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Effect of viewing directions in projection-based multi-viewer display systems

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Abstract. The goal of this paper is to study the effect of viewing directions in projection-based multi-viewer display systems. Such systems display different images to several users watching a common screen. While different separation techniques have been used in cinema, we are interested in applications which require a more demanding viewing angle and more independent views, such as multi-sided immersive environment. We compare the luminous efficiency, crosstalk and colorimetric properties of polarization and spectral multiplexing as a function of the viewing direction. We find that, whereas for spectral separation the crosstalk does not depend on the viewing angle, for polarization separation the crosstalk increases with the viewing angle due to depolarization induced by conventional screens.

Keywords: multi-user display, three-dimensional projection, spectral comb filtering, polarization, colorimetry, crosstalk.

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1 Introduction

Projection-based multi-user display systems provide different images simultaneously on the same screen. The most common application is three-dimensional (3-D) cinema, where two images intended to left and right eyes of the viewers are displayed to create a visual perception of depth. However, for this application, the viewing angle, which is the maximum angle at which a display can be viewed with acceptable visual performance, is limited to about 30 deg. Here, we are interested in other applications of multi-view display systems where the required viewing angle is much broader. It is the case for collaborative applications, where different users can collaborate on a same platform while each visualizing its own layer of information^{1,2} (see figure 1). Likewise, in multi-sided immersive environment, called caves,³ due to the position of the viewer standing next to large screens, some viewing directions are much more challenging in terms of visual quality.

Increasing the number of independent displayed images can be very useful, particularly for ap-

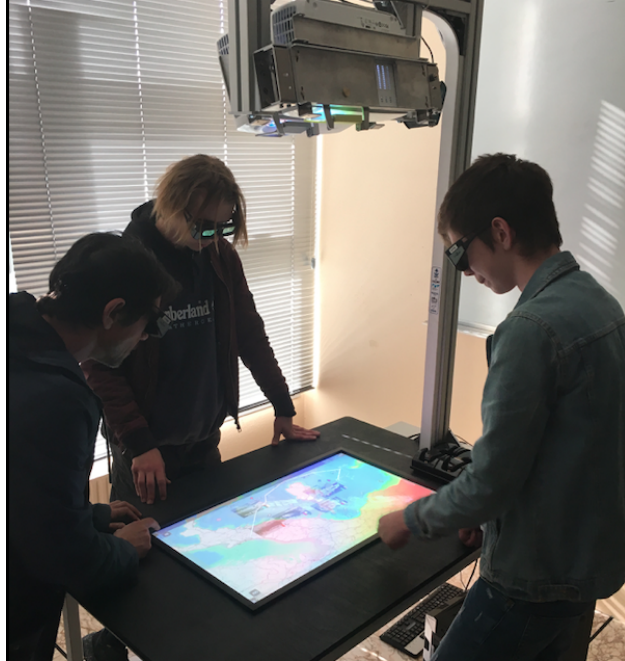


FIGURE 1: Collaborative immersive table

plications where an independent 3D view is required for each user. It enables for instance several users to simultaneously enjoy being in a cave, each one watching the scene with its own perspective. For collaborative platforms, each user can, depending on the application, watch a 3-D object from different perspectives or watch different 2-D or 3-D images. In both applications, the total number of displayed images has to be at least equal to twice the number of independent 3-D viewers. A larger number of displayed images thus enables a wider range of applications.

However, displaying simultaneously independent images while maintaining good visual properties is challenging. There are two parameters in particular that can deteriorate visual quality depending on the technology used, which should be considered here : the angle of incidence and the viewing direction. On the one hand, since a projector doesn't emit a collimated beam, it will necessarily pass through the filter with a certain angle of incidence, and the worst angle of incidence depends on the throw ratio of the projector. Depending on the technology used, the effect of the angle of incidence is different and is discussed in section 2. On the other hand, the effect of the viewing di-

rection is the main concern of this paper, since the viewers can move freely regarding to the screen for the applications we are interested in.

2 Separation techniques for projection-based multi-viewer display systems

Displaying simultaneously several independent images on the same screen to different viewers requires to use a separation technique. In caves or immersive collaborative tables, which are the applications we are interested in, the viewers are free to move their heads or bodies, so we don't deal here with the multi-view displays that restrict the viewing position to one or more very specific spots such as autostereoscopy⁴ or retro-reflective sheetings.⁵ Rather, we deal with projection displays that use filtering and eyeglasses to separate the different images. There are three main filtering techniques for such applications.

The first one has been known since the 19th century and is called anaglyph.⁶ It is based on spectral separation and uses two different color filters with complementary bandwidths. Images intended to left and right eyes are encoded after the projector with these complementary filters, and the viewer wears eyeglasses with both corresponding colors. Initially it was used with a cyan and a red filter. However, it is not used anymore in the cinema industry because of its poor color rendering. Instead, a better spectral separation technique has been proposed at the beginning of this century by Infitec GmbH,⁷ called spectral comb filtering or wavelength multiplex visualization. It consists of two comb filters with complementary transmittance profiles in the visible light range. Each eye can perceive some red, green and blue, which reduces the difference in the color perceived by left and right eyes and visual fatigue. Such filters can be optimized to the light source to minimize the color difference and maximize the luminous efficiency as demonstrated in a previous work.⁸ They can be used with conventional projectors (Ultra-High-Performance or Xenon lamp projectors), but

also with six primaries laser projectors,⁹ emitting two different triplets of red, green and blue lasers. The first drawback of these filters is their cost. The thin bandwidths of the filters require the use of interference filters, which are made of a stack of dozens of thin films. The second drawback is that their transmittance depends on the angle of incidence of the light. In non normal incidence, the transmittance profile drifts towards the shorter wavelengths.⁸ This issue can be addressed by using curved lenses in order to reduce the maximum angle of incidence. Another issue that can occur due to the reflective nature of the filters, is a ghost image of the viewer's eye.¹⁰ However, if the glasses are designed to prevent the surrounding light from illuminating the eyes, the ghost image vanishes, since the only light that illuminates the eyes is the light that passed through the filter and which will, after diffusion from the viewer's eye, go through the filter again without being reflected since it has the corresponding spectrum. The major advantage of spectral separation is that it can be used with any kind of projection screen.

A second separation technique most commonly used consists in using two orthogonal polarization states.¹¹ Similarly as in spectral separation, the images must be encoded after emission from the projector. A polarization maintaining screen is used and the viewer's glasses have orthogonally polarized filters. The simplest way to implement this technique is to use horizontally and a vertically polarized filters. It enables to create a good extinction ratio. However, it is very sensitive to the tilt angle of the head to the left or right, following Malus's law. For this reason, circular polarizers have been preferred for this application¹² and has been most widely used in cinema industry. Circular polarization is obtained thanks to a linear polarizer followed by a quarter wave plate with its fast axis at $\pm 45^\circ$ to the axis of the linear polarizer. It creates a left or right circular polarization, which is reflected on a polarization preserving screen and then decoded by corresponding circular polarizers on the glasses. Tilting the head to the left or right should have no more influence on the luminous

efficiency. In practice however, a quarter-wave plate can not be perfectly quarter-wave for all the wavelengths of the visible range, and the phase shift introduced by a waveplate is dependent on the wavelength and the angle of incidence.^{13,14} The polarization at some wavelength will be slightly elliptical. As a result, there is a certain rotational angle of the eyeglasses that better compensates this elliptical polarization, and for which the extinction is higher.

The last separation technique consists in sequential images, synchronized for instance with liquid crystal active shutters, also called time-division multiplexing.¹⁵ It is the separation technique that usually gives the best extinction. The drawback of this technique is the higher price of the glasses, the liquid crystal shutters being more expensive than polarizers. However it can also be used with any kind of white matte projection screens.

While polarization separation technique can not be used to separate more than two channels because it is not possible to have more than two orthogonal polarization states, there is in theory no limits in the number of channels that could be separated in time or by spectral multiplexing. With time multiplexing, it is necessary to increase the frame rate of the projectors and to reduce the response time of the shutters,² and with spectral separation, it is possible to use comb filters with thinner bandwidths. In practice, they are limited by the luminous efficiency since it decreases at least proportionally with the number of channels,¹⁶ or by the spectral width of the light source (for spectral multiplexing).

Thus, to increase even more the number of displayed images, it is possible to combine different separation techniques.¹⁷ The combination of time and polarization separation has already been studied^{1, 18} and our goal is to compare it with the combination of time and spectral separations. Thus, we need first to compare the spectral and polarization separation techniques in terms of luminous efficiency, crosstalk and colorimetry as a function of the viewing direction, in accordance

with the uses we focused on. Our projection-based multi-viewer display system is made up of two projectors, projector filters, a screen and glasses.

3 Experiment

To study the effect of viewing direction for different technologies, we designed a circular guideway allowing rotations around a spot on the screen (see figure 2). An optical fiber, connected to a spectrometer (Ocean Optics HR4000), is held at 5 cm around the point of interest. The spectrometer was properly calibrated in wavelength using a mercury lamp, and in intensity using an Halogen Light Source (Ocean Optics-HL2000 with a 2500 K color temperature) to get intensity spectrum measured in relative irradiance. The screen was illuminated by a white spot from a polar

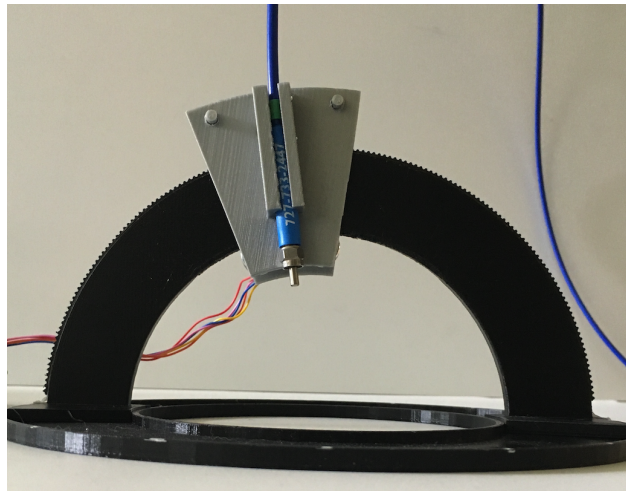


FIGURE 2: Picture of the experimental measurement guideway

angle of -15° and an azimuthal angle of 145° from a projector (BenQ W1070), in such a way that the shadow of the fiber and the guideway almost do not overlap the measured spot. We measured the intensity spectrum (in relative irradiance) on a hemisphere at 8 different azimuthal angles (every 22.5° , $\pm 2^\circ$), and for each azimuthal angle, we measured 15 polar angles (every 10° from -70° to 70° , $\pm 1^\circ$), giving a total of 120 measurements points. The polar angle rotation was made

automatically with a belt and a step motor, whereas the azimuthal rotation was done manually.

We tested two different technologies : circular polarization filters combined with a conventional silver screen (ST Silver Screen from Sreen-Tech), and optimized interference filters⁸ (spectral filter) combined with a matte white screen. We measured first the angular reflective properties of the silver and the matte white screens to characterize them. We also measured the reflection of the spot on an optical metal mirror since the silver screen can be seen as a compromise between a mirror and a matte white screen. Then, for both separation techniques and each angle, we measured the spectrum, having set-up the filter corresponding to the technology in front of the projector, and the corresponding transmitting filter or the corresponding blocking filter in front of the fiber input. For circular polarization, the rotational angle was chosen, for each azimuthal angle, such that it minimizes the intensity at normal incidence when the filters are crossed (blocking state), and maximizes the intensity at normal incidence with the transmitting filter, which is the most favorable case (the fast axes of the quarter wave plates are perpendicular). It reflects the case of cinema or caves, which is slightly different from collaborative tables. The difference is that for caves and cinema, all the users have their glasses positioned so that the extinction is maximum whereas in collaborative immersive tables, the rotational angle of the glasses of each user is different, as illustrated in figure 3.

4 Results

We considered three main quality criteria : the luminous efficiency, the crosstalk and the colorimetry.

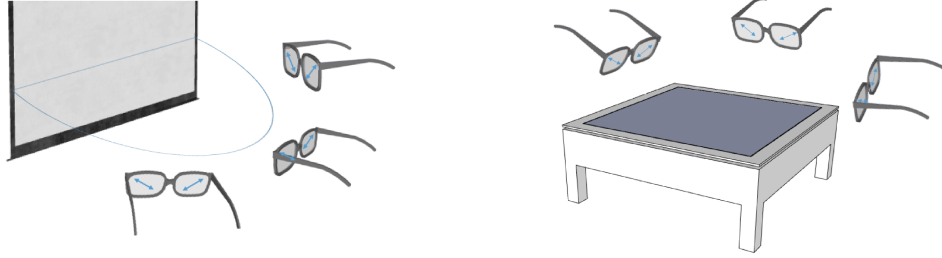


FIGURE 3: Illustration of viewing directions for (a) cinema or cave and (b) collaborative immersive table

4.1 Luminous efficiency

From the relative irradiance measured for each wavelength of the visible range, which is a radiometric unit, we transform it into a photometric unit (physiological unit), which reflects more accurately the perceived brightness, by integrating the product of the relative irradiance and the photopic sensitivity function. What is plotted in figure 4 is thus this average perceived brightness, normalized by the brightness of the matte white screen at normal reflection. Figures 4a, 4b, 4c contain the same informations as Figures 4d, 4e, 4f, but they are plotted here to help the reader visualizing the geometry of the hemisphere on which the viewing directions are measured. On Figures 4d, 4e and 4f, ψ is the azimuthal angle, and for each azimuthal angle, the perceived brightness is plotted as a function of the polar angle.

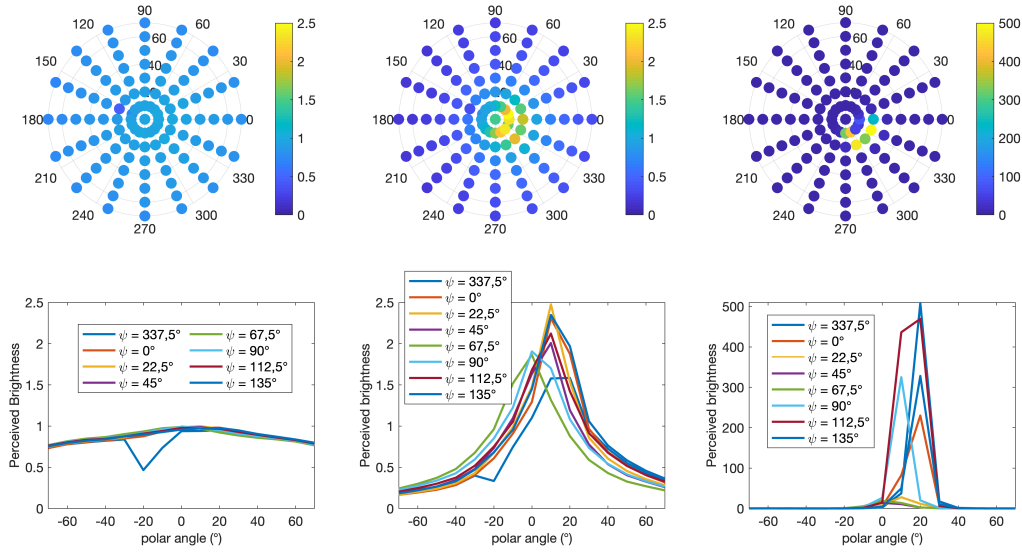


FIGURE 4: Reflected brightness of the matte white screen (a) and (d), the silver screen (b) and (e) and the mirror (c) and (f)

The drop at a polar angle of -20° and azimuth of 135° is due to the shadow of the fiber's support, which slightly overlap the measured spot, since it is the point closest to the direction of the source. Our matte white screen is found to be a good diffuser, its relative irradiance varying between 1 (at normal incidence) and 0.8 at 70 degrees and the silver screen has a gain of 2.5, which is the ratio of the light reflected by the screen compared to a matte white surface. For comparison, typical screen gain used in cinema are between 1.8 and 3. The case of the optical mirror gives accurately the position of the specular reflection of the measured spot. Naturally, the position of the hot spot (for the silver screen) or the specular reflection (for the mirror) is symmetrically opposite to the incident light from the projector. As with any polarization maintaining screen, the gain drops drastically when we deviate from the specular reflection.

Figures 5a and 5b show the perceived brightness through the passing filters for the spectral filter and the circular polarizer, as a function of the viewing directions. Naturally, it follows the

behavior of the angular properties of the white matte screen and the silver respectively.

However, to differentiate between the contribution of the filters and the contribution of the screen on the brightness, we computed the luminous efficiency, which is the ratio of the brightness perceived through the filter divided by the corresponding screen's brightness without filters. As shown on Figures 5c and 5d, the efficiency of the spectral filter is almost constant at about 30% while the efficiency of the polarizer depends on the polar angle and drops by about 0.05 (more than 15% efficiency drop) between specular reflection and 70° . The larger variability in Figure 5d within the $[-30^\circ + 30^\circ]$ range is due to the slight shadow of the polarizer on the measured spot, which reduces the precision of the data after normalization. The estimated precision in this range is thus ± 0.04 while it is ± 0.01 outside of this range.

The drop in luminous efficiency in the polarization case is due to the fact that the screen doesn't preserve properly the polarization. Thus, with an increasing viewing angle, the ratio of polarized light decreases, so does the efficiency. For both cases, the azimuthal angle has no impact on the luminous efficiency, the only differences that appears between the azimuthal angles are due to the geometry of the set-up. The rotational angle has no impact on the spectral filter, in contrast to the polarizer.

4.2 Crosstalk

The crosstalk as defined by Lipton¹⁹ is the incomplete isolation of the left and right image channels so that one leaks or bleeds into the other. The crosstalk has been a constant concern for the 3-D applications because if it is not mitigated, it can create a visual effect called ghosting, which is the perception of ghosts, shadows or double contours. We computed it as the ratio of the

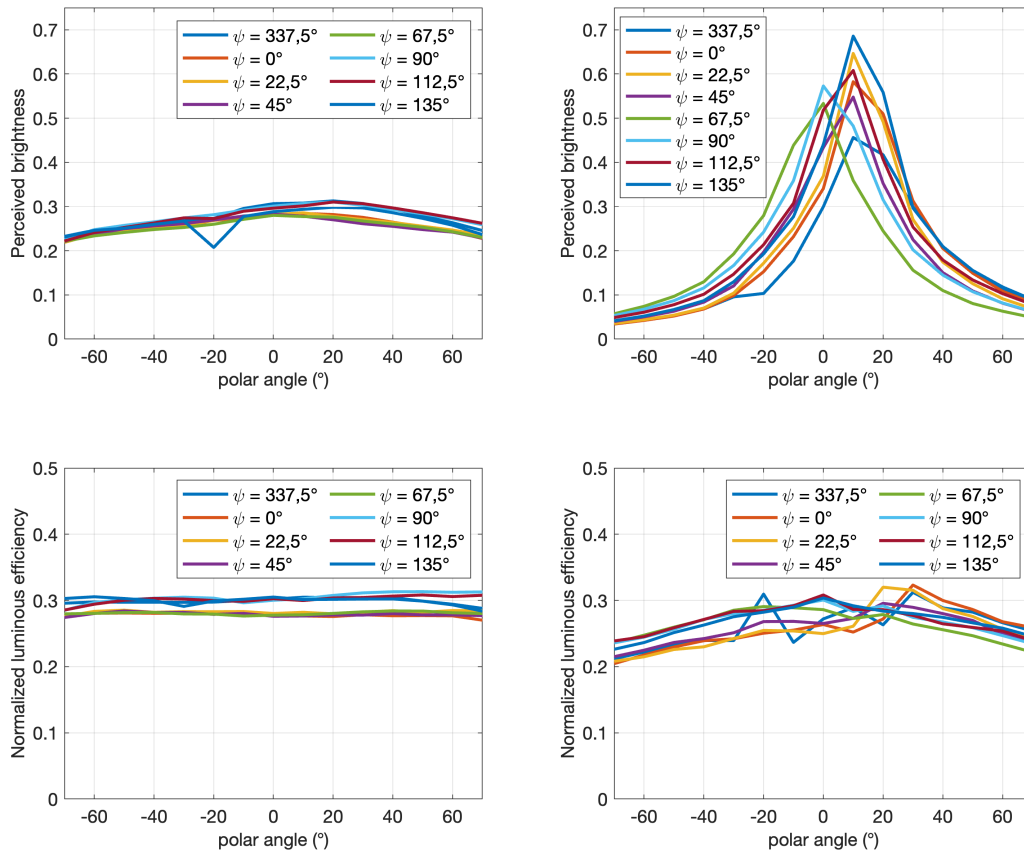


FIGURE 5: Perceived brightness and luminous efficiency of (a) spectral filter, (b) circular polarizer, (c) normalized spectral filter and (d) normalized circular polarizer

luminous efficiency of the blocking state over the luminous efficiency of the passing state, and plotted it for the spectral filter and the polarizer on Figure 6.

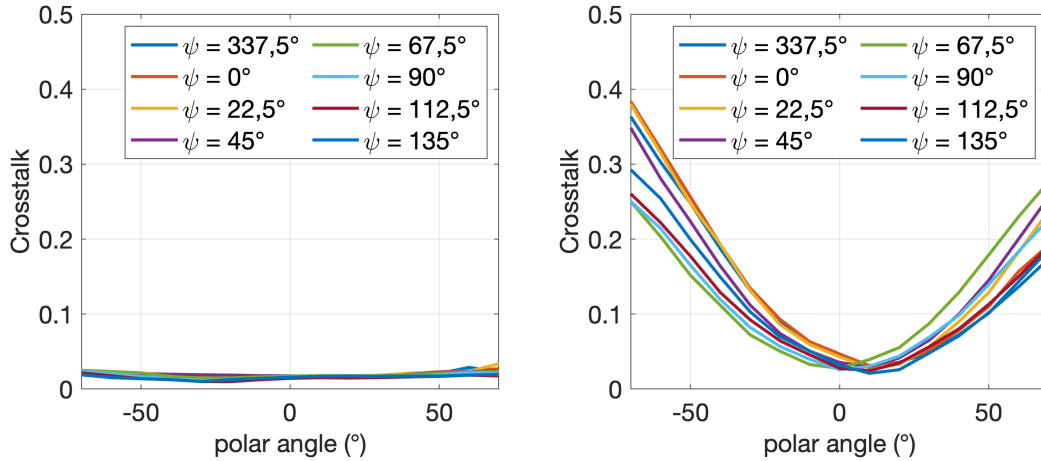


FIGURE 6: Angular crosstalk with (a) spectral filter and (b) circular polarizer

Figure 6a shows that spectral crosstalk is almost constant and less than 2% from any viewing direction. However, with the polarizers and the silver screen, the crosstalk is highly dependant on the polar angle. It varies between 2% and 38% for the worst case (Figure 6b).

The luminous efficiency through the blocking state has been plotted on figure 7. It comes out here that the blocking state of the polarizers is less and less effective with the increasing polar angle, meaning that the contrast is decreasing with the polar angle. It implies here again that the polarization state is less and less preserved with the increasing polar angle.

4.3 Crosstalk on a 4 images display

In the previous section, we compared the spectral and polarization crosstalk for a two images display. In practice, we are interested in projection systems that display at least four images, thanks to a combination of separation techniques. On such displays, different types of crosstalk will appear. We verified this on a four images display combining spectral and polarization separations. Typically, two eyeglasses share the same spectral transmittance but have orthogonal polarizers, while

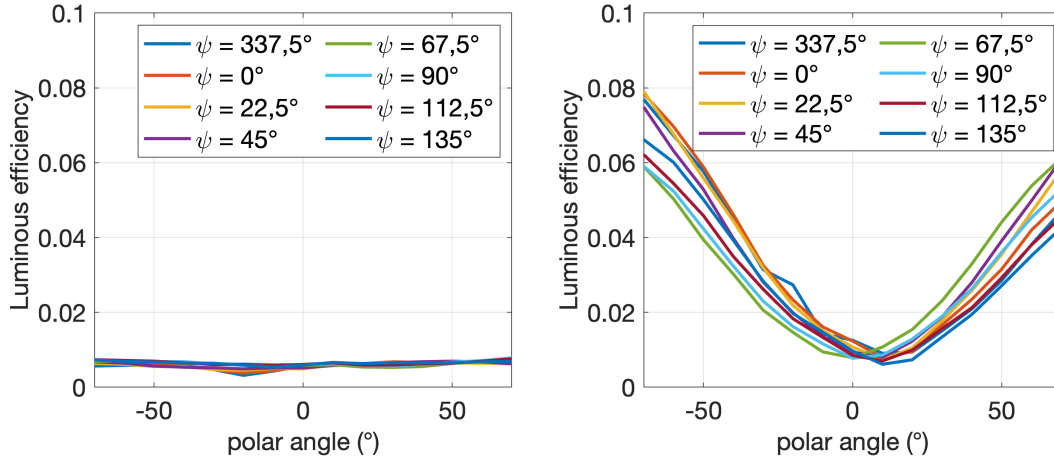


FIGURE 7: Efficiency of blocking state with (a) spectral filter and (b) circular polarizer

both other eyeglasses have the complementary transmittance, and orthogonal polarizers. Each user will, in addition to its own intended image, be likely to perceive different ghost images, depending on whether they come from an image with the opposite spectrum, the opposite polarization or the opposite spectrum and polarization. For the image that has the opposite spectrum (respectively the opposite polarization), the crosstalk will be similar to the spectral (polarization) crosstalk on a two images display, while the image that does not share neither polarization nor spectrum, will have a crosstalk in the order of magnitude of the product of both crosstalk types. The measurements we made confirmed this relationship between the two-channels crosstalk (crosstalk that occurs on a two images display) and crosstalk that appear in a higher number of images display. Figure 8 illustrates that the four channels polarization crosstalk is very similar to the two channels polarization crosstalk shown in Figure 6b.

Thus, knowing the two-channels crosstalk is sufficient to anticipate the crosstalk that will appear on systems displaying a greater number of views.

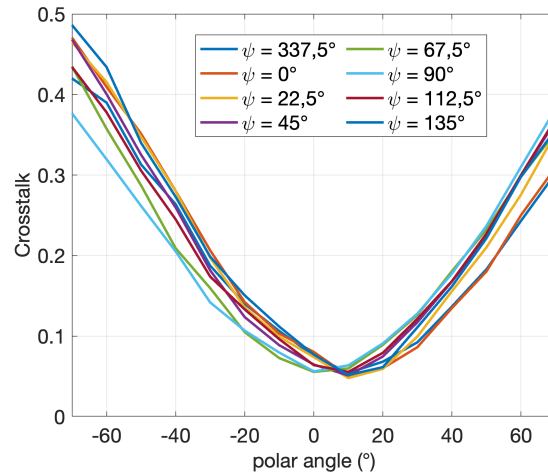


FIGURE 8: Polarization crosstalk in a 4 images display

4.4 Colorimetry

The measurements with the spectrometers enables us to study the colorimetric properties of our filters. From the relative irradiance spectrum, we computed the CIELAB 1976 coordinates. In this color space, we computed the standard deviation of the color differences between the measured colors and the average color produced through the spectral filter or the circular polarizers. We found a standard deviation of 0.6 with the spectral filters and 1.1 with the polarizers. Both of them are below the just noticeable difference (2.3),²⁰ which means that it is not possible to visually perceive any effect of the viewing direction. Besides, the color gamut, which is the set of colors that can be displayed is presented in figure 9. It depends mainly on the primary colors of the projector and of the transmittance of the filters. Since the spectral filters are optimized for this projector⁸ and the transmittances of the polarizers are almost constant as a function of wavelength, then the gamut of the projector is not much altered in both cases studied. The reason is that the polarizers have a flat transmittance profile as a function of the wavelength and that the spectral filters have been optimized to the projectors to minimize their impact on the color gamut. Thus, here colorimetry is not a particularly decisive criterion for encouraging one technology over another.

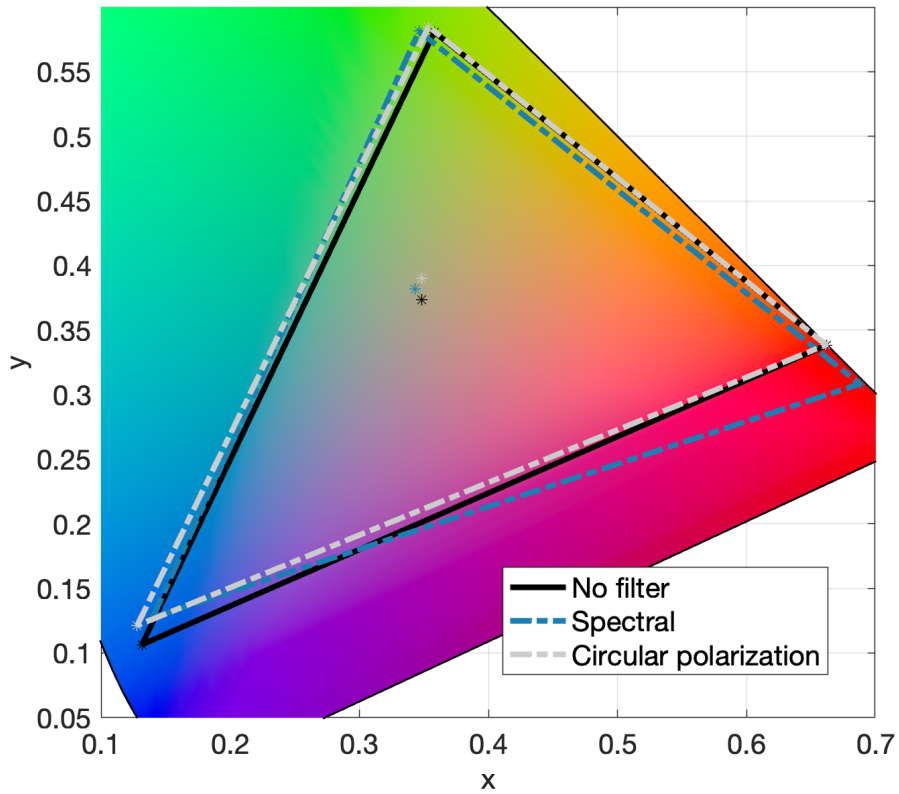


FIGURE 9: Color gamut

5 Discussion

Our measurements confirmed that, while there is no significant impact of the viewing directions on the colorimetry for either the polarizers or the optimized spectral filters, the luminous efficiency and the crosstalk are highly dependant on the polar angle for the polarization separation technique. It is not fundamentally due to the polarizers themselves, but to the challenge it is to make a polarization preserving screen that diffuses light. We observed that in addition to the loss of brightness with the polar angle in polarization separation, which is due to the higher gain of the silver screens, there is also an increase in the crosstalk with the polar angle, which is related to an increasing partial depolarization with the viewing direction.

The main factors of silver screens that tend to change the polarization state are the diffuse scatte-

ring from features with a size equal or smaller than the visible wavelengths, the phase shift between the components of the light at high incidence, and the multiple reflections that can occur on the surface of the screen if the slopes of the surface are important.²¹ To some extent, RealD's new polarization preserving screens have addressed some of these issues by designing the slope distribution of the surface so as to prevent double (or more) reflections, and by removing any features with a size equal or smaller than the visible wavelengths.²² While this is satisfying for movie theaters because of the relatively small viewing angles required, for the multi-sided environments (Caves) and immersive collaborative tables, even those optimized screens could not provide satisfying visual quality from any viewing directions. Indeed, they can not have a Lambertian reflectance, which is the best way to provide every users with the same amount of brightness.

In contrast, we have shown that the spectral filters coupled with a matte white projection screen have no dependency on the viewing angle, and that the low amount of crosstalk is satisfying.

For these reasons, for applications that require a high viewing angle, it is preferable to use spectral separation instead of polarization one. While for applications requiring more independent views, such as Caves, the combination of time and spectral separations would offer a better visual quality, by using for instance 3-D projectors separated by spectral filters, coupled with active glasses equipped with corresponding spectral filters.

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References

- 1 V. N. H. Silva, D. Stoenescu, T. C. Nassour, *et al.*, “Ghosting impingements in 3d dual-view projection systems,” *Journal of Display Technology* **10**(7), 540–547 (2014).
- 2 A. Kulik, A. Kunert, S. Beck, *et al.*, “C1x6 : a stereoscopic six-user display for co-located collaboration in shared virtual environments,” in *Proceedings of the 2011 SIGGRAPH Asia Conference on - SA '11*, 1, ACM Press, (Hong Kong, China) (2011).
- 3 C. Cruz-Neira, D. J. Sandin, and T. A. DeFanti, “Surround-screen projection-based virtual reality : The design and implementation of the cave,” in *Proceedings of the 20th Annual Conference on Computer Graphics and Interactive Techniques, SIGGRAPH '93*, 135–142, ACM, (New York, NY, USA) (1993).
- 4 N. A. Dodgson, “Autostereoscopic 3d displays,” *Computer* **38**, 31–36 (2005).
- 5 S. R. Chapman and M. Wang, “Retroreflective sheeting for projector-based display system,” (2019). US Patent App. 16/116,060.
- 6 W. Rollmann, “Zwei neue stereoskopische Methoden,” *Annalen der Physik* **166**, 186–187 (1853).
- 7 H. Jorke and M. Fritz, “Infitec-a new stereoscopic visualisation tool by wavelength multiplex imaging,” *Proceedings of Electronic Displays* **2003** (2003).
- 8 T. Le Deun, D. Stoenescu, and J.-L. de Bougrenet de la Tocnaye, “Design of optimized anaglyph-type filters for three-dimensional projection systems,” *Optical Engineering* **57**, 57 – 57 – 8 (2018).
- 9 K. C. Rohwer, H. Jorke, and A. Simon, “Stereoscopic laser display system using six primary colors,” **616**, 4 (2013).

- 10 G. D. Sharp, S. Gilman, M. Schuck, *et al.*, “66.1 : Feasibility of 3d-cinema with uncompromised performance,” in *SID Symposium Digest of Technical Papers*, **46**(1), 976–979, Wiley Online Library (2015).
- 11 L. Pictet and M. Cantoni, “Process and apparatus for the projection of stereoscopic kinematographic films,” (1925). CA253373A.
- 12 V. Walworth, S. Bennett, and G. Trapani, “Three-Dimensional Projection With Circular Polarizers,” in *Optics in Entertainment II*, **0462**, 64–70, International Society for Optics and Photonics (1984).
- 13 P. D. Hale and G. W. Day, “Stability of birefringent linear retarders (waveplates),” *Applied Optics* **27**, 5146 (1988).
- 14 P. D. Hale and G. W. Day, “Stability of birefringent linear retarders(waveplates),” *Appl. Opt.* **27**, 5146–5153 (1988).
- 15 A. K. Srivastava, J. L. de Bougrenet de la Tocnaye, and L. Dupont, “Liquid Crystal Active Glasses for 3d Cinema,” *Journal of Display Technology* **6**, 522–530 (2010).
- 16 B. Froehlich, J. Hoffmann, K. Klueger, *et al.*, “Implementing multi-viewer time-sequential stereo displays based on shuttered lcd projectors,” in *4th Immersive Projection Technology Workshop, Ames, Iowa*, Citeseer (2004).
- 17 J.-L. de Bougrenet de La Tocnaye, E. Daniel, L. Dupont, *et al.*, “System for simultaneously displaying multiple multimedia streams, including multiple viewing spectacles and a displaying medium,” (2015). US Patent App. 14/765,476.
- 18 V. Nunes Henrique Silva, *Liquid Crystal Shutters for Stereoscopic Vision and 3D Dual View Application*. Theses, Télécom Bretagne, Université de Bretagne-Sud (2013).

- 19 L. Lipton, "Factors Affecting "Ghosting" In Time-Multiplexed Piano-Stereoscopic Crt Display Systems," in *True Three-Dimensional Imaging Techniques & Display Technologies*, **0761**, 75–79, International Society for Optics and Photonics (1987).
- 20 M. Mahy, L. Van Eycken, and A. Oosterlinck, "Evaluation of uniform color spaces developed after the adoption of cielab and cieluv," *Color Research & Application* **19**(2), 105–121 (1994).
- 21 D. A. Coleman and G. D. Sharp, "Polarization preserving front projection screen material," (2011). US8072681B2.
- 22 D. Coleman and G. Sharp, "54.2 : Invited paper : high efficiency polarization preserving cinema projection screens," in *SID Symposium Digest of Technical Papers*, **44**(1), 748–751, Wiley Online Library (2013).

First Author

Biographies and photographs of the other authors are not available.

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