

25.1: Interference Filter System for High-Brightness and Natural-Color Stereoscopic Imaging

Arnold Simon and Helmut Jorke

INFITEC GmbH, Lise-Meitner-Strasse 9, 89081 Ulm, Germany

Abstract

We demonstrate a significant improvement of the color and transmission performance of a complementary interference filter system used for stereoscopic imaging. A 3D transmission of 30% for a UHP lamp projection system was achieved. The differences in color and luminance between left and right filter were minimized.

1. Introduction

Stereoscopic imaging in projection system has gained plenty of interest since the success of 3D cinema movies in the past. Currently three basic stereoscopic technologies for large venues are at present in the market share their common glasses based approaches [1].

1) Polarization technology either utilizes the prepolarized light emission of the projector or uses a polarizer filter system in front of the projector. Although, this system requires a polarization maintaining screen it is still attractive since passive low cost glasses can be used.

2) Active systems are blocking time sequentially left or right image by an active LCD shutter as filter of the glasses. This system requires continuous synchronization to displaying system. Usually, those glasses are battery driven.

3) Interference filter systems left and right images are multiplexed into two complementary spectral ranges. Spectral filtering is implemented into the projector which can be a dual projector system or a single projector with a rotating filter wheel. Glasses are passive and based on interference filter technology [2].

In stereoscopic projection white screen technologies avoid the so called “hot spot” effect and offer homogeneous image quality. Furthermore passive systems are desired because they are robust, easy cleanable and cheap.

2. Interference filter design configurations

2.1. Triple band interference filter system

Full color stereoscopic interference filter imaging requires at least one independent stimulus for each color receptor in the human eye. The nature of the eye having three cones defines the triple band filter system as the minimum concept for full color stereoscopic images.

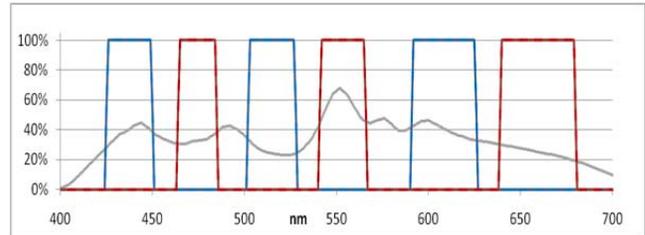


Figure 1. Projector white output spectrum and triple band filter configuration

Colors of the left and right channel usually differ and therefore require an electrical color correction.

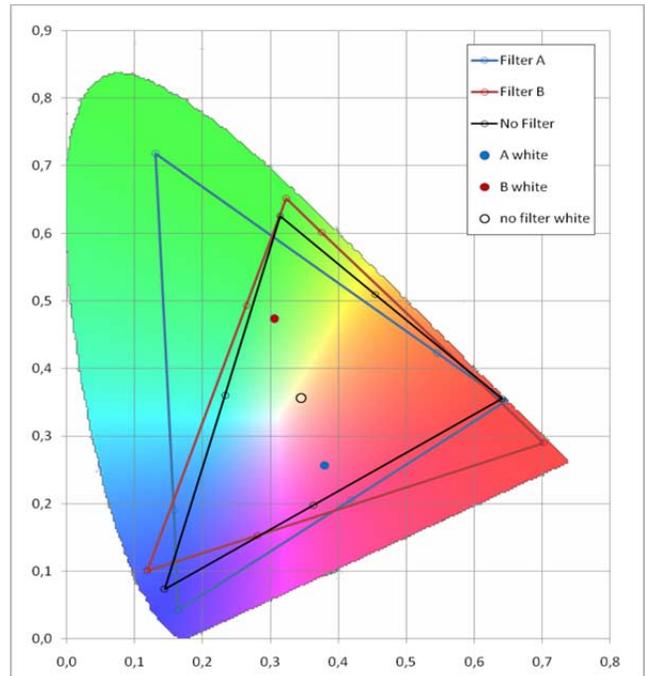


Figure 2. Color gamut of triple band A and B filter for a UHP projector (CIE1931 x-y-diagram)

Most high end projectors support color correction and compensate differences so that left and right eye perceive the same color gamut and brightness. Although the average transmission of the filter amounts 30-32%, the requirement of equal white points and similar luminance for each color reduces this value to approximately 8% for the B-filter and 12% for the A-filter. The luminance differences of left and right filter may additionally adjusted if desired. A recent study [3] indicates that even luminance level differences of up to 60% do not affect the ability to perceive full stereo depth.

Table 1. Triple band filter simulation data before color correction

	Filter A				Filter B				No Filter		
	x	y	Y	Y _{3D/2D}	x	y	Y	Y _{3D/2D}	x	y	Y
R	0,646	0,352	5,8	62%	0,702	0,290	0,7	8%	0,641	0,355	9,3
G	0,131	0,718	2,9	13%	0,323	0,652	10,7	48%	0,315	0,626	22,4
B	0,164	0,042	0,6	25%	0,119	0,101	0,7	27%	0,144	0,074	2,4
C	0,158	0,190	3,6	14%	0,265	0,493	11,4	46%	0,234	0,360	24,8
Y	0,545	0,423	8,8	28%	0,375	0,601	11,4	36%	0,454	0,509	31,6
M	0,419	0,206	6,4	54%	0,281	0,153	1,4	12%	0,363	0,198	11,8
W	0,380	0,257	11,5	26%	0,306	0,474	15,6	36%	0,345	0,356	43,8

Table 2. Triple band filter simulation data after color correction

	Filter A				Filter B				No Filter		
	x	y	Y	Y _{3D/2D}	x	y	Y	Y _{3D/2D}	x	y	Y
R	0,646	0,352	1,1	12%	0,646	0,352	0,8	8%	0,641	0,355	9,3
G	0,305	0,590	2,6	12%	0,305	0,590	1,8	8%	0,315	0,626	22,4
B	0,155	0,120	0,3	12%	0,155	0,120	0,2	8%	0,144	0,074	2,4
C	0,234	0,360	2,9	12%	0,234	0,360	2,0	8%	0,234	0,360	24,8
Y	0,444	0,495	3,7	12%	0,444	0,495	2,6	8%	0,454	0,509	31,6
M	0,363	0,198	1,4	12%	0,363	0,198	1,0	8%	0,363	0,198	11,8
W	0,345	0,356	5,1	12%	0,345	0,356	3,6	8%	0,345	0,356	43,8

The improvement of the efficiency drawbacks shown in table 2 was subject for the further analysis and design of new filter solutions.

2.3. 3-4-band interference filter system

The advantage of achieving the same color cues using different spectra (color metamerism) can be used to better adjust the colors of left and right filters. Same color stimulus can be achieved if a narrow band emission is substituted by the emission of two adjacent color side bands. Taking this approach the 3-3 filter can be substituted by a 6-3 band system. A reduction to a 4-3 band system is possible when combining bands long wavelength blue with short wavelength green and long wavelength green with short wavelength red.

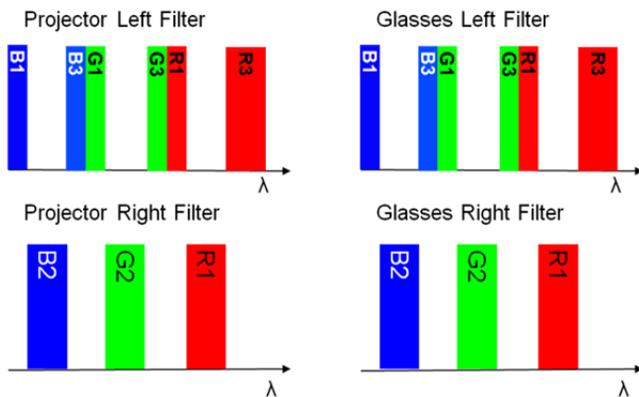


Figure 3. Color metamerism interference filter concept

Even higher pass band systems are thinkable. A 5-6 band pass system could also use this color metamerism. However, the required spacing of 2-3% between left and right transmission bands reduces the transmission to 75-50% of the value of the 3-4 band filter system.

3. Interference filter optimization for UHP lamp projector

Based on the projector output spectra a filter was calculated under the requirement of well balanced color coordinates and luminances. The result is shown in figure 6 and table 3.

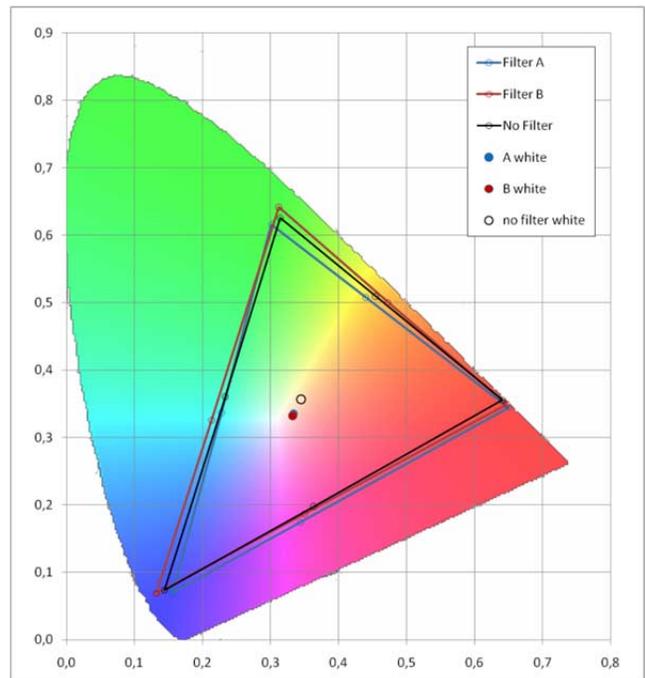


Figure 4. Color gamut of A (4-band) and B (3-band) filter for a UHP lamp projector (CIE1931 x-y-diagram)

Table 3. 3-4 band filter simulation data before color correction

	Filter A				Filter B				No Filter		
	x	y	Y	Y _{3D/2D}	x	y	Y	Y _{3D/2D}	x	y	Y
R	0,650	0,344	2,7	29%	0,648	0,349	3,1	33%	0,641	0,355	9,3
G	0,301	0,616	7,4	33%	0,312	0,642	6,3	28%	0,315	0,626	22,4
B	0,156	0,070	0,9	36%	0,132	0,068	0,8	34%	0,144	0,074	2,4
C	0,228	0,336	8,3	33%	0,213	0,326	7,2	29%	0,234	0,360	24,8
Y	0,440	0,508	10,1	32%	0,473	0,500	9,4	30%	0,454	0,509	31,6
M	0,344	0,174	3,6	30%	0,350	0,187	4,0	34%	0,363	0,198	11,8
W	0,334	0,335	14,4	33%	0,332	0,332	13,1	30%	0,345	0,356	43,8

4. Results and Discussion

Simulation results of the 3-4 band filter system show a significant improvement in the transmission of the interference filter system in combination with a UHP lamp projector. Left and right 3D color gamut are not only almost identical, also the difference between 2D and 3D color gamut is neglectable.

The transmission efficiencies of active glasses is approx. 37% less the contribution of the switching times, which usually measure between 1 ms to 2.5 ms [4]. Additionally, shutter glasses also require more or less a color correction. In some cases the ON-transmission is greenish. Assuming an average switching time of 2 ms at 120 Hz frame rate, the shutter systems end up at 76% duty cycle or 28% system transmission.

The transmission efficiencies of the interference filters systems is also limited by the optical transmission of the filters, which is approx. 98% for the projector filter and 90% for the glasses filter. In total with the average transmission of 31.5% of table 3 the interference filters system achieves a total transmission of 28%.

The comparison shows, interference filter technology and active glasses technology are very similar in their system transmission.

However, interference filter technology may benefit from its passive glasses technology which is robust, easily cleanable and environmentally friendly. The improvement of the production technology of the interference filters may also reduce costs in the future.

5. References

- [1] M. Pölönen, M. Salmimaa, V. Aaltonen, J. Häkkinen, J. Häkkinen, and J. Takatalo, "Subjective measures of presence and discomfort in viewers of color-separation-based stereoscopic cinema", *J. SID* 17/5, 459 (2009).
- [2] H. Jorke, A. Simon, and M. Fritz, "Advanced stereo projection using interference filters", *J. SID* 17/5, 407 (2009).
- [3] R. Patterson, A. S. Boydstun, J. A. Rogers, and L. M. Tripp, "Stereoscopic depth perception and interocular luminance differences", *SID Digest*, 815 (2009).
- [4] M. Hammer and E. H. Langendijk, "Reduced cross-talk in shutter-glass-based stereoscopic LCD", *JSID* 18/8, 577 (2010).