SPECTRA OF THE MONTH

# MEASURING THE SPECTRUM OF HOLIDAY LIGHTS!

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## INTRO

# BACKGROUND OF APPLICATION

December is a month filled with secular and spiritual celebrations, with perhaps the most notable holiday being Christmas. Common Christmas traditions include putting up a Christmas tree, giving gifts to friends and family, and decorating the inside and outside of your living space with Christmas lights. Intricate light decorations have become so popular that some cities will host special festivals of lights for the holiday season, and individual will participate in competitions to see who can present the most grandiose light show outside their house. Originally, Christmas lights were constructed using inexpensive incandescent bulbs connected in series. This configuration made it challenging to identify and fix issues if one bulb malfunctioned, as the entire string of lights would lose power. Nowadays, lights are commonly wired in parallel, despite the increased cost. This design allows for easier troubleshooting, as a malfunctioning bulb is easily identified and replaced without affecting the entire string. Furthermore, modern Christmas lights often feature energy-efficient LED bulbs, which generate less heat. Although incandescent bulbs are still available at a lower cost, they are less common in today's market.

In this experiment, our primary objective was to gauge the effectiveness of different Christmas light setups in our local neighborhood. To achieve this, we conducted field measurements using a meticulously calibrated irradiance system to accurately determine the true intensity of the lights. We systematically measured the lights of nine houses and subsequently compared the resulting spectra. The focus was to discern whether distinguishable differences between incandescent and LED bulbs could be identified from a distance


**FIGURE #1** Examples of a Christmas light setup measured for this experiment, including one that was determined to be (left) lit with incandescent bulbs and (right) one that was lit with LED bulbs.

# DESCRIPTION OF SPECTROSCOPY SETUP

The setup for this experiment (Figure 2) utilized our new NEXOS Spectrometer AvaSpec-PCT2048CL. This compact instrument is the next-generation photonics backbone spectrometer, designed to empower a wide range of applications in various industries. This device is built using our new semi-automated manufacturing technique that ensures higher levels of consistency and reproducibility unit-to-unit. The compact spectrometer offers USB2.0 communication as well as RS232 and SPI communication protocols, a CMOS linear array detector, ultra-low stray light as low as 0.1%, and a signal/ noise ratio of 375:1. Furthermore, this spectrometer can be customized with a wide range of gratings (13 total available) and the replaceable slit option is now standard for non-OEM units, which provides even more flexibility for a variety of application needs. The unit used in this experiment was optimized for the visible spectrum as well as part of the UV and NIR spectrum with a range of 300-800 nm.


**FIGURE #** Experimental setup for Christmas light measurements. The cosine corrector was attached to one end of the fiber optic cable while the other end was attached to the spectrometer. The spectrometer was connected to the tablet via USB2.0 connection and was carried in a small backpack during field measurements (not pictured).

Rather than employing one of our Avantes light sources, we utilized the light emitted by the Christmas lights being measured as the light source for this experiment. Other accessories used for this experiment included a 600-micron core fiber optic cable (FC-UVIR600-1-BX), a direct-attach cosine corrector (CC-VIS/NIR) that was attached to the fiber optic cable to measure the Christmas light setups, a Microsoft Surface Go 3 tablet to take field measurements, and a small backpack to hold the spectrometer while measurements were taken.

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# DESCRIPTION OF METHODOLOGY

The light samples used for this experiment were decorative setups in our local neighborhood. No preparation was performed on the samples. Measurements were taken from a similar distance to average the color peaks present in the Christmas lights.

For data analysis, we used the Absolute Irradiance mode in AvaSoft, our custom software package. This mode converts the raw counts measured by the spectrometer (i.e., scope mode) into an intensity measurement (µW/cm^2/nm) that can be used to rigorously quantify the data measured by the instrument. This conversion is done through the use of an irradiance calibration of the spectrometer, which is performed in-house using a NIST-traceable light source. We used an integration time of 800 milliseconds, which can be adjusted to increase or decrease the amount of light being measured at one time and affects the overall magnitude of the reported spectrum. We set averaging to 10 to provide a smoother spectrum and to avoid outlier data affecting the analysis.

# TEST DATA AND RESULTS

Displayed below are the irradiance spectra of the samples in absolute irradiance mode for each measurement.

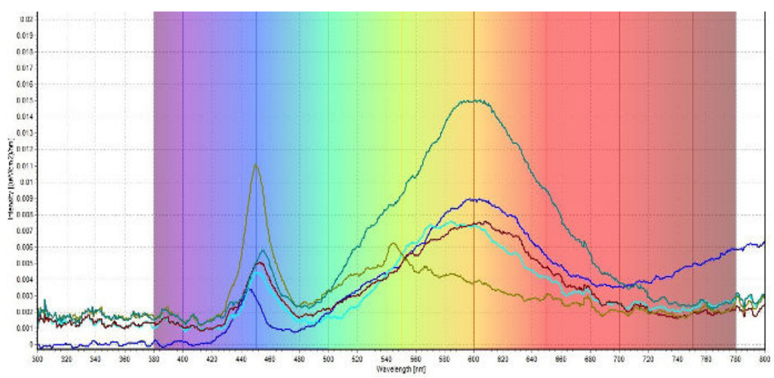

**FIGURE #3:** Irradiance spectra of samples determined to be LED setups.

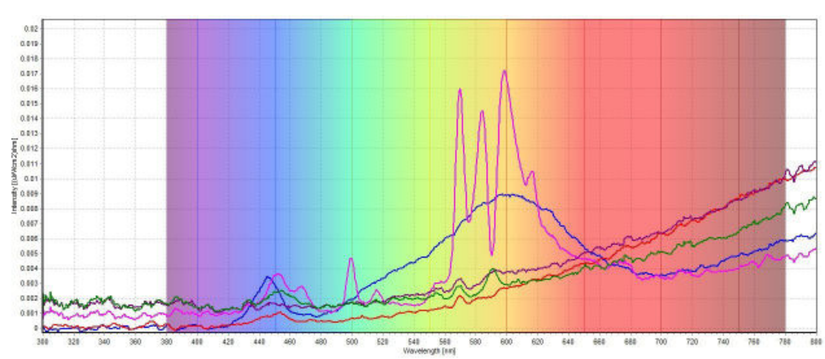

**FIGURE #4:** Irradiance spectra of samples determined to be incandescent setups.

# TEST DATA AND RESULTS AND ANALYSIS

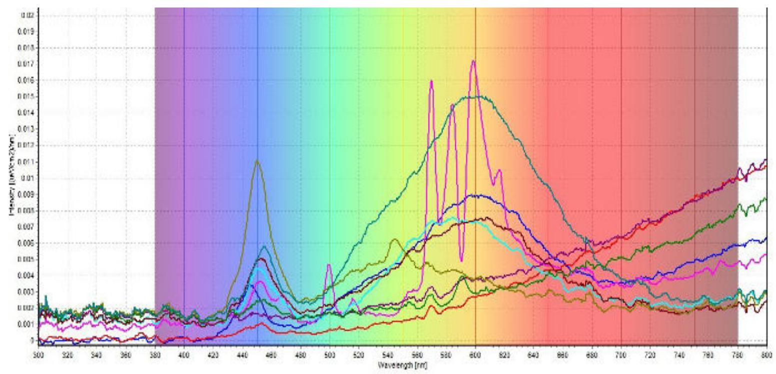

**FIGURE #5:** Irradiance spectra of all samples, shown together for comparison.

Analyzing the spectra, there appears to be a general trend of rising slopes in the NIR region for incandescent bulbs and lower magnitudes with slopes near zero in this region for LED bulbs. Additionally, the LED bulbs showed some specific peaks in the visible range that could be attributed to their specific colors. The data sets were categorized by these metrics into LED setups (Figure 3) and incandescent setups (Figure 4). Two data sets were of particular interest during analysis. House 1, designated as the dark blue line, had a hump in the 540-660 nm region that was determined to be LEDs, though still had a rising slope in the NIR region. This seems to indicate that this house had both LED and incandescent lights in their Christmas light setup. Because of this, the data for House 1 was included in both the LED and incandescent setups. House 3, designated as the pink/magenta line, had many additional distinct peaks in the 560-620 nm region. Upon further analysis, these peaks seem to correlate with metal halide light bulbs, which are often used in streetlights. Indeed, it can be seen in the photo taken of this house that a nearby streetlight likely had some effect on the measured spectra (Figure 6).

**FIGURE #6** Photo of House 3, showing the streetlight that was measured in the data set.

# CONCLUSION

In conclusion, the present experiment highlights the use of our new NEXOS spectrometer in determining spectral differences between LED and incandescent Christmas light setups in the field. Simple comparison of a rising slope in the NIR range and distinct peaks in the visible range were used to determine the difference between the LED and incandescent bulb setups, while other peaks were attributed to streetlights rather than Christmas lights. The AvaSpec-PCT2048CL is an ideal solution for OEM applications or any other cases where compact form factor is critical, such as field work.

## CONTACT

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