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CRITICAL DESIGN FACTORS IN NVIS FILTER DESIGN

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Critical Design Factors in NVIS Filter Design
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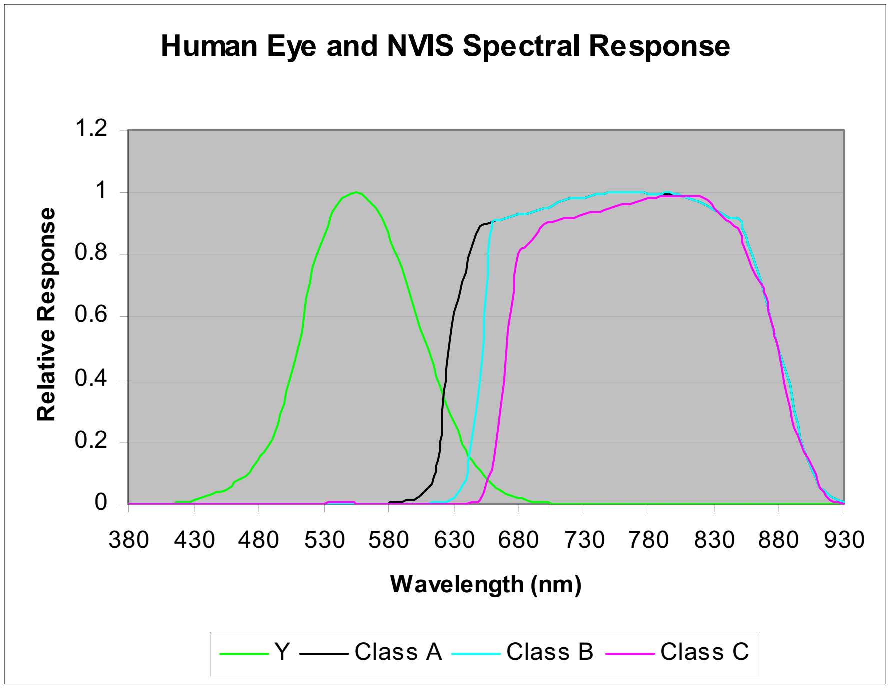
Introduction

The design of filters for NVIS compatible lighting components requires the lighting engineer to carefully consider both the spectral response characteristics of the human eye and the spectral response characteristics of the NVIS goggles. The specific requirements governing the luminance, chromaticity and NVIS Radiance of NVIS compatible lighting components is described in MIL-STD-3009. This specification also describes the requirements of measurement instrumentation capable of properly evaluating these characteristics.

It is easy to casually glance at the broad spectral response characteristics of the NVIS goggles and specify filters with deep attenuation in the near infrared spectrum in order to avoid the accumulation of NR in the regions where the goggles are most sensitive. This paper will show that the most critical spectral region for NVIS filter design is the overlap wavelengths where the spectral response characteristics of the human eye is falling and the spectral response of the NVIS goggles is rising. It is in this overlap region that most of the NR of a lighting component is accumulated and the area where NVIS filter design is most critical.

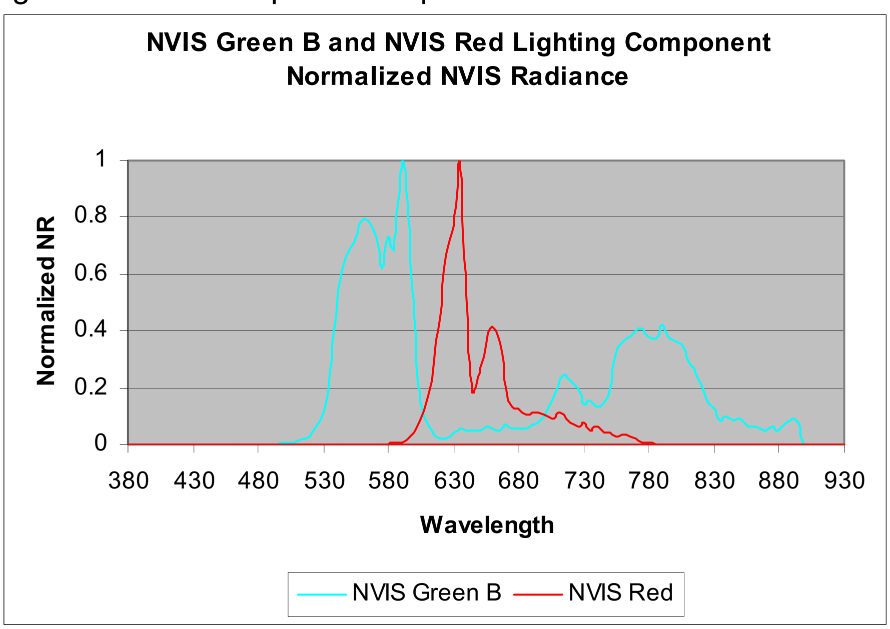
Comparison of the Spectral Response of the Human Eye and the NVIS

Figure 1 shows the spectral response characteristics of the human eye and the NVIS Class A, B and C. The peak spectral response of the human occurs at 555 nanometers whereas the peak response of the NVIS goggles occurs at approximately 800 nanometers. Note, however, that there is a substantial overlap of the NVIS spectral response with the visual wavelengths between 580 nanometers and 700 nanometers. The Class A NVIS has the greatest overlap in the visual region followed by NVIS Class B and NVIS Class C. The decreased visual response of the Class B and Class C NVIS is intentional because they were designed to allow red warning indicators and multicolor CRT displays within fast jets that fly at higher altitudes where NVIS sensitivity is not as critical.



Comparison Of Human Eye and NVIS Spectral Response
<u>Figure 1</u>

In order to clearly define the critical wavelengths for NVIS filter design, Figure 2 shows normalized NVIS Radiance plots of a Class A NVIS Green B and Class B NVIS Red lighting component. Note that the peak NVIS Radiance in both cases occurs between 580 nanometers and 700 nanometers in the visual wavelength overlap region of the NVIS spectral response curve.

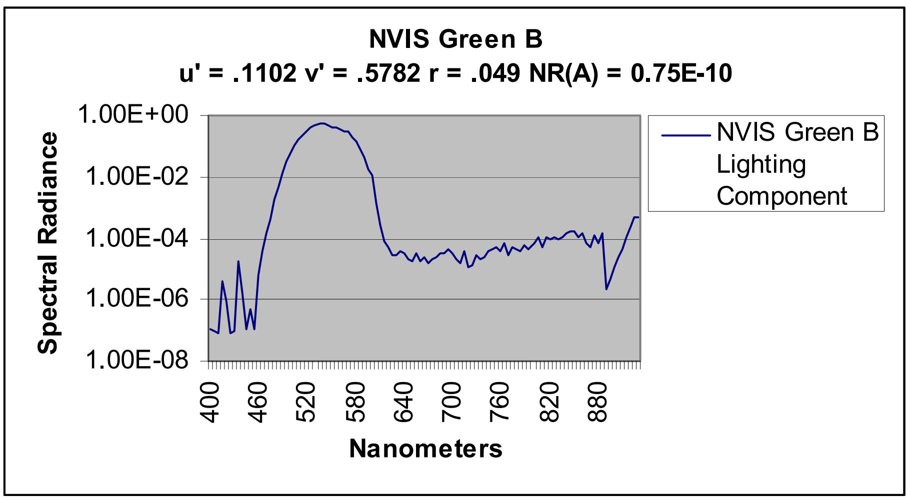


Comparison of NVIS Green B and NVIS Red NR
<u>Figure 2</u>

The NVIS response in the visual region occurs for two reasons: First, all NVIS goggles, particularly the Class A and Class C NVIS, have attenuated but measurable visible response. Second, and most important, the slope of the lighting component filter design on the long wavelength side determines how much residual energy of the lighting component will be visible to the NVIS goggles at wavelengths where the goggles are increasing to maximum sensitivity. Therefore, filter characteristics in the overlap region of 580 nanometers to 700 nanometers is the most critical for NVIS Radiance.

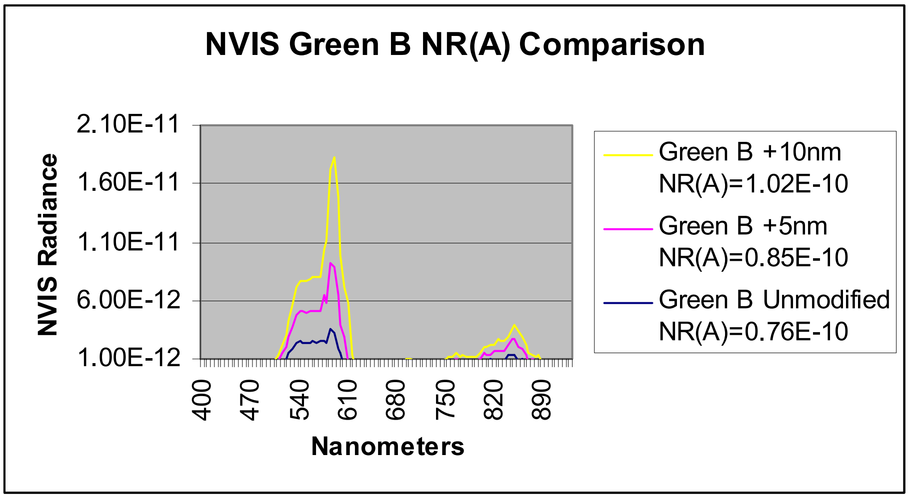
Construction of a Sample NVIS Green B Filter

Figure 3 shows the spectral radiance characteristics of an incandescent light source that has been filtered so that it meets the criteria as defined in MIL-STD-3009 for an NVIS Green B advisory lighting component. The filter consists of a green acrylic filter element and near-infrared absorbing glass. Both filter elements were chosen to provide sharp cutoff characteristics in the visible overlap region.



NVIS Green B Spectral Radiance
Figure 3

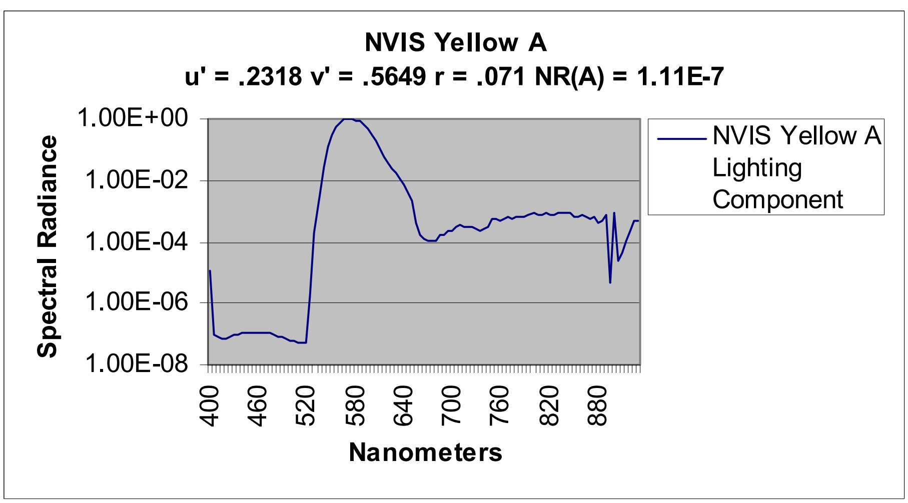
Figure 4 shows the NVIS radiance plot of the lighting component shown in Figure 3 and the same lighting component mathematically modified to extend the long wavelength side of the spectral radiance by 5 and 10 nanometers respectively. Even though the chromaticity radius of the lighting component has shifted only 0.003 and is well within specification limits, note the rapid rise of the peak NR.



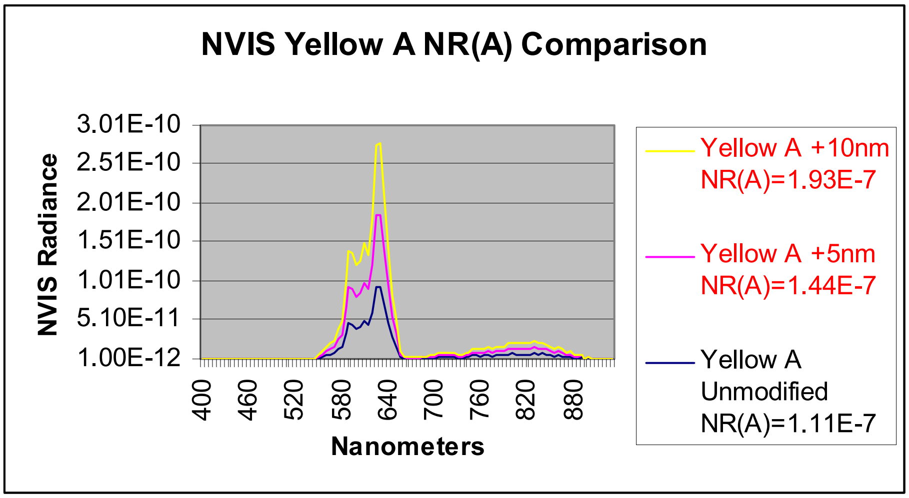
NVIS Green B NVIS Radiance Comparison
Figure 4

Crowding the Class A NVIS Spectral Response Curve with NVIS Yellow

While a 10 nanometer shift in the NVIS Green B filter did not produce excessive NR, the problem becomes more complex as the spectral radiance of the lighting component approaches the rising edge of the NVIS spectral response. Figure 5 and Figure 6 show the spectral radiance and the NR of an NVIS Yellow Class A lighting component. Since the peak spectral radiance of NVIS Yellow A is much closer to the rising edge of the Class A NVIS spectral response, the NR climbs much more rapidly as the filter is modified by 5 and 10 nanometers. In this case, the NR has increased by 74% and the only spectral radiance curve that does not produce excessive NR is the unmodified data.



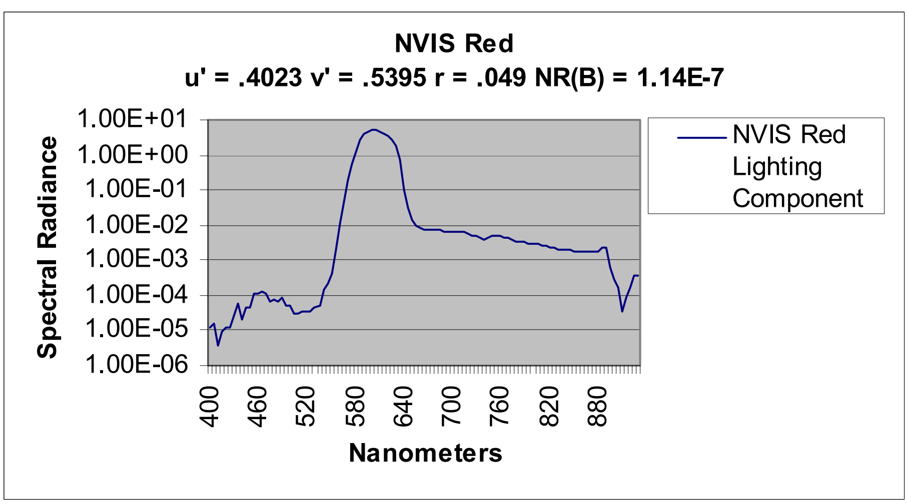
NVIS Yellow Class A Spectral Radiance
Figure 5



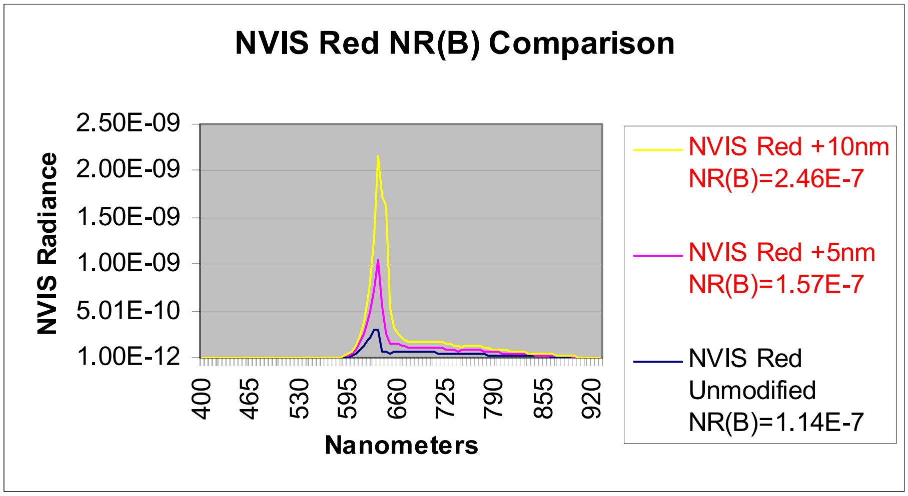
NVIS Yellow A NVIS Radiance Comparison
Figure 6

Unique Problems with Class B NVIS Red Warning Displays

The design of an NVIS Red lighting component presents several unique problems not present with other NVIS colors. First, the specified NVIS Red color is very close to the rising edge of the Class B NVIS spectral response. Second, the spectral radiance of an NVIS Red display is located in a wavelength region where the spectral response of the human eye is rapidly diminishing. This means more spectral radiance is required to produce luminance and this additional spectral radiance creates additional NR. These two factors together make NVIS Red filters the most difficult to design and specify, requiring very efficient filters manufactured to exacting tolerances. Figure 7 shows the spectral radiance of a compliant NVIS red warning display. Figure 8 shows the compliant NR and the filter modified by 5 and 10 nanometers respectively showing a 210% increase in NR(B) at 10 nanometers.



NVIS Red Spectral Radiance
Figure 7

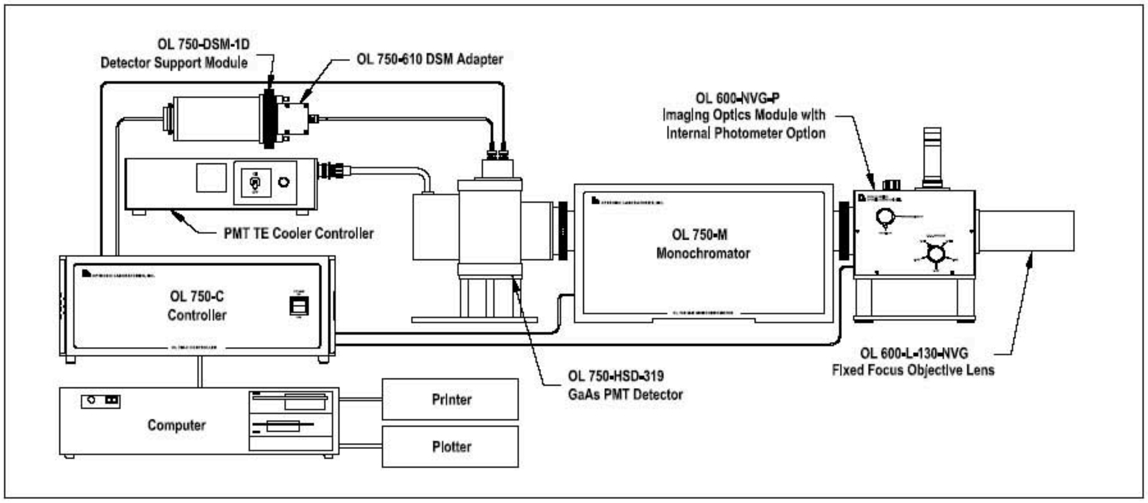


NVIS Red NVIS Radiance Comparison
<u>Figure 8</u>

Analysis and Manufacture of Proposed Filter Designs

It is important to analyze any proposed filter design with an analytical spectroradiometer fully compliant with Appendix A of MIL-STD-3009. A fully compliant spectroradiometer system designed specifically for NVIS measurement is shown in Figure 9. The basic system consists of an input objective lens, measurement apertures, a high efficiency Czerny-Turner monochromator, a cooled GaAs photomultiplier and a microprocessor-based controller.

Once a filter design is qualified, care must be taken to write detailed manufacturing and quality control procedures to insure that a filter design remains as qualified. This includes incoming inspection procedures of raw materials and filter elements, exacting specifications of any adhesives and sealants used and detailed assembly procedures. All NVIS compliant lighting components should be routinely inspected against design parameters to insure that nothing within the manufacturing process has changed.



Compliant NVIS Spectroradiometer
Figure 9

Conclusions

The specification and design of filters for NVIS compliant lighting components requires attention to detail in order to manufacture a product that is both consistent and compliant. Care should be taken in the design to avoid drifts in filter characteristics, particularly in the visible/NVIS overlap region of 580 nanometers to 700 nanometers where most of the NR of a lighting component is accumulated. Particular care should be given to NVIS Yellow and NVIS Red warning indicators that are particularly sensitive to filter characteristics due to their proximity to the rising edge of the NVIS response curve.