INFITEC - A NEW STEREOSCOPIC VISUALISATION TOOL BY WAVELENGTH MULTIPLEX IMAGING

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ABSTRACT

Generation of stereoscopic 3-D images e.g. for visualisation of virtual objects, is currently using techniques like active stereo taking shutter glasses or passive stereo taking polarisation filters. INFITEC is a new technique to display stereoscopic images where the image information is transmitted in different wavelength triplets of the visible spectrum of light. The cross talk in this system is found to be extremely small. As the spectra of the left and right eye image in INFITEC systems are complementary to each other, both images can be generated in principle, by one light source only. Beyond that, wavelength multiplex imaging is compatible to the multiple-viewer functionality.

INTRODUCTION

Spatial imaging techniques are of importance to a variety of applications that reach from the field of amateurs and fanciers to the field of professional users. Applications in the latter field are usually combined with digital imaging techniques and they have experienced a particular rapid growth in the past years. Driven by the increasing capabilities of graphic boards, there is meanwhile- under the caption virtual reality (VR) - a large number of applications that deal with the spatial visualisation of virtual objects.

In practice, the new feasibilities are already used, for instance, in the development of new products, where they enable an identification of deficiencies in the design or the construction prior to the cumbersome prototypical realisation of the new product.

THE STEREOSCOPIC DISPLAY

Natural perception of depth depends upon different perspectives that are related to different positions of a spectator eyes. To create artificial perception of depth the visualisation system has to display two images that are related to the positions of the left and of the right eye. In such a stereoscopic display the images need to be assigned to the respective eye of a spectator. This is accomplished in different ways:

- in autostereoscopic systems images are assigned to different angles of sight (the principle of this technique is illustrated in Fig. 1). Autostereoscopic systems do not need special glasses from the side of the viewer. They also can display, in principle, a multitude of perspectives of the same object. So, they allow several viewers to get their respective perspective of the object displayed (multiple-viewer functionality). The drawback of autostereoscopic systems is their poor resolution. In order to display a number n of perspectives (n is typically in the order of ten) the resolution is diminished by a factor of n (s. Fig. 1).

- in large screen stereoprojection displays - which are preferably used in VR systems as they provide most easily the sensation of immersion - images are assigned either by the active or by the passive stereo technique. In active stereo systems left and right eye image are intermittently displayed. To assign images to the respective eye the viewer has to wear shutter glasses that are suppressing the wrong image. As the shutter function is normally done by liquid crystal panels, these glasses need a power supply (this is why the technique is called active stereo). Alternatively, in stereoprojection systems, the passive stereo technique is used. In these systems normally the light of the left and the right eye image is polarised where the respective polarisations are perpendicularly to each other. The viewer also needs glasses consisting of polarisation filters (which do not need any power supply wherefore the technique is called passive stereo). The advantage of active and passive stereo over against the autostereoscopic display is (besides the normally larger size) the availability of full resolution. A serious drawback, however, is the restriction to two images which impedes that a second viewer can get a spatial image of the virtual object from all sides in parallel (no multiple-viewer functionality).

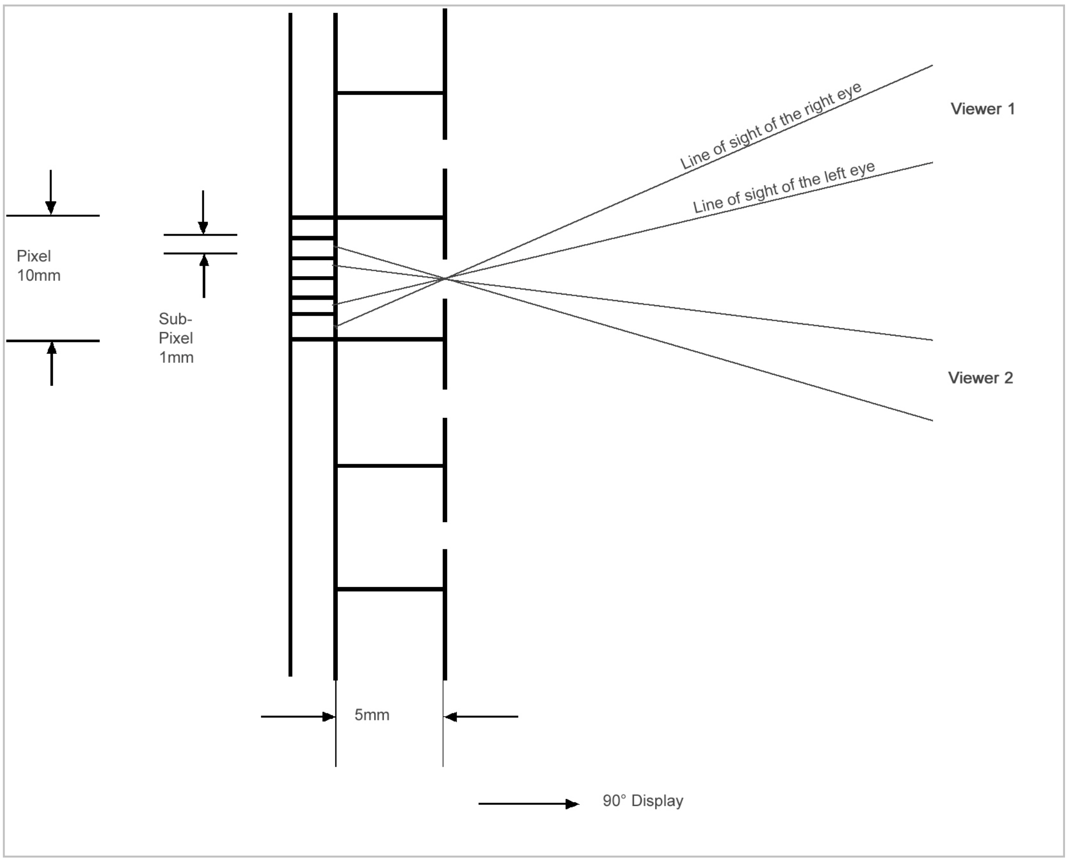

Fig. 1 Autostereoscopic display - schematic set-up

In the following section we want to discuss a new way of passive stereo that allows to display full resolution images. In addition, this way is basically compatible also to the multiple-viewer functionality.

WAVELENGTH MULTIPLEX VISUALISATION - WORKING PRINCIPLE

Light incoming into the human eye is separated into three spectral ranges by three types of receptors that are related to the primary colours blue, green and red. The sensitivities of these receptors over the wavelength are depicted in Fig. 2. Table 1 summarises the wavelengths of maximum sensitivity and the FWHM of the curve of the respective receptor type.

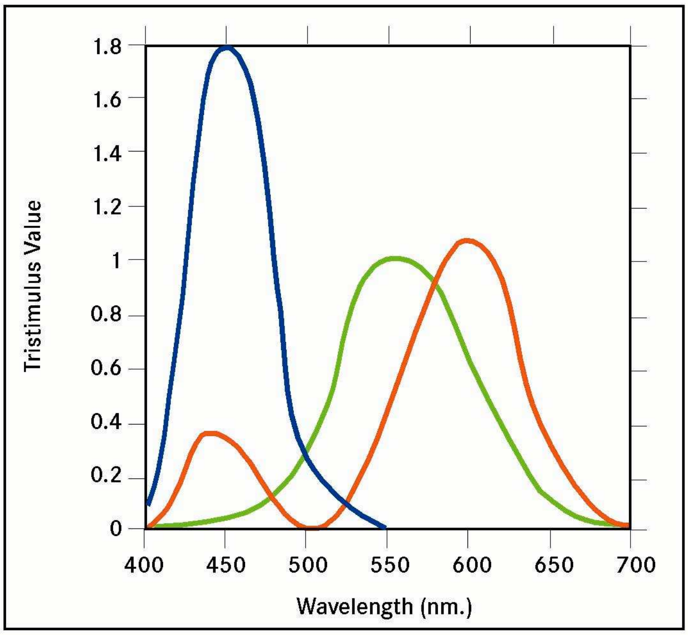

Fig. 2 Colour receptor sensitivity

Table 1 Wavelength of maximum sensitivity and full –width at half maximum (FWHM) of receptors in the human eye

	λ_{max}	$\Delta\lambda$
blue receptor	450nm	60nm
green receptor	550nm	80nm
red receptor	600nm	70nm

According to the three types of receptors in the human eye, colour displays are build up by three pixel types. Each pixel type is emitting light within the sensitivity range of the correlated receptor type.

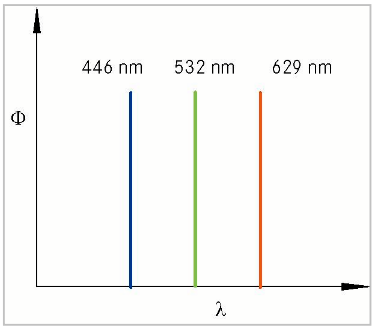

Fig. 3 Spectrum of the laser display

The spectral width of the emission is normally not of decisive importance. This parameter is determining merely the saturation of the primary colour. Most saturated colours are obtained by displays with very narrow-bandwidth primary colours, such as the laser display where almost monochromatic primary colours are used (Fig. 3).

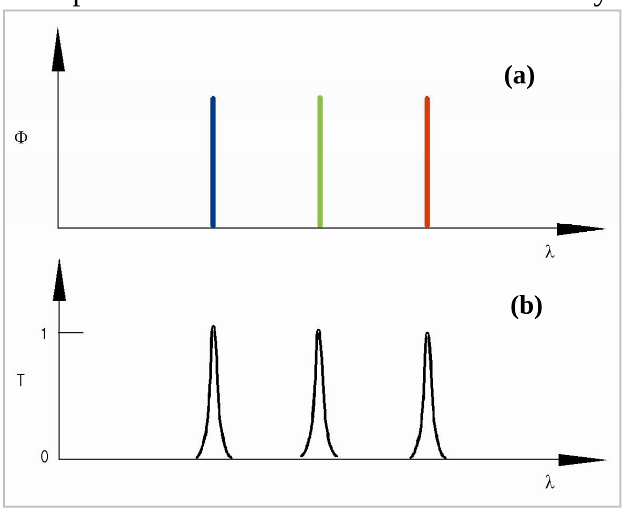

Fig. 4 Display spectrum (a) and input filter characteristic (b) in wavelength multiplex imaging

In wavelength multiplex displays, however, another feasibility being inherent in displays with narrow-bandwidth primary colours is used, namely the possibility of transmitting image information in different triplets of primary colours in parallel. In order to assign the information to the corresponding receiver (which is the eye of the viewer) the information has to be filtered by analogy with the filtering of transmitter signals in broadcasting by the oscillatory circuit at the input (Fig. 4). At optical frequencies the corresponding circuits are represented by high Q interference filters that consist of a multilayer deposition of dielectric materials on, for instance, a glass substrate. These filters can be integrated in standard eyeglasses.

The Q value (that is related to the selectivity of the filters) is determining the maximum size of image content that can be displayed in parallel. Physically, interference filters are coupled resonators where the number of resonators is determining the selectivity of the filters. Increasing the number of resonators increases the selectivity of the filters.

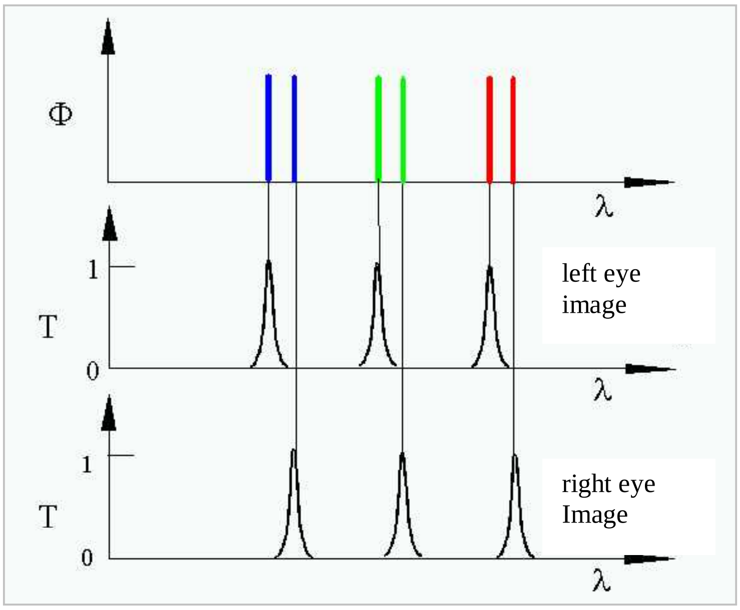

Fig. 5 Stereoscopic imaging taking two primary colour triplets

Taking two triplets B1-G1-R1 and B2-G2-R2, for instance, the wavelength multiplex principle can be used to display stereoscopic images (Fig. 5). To increase the number of viewers of a virtual object in parallel (multiple-viewer functionality, s. previous section), the number of triplets has to be increased to twice the number of viewers (two stereoscopic perspectives for each viewer). The boundary condition that has to be observed for all the triplets is that all monochromatic primary colours (B1 ... Bn, G1 ... Gn, R1 ... Rn) are lying within the bandwidth of the respective human eye receptor. From the FWHM of these curves (Fig. 2) we see, that the bandwidth, available to each primary colour, amounts to about 50nm. So, wavelength multiplex visualisation is capable to combine the advantage of autostereoscopy (multiple-viewer capability) with that of stereoscopy (high image quality by high definition).

Besides that, there is a feature of the wavelength multiplex scheme regarding image contrast which is especially advantageous to the front projection situation: as the narrow-band interference filters permit only part of the daylight to pass, interference filters do enhance efficiently the contrast ratio in light rooms which may be of interest also to mono-display applications (one wavelength triplet only).

Another aspect of practical relevance may be the feasibility of depositing the dielectric multilayer, which causes the interference filter characteristic, onto glasses with optical correction. So, users with eyeglasses do not need extra-glasses as they can use correction glasses with the specific dielectric multilayer deposition.

THE INFITEC SYSTEM - A FIRST FULL COLOUR WAVELENGTH MULTIPLEX REALISATION

Obviously, the laser display would be the most ideal display to wavelength multiplex imaging due to the high coherency of primary colours. Unfortunately, wavelengths used in existing systems are not tuneable and, on the other hand, laser light sources that would be tuneable do not provide the power levels required in displays.

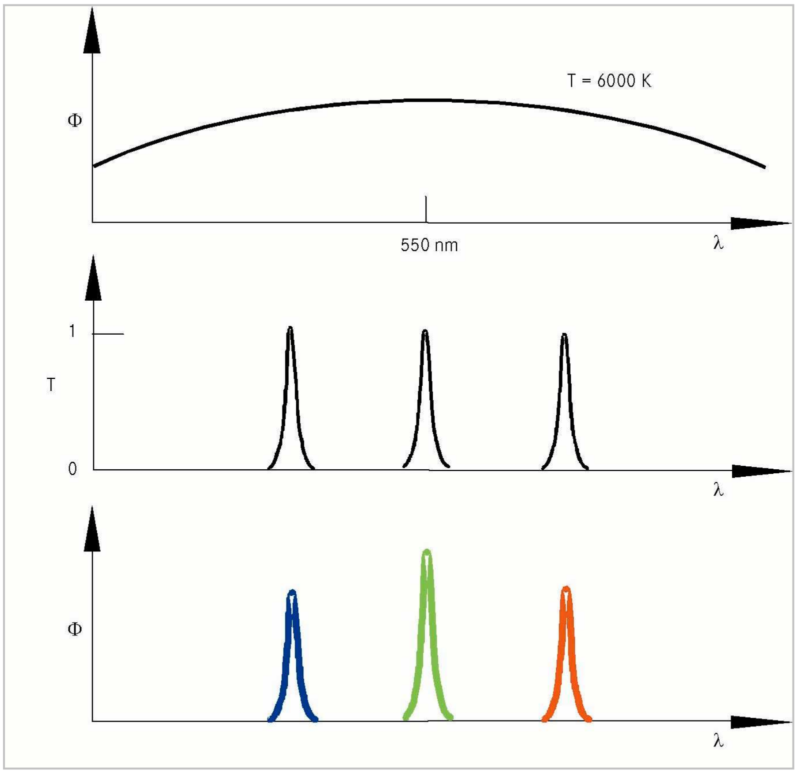

Fig. 6 Generation of wavelength triplets in the INFITEC - system

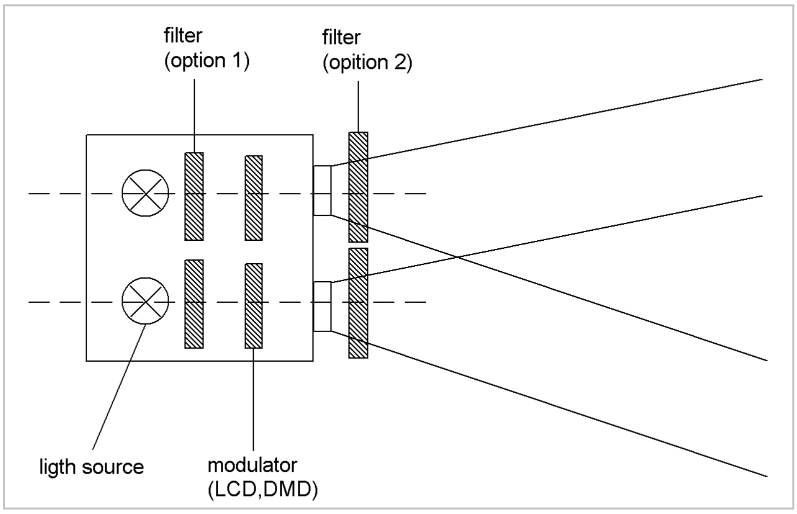

Fig. 7 Projection system with integrated triple band filters to generate two sets of primary colours

Therefore our experimental work started with another system, namely a projection system with thermal emission light sources (Fig. 6) where the triple band emission characteristic was generated by triple band filters integrated in the projection system (Fig. 7). Emission spectra measured without and with filters integrated are shown in Fig. 8 a - c, respectively.

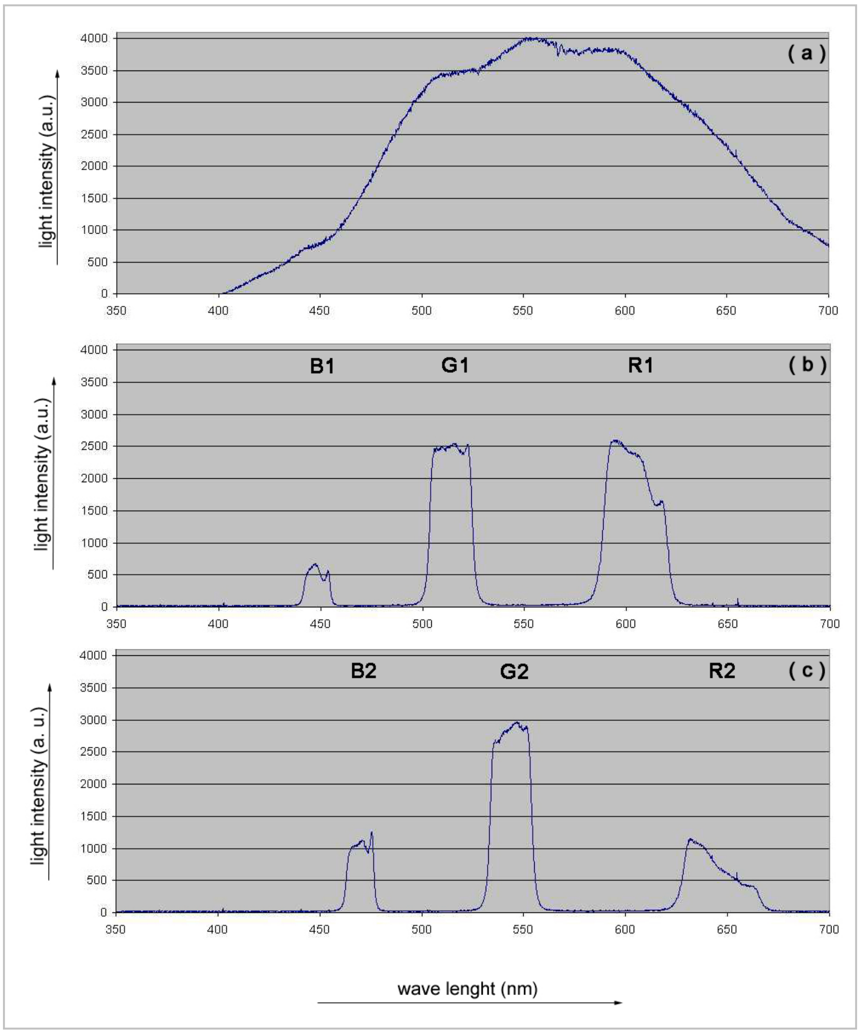

Fig. 8 Spectrum of a broadband thermal light source without (a) and with type A (b) and with type B filter (c)

Stereoprojection with such an INFITEC (interference filter technique) system using an interference filter Type A (primary colours B1 - G1 - R1) to the left eye image and a filter type B (primary colours B2 - G2 - R2) to the right eye image reveals a very clear channel separation with virtually not any cross talking which exceeds clearly that in stereoprojection systems that work with polarisation filters.

Regarding colours the left eye image appears to be slightly reddish where the right eye image appears to be slightly greenish. A view to both images simultaneously, however, makes these colour displacements invisible to a majority of viewers and colours appear in a natural way. Major reasons to the colour displacements are (i) the closer proximity of the R1 primary to the maximum of the red receptor and (ii) the closer proximity of the G2 primary to the maximum of the green receptor (Fig. 2).

We found that colours in the left and in the right eye image can be efficiently approximated by an electronic mixing of the primary colour signals according to a scheme

$$R' = a_{11}\, R + a_{12}\, G + a_{13}\, B \qquad (1)$$

$$G' = a_{21}\, R + a_{22}\, G + a_{23}\, B \qquad (2)$$

$$B' = a_{31}\, R + a_{32}\, G + a_{33}\, B \qquad (3)$$

where this scheme needs to be applied both to the left and to the right eye image signals. With this scheme we are able to approximate colours in a satisfactory way also with projection systems that produce very strong and not acceptable colour displacements otherwise. Generally, projection systems with lamps exhibiting line emissions (s. Fig. 9 a) belong to that group as the intensities in respective primary colours are very different (s. Fig. 9 b, c).

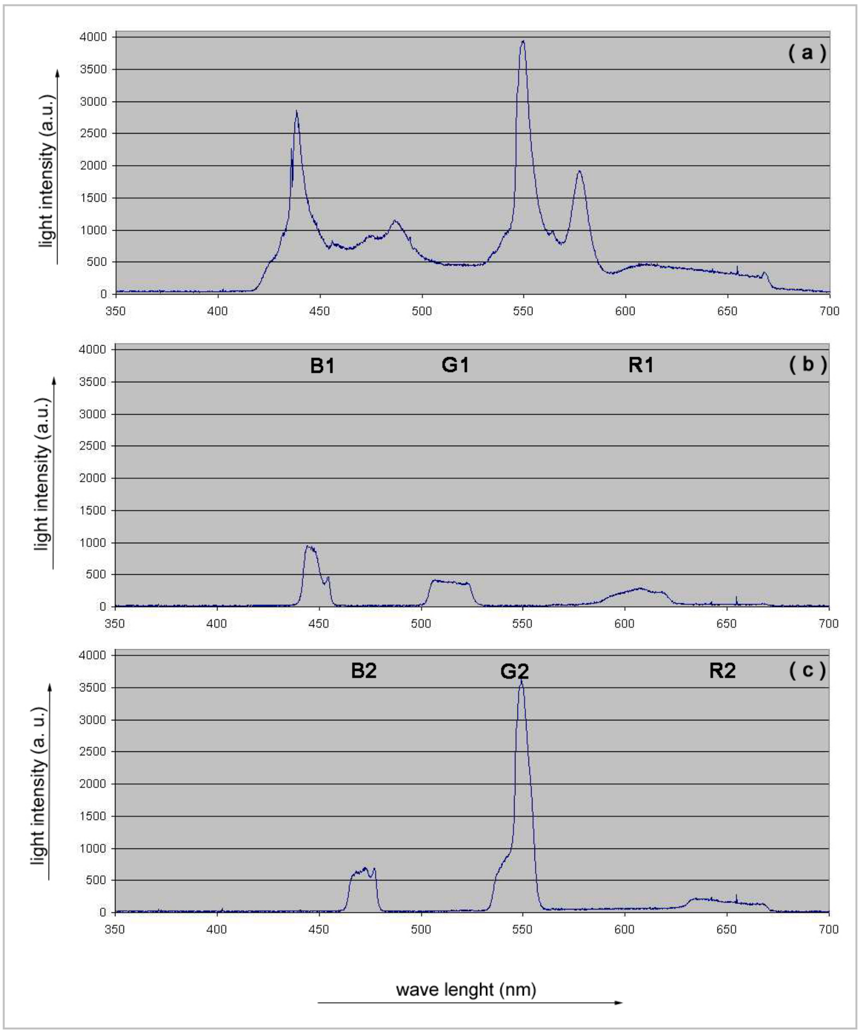

Fig. 9 Spectrum of a UHP (ultra high pressure) lamp without (a) and with type A (b) and with type B filter (c)

In future laser display systems corresponding primaries can be presumably put close together which, in turn, would reduce the need for an additional electronic colour correction scheme.

PERSPECTIVES AND OUTLOOK

Wavelength multiplex visualisation is a way to display stereoscopic images to a multitude of viewers in a correct viewing perspective at the same time. To get full access to that functionality, however, display techniques with very narrow bandwidth primary colours need to be available.

In a short term perspective, wavelength multiplex imaging can be realised by the INFITEC approach, where narrow bandwidth primary colours are generated by filtering the emission of a broadband emitting light source. As the spectra of the left and right eye image in the INFITEC system do not have common parts (they are complementary to each other in a sense) both spectra can be generated, in principle, by one light source. This opens the prospect of a compact and low weight stereoprojector that needs one light source and one objective only.