Stereo Projection Using Interference Filters

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Abstract

Stereo projection using interference filters is an advanced wavelength multiplexing approach, that specifically takes into account the nature of the human eye, which is characterized by three types of color receptors. Accordingly, the filters used to code image information for the left and for the right eye image have three narrow bands each. In the present paper the current status of the interference filter technique for stereo imaging is outlined.

Introduction

Stereo imaging techniques cover a wide range of applications in science, medicine, simulation, education, presentation, entertainment and gaming. Common feature of these techniques is the high degree of realism experienced when image content is provided in a most natural way, namely in a way that each eye of the viewer gets its specific image content/perspective.

In order to optimize the sensation of realism and, thus, to really approach the claim of visual high fidelity, the stereoscopic principle need to be supplemented by an optimisation of some residual image quality parameters, such as

- definition of the image
- channel separation between the left and right image
- image homogeneity
- degree of fidelity in color reproduction

In the present paper we want to explain the basic approach of stereo projection using interference filters and want to show the present status of this technique regarding those parameters which are crucial to stereo imaging in real visual high fidelity.

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Basic Approach

Visualisation by wavelength multiplexing codes image information in different spectral ranges. A well known representative of the wavelength multiplexing approach is the classic anaglyph approach were the whole wavelength range of visible light (400 – 700 nm) is basically subdivided into two ranges (red and green or cyan). Using more narrow wavelength bands, however, the number of images shown in parallel, can be significantly enhanced. The situation resembles the situation in wireless communication technology, where, for instance, in the very high frequency (VHF) range there is place for a multitude of different carriers.

On the other hand, perception of light in the human eye is characterized by the presence of three receptor types which are associated with the primary colors blue, green and red. Sensitivities of these receptor types versus wavelength are depicted in Fig. 1. Thus, in order to avoid that the wavelength multiplex scheme conflicts with the nature of the human eye, image information of one image has to be coded in three narrow bands in parallel. These narrow bands have to be placed such, that the first lies within the sensitivity range of the blue, the second within the sensitivity range of the green and the third within the sensitivity range of the red receptor type. For each of these narrow bands the available total band width is defined by the bandwidth of the respective receptor type, which is about 50 nm (s. Fig. 1).

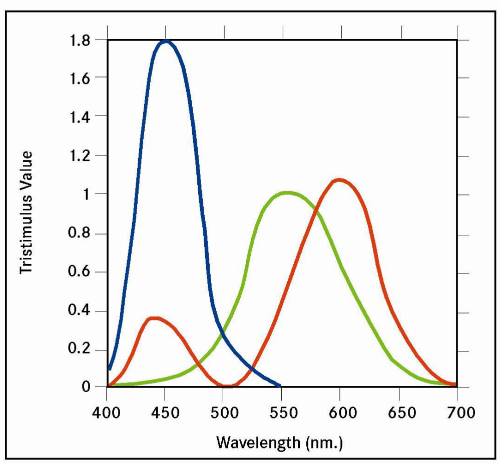


Fig. 1: Sensitivities of the receptor types for blue, green and red in the human eye.

To separate the image information again and to assign the correct image information to the respective eye, each eye has to be supplied with a narrow bandwidth filter. This filter must have a triple band characteristic to transmit selectively the narrow bands associated with the image content coded in these narrow bands (s. Fig. 2). Using, for instance, two triples of narrow bands, stereoscopic images can be shown by wavelength multiplexing where each image is a full-color image (Fig. 3).

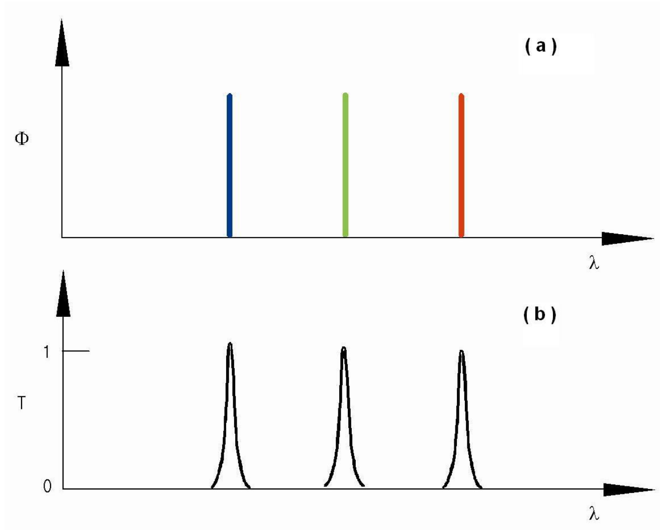


Fig. 2: Spectrum of the image (a) and corresponding filter characteristic on the side of the viewer (b) in narrow band wavelength multiplexing visualisation systems.

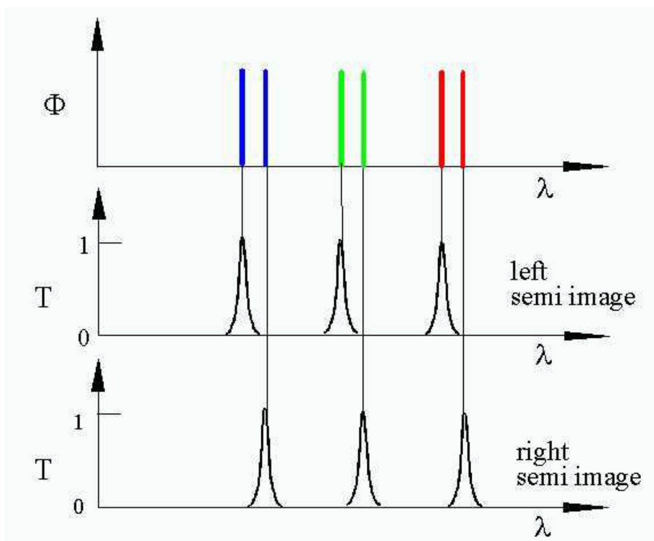


Fig. 3: Stereo imaging using two wavelength triples.

The Infitec System

To separate image content in wavelength multiplex systems very narrow and selective filters are required. Conventional dye filters do not show the required selectivity. Instead, only very high Q interference filters are sufficiently selective to fit the requirements of the wavelength multiplex visualisation scheme for demanding applications. Interference filters normally consist of dielectric coatings deposited on a substrate. This substrate can be also a curved glass substrate used for eyeglasses and, so, can be mounted in any glasses frame. For those people who need corrective glasses, the coating can be deposited also on a corrective glass substrate.

In the conceptual approach, narrow band filters are key elements on the side of the viewer. In practice, however, narrow band filters are also key elements in the image generating system. This is shown in Fig. 4: by integration of filters in standard digital projectors, the light emitted gets a triple band characteristic which is needed to code images in two wavelength triples. Filters can be mounted either inside (option 1) or outside (option 2) of the projector. Because of the high importance of interference filters for these kinds of wavelength multiplex visualisation systems both on the side of the viewer and on the side of the image generator, the abbreviation Infitec (= interference filter technique) was introduced and registered as a trademark.

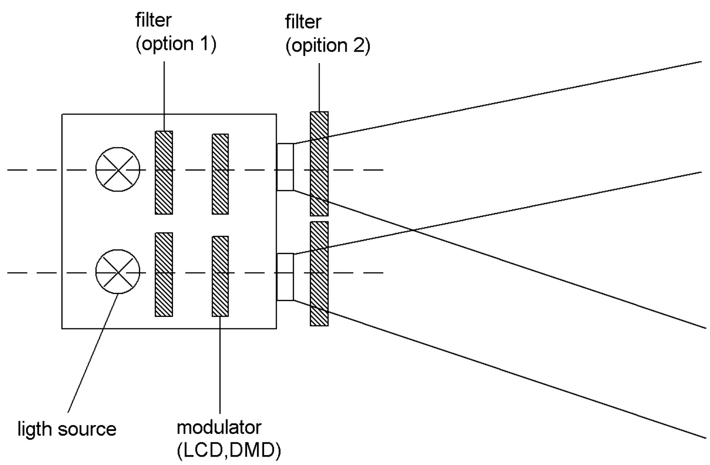


Fig. 4: Schematic set-up of an interference filter technique (Infitec) system for stereo imaging using conventional digital projectors.

Current Status of the Infitec System

Subsequently, the current status of the Infitec system is outlined considering the parameters discussed before

- image resolution
- channel separation between the left and right image
- image homogeneity
- degree of fidelity in color reproduction

in detail.

Image Resolution

In Infitec systems each image (left and right) shows, in principle, the full resolution of the basic projector used. There is no need for a compromise between the image resolution and the number of images shown in parallel like in the auto stereoscopic systems which are based on a directional multiplexing principle [1].

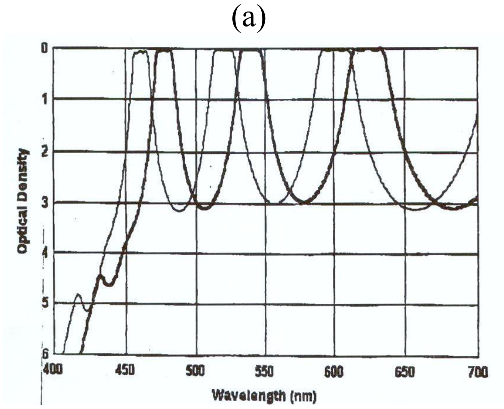
As will be shown in the subsequent section “Fidelity in Color Reproduction” Infitec needs a color correction of image signals in order to re-store balanced colors again. This is because the primary colors B1 – G1 – R1 of the left eye image differ from the primary colors B2 – G2 – R2 of the right eye image. Thus, the accessible definition may be below that of the projector in case that the image data/signal processing for Infitec color correction processes signals not up to the native resolution of the projector. This is discussed in more detail in the subsequent section “Fidelity in Color Reproduction”.

Channel Separation

Channel separation depends in the Infitec system on the selectivity of the interference filters. Normally, the channel separation is significantly higher than in stereo projection systems that rely on polarisation filters (linear and circular).

Interference filters are systems consisting of coupled resonators (cavities). The Q-value (and so the selectivity) of the filter depends on the number of coupled resonators. Fig. 5 shows characteristics of triple band interference filters. Fig 5 a reveals the characteristics of the left (type A) and right (type B) filter used in current Infitec systems. These filters consist of three coupled resonators. The channel separation is about 1:1000. In Fig. 5 b, for comparison, characteristics of four cavity filters are shown. The channel separation exceeds in that case a value of 1 : 10000. The number of cavities should not exceed the minimum number required as the effort in fabricating these filters increases with the number of cavities.

(a)



(b)

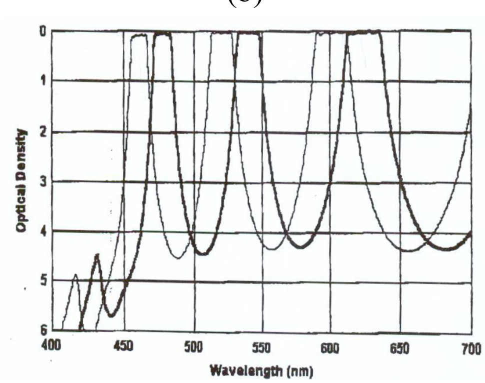
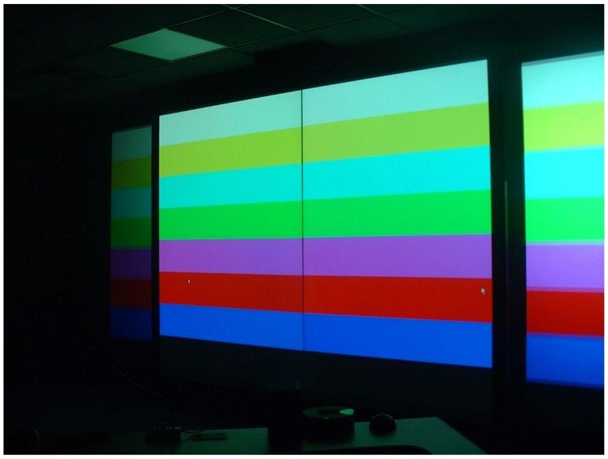


Fig. 5: Triple band characteristics of a three cavity design (a) and of a four cavity design (b).

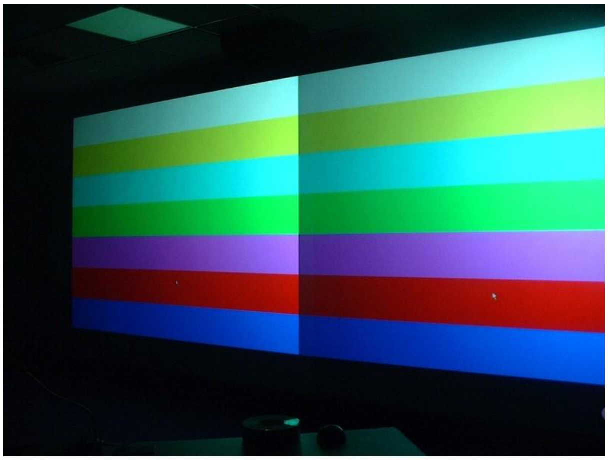
Image Homogeneity

The Infitec system requires no special screen as the only condition which need to be fulfilled by the screen is preservation of the spectral composition of the scattered light. This condition is fulfilled with all conventional screens. Thus, also highly diffuse scattering screens with a gain of unity can be used. This holds both, for front and for rear projection. So, Infitec opens a new way to show stereo images in a homogeneity quality normally known only from mono projection. Hot spot phenomena, well known from stereo imaging using polarisation filters, can be completely eliminated. This is illustrated in Figures 6 and 7.



Hard-Edged Image on White Screen

Fig. 6: Two channel stereo wall using Infitec on a low gain screen.



Hard-Edged Image on Non-Depolarizing (Silver) Screen

Fig. 7: Two channel stereo wall using polarisation filters in combination with a large gain non-depolarizing screen (silver screen).

Fidelity in Color Reproduction

Infitec filters generate two new sets of primary colors for the left and for the right eye image. These two sets are represented by two different triangles in the CIE diagram. To transform these triangles onto a common triangle, image data need to be processed before they enter the imager (LCD, LCoS or DMD chip) of the digital projector. The algorithm for this color conversion is a customary algorithm for calibrating colors in electronic imaging systems [2].

The parameters in this algorithm depend on various other parameters, such as the emission characteristics of the lamp in the projector and on the filter characteristics to generate the primary colors in the projector. Also, naturally, these parameters are strongly influenced by the Infitec filter characteristics. In practise, parameters need to be acquired for each projector type individually to get well balanced colors.

There are different ways to implement this algorithm. For application which do not require interactive real-time rendering, data can be pre-processed using a proper software. This holds for all 3-D video and 3-D cinema applications. For this kind of applications, there is no limitation in resolution for the color data conversion.

For interactive 3-D applications, on the other hand, a fast electronics is required that processes image data in real-time. This electronics is available in an analog version and in a digital version.

Regarding the color gamut: Infitec filtering generates very narrow new primary colors. So the two primary color sets are represented by larger triangles than the original triangle of the basic projector. The algorithm to transform the triangles to a common triangle reduces the enhanced gamut of the non-corrected triangles again to a gamut, which roughly corresponds the original gamut.

Conclusion and Outlook

Conventional stereo display techniques by projection separate images for the left and right eye by (i) wavelength multiplexing (this is know also as the classic anaglyph approach, using for instance red-green filters), by (ii) polarization (linear or circular polarization) or by (iii) time multiplexing (shutter glasses technique). Stereo projection using interference filters is an advanced wavelength multiplexing approach, that specifically takes into account the nature of the human eye, which is characterized by three types of receptors, which are associated to the primary colours blue, green and red. Correspondingly, the two filters used for the left and for the right eye have three narrow transmission bands, respectively . The three transmission bands B1, G1 and R1 of the filter type A for the left eye image and the three transmission bands B2, G2 and R2 of the filter type B for the right eye image are placed such in the visible spectral range (400 to 700 nm) that (1) conjugated transmissions bands (B1-B2, G1-G2, R1-R2) are within the sensitivity range of the respective receptor and (2) conjugated transmission bands do not overlap.

Key features of present Infitec stereo imaging systems are:

- full colour capability.
- superior channel separation.
- passiveness of glasses.
- compatibility with any white screen for mobile and portable presentations.
- compatibility with standard cinema screens.
- compatibility also with low gain screens (rear and front projection) for superior image homogeneity, especially in tiled display systems.
- compatibility with any digital projection technology (LCD, DLP and D-ILA).

Infitec stereo imaging is currently implemented in systems where images are generated by projection. Not yet addressed are display systems, where narrow band light sources itself, such as e.g. light emitting diodes, are used. This may be a further area of advanced display systems that are based on the wavelength multiplexing visualisation scheme.

References

[1] H. Runge, D. Just, "Autostereoskopisches Display", 16. Electronic Displays 2001, Wiesbaden, Germany, September 2001, p. 159 – 165

[2] W. Kresse, D. Reimers, C. Knöpfle, „Color Consistency for Digital Multi-Projector Stereo Display Systems", Proceedings of the Workshop on Virtual Environments 2003, Zürich, Switzerland, p. 271 – 279. ISBN 1-58113-686-2, ACM Press, New York.