Design of Efficient Filters for Full-Color Displays Used with Night Vision Devices.

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ABSTRACT

The red end of the desired "full-color spectrum" from military cockpit displays conflicts with the response of night vision devices, and therefore both must be filtered to be mutually compatible. Active Matrix Liquid Crystal Displays (AMLCD) require a properly chosen light source and built-in pixel color filters to produce full-color displays. The design of such filters can proceed only after the appropriate data has been gathered and the engineering trade-offs have been made. This pre-design phase includes choosing the proper lamp, pixel filters, and system design scheme. Three filter system designs are considered here. One, which seems to be the most common in use at this time, is to use a short wave pass edge filter at the display to limit the output of the display to wavelengths shorter than ~650 nm, and to have a long wave pass filter on the night vision device which transmits only wavelengths longer than ~650 nm. Many current versions of this type actually limit the light by the choice of phosphor to more nearly 620 nm, which gives an orange color to represent saturated "red". The second design uses a filter to pass a narrow band of red light which may be at wavelengths even longer than 650 nm, and then use a complementary narrow band blocking notch filter at the night vision device to prevent the entrance of conflicting light. The third design is an extension of the second for even better color rendition and more efficiency of the night vision device.

Keywords: liquid crystal display, night vision device, optical coating design, multiple bandpass filters, blocking notch filters

INTRODUCTION

As we have discussed in a previous paper[1], Active Matrix Liquid Crystal Displays (AMLCD) are in common use in television displays, laptop and desktop computers, aircraft cockpit displays ("glass cockpits"), etc. These systems need a light source, such a fluorescent lamp with adequate blue, green, and red emissions; and they need a pattern of blue, green, and red pixel filters built into the AMLCD. These pixel filters are usually of the absorption type so that they can be easily processed with typical semiconductor/flat panel techniques. The choice of lamps and pixel filters determines the gamut of colors which can be displayed or the "pallet". There is some room for improvement in these pixel filters to enhance the range of colors which can be displayed, but that is not the main thrust of this paper. The general appearance of most laptop computer and flat-panel TV displays shows that the goals of a satisfactory pallet and sufficient brightness have been reasonably achieved.

When such displays are adapted to commercial aircraft there are no peculiar problems to overcome, but when adapted to military aircraft which employ night vision (NVIS) devices, there is a conflict which needs to be resolved. The response of the human visual system to the display is from ~380 to ~780 nm, and red is generally perceived as the wavelengths longer than ~620 nm. The NVIS devices (Generation 3) without any filtering are responsive from ~450 to ~900 nm (see Fig. 1). The NVIS will amplify any such light which reaches it by several orders of magnitude. This can allow aircraft pilots to "see in the dark" (or nearly so) with such visual aids. However, even small amounts of offending light from the spectral region of overlap of the light from the display and the NVIS sensitivity can cause saturation and temporary blinding of the NVIS device (and possibly its user). Figure 1 shows the relative amount of light by wavelength (dotted curve) in the typical night sky according to data from the Marconi[2] web site. The response of a bare (unfiltered) Generation 3 NVIS device is shown in the upper solid curve[3].

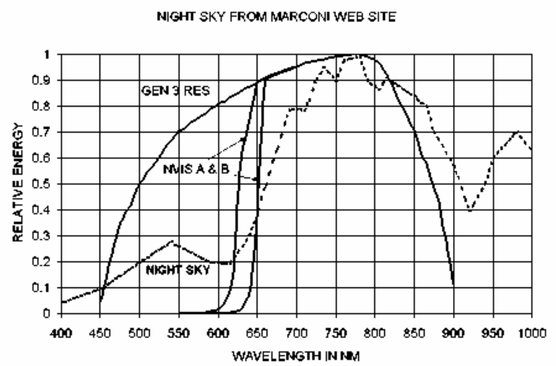

Figure 1. Typical night sky illumination (dotted), the response of a Generation 3 night vision device, and the response of NVIS-A and -B devices.

Two of the more common NVIS devices in use at this time are referred to as meeting NVIS-A or NVIS-B of military specification MIL-L-85767A. These have incorporated long wave pass (LWP) filters to give the truncated short wavelength responses also seen in Fig. 1. If the cockpit display has a short wave pass (SWP) filter for A at ~620 nm or for B at ~650 nm, then little or no offending light will pass from the display to the NVIS. Thus the conflict is resolved at the expense of not having the truly red light of the display available to the observer and blocking the flux from the night sky shorter than these cut-off wavelengths. The practice is for the pilot to look ***under*** his NVIS goggles to observe the display in the same manner as crewmen in the cockpit who may not be wearing NVIS goggles.

This first solution looses any light response benefit from the "foothill" of night sky and Gen 3 sensitivity at wavelengths shorter than 620-650 nm and it has limited red light due to the SWP filter (and the usual choice of illuminating phosphors). The second approach suggested by Cohen and Scoughton[4] would be to start with an unfiltered Gen 3 tube and add filters to the display which would pass only narrow (but hopefully energetic) bands of energy from the lamp and pixel filters and otherwise block other wavelengths. Then the Gen 3 tube would be provided with narrow blocking notch filters which would obstruct the light from these narrow bands. This would appear at first sight to have the potential to be more efficient in its use of the Gen 3 tube response and available night sky light, and it would provide the potential for more red light. This is the principal subject of this paper.

SYSTEM DESIGN

Figures 2 and 3 show the spectral energy versus wavelength for two different lamps whose data can be found on the internet[5,6]. Figure 2 shows a lamp spectrum with blue, green, and orange peaks which would work well with even a 620 nm SWP filter but would not include a deep red color. Figure 3 shows a lamp spectrum which is better suited to the second approach, since it has a strong red peak at 660 nm. This would provide more red light, but would not be well suited to either a 620 nm or a 650 nm SWP filter in common use with the source seen in Fig.2.

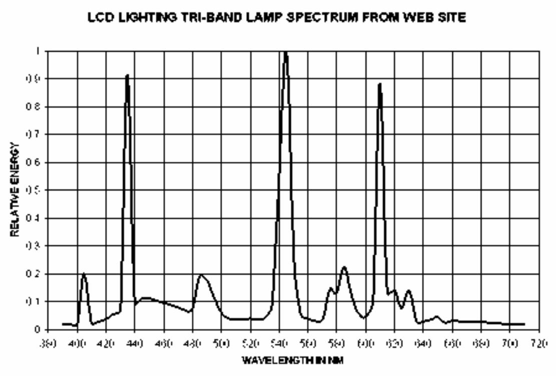

Figure 2. Spectral energy versus wavelength for a Tri-Band fluorescent lamp from LCD Lighting.

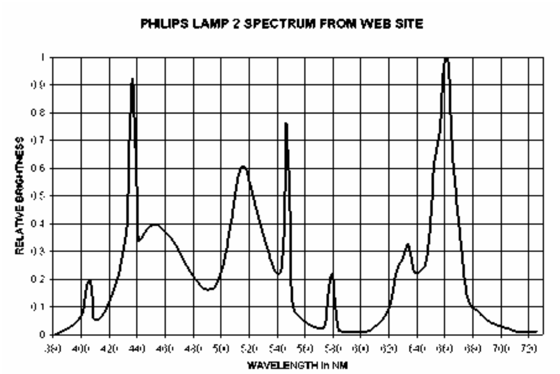

Figure 3. Spectral energy versus wavelength for a Philips "Lamp 2".

Figures 4 and 5 show the spectral transmittance of two different sets of blue, green, and red pixel filters which have been used in AMLCD displays[7]. The spectral product the transmittance of these pixel filters times the spectral flux of either of the lamps shown will allow some flux from one color band to "contaminate" another color band. The effect of this is to wash out the saturation of the primary color and reduce the range or pallet of colors which can be produced by the display. The filters in Fig. 5 have less overlap between colors, and these can potentially provide more saturated primary colors for a broader pallet of colors. It would be ideal to have no overlap in the green and blue pixel filters. This would be a desirable goal for the future development of AMLCD displays.

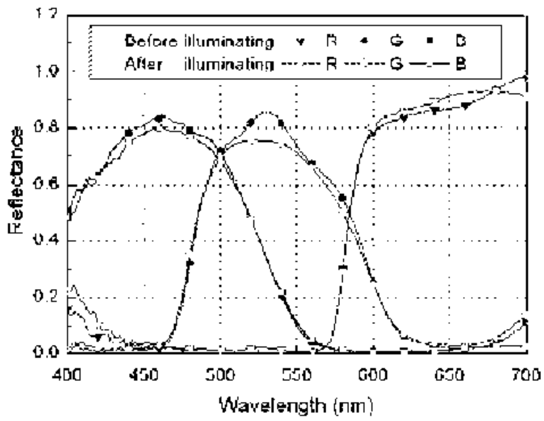

Figure 4. Typical blue, green, and red pixel filters[8].

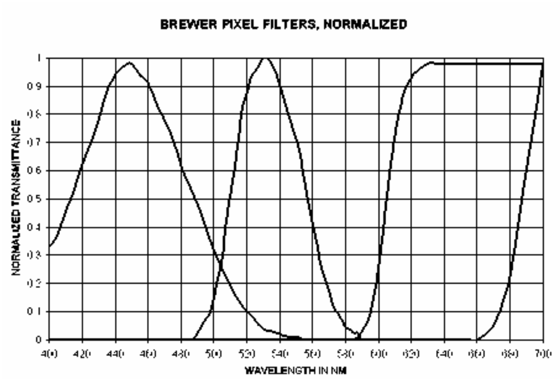

Figure 5. Brewer blue, green, and red pixel filters.

FILTER DESIGN

The previous paper[1] reported the efficiency of the first approach which is represented by the NVIS-B filter curve multiplied by the Gen 3 tube response and multiplied by the available night sky energy to be **84.2%** of the same energy without the NVIS-B filter. The first system has one filter (for these purposes) over the source and one filter over the NVIS. There are less than 100 layers in the combination of the first system filters. Figures 6 shows examples of typical filters which might be designed for this approach. Figure 7 shows the night-sky light response of the NVIS (solid line) and the display light provided to the observer (dashed line).

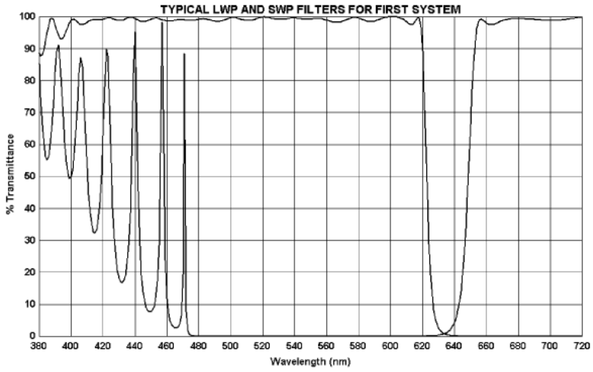

Figure 6. Short wave pass filter for display at ~620 nm and long wave pass at ~650 nm for NVIS used in First Approach.

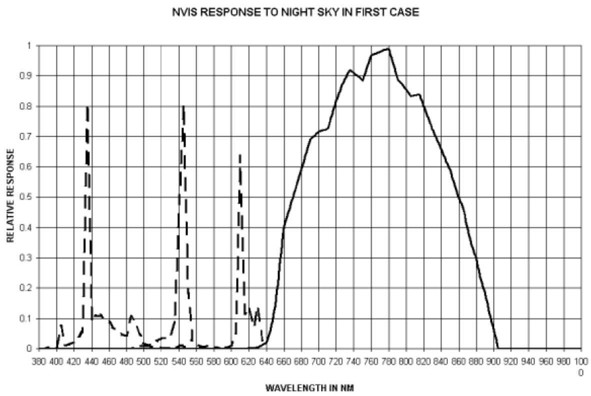

Figure 7. Solid line is the NVIS response of the First System to the night sky through its blocking filter. The dashed line is the display light seen by the unaided observer.

The second approach which allows the NVIS to use some of the night sky light between 550 and 620 nm, but provides much more red light to give the viewer full color as opposed to the first approach, has a calculated efficiency of **82.6%**. This second system consists of two multilayer filters over the display source as seen in Fig. 8 and two multilayer filters over the NVIS as seen in Fig. 9, although each pair may be deposited on the same substrate. There are approximately 150 layers in the combination of the second system filters. Figure 10 shows response of the NVIS with the special filters of this second approach in the solid line and the light provided by the display to the unaided eye in the dashed line.

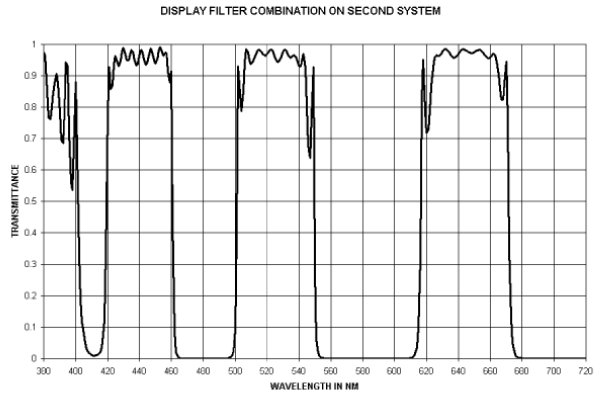

Figure 8. Two multilayer filter combination for display in Second Approach.

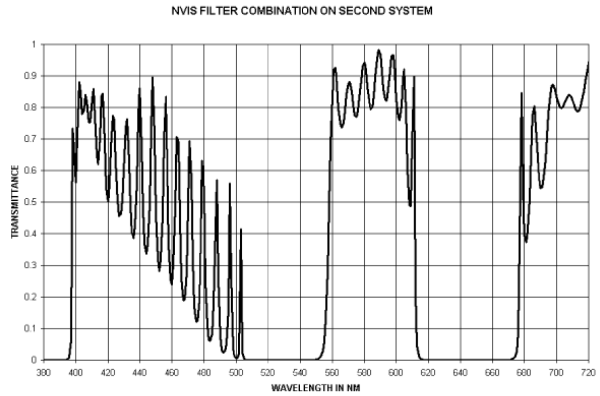

Figure 9. Two multilayer filter combination for NVIS in Second Approach.

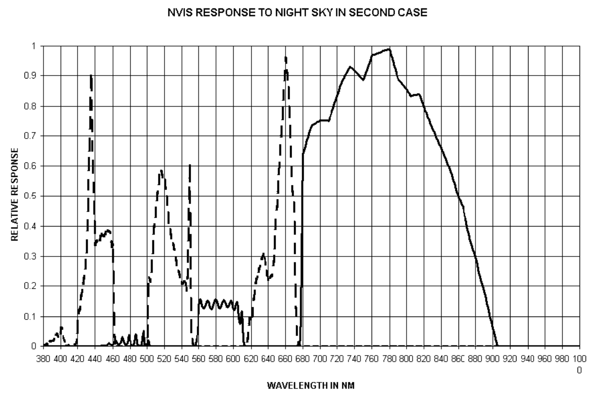

Figure 10. Solid line is the NVIS response of the Second System to the night sky through its blocking filter. The dashed line is the display light seen by the unaided observer.

The third approach allows the NVIS to use yet more of the night sky light between 550 and 620 nm, and provides more red light to give the viewer full color as opposed to the first approach. It has a calculated efficiency of **84.2%**. This, incidentally, is just the same NVIS efficiency as the first approach. The third system consists of three multilayer filters over the source as seen in Fig. 11 and one multilayer filter over the NVIS as shown in Fig. 12.

There are approximately 190 layers in the combination of the third system filters. Figure 13 shows response of the NVIS with the special filters of this third approach in the solid line and the light provided by the display to the unaided eye in the dashed line. One advantage of the third system is that it provides an even greater pallet of colors than the second approach, as seen in Fig. 14. However, this result is predicated on the future availability of pixel filters with no "cross-talk" between the lamp bands passed in Fig. 13. The multilayer designs move the width the RGB bands to very high saturation, but pixel filters with "cross-talk" could partially defeat this advance.

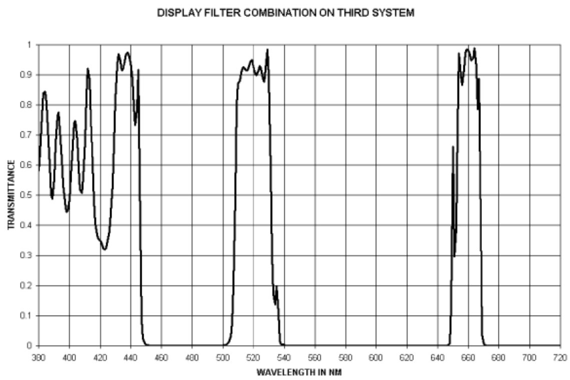

Figure 11. Three multilayer filter combination for display in Third Approach.

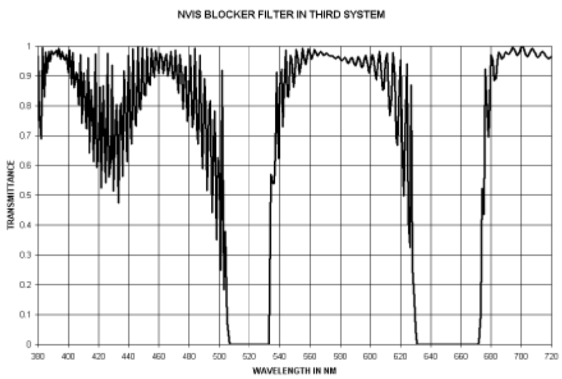

Figure 12. Multilayer filter for NVIS in Third Approach.

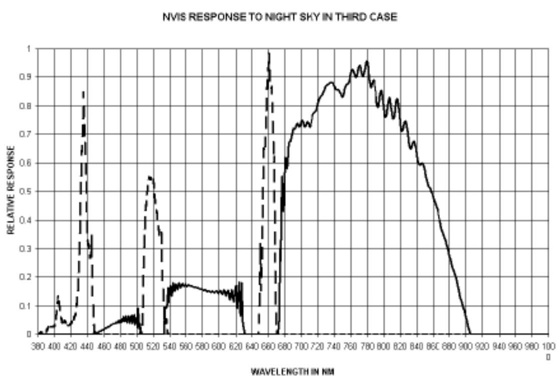

Figure 13. Solid line is the NVIS response of the Third System to the night sky through its blocking filter. The dashed line is the display light seen by the unaided observer.

It can be seen in Fig. 14 that the first, second, and third systems move progressively toward a broader pallet, especially with respect to the red and incidentally the violet in the third case.

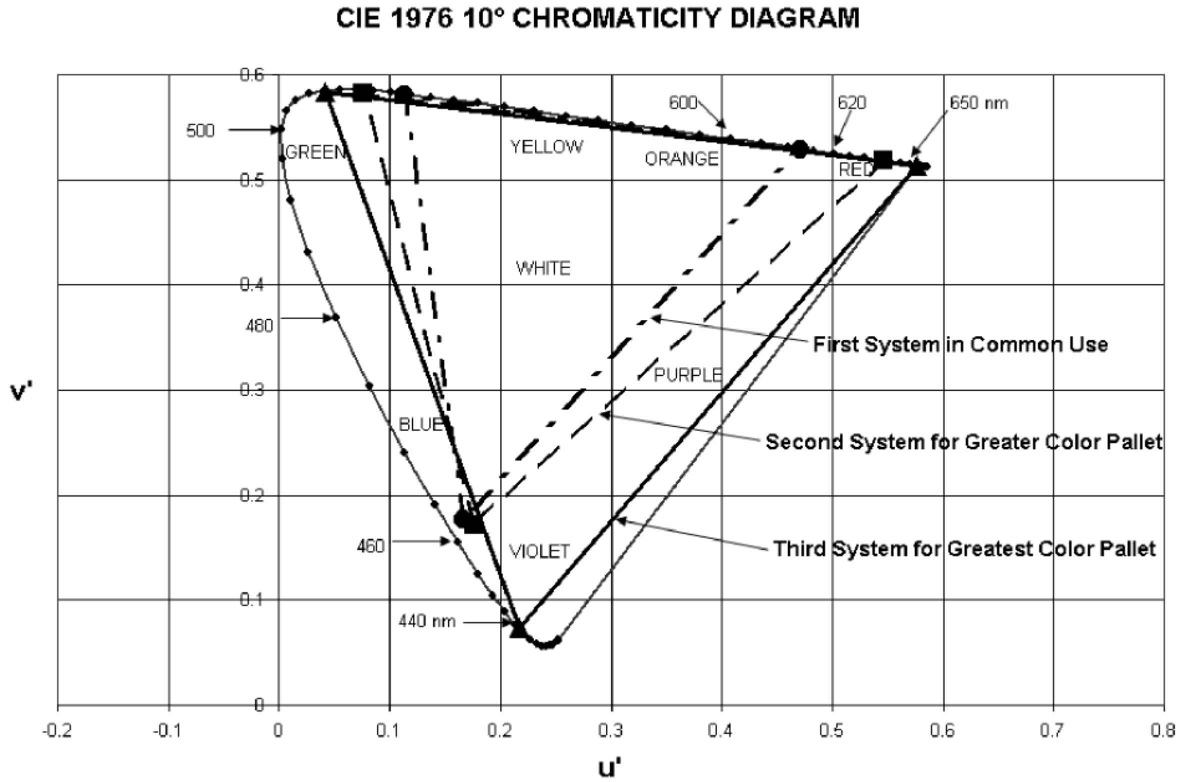

Figure 14. CIE Chromaticity Diagram showing the performance of the First, Second, and Third systems described.

CONCLUSIONS

Three filter design approaches have been shown with the ability to make NVIS goggles or similar devices compatible with color display systems. The second and third approach allow a true full-color display. The technology exists to achieve these results. True full-color displays are more complex and therefore likely to be somewhat more expensive. The differences between the three approaches in NVIS efficiency are not great

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