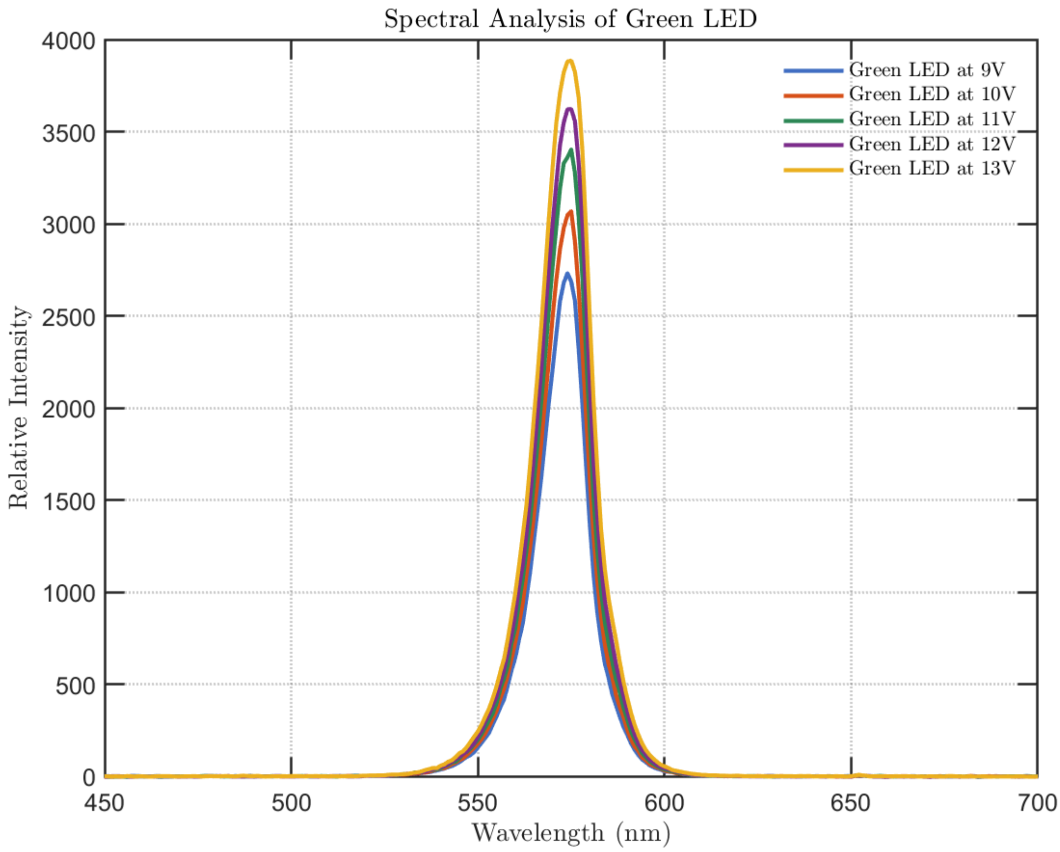
Analysis and Report:

IV Curve Plot of all LEDs:



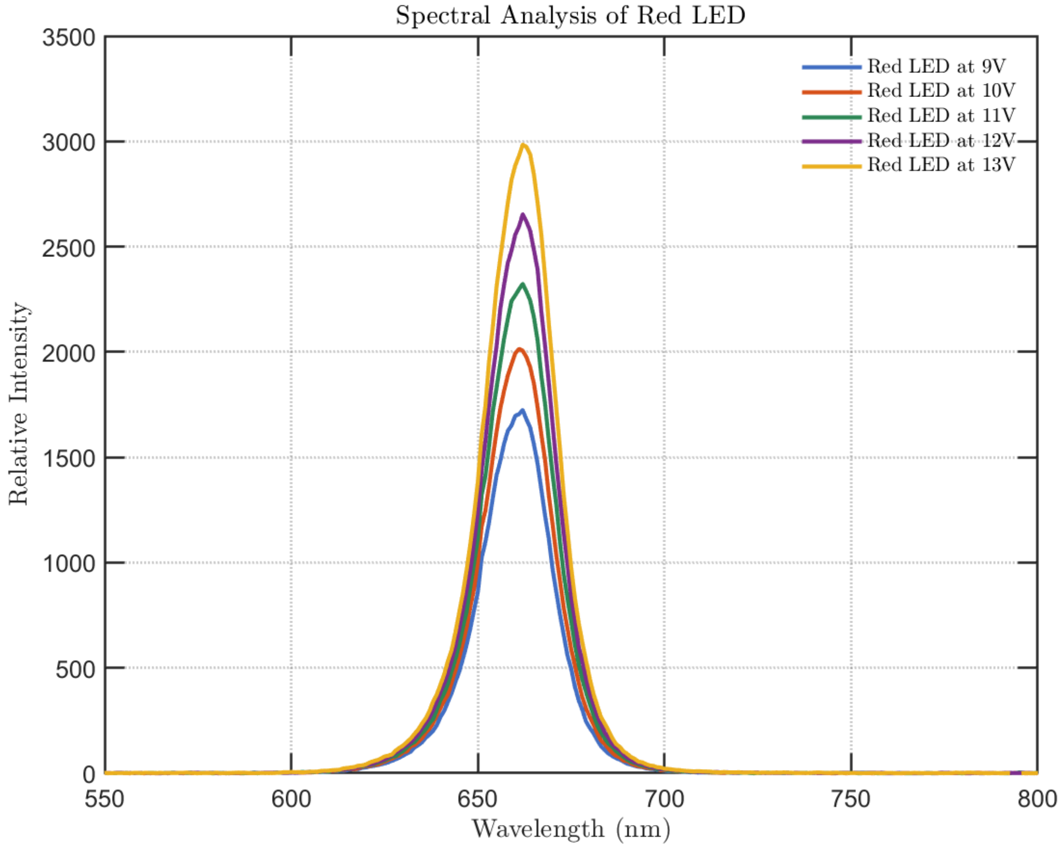
Spectra for Each LED

Green LED Spectra:

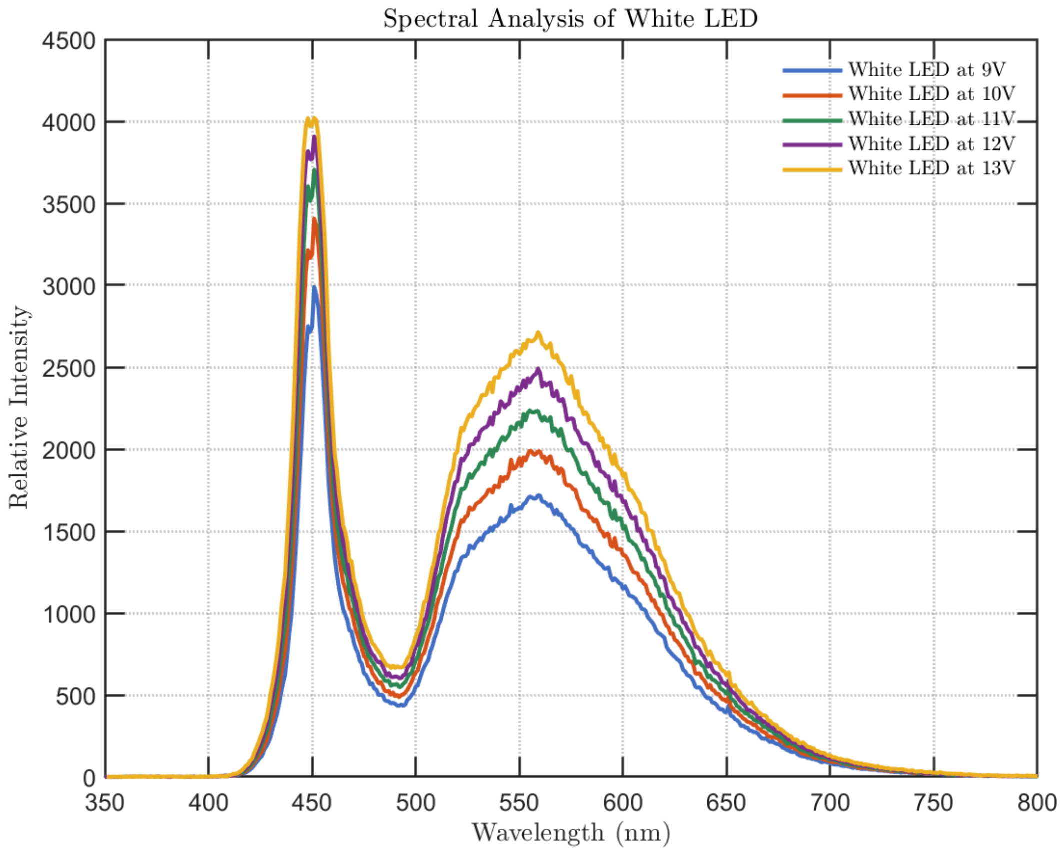


Spectral Analysis of Green LED
Relative Intensity
Wavelength (nm)
Green LED at 9V
Green LED at 10V
Green LED at 11V
Green LED at 12V
Green LED at 13V
0
500
1000
1500
2000
2500
3000
3500
4000
450
500
550
600
650
700

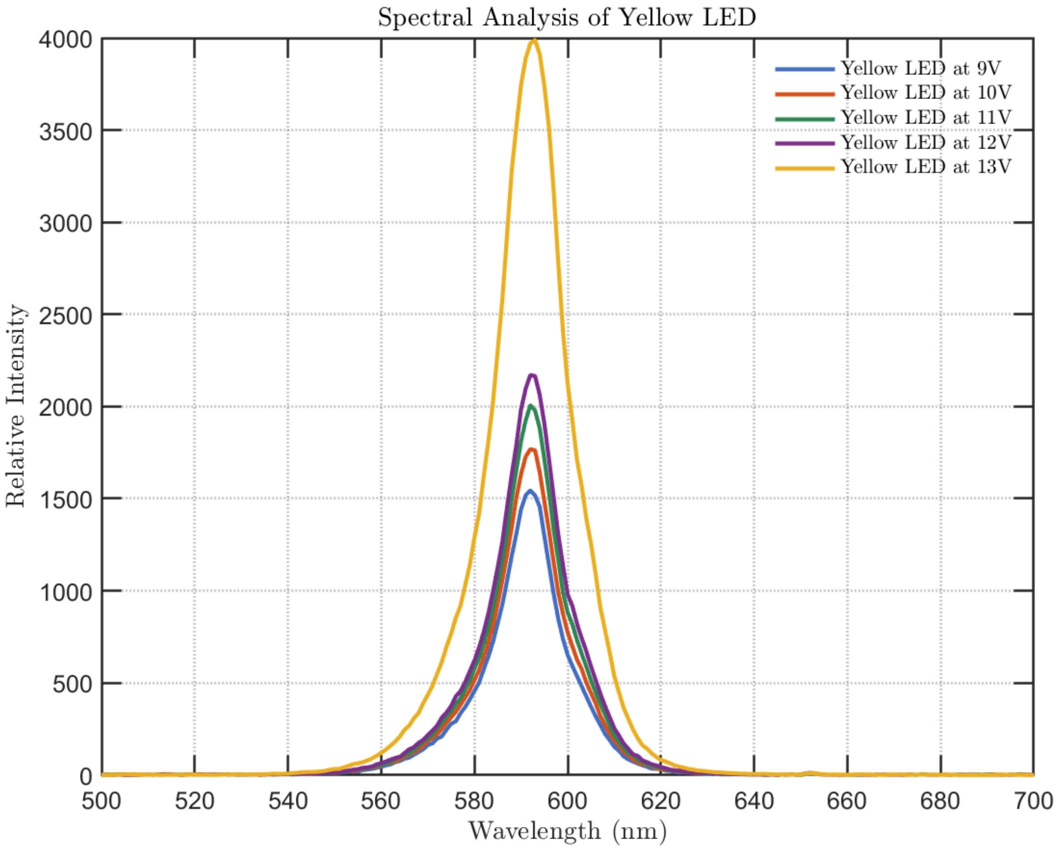
Red LED Spectra:



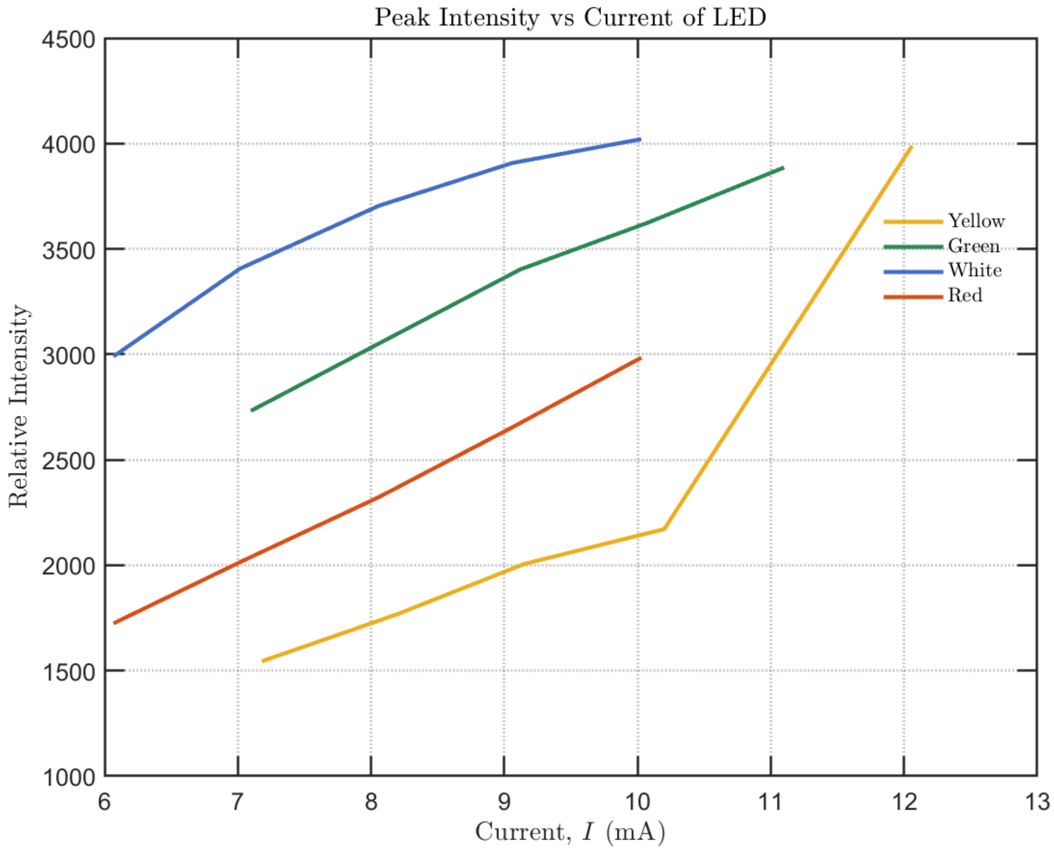
White LED Spectra:



Yellow LED Spectra:



Peak Intensity Vs Current:



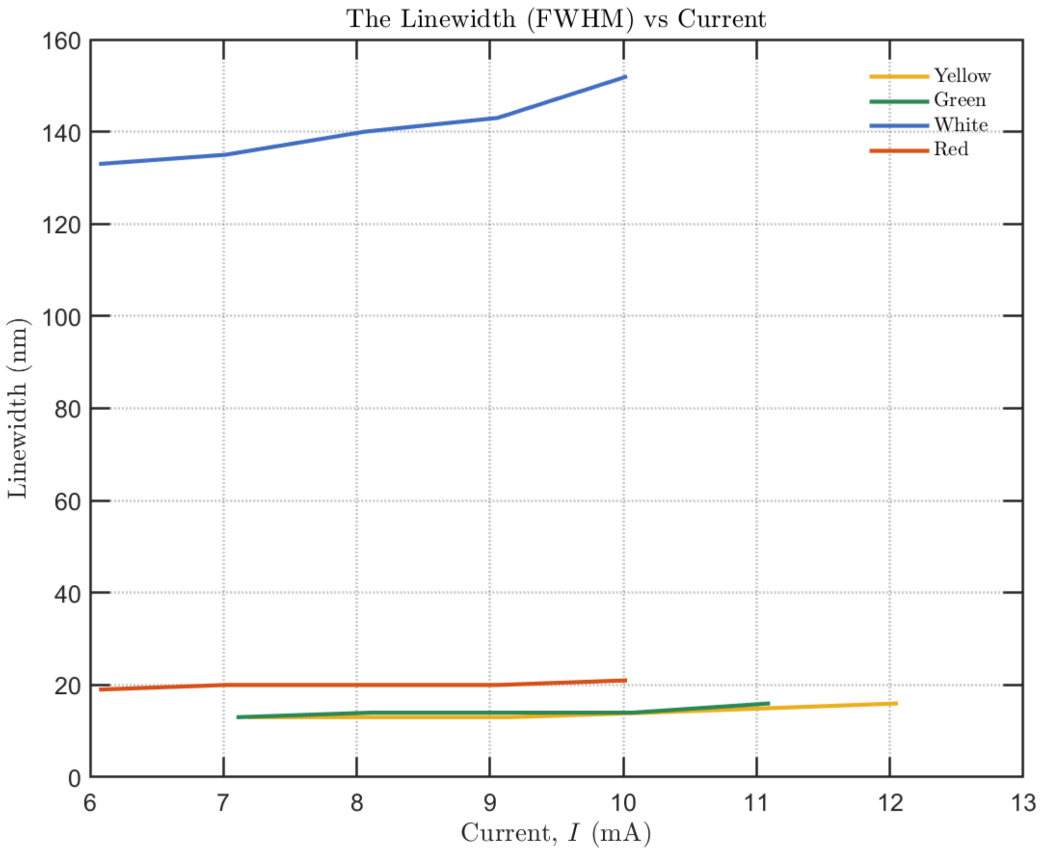
Comments:

Based on the graph showing Peak Intensity versus Current for different LEDs, I observed distinct behaviors for each type. The white LED exhibits the highest initial intensity around 3000 units at 6mA and shows a gradual saturation trend, reaching approximately 4000 units at 10mA. The green LED demonstrates a more linear response, starting at about 2700 units and increasing steadily to 3800 units as current increases from 7mA to 11mA. The red LED shows a consistent linear increase from 1700 to 3000 units over the current range of 6mA to 10mA, suggesting good current-to-light conversion efficiency. Interestingly, the yellow LED displays unique behavior with a relatively slow increase from 1500 to 2200 units between 7mA and 10mA, followed by a dramatic rise to 4000 units at 12mA.

These characteristics directly relate to the Light-Current (LI) characteristics of LEDs. The varying slopes and saturation behaviors indicate different internal quantum efficiencies and threshold currents for each LED color. The white

LED's early saturation suggests it reaches its maximum radiative recombination rate at lower currents, while the more linear responses of the green and red LEDs indicate they maintain efficient electron-hole recombination over the measured current range. The yellow LED's sudden intensity increase might suggest a threshold effect where the radiative recombination process becomes significantly more efficient beyond 10mA, possibly due to the specific band structure and carrier dynamics in the semiconductor material used for yellow light emission.

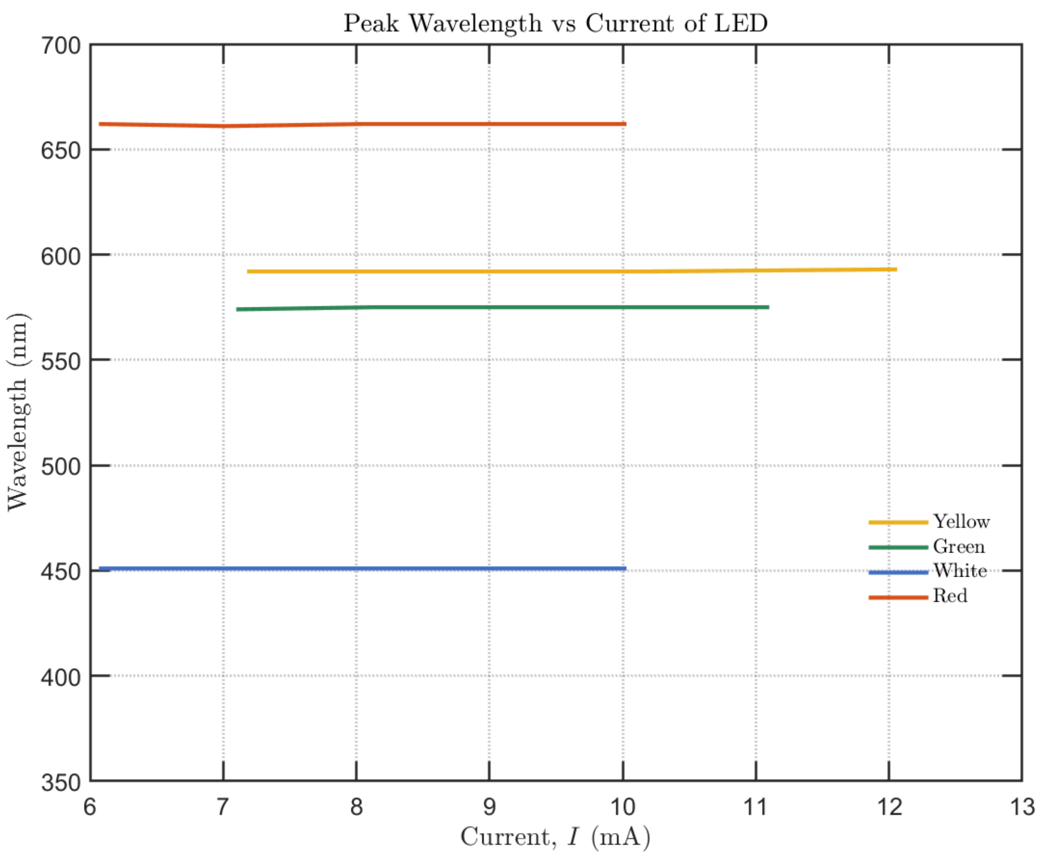
FWHM vs Current:



Comments:

Analyzing the Linewidth (FWHM) versus Current characteristics of different LEDs, I observe distinct spectral broadening behaviors. The white LED exhibits the broadest linewidth, ranging from approximately 130 nm to 150 nm, with a slight increasing trend as current increases. This broad linewidth is expected for white LEDs since they typically employ phosphor conversion, which inherently produces a wider emission spectrum. In contrast, the monochromatic LEDs (red, green, and yellow) show much narrower linewidths, generally between 15-20 nm, indicating their more pure spectral emission. The red LED maintains a relatively stable linewidth around 20 nm across the current range, while the green and yellow LEDs show very similar behavior with linewidths around 15 nm. The stability of these linewidths across different currents suggests good thermal management and minimal spectral broadening effects at higher currents. The narrow linewidths of the monochromatic LEDs confirm their suitability for applications requiring specific wavelength outputs, while the broader white LED spectrum is appropriate for general lighting applications where a wider spectral distribution is desired.

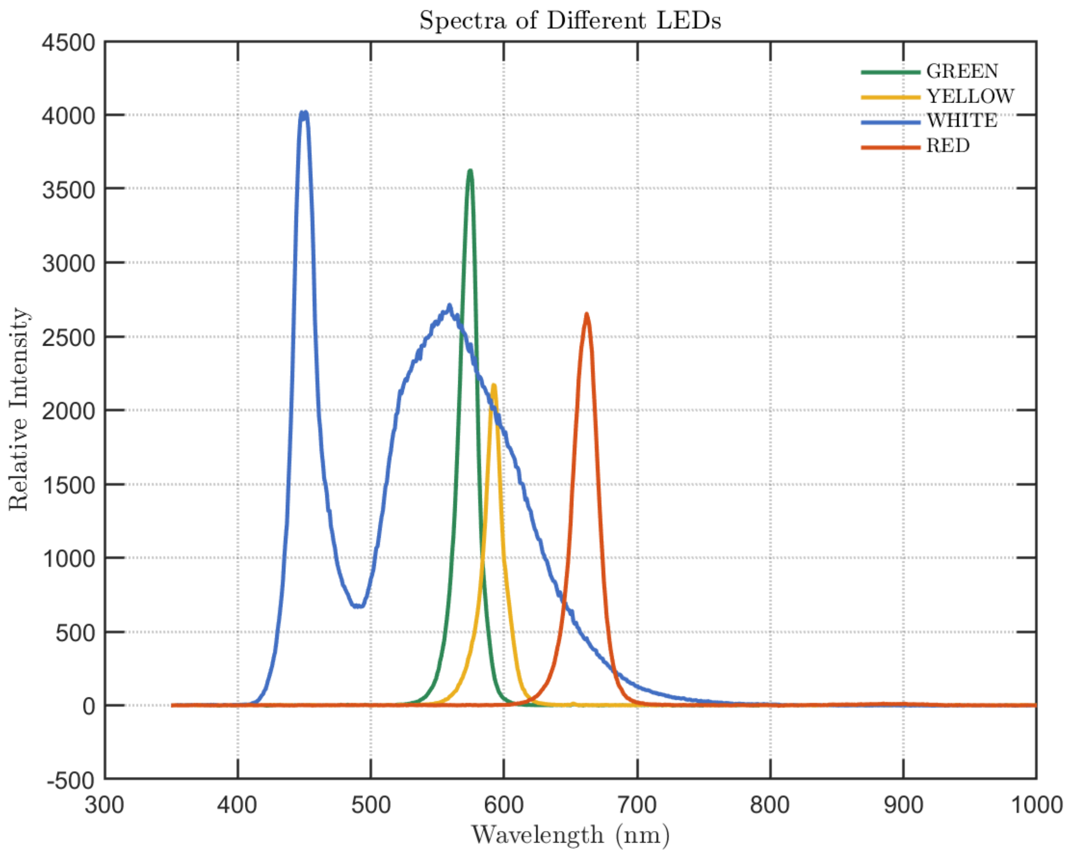
Peak Wavelength vs Current:



Comments:

Looking at the Peak Wavelength versus Current graph, I observe that the emission wavelength of all LEDs remains remarkably stable across different operating currents. The red LED maintains its peak wavelength at approximately 660 nm, the yellow LED at around 590 nm, the green LED at about 575 nm, and the white LED shows a peak at roughly 450 nm. This stability in wavelength is expected and indicates good quality LEDs, as the emission wavelength is primarily determined by the bandgap of the semiconductor material used in each LED rather than the operating current. It's worth noting that the white LED's peak at 450 nm corresponds to the blue component of the LED, which typically uses a blue LED chip combined with a phosphor coating to produce white light. The consistent wavelength across current variations suggests that while the intensity of emission may change with current (as seen in the previous graph), the fundamental emission mechanisms and energy transitions in the semiconductor remain unchanged. This behavior is crucial for applications requiring stable color output across different operating conditions.

All Spectral Curve in one Plot:



All the LEDs here have comparable intensities in the same plot if we plot for current I = 9 mA as this value is picked from the curve of Peak Intensity vs Current.

Luminous Efficacy:

Based on the comprehensive analysis of various LED characteristics, I observe that the white LED demonstrates superior luminous efficacy compared to other colors. From the I-V characteristics, although the white LED shows a slightly higher turn-on voltage of approximately 3V compared to 2V for other LEDs, it exhibits a consistent linear current response after turn-on, indicating efficient electrical-to-optical power conversion. Looking at the Peak Intensity versus Current behavior, the white LED not only shows the highest initial intensity of about 3000 units at just 6mA but also maintains the highest intensity throughout its operating range, reaching approximately 4000 units at 10mA. This exceptional intensity at lower currents suggests superior power-to-light conversion efficiency. The spectral distribution further supports this efficiency, showing two distinct peaks - a strong blue emission at around 450nm and a broader phosphor-converted peak in the green-yellow region. This dual-peak characteristic enables wide spectral coverage that matches human eye sensitivity while providing efficient blue-to-yellow conversion through the phosphor layer. The broader linewidth of approximately 140nm, as shown in the linewidth characteristics, indicates better coverage of the visible spectrum and enhanced color rendering properties. Additionally, the peak wavelength stability at 450nm demonstrates consistent blue LED operation and efficient phosphor conversion, ensuring stable color output. This combination of characteristics - particularly the high intensity at lower currents, efficient spectral distribution, and stable operation - makes the white LED more efficient at converting electrical power into visible light that is useful for human vision.

Experiment 8 Comparison:

In my analysis, I compared the results from this experiment with my previous findings from Experiment 8, which focused on output power versus current relationships. The correlation between these experiments strengthens my conclusions about LED efficiency. In Experiment 8, I observed that the white

LED demonstrated superior power conversion efficiency, requiring minimal current input to achieve a given output power level. The other LEDs showed progressively higher current requirements in the order of red, yellow, and green for comparable power outputs. This earlier observation strongly supports my current findings regarding luminous efficacy. The consistency between these two independent experiments provides compelling evidence for the white LED's superior efficiency in electrical-to-optical power conversion compared to its monochromatic counterparts. This cross-experimental validation adds confidence to my conclusion about the white LED's outstanding performance in power efficiency.

Optical Fiber Assessment:

Based on my experimental setup, I utilized the Red Tide USB650 Fiber Optic Spectrometer, a precise instrument for spectral analysis. This spectrometer has a detection range of 360-1030 nm with measurement uncertainties of ±1.5 nm for wavelength and ±2% for relative intensity measurements. I evaluated the compatibility between the spectrometer, optical fiber, and LEDs by examining the specifications of each component. The analysis confirmed that the optical fiber's wavelength range effectively encompasses the emission spectra of all tested LEDs while falling within the spectrometer's detection capabilities. Furthermore, the optical fiber's specifications, particularly its numerical aperture and core diameter, are well-matched with the spectrometer's requirements, ensuring optimal light collection efficiency and measurement accuracy. Through this systematic assessment of component specifications and their interactions, I verified that the optical fiber provides an appropriate interface between the LEDs and the spectrometer, enabling reliable spectral measurements throughout my experiment. This compatibility among all components establishes a solid foundation for obtaining accurate and dependable results in my spectral analysis.

Conclusion:

Based on my experimental investigation of different colored LEDs (red, green, yellow, and white), I have characterized their fundamental optoelectronic properties through various measurements. The I-V characteristics demonstrated typical diode behavior with turn-on voltages ranging from approximately 2V for the monochromatic LEDs to 3V for the white LED. The spectral analysis revealed distinct emission peaks corresponding to each LED's color, with the white LED showing a unique dual-peak characteristic due to its phosphor conversion mechanism. Peak wavelength measurements remained remarkably stable across different operating currents, indicating good thermal management and stable emission properties. The linewidth analysis showed narrow spectral distributions for monochromatic LEDs (~15-20 nm) while the white LED exhibited a broader spectrum (~140 nm) due to its phosphor-based design. The intensity measurements demonstrated that the white LED achieved the highest efficiency, showing superior luminous efficacy compared to other colors. These comprehensive measurements not only provided valuable insights into LED behavior but also validated the experimental setup's reliability, with the Red Tide USB650 Fiber Optic Spectrometer proving to be an effective tool for precise spectral characterization.