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Pulsed System for Optical Discharge of Thin-film Insulators

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Introduction

Much research is being performed in order to characterize the charging of spacecraft materials. The importance and applications of this research is numerous and especially useful to the development of satellites[1]. The USU Materials Physics group is currently performing research in this field related to electron emission for spacecraft materials[1]. This includes testing sample material in an ultra high vacuum chamber. A problem encountered in this testing is that negative charge can build up on the sample material and modify the electron emission measurements[2]. To remedy this problem, my senior project was to develop, install and test a pulsed system for the optical discharge of thin-film insulating samples. The project included testing the wavelength, intensity and percent transmission of multiple LED's and coating LED's with a vacuum safe epoxy.

Theory

The internal LED source will provided a solution by irradiating the surface of the sample with light, of the appropriate energy, producing the photoelectric effect. To be effective the photon energy must be greater than the workfunction of the material being tested; if so, electrons from the sample will be emitted thereby lowering the negative charge build up. If the charge becomes positive the sample can then be neutralized using an electron gun which has already been installed in the vacuum chamber[2]. This has been shown to be effective in discharging such insulators as Kapton™ and polyethylene[2]. This procedure will also work with the exterior LED's and fiber optic cables.

The internal LED's are not compatible with an ultra-high vacuum chamber which operates at 10^{-9} Torr. To compensate the LED's must be coated with an epoxy that will make them compatible with the ultra-high vacuum chamber.

Procedure

The first phase of the project was to build circuitry that allowed the LED's to be switched on while testing the wavelength and intensity. This included using a potentiometer that allowed the resistance to be set so that the intensity of light was not too great for the spectrometer. The external LED's were tested four times each. During the first phase of testing the light was sent through a fiber optics cable to the spectrometer. The resistance was adjusted for the spectrometer and then kept the same for the remaining test. For the next three tests a piece of optical equipment was added each time including; an ultra-high vacuum feed-through, an ultra-high vacuum safe fiber optic cable, and an ultra-high vacuum safe quartz lens. This procedure was also performed on an exterior tungsten source and a deuterium source. For the internal LED's that were vacuum coated the test was run three times; once to an uncoated LED through a fiber optic cable (the cable was used so that the light was directed into the spectrometer), then to the coated LED through a fiber optic cable, and last to the coated LED through a fiber optic cable and through a lens. The data was then analyzed.

The second phase of the project was to coat the internal LED's with a vacuum safe epoxy. The epoxy was first combined in the proper ratios according to weight. It was then thoroughly mixed using a glass straw. The LED was then dipped into the container holding the epoxy. Once coated the LED was mounted onto a thin piece of cardboard and then placed in a bottle vacuum chamber which operated at approximately 10 m Torr. The bottle vacuum chamber was then placed in an oven overnight at approximately 50 degrees Celsius. This procedure was then repeated so that each internal LED had two coats of epoxy on it.

The final phase of the project was to assist in mounting the internal LED's in the vacuum chamber.

Analysis

The spectrometer data taken on the LED's was analyzed in two ways. The first was to graph the intensity of the four tests against the wavelength and to find the peak wavelength of the emitted light. It was noted that some LED's had a peak wavelength consistent with the manufacture's specifications while some were drastically different. Second using the first test as a reference a graph of the percent transmission was made for the subsequent tests. These graphs can be found that in Appendix A.

For the coated LED's, microscopic pictures were taken at 10x and 60x magnifications. The pictures were then inspected to see if there was a complete coating. Once this was accomplished the LED's were then tested in the ultra-high vacuum chamber and were found to be compatible with the low-pressure conditions.

Conclusion

In order to test that the optical system was a success, a test was performed on a gold sample in the Fatman vacuum chamber. While no data was specifically collected and analyzed, the photoelectric effect was observed. Only the high energy deuterium light source was able to produce the effect this is consistent with the high work function for polycrystalline gold of 5.1 eV.

Refrences

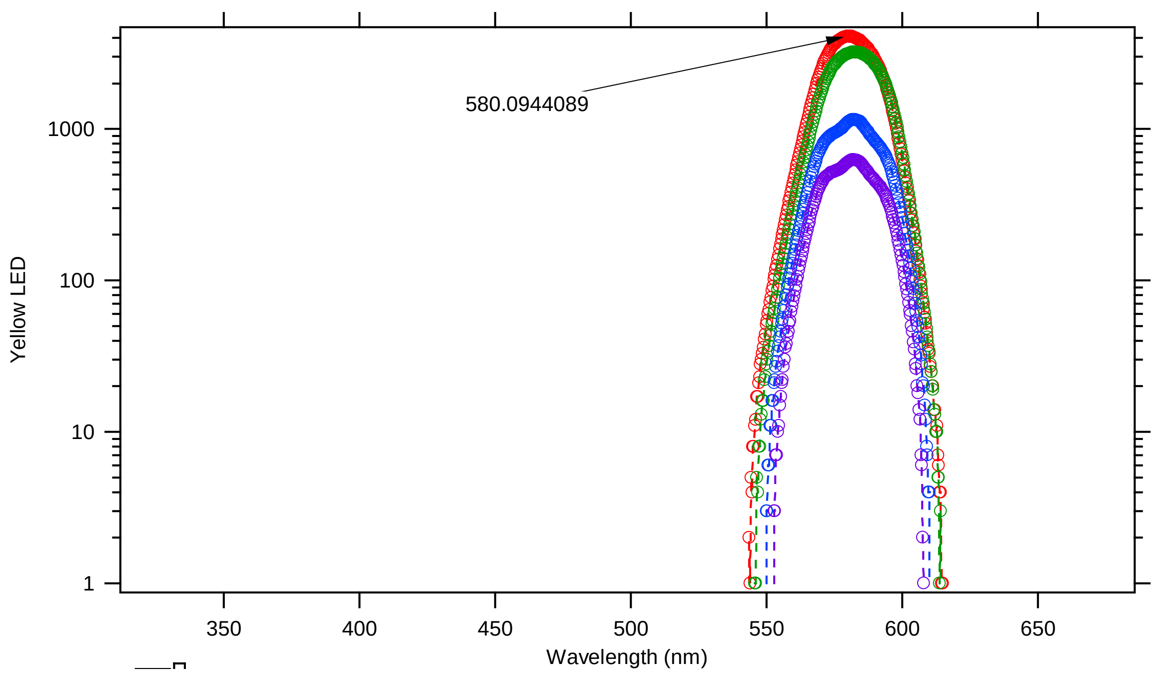
1. J.R. Dennison, C.D. Thomson, J. Kite, V. Zavyalov, Jodie Corbridge, “Materials Characterization at Utah State University: Facilities and Knowledgebase of Electronic Properties of Materials Applicable to Spacecraft Charging”, Poster Session.

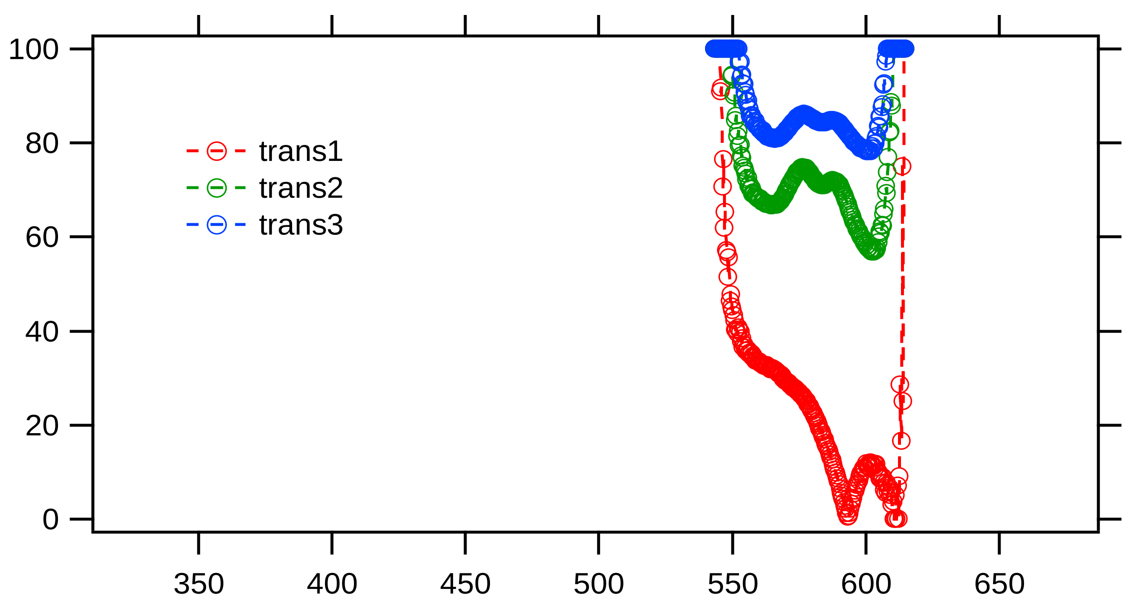
2. J.R. Dennison, “Electronic Properties of Materials with Application to Spacecraft Charging—Extension of Materials Database”, NASA Space Environments and Effects Program Fifth Quarterly Report, Oct, 1 2004 to Dec 31, 2004.

Appendix A

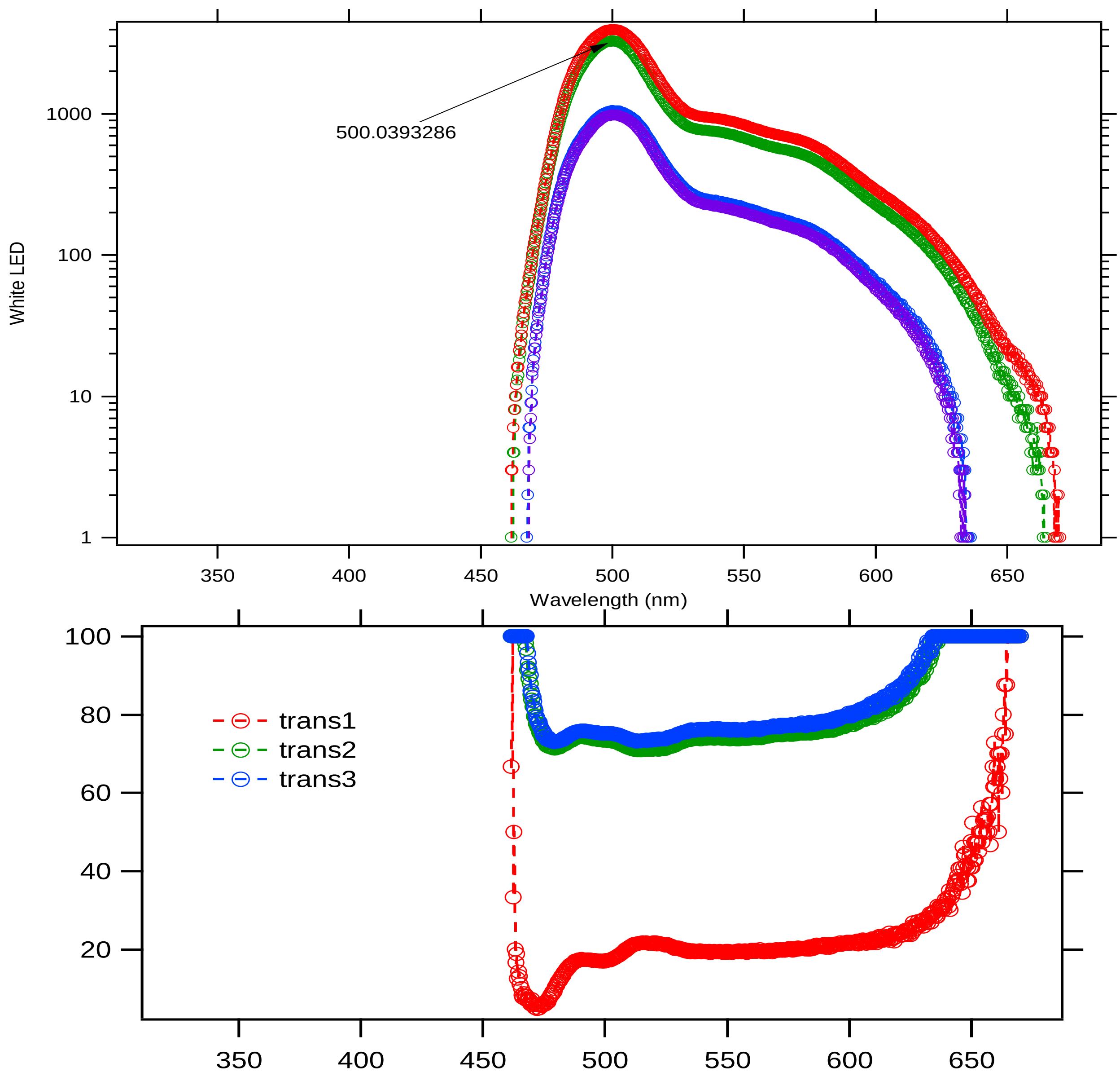
LED: Yellow

Peak Wavelength Measured (nm): 580.0
Spectrometer used: Ocean Optics
Purchased From: theledlight.com
Forward Voltage Typical (v): 1.94
Maximum (v): 2.4
Current (mA): 20
Calculated Resistor Value (Ohms): 163
Resistor Value Used (Ohms): 110

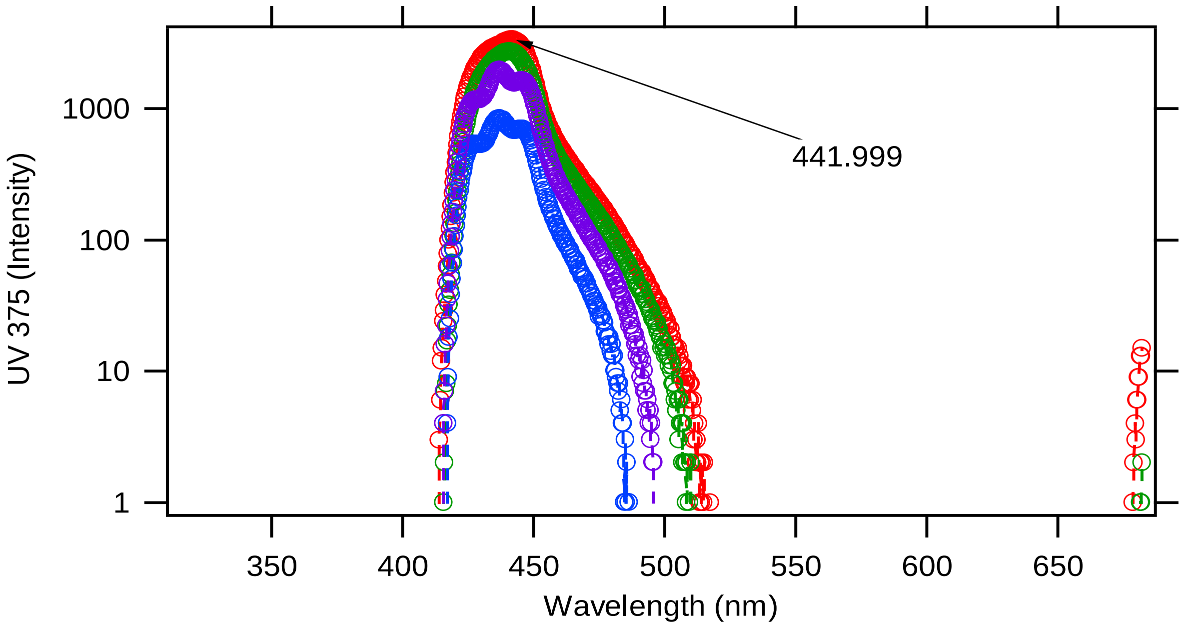


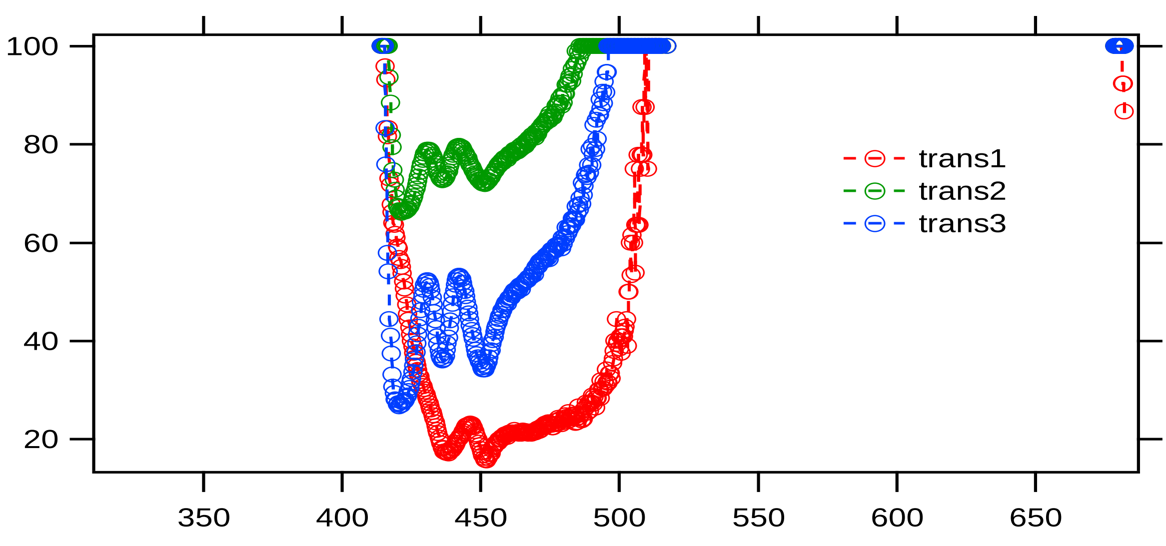


LED: White
Peak Wavelength Measured (nm): 500.0
Spectrometer used: Ocean Optics
Purchased From: theledlight.com
Forward Voltage Typical (v): 3.6
Maximum (v): 4.0
Current (mA): 20
Calculated Resistor Value (Ohms): 80
Resistor Value Used (Ohms): 70

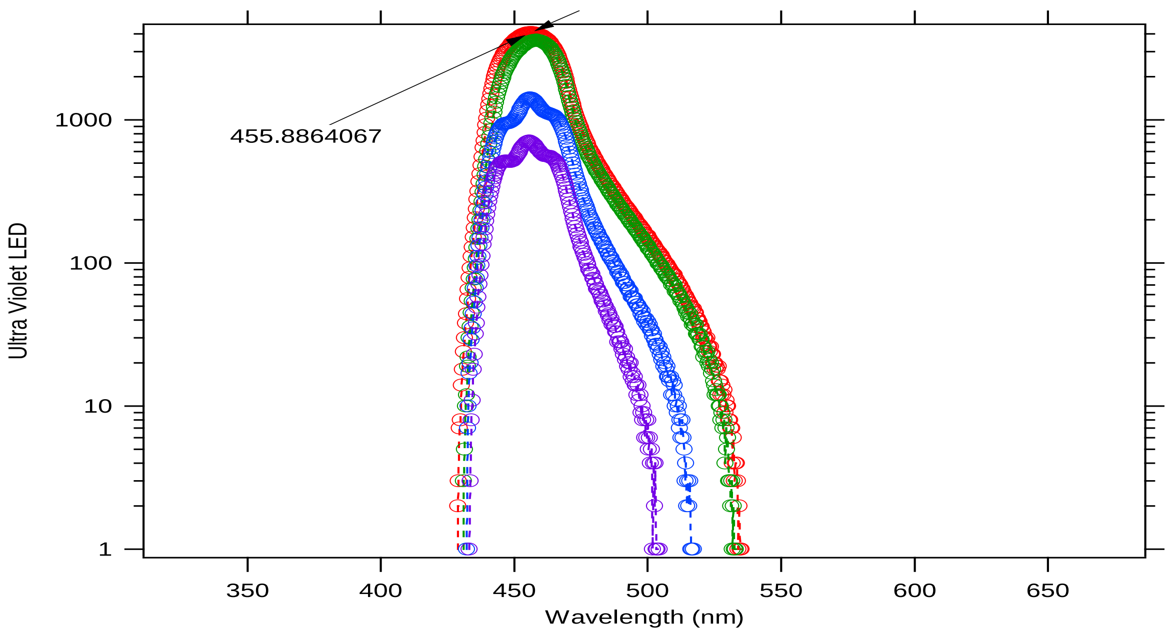


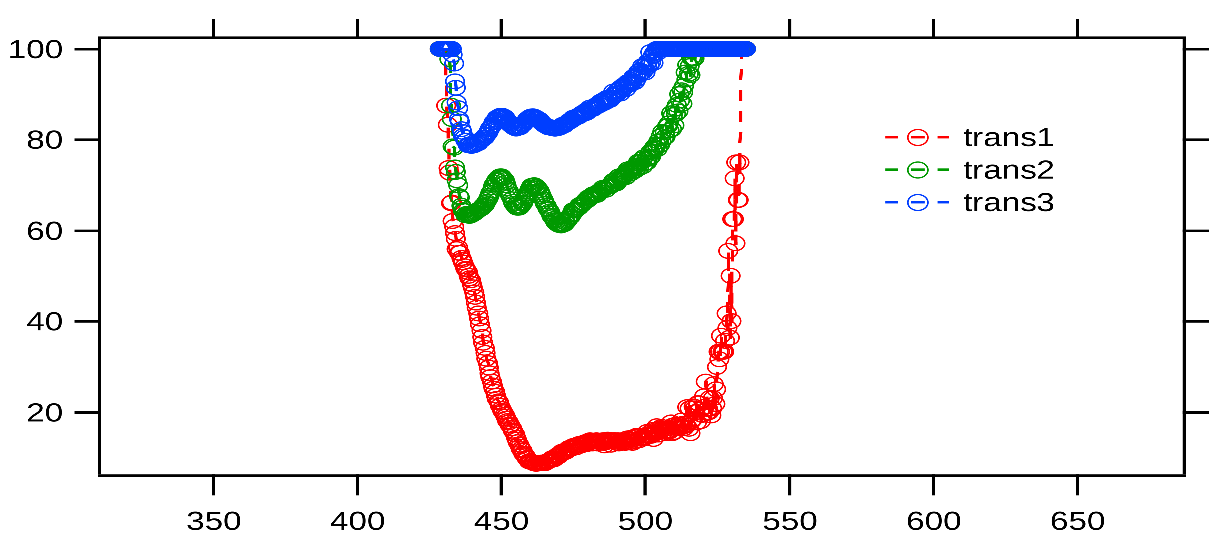
LED: UV 375 with 10 deg view angle
Peak Wavelength Measured (nm): 442.0
Spectrometer used: Ocean Optics
Purchased From: theledlight.com
Forward Voltage Typical (v): 3.5
Maximum (v): 4.0
Current (mA): 10
Calculated Resistor Value (Ohms): 170
Resistor Value Used (Ohms): 57



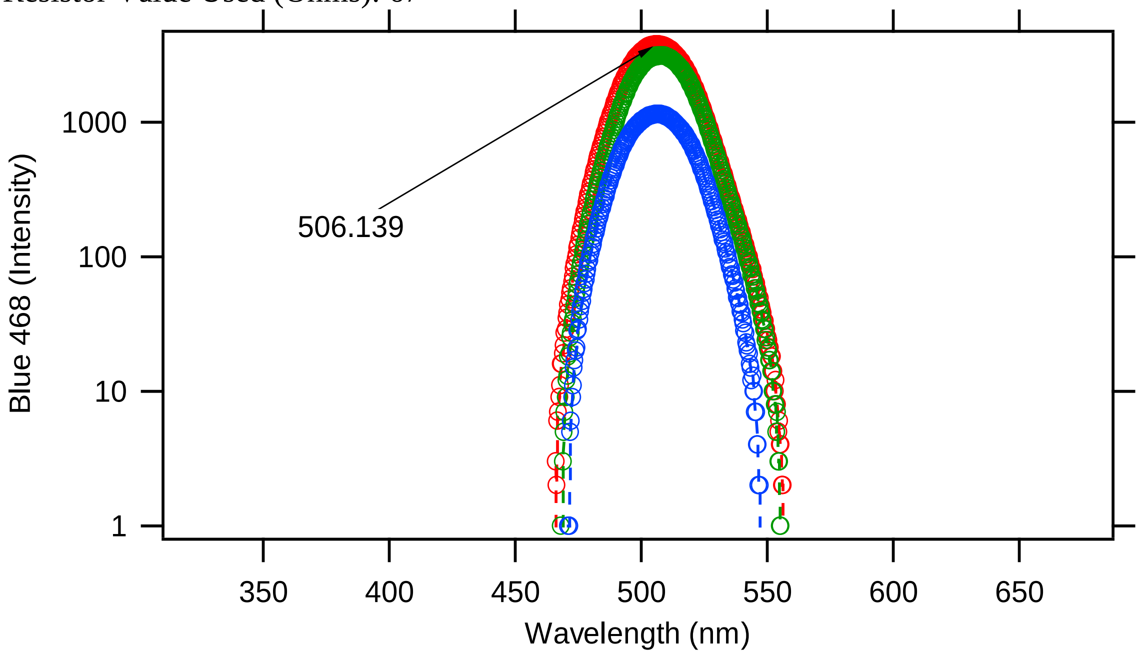


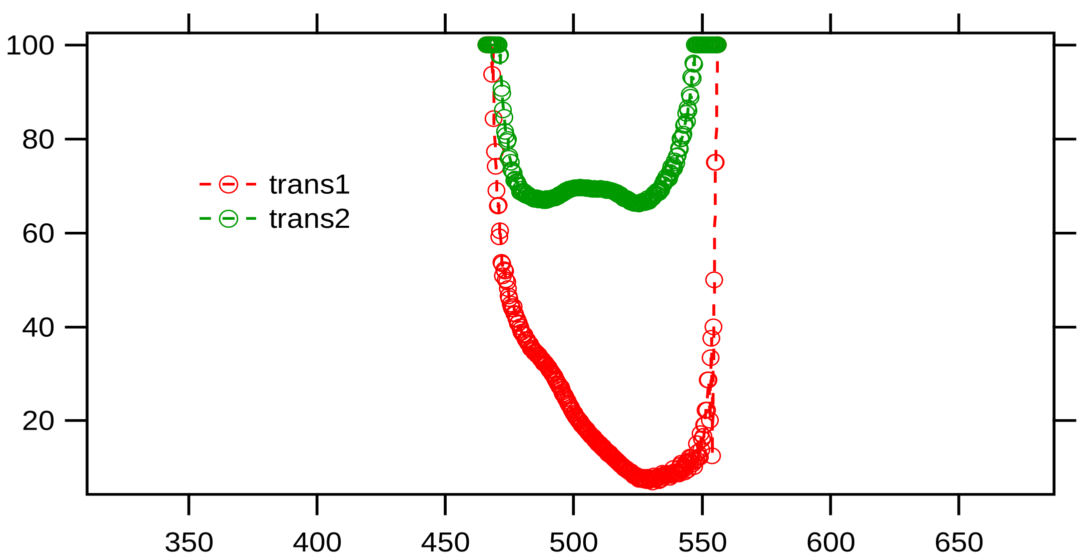
LED: UV 395
Peak Wavelength Measured (nm): 455.9
Spectrometer used: Ocean Optics
Purchased From: theledlight.com
Forward Voltage Typical (v): 3.7
Maximum (v): 4.2
Current (mA): 30
Calculated Resistor Value (Ohms): 50
Resistor Value Used (Ohms): 44



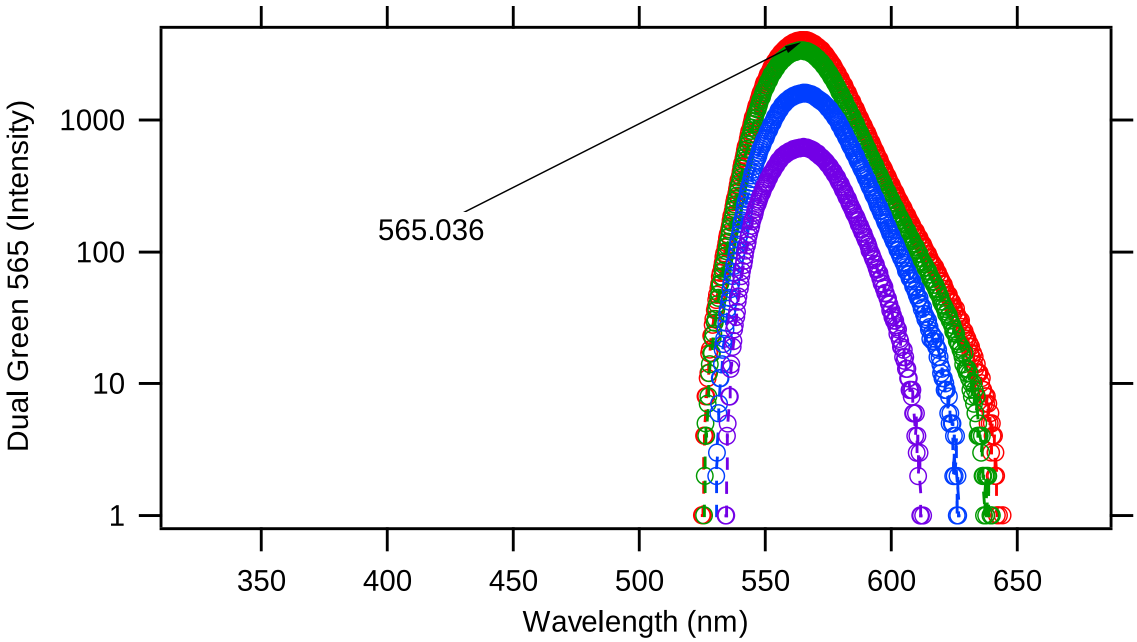


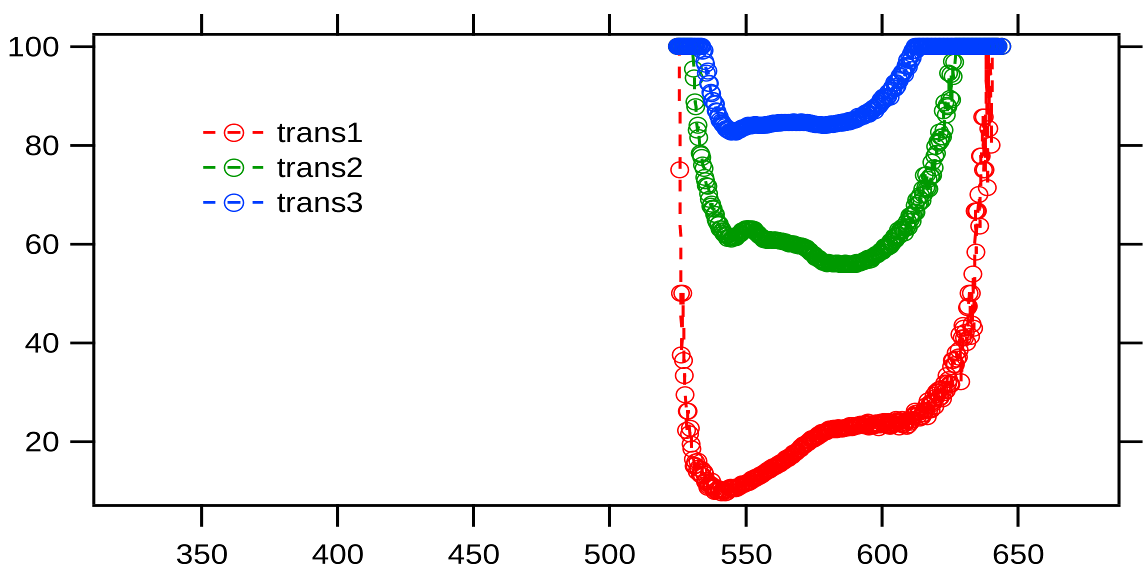
LED: Blue 468
Peak Wavelength Measured (nm): 506.1
Spectrometer used: Ocean Optics
Purchased From: theledlight.com
Forward Voltage Typical (v): 3.2
Maximum (v): 3.5
Current (mA): 20
Calculated Resistor Value (Ohms): 100
Resistor Value Used (Ohms): 67

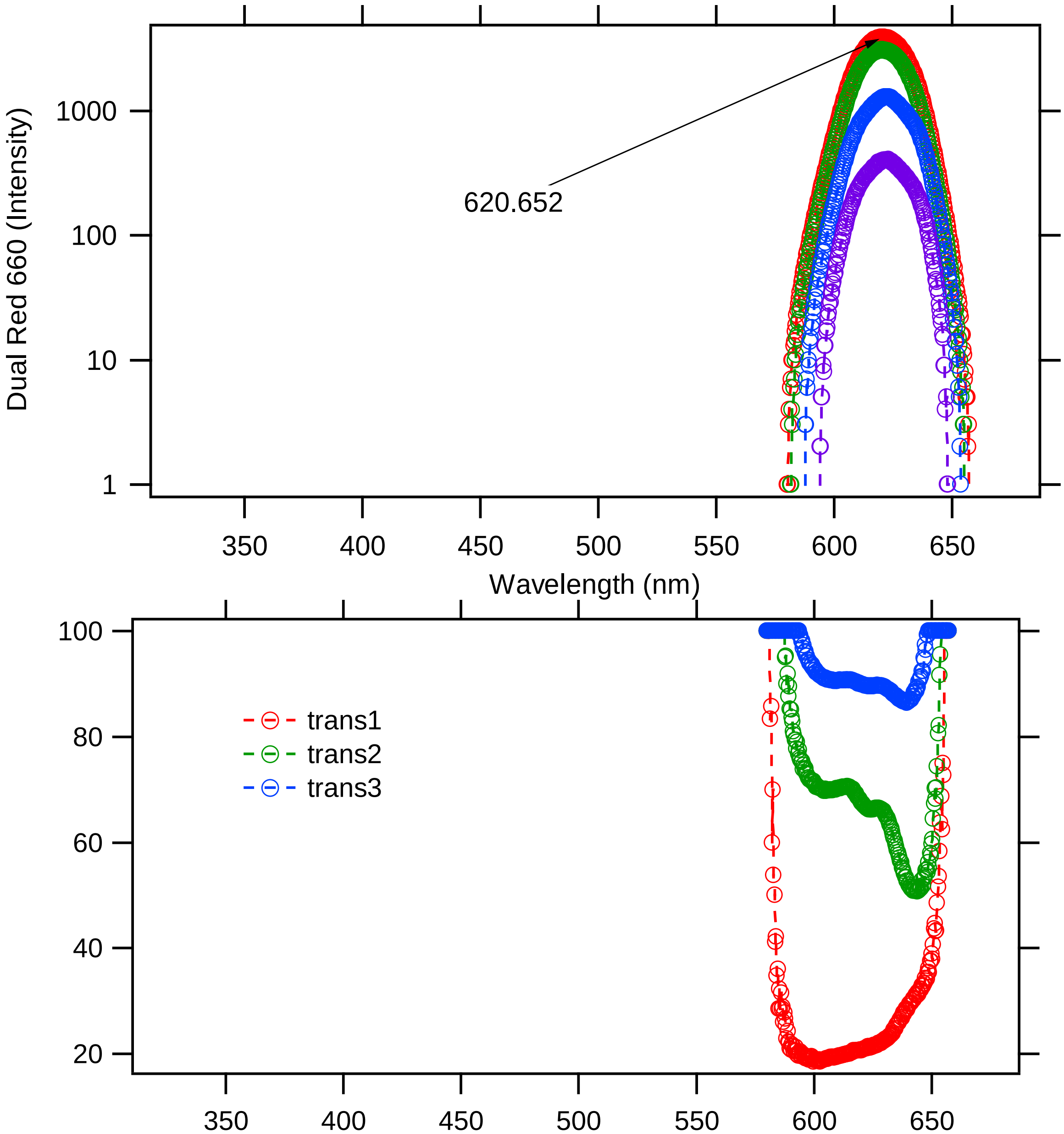




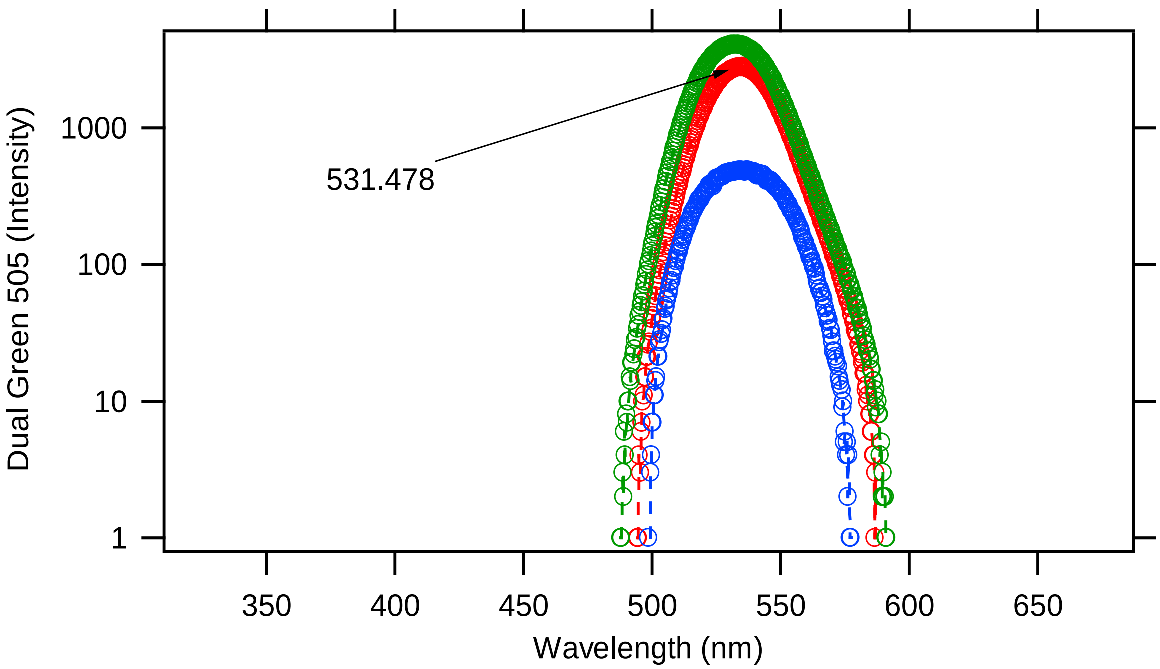
LED: Dual 565/660
Peak Wavelength Measured (nm): 565.0/620.7
Spectrometer used: Ocean Optics
Purchased From: Roithner Lasertech
Forward Voltage Typical (v): 2.2/1.9
Maximum (v): 2.4/2.3
Current (mA): 20/20
Calculated Resistor Value (Ohms): 150/165
Resistor Value Used (Ohms): 100/110

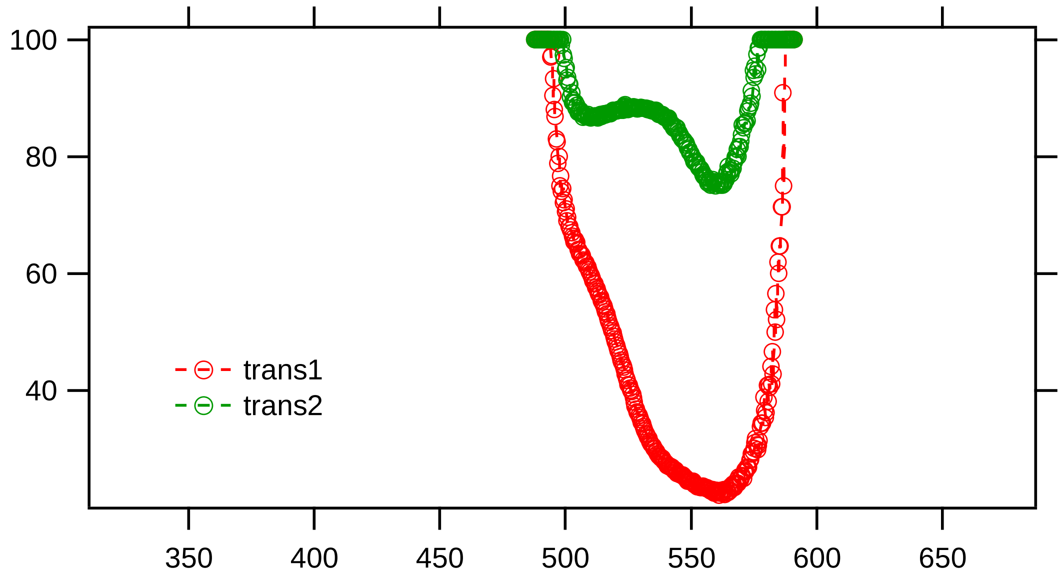


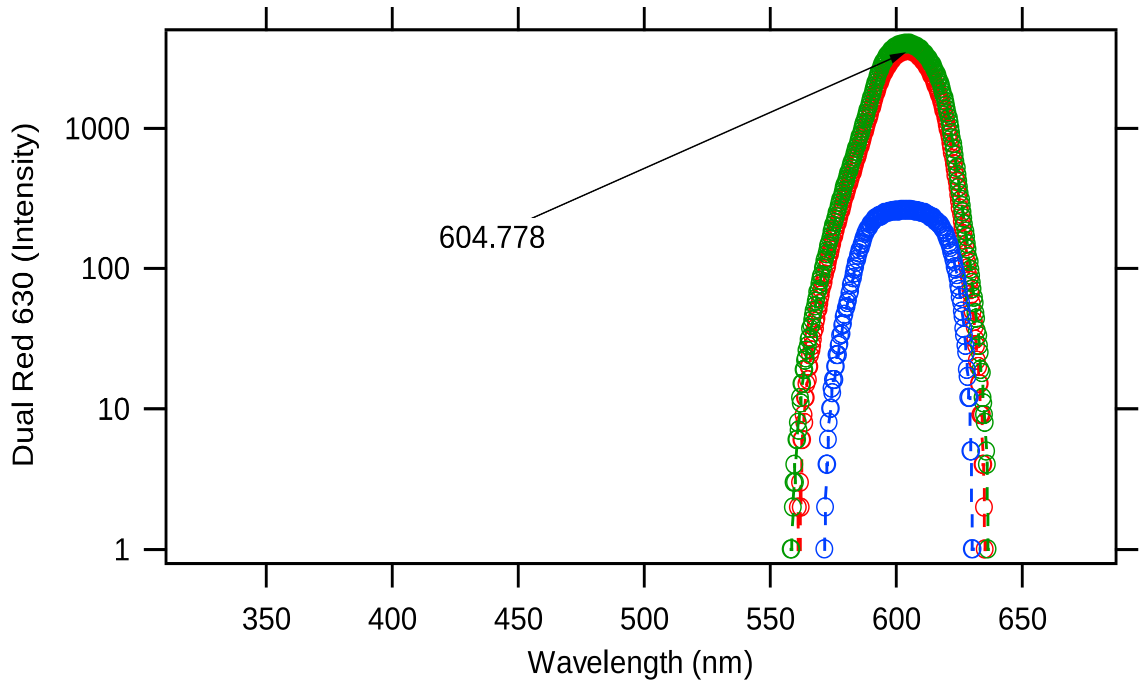


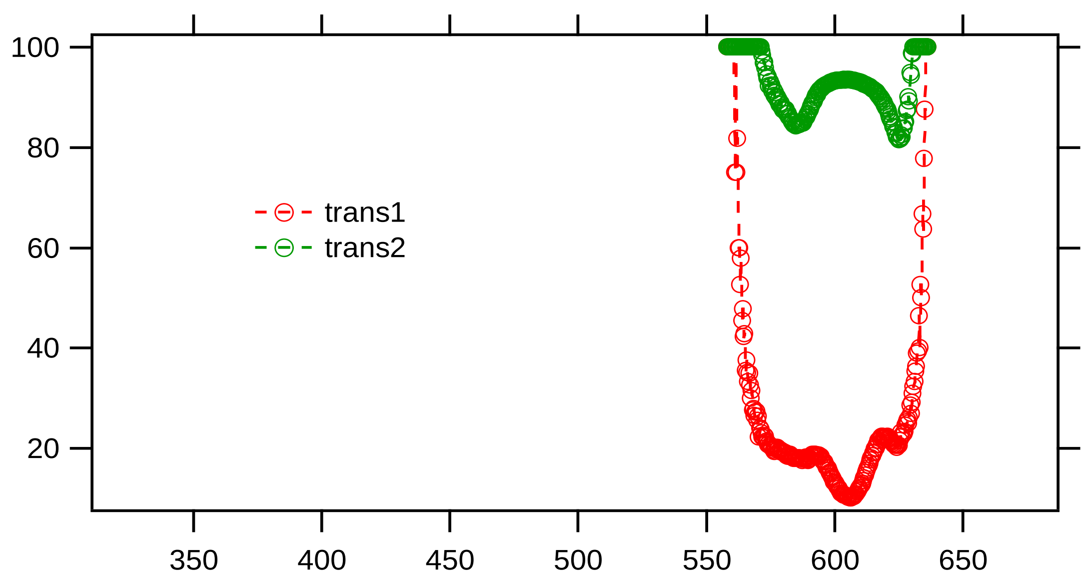

620.652
1000
100
10
1
Dual Red 660 (Intensity)
350
400
450
500
550
600
650
Wavelength (nm)
100
80
60
40
20
trans1
trans2
trans3

LED: Dual 505/630
Peak Wavelength Measured (nm): 531.5/604.8
Spectrometer used: Ocean Optics
Purchased From: Roithner Lasertech
Forward Voltage Typical (v): 3.5/2.0
Maximum (v): 4.3/2.3
Current (mA): 20/20
Calculated Resistor Value (Ohms): 85/160
Resistor Value Used (Ohms): 67/64



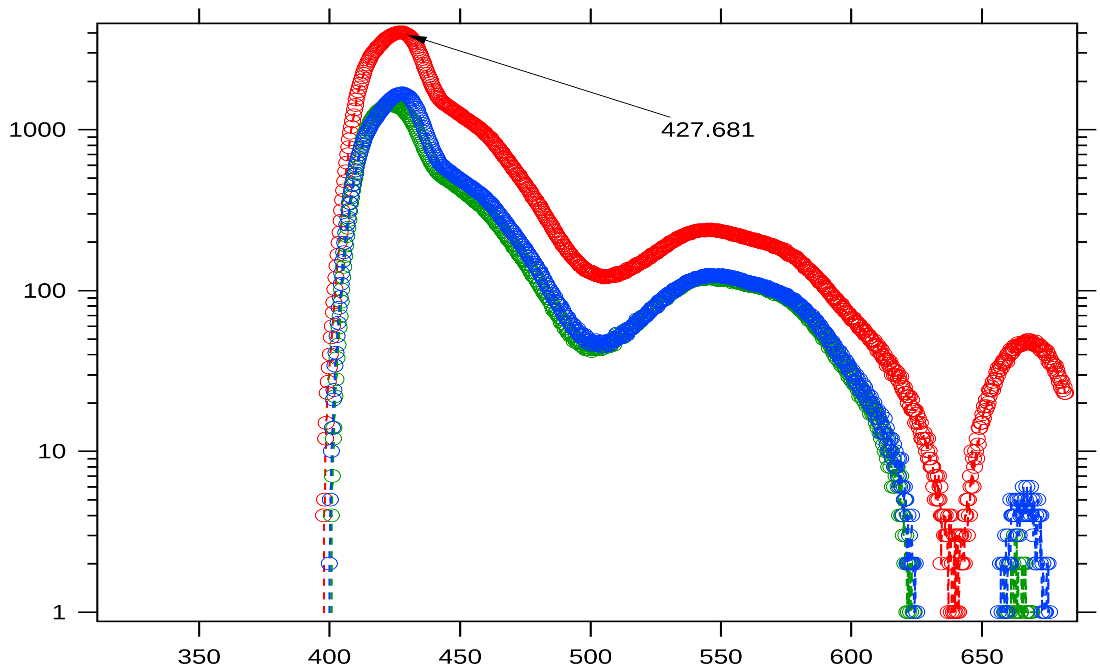


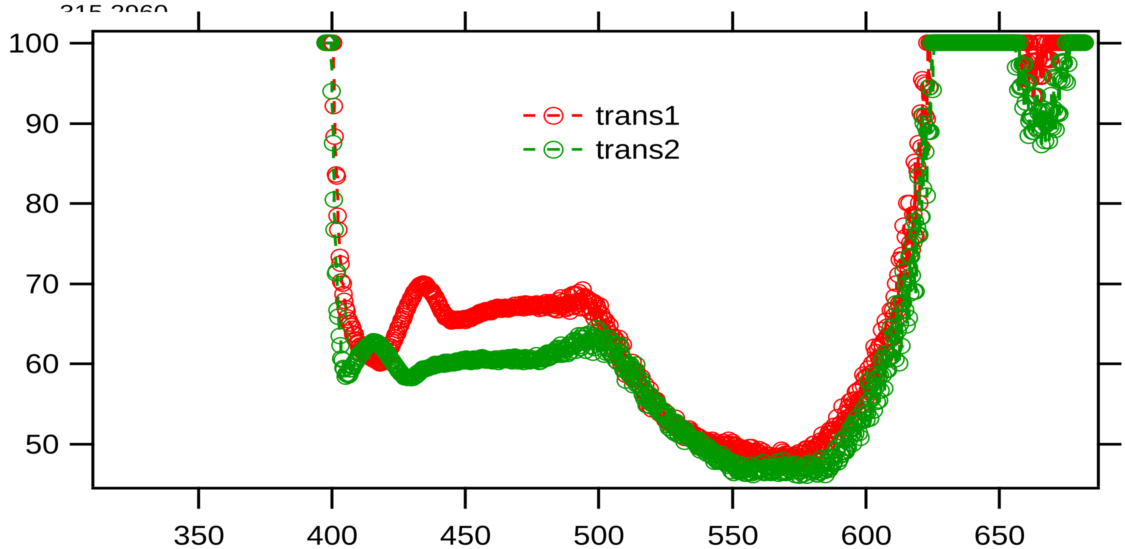




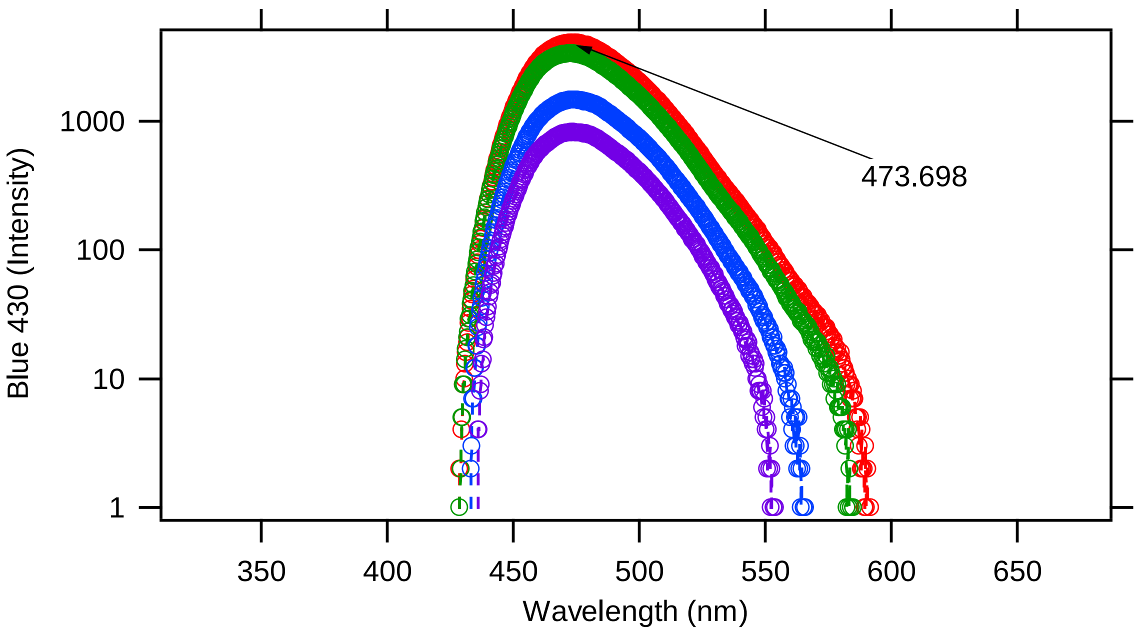
On these coated LED's for the first graph of each LED the green trace is an uncoated LED through the fiber, red is coated through fiber, blue is through coated and lens.

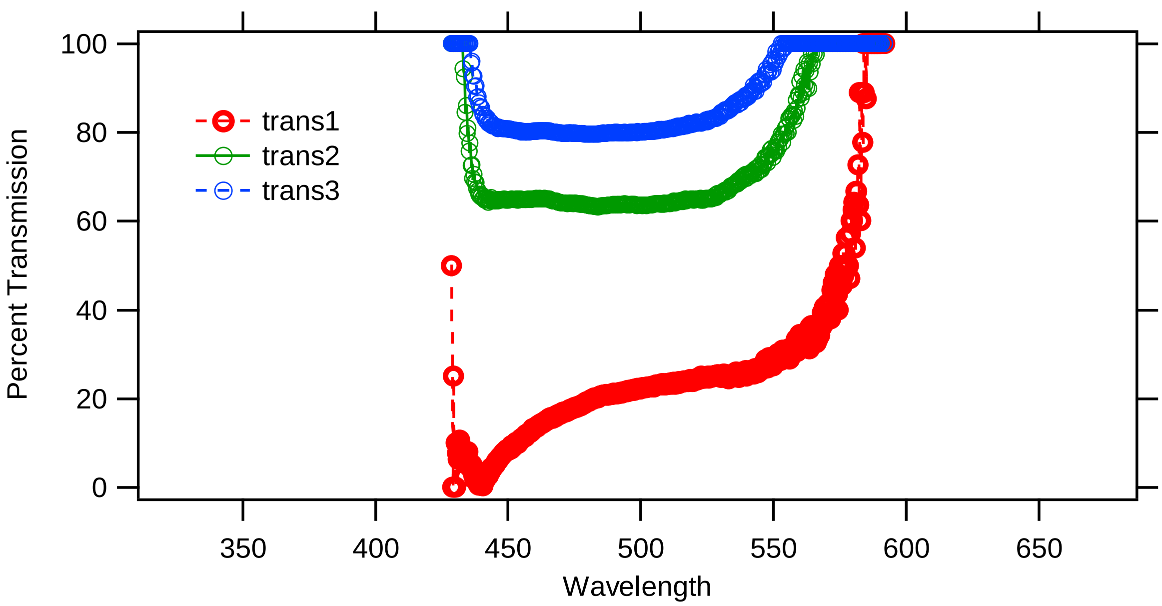
LED: UV 350
Peak Wavelength Measured (nm): 427.7
Spectrometer used: Ocean Optics
Purchased From: Roithner Lasertech
Forward Voltage Typical (v): 3.7
Maximum (v): 4.0
Current (mA): 20
Calculated Resistor Value (Ohms): 75
Resistor Value Used (Ohms): 50



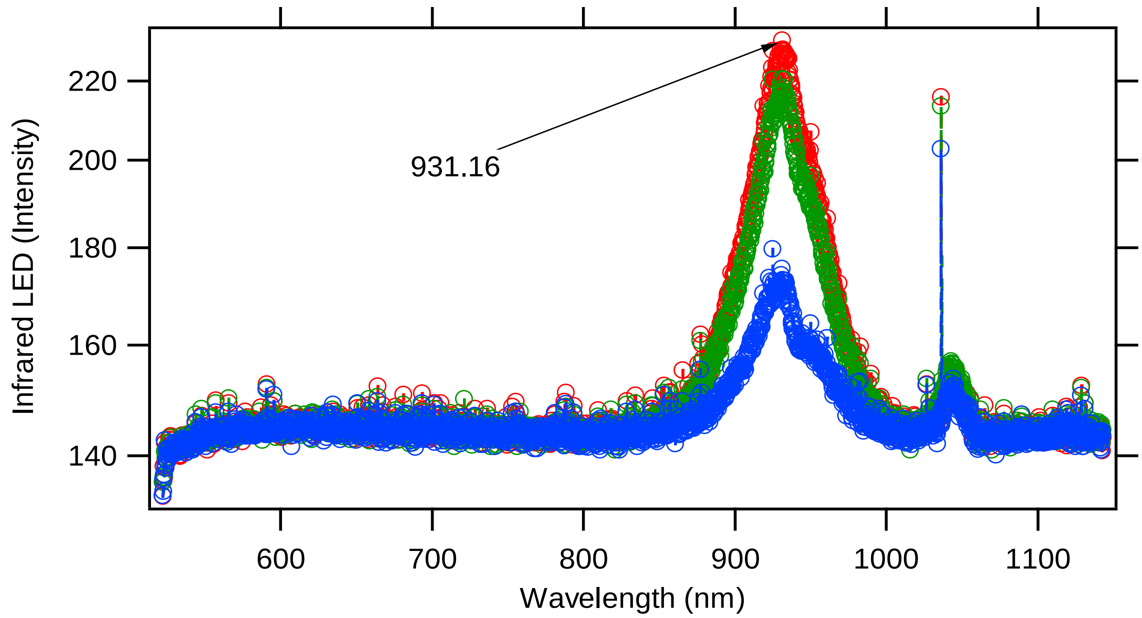


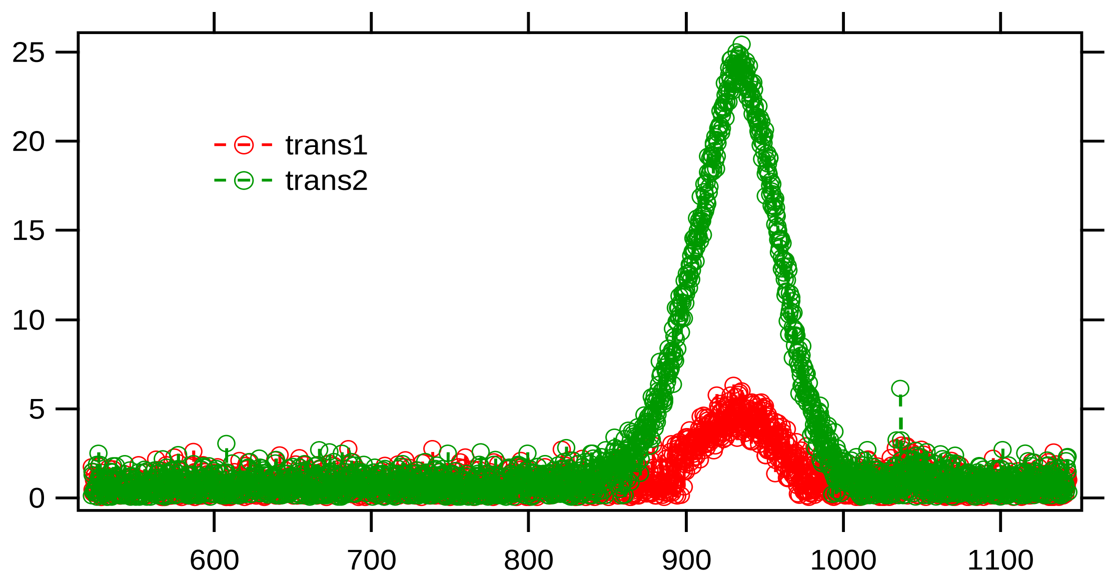
LED: Blue 430
Peak Wavelength Measured (nm): 473.7
Spectrometer used: Ocean Optics
Purchased From: Radio Shack
Forward Voltage Typical (v): 5.0
Maximum (v): 6.0
Current (mA): 30
Calculated Resistor Value (Ohms): 6
Resistor Value Used (Ohms): 7





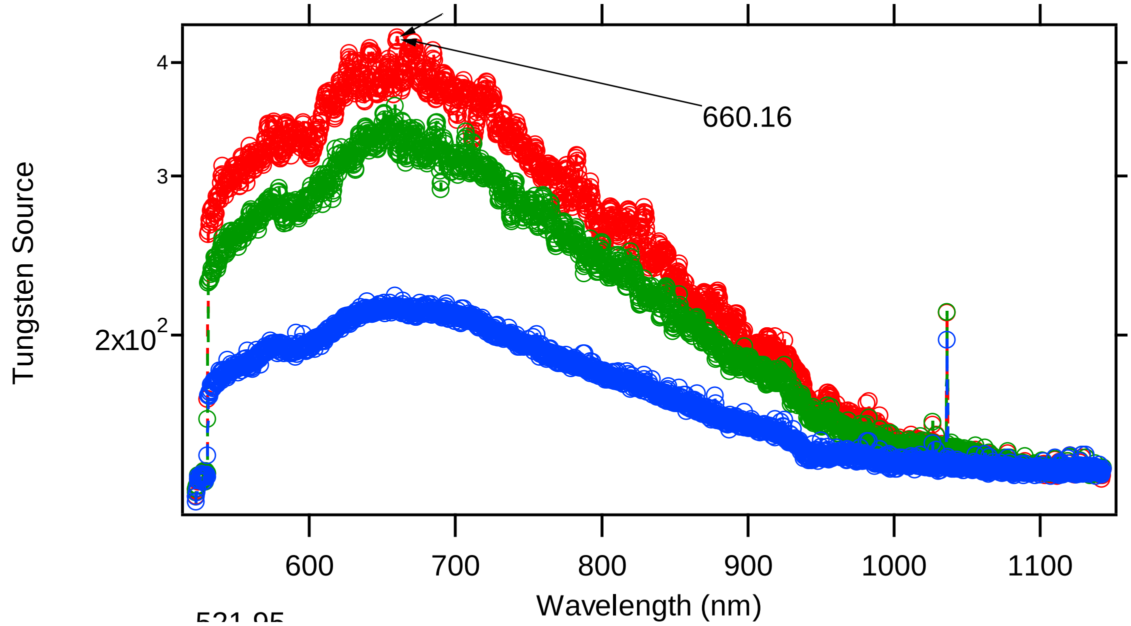
LED: Infrared 940
Peak Wavelength Measured (nm): 931.2
Spectrometer used: Ocean Optics USB 2000
Purchased From: Radio Shack
Forward Voltage Typical (v): 1.2
Maximum (v): 1.6
Current (mA): 100
Calculated Resistor Value (Ohms): 40
Resistor Value Used (Ohms): 40

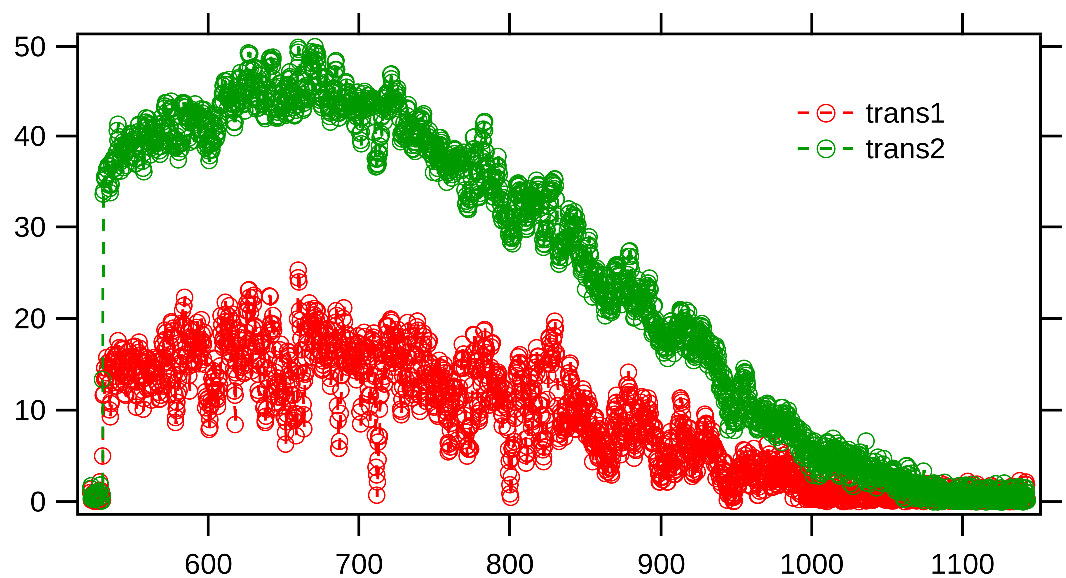




Light Source: Tungsten

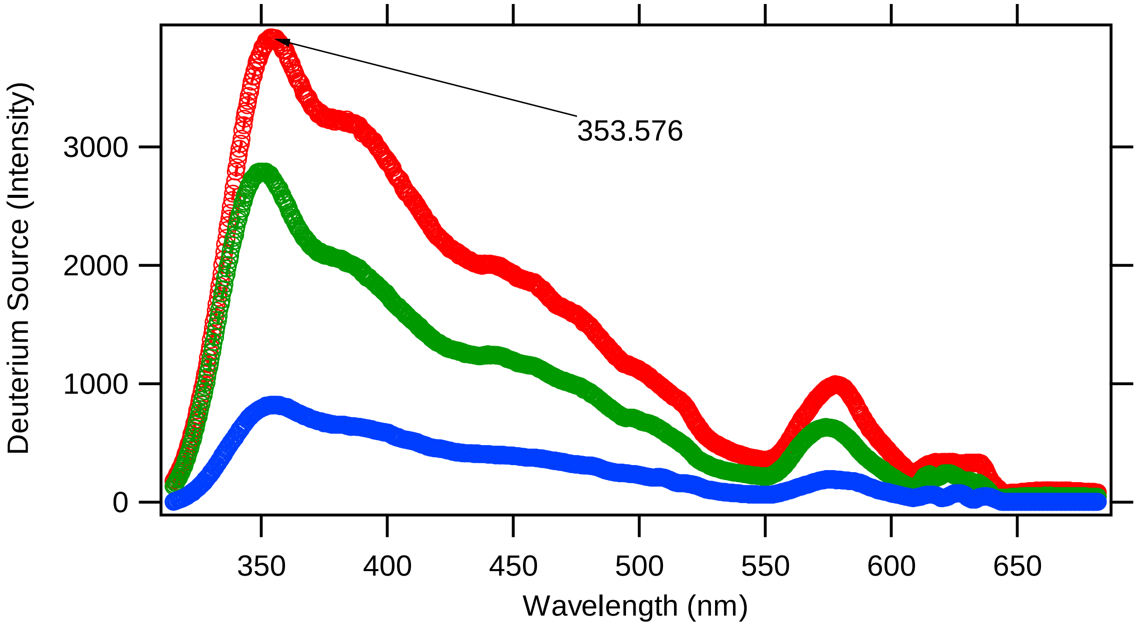
Peak Wavelength Measured (nm): 660.2
Spectrometer used: Ocean Optics USB 2000
Purchased From: Ocean Optics

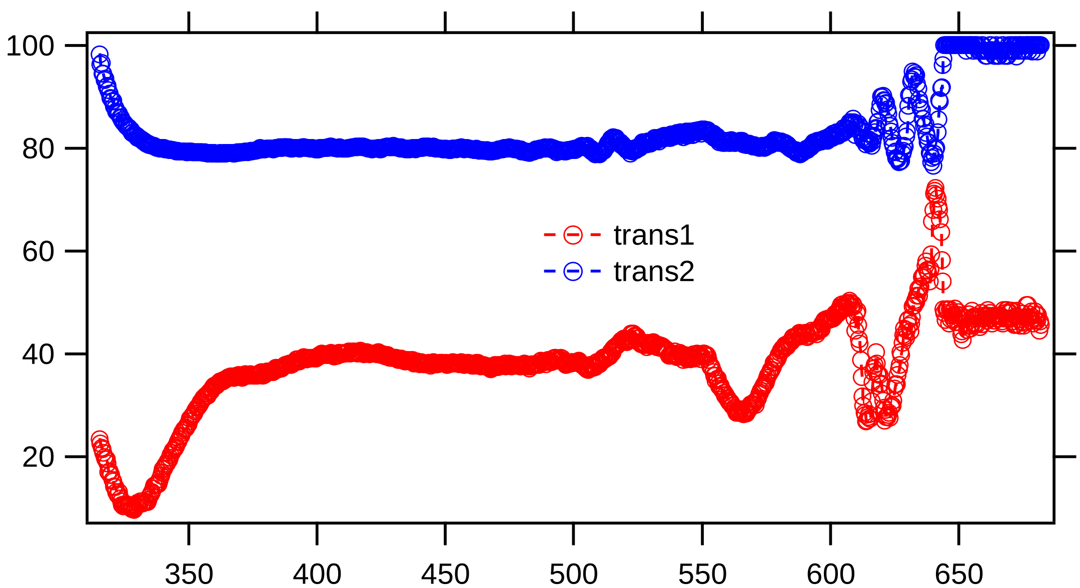




Light Source: UV Deuterium

Peak Wavelength Measured (nm): 353.6
Spectrometer used: Ocean Optics
Manufacture: Analytical Instrument Systems, Inc.
Model: D 1000 CE Remote





Appendix B
Equipment List

Epoxy:
!Epoxy Technology
Product: EPO-TEK 301
Batch No.: 58-3939/49-3939

Hot Plate:
Thermolyne Sybron Corporation
Model HP-A1915B
Type 1900 Hot Plate

Oven:
Thermolyne Sybron Corporation
Hot Plate Oven
OV-10600

Bottle Vacuum Pump:
The Welch Scientific Company
Duo-Seal Vacuum Pump

Spectrometers:
1- Ocean Optics
2- Ocean Optics USB 2000