Abstract Title: Stereoscopic Display Apparatus

A stereoscopic display apparatus has a display apparatus, e.g. projector (16), capable of supplying two images, a polarization modulator (48) capable of polarising the two images in orthogonal polarisations, and a colour modulation apparatus (46) capable of encoding the two images with different spectral content. In one arrangement, a projection screen (50) with limited polarisation preserving properties is included. Eyewear (52, 54) is provided in which the polarisation and spectral content is decoded by means of polarisation interference filters aligned to the output polarisation of the display. This produces low levels of cross talk using low cost eyewear. Direct view arrangements are also provided. A multi-view stereoscopic display apparatus provides more than two images so that users can select the amount of depth required in a 3D stereoscopic presentation.


**Stereoscopic Display Apparatus**

The present invention relates to an apparatus for the display of 3D stereoscopic images. Such systems may be used in computer monitors, projection systems, cinema including digital cinema, games apparatuses, professional displays and 3DTV applications. The disclosed embodiments herein relate generally to projection display and direct view displays and associated eyewear and more particularly to architectures and techniques for providing improved performance.

Stereoscopic display apparatuses provide at least two distinct images to each eye of an observer in which the observer wears some form of eyewear. In autostereoscopic displays, no eyewear is used. The brain fuses the images to give the appearance of depth. An important factor for viewer comfort when observing such displays is the cross talk between the left and right eye images. High levels of cross talk result in the visualisation of erroneous (pseudoscopic) homologous points, which can disrupt in the human visual system. Acceptable levels of cross talk, defined by the cross talk threshold depend on the contrast of the image presented and the amount of depth to be shown. Levels of less than 1%-5% are often required for comfortable viewing while it has been reported that the cross talk visibility threshold is less than 0.5%. The visual effect of cross talk can be reduced by contrast reduction of images, but disadvantageously this degrades image performance, and reduces the contrast of edges in the scene, thus reducing the impact of the stereoscopic image.

Many stereoscopic displays have been demonstrated, including two colour anaglyph, shutter glasses, crossed polarisation and multi-colour anaglyph. In each system, a display provides view data coded appropriately, with eyewear decoding the image for left and right eyes. Stereoscopic displays are well suited to large audiences, where it would not be economic to provide separate autostereoscopic (glasses free) images to each observer.

Two colour anaglyph displays typically rely on broad spectral filters placed over each eye. This results in a restricted colour gamut seen in each eye. While the brain somewhat fuses and compensates the colour of the image, it is problematic to provide adequate colour and intensity matching between the two eyes, resulting in false depth cues and viewer discomfort.

Multi-colour anaglyph, or 'spectrally selective' systems such as described in U.S. Pat. No. 7,001,021 seek to overcome the difficulties with two colour anaglyph by presenting complementary comb spectra to each eye, so that red, green and blue data of different respective spectra is received by each eye. Such displays are capable of achieving full colour images in each eye, with compensation for gamut and intensity differences achieved by processing of source data. Cross talk levels in such displays are set by the degree of spectral separation between the left and right eye colour bands.

The appropriate separation of the spectra can be achieved by vacuum deposited (isotropic) interference filters, or by polarization (birefringent) interference filters such as described in U.S. Pat. Appln. No. 2007/0188711. Cross talk performance of the display is determined by the quality of separation provided by the encoding and decoding filters. Isotropic interference filters can
demonstrate low levels of cross talk, but have a high cost. These filters also can suffer from poor off-axis viewing meaning that the image cross talk, intensity and colour gamut seen by each eye may vary depending on viewing angle through the glasses.

The eyewear described above is passive, with no active component. Shutter glasses are a form of active eyewear, requiring a switchable component in the eyewear. The shutter glasses such as described in U.S. Pat. No. 4,884,876 rely on separation of left and right eye images in the time domain by opening and closing a shutter over each eye in synchronisation with the delivery of respective left and right eye images. When used in cooperation with fast response display systems such as the Texas Instrument DLP™ imager, such displays are capable of providing low levels of image cross-talk. However shutter glasses are relatively expensive, tend to be bulky, require a power source and synchronisation; further can create distracting flicker from the background around the display.

Polarisation systems such as described in U.S. Pat. No. 4,792,850 advantageously allow the use of passive glasses. In such a display, the polarisation output of a display is switched in synchronisation with the output of a display device such as a CRT or DLP imager. The glasses worn by the observer are of orthogonal polarisation (either linear or circular) so that each eye sees a respective image. Such displays when used in projection rely on the use of a polarisation preserving screen, such as a silvered screen. Achromatic switcher designs are described in U.S. Pat. No. 2006/0291053. Such switchers ensure that the rotation of polarisation is substantially maintained across the visible spectrum. Performance of the system is limited by cross talk generated at the partially polarisation preserving screen.

U.S. Pat. No. 7,002,619 describes a dual projector display system which seeks to overcome the problem with cross talk arising from light leakage in shutter glasses. Two projector systems suffer from high cost of projectors, and the difficulties in matching the alignment, intensity and colour gamuts through the lifetime of operation.

According to a first aspect of the present invention there is provided a stereoscopic image display apparatus comprising:

- at least one image display apparatus;
- at least one colour encoding filter;
- at least one polarisation encoding filter;
- first and second eyewear comprising first and second polarisation interference filters that cooperate to decode polarisation and spectrum of images.

According to a further aspect of the present invention there is provided a stereoscopic image display apparatus comprising:

- an image display apparatus capable of providing at least first and second images;
at least one colour encoding filter which encodes the colour output of the first and second images with respectively first and second different visible coding spectra;

at least one polarisation encoding filter which encodes the polarisation output of the first image substantially with a first polarisation state and encodes the polarisation output of the second image substantially with a second polarisation state;

first eyewear comprising a first polarisation interference filter comprising a first eyewear input polariser which substantially extinguishes light with the second polarisation state, at least one retarder stack and at least a further polariser, which cooperate to provide a first eyewear transmission spectrum;

second eyewear comprising a second polarisation interference filter comprising a second eyewear input polariser which substantially extinguishes light with the first polarisation state, at least one retarder stack and at least a further polariser, which cooperate to provide a second eyewear transmission spectrum;

in which the first eyewear transmits a portion of the first visible coding spectrum and a lesser portion of the second visible coding spectrum;

in which the second eyewear transmits a portion of the second visible coding spectrum and a lesser portion of the first visible coding spectrum.

According to a further aspect of the present invention there is provided a multi-view stereoscopic display system comprising:

image display apparatus arranged to provide at least three images;

at least one colour encoding filter arranged to encode respective images with one of at least two different visible coding spectra;

at least one polarisation encoding filter arranged to encode respective images with first or second polarisation states;

eyewear each comprising spectral and polarisation decoding filters;

where the spectral and polarisation decoding filters comprise polarisation interference filters.

The present invention provides a display system capable of providing partially polarisation encoded and partially colour coded image sequences to retarder stack eyewear capable of analysing polarisation and spectra in cooperation. It is the purpose of the present invention to provide a stereoscopic display with low levels of image cross talk and wide viewing angle with low cost passive glasses using simple polarisation interference filters. Such displays are well suited to viewing by large audiences while providing high levels of viewing comfort and tolerance to viewing direction at low cost.

In a projection stereoscopic apparatus, real polarisation preserving screens suffer from depolarisation effects due to skew ray depolarisation and surface scatter as well as from plasticizers
used in the construction of the screen. The present invention is capable of maintaining levels of image cross talk below a threshold with such screens because of the spectral separation of the eyewear cooperates with the polarisation coded images. Advantageously, the reflection profile of the screen may be modified to reduce screen gain and thus reduce screen hot spots. Reducing screen gain may increase depolarisation of the screen however the present invention maintains system cross talk below a threshold. Such screens may for example provide more acceptable performance when used in 2D projection mode. Linearly polarised eyewear is sensitive to increased cross talk by head tilt. In order to overcome this, circular polarisers have been implemented, which typically create some chromaticity effects with head tilt.

Prior art spectrally selective eyewear is designed to achieve adequate finesse so that the cross talk falls below an acceptable threshold. Such filters have to be designed so that the overlap between left and right eye spectra is minimised. Prior art spectrally selective eyewear using isotropic interference filters suffer from high cost and variation of spectrum with viewing angle. As an observer’s eyes move with respect to the central position of the glasses, the spectrum also shifts. This may result in change in brightness, colour and increase in cross talk levels across the image. Such filters are typically formed in vacuum coating equipment and to achieve adequate spectral selectivity, a number of accurately tuned layers must be deposited. The high cost of such filters means they must be frequently re-used meaning that they are also sensitive to scratching during repeated heavy use and cleaning, degrading the picture quality. Prior art spectrally selective eyewear using polarisation interference effects requires complex retarder stacks incorporating large numbers of elements in order to achieve the adequate spectral selectivity so suffer from high cost.

The eyewear of the present invention comprises a pair of polarisation interference filter comprising a stack of polarisers and small number of retarders with overlapping of the third and fourth spectra. Such a simple stack is cheaper to manufacture than the complex retarder stacks required in prior art systems. Low cross talk is achieved by orthogonal input polariser angle direction in combination with the polarisation encoded output of the display system. As the width of slope of the transmission spectrum for each peak is typically broader than complex retarder system, the offset in spectrum with viewing angle maintains an overlap with the input spectrum.

Further, the spectral selectivity of the interference filter compensates for off-axis depolarisation effects at the screen and in the polariser elements. To improve spectral angular performance further, simpler wide-fielding architectures may be used in the retarder stack than in prior art systems, reducing device cost. The present invention also shows insensitivity to head tilts due to the spectral selectivity of the eyewear.

The polarisation separation of the light from respective views entering the eyewear and the spectral overlap of the light entering the eyewear are individually above acceptable thresholds for comfortable viewing of images, for example greater than 1% luminance cross talk per colour channel (red, green or blue) and typically greater than 2% luminance per colour channel for polarisation effects
and greater than 5% luminance per colour channel for colour selectivity effects. In combination, the cross talk of the observed image falls below the acceptable threshold for cross talk, for example 1% luminance per colour channel or less.

Such a display does not rely on high performance polarisation switchers, high performance silvered screens or high performance isotropic interference or complex retarder stack polarisation interference colour selective eyewear. The system is tolerant to cross talk changes arising from head tilts using linear polarisation filters and for high viewing angles.

Further, such a display is capable of providing a multi-view function such that observers can select whether they wish to view a 2D image, a low depth image or a high depth image.

Advantageously, users can tune display output to meet their individual viewing comfort needs.

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 shows a prior art projection system using crossed polarisers;

Fig. 2 shows a prior art projection system using a time sequential switchable polariser;

Fig. 3 shows a prior art projection system using a time sequential colour encoding filter;

Fig. 4 shows schematically prior art spectra;

Fig. 5 shows a first embodiment of the present invention comprising a time sequential projection system;

Fig. 6 shows a further embodiment of the present invention comprising a dual projection system;

Fig. 7a shows a transmissive direct view display apparatus comprising a further aspect of the present invention;

Fig. 7b shows an emissive direct view display apparatus comprising a further aspect of the present invention;

Fig. 8 shows the structure of a polarisation switcher;

Fig. 9 shows the simulated output of the polarisation switcher of Fig. 8;

Fig. 10 shows examples of structures of eyewear for the present invention;

Fig. 11a shows the simulated transmission of the eyewear of Fig. 10a;

Fig. 11b shows the simulated transmission of one embodiment of the eyewear of Fig. 10b;

Fig. 11c shows the simulated transmission of a different embodiment of the eyewear of Fig. 10b;

Fig. 12a shows a first set of eyewear for a multi-view cinema system; and

Fig. 12b shows a second set of eyewear for a multi-view cinema system.

A prior art stereo display system is shown in Fig. 1. Image projectors 2, 4 illuminate a projection screen 10 through polarisers 6, 8 arranged to encode the polarisation of the respective images. The output polarisation of polarisers 6, 8 are orthogonal, and they may comprise linear or circular polarisation states. The projection screen 10 has a polarisation preserving property and directs
the light back towards an observer (not shown) with passive eyewear 12,14. Filters 12,14 comprise polarisers aligned to the filters 6,8 respectively.

Cross talk performance in such a display is dominated by the reflectivity of the projection screen. For example a depolarisation ratio of 20:1 will create 5% cross talk. Such cross talk levels will cause visual stress for many users of stereoscopic displays, particularly for high contrast images.

Cross talk in screens arises from skew ray depolarisation, and surface scatter for example due to surface contamination and the binder and plasticizer materials used to form the screen surface. Further, silvered screens tend to exhibit high levels of gain that can cause hot spots in images. It is the purpose of this invention to reduce the polarisation performance requirements of the screen while maintaining low levels of cross talk with low cost eyewear. In this way, it is possible to design the screen to achieve higher levels of image performance, for example reducing the visibility of hot spots while maintaining low cross talk.

Fig.2 shows a time sequential projector, in which left and right images are produced by projector 16. Filter 18 comprises a switching polarisation rotator capable of encoding image output polarisation by producing orthogonal output polarisation states in synchronisation with the image data from a high frame rate projector such as the DLP™. The eyewear passes left eye data through filter 12 and right eye data through filter 14 in sequence.

Fig.3 shows a prior art time sequential spectrally selective stereoscopic display. The filter 20 comprises a spinning isotropic interference filter wheel with left and right eye spectra. The spectral output is synchronised with the projector image 16. The screen 22 is a non-polarisation preserving screen. The eyewear 24,26 comprises isotropic interference filters with spectra which match the filter 20 spectra. Transmission spectra for filter 20 are shown schematically in fig.4 which plots transmission 28 against wavelength 30. The first spectrum comprises blue, green and red transmission peaks 32,34,36 respectively, while the second spectrum comprises blue, green and red transmission peaks 38,40,42 respectively.

Cross talk in such a system is determined by the spectral overlap of the spectra. To achieve low levels of cross talk, there should be minimal overlap of the two spectra. The total spectral cross-talk is defined as the ratio of the luminance of the incorrect spectrum passed by the spectral filter to the luminance of the correct spectrum passed by the spectral filter. The channel spectral cross talk is the luminance ratio across a single colour channel (red, green or blue) and the average spectral cross talk is the average of the channel spectral cross talks for the three colour channels. Such values may or may not take into account the nature of the illuminant.

With multi-cavity designs using dielectric isotropic interference filters, Fabry-Perot filters and metal-dielectric filters it is possible to achieve high levels of image separation with low spectral cross talk. However, such filters are expensive to manufacture, and therefore typically are required to be re-used. Such re-use requires cleaning of the glasses to prevent biological contamination between users, and means that the glasses are prone to scratching which can degrade image quality. Further, such
glasses have off-axis viewing limitations in which the spectral peak shifts with viewing angle. That means that as the eyes of the observer look off axis through the filters 24, 26, the position of the spectral peak shifts. This may not match the peak output spectrum of the projector, so that the brightness reduces, or the observed light seen through the first spectral filter may come from the second spectrum, so the image cross talk increases.

If the isotropic filters of the prior art are replaced by birefringent, polarisation interference filter complex and thus expensive stacks of retarders are required in order to meet the spectral cross talk requirements. Such filters are thus high order ripple filters, which show very low levels of spectral ripple (low ripple factor) outside the required transmission bands.

Fig. 5 shows a first embodiment of the invention. A projector 16 generates field sequential left and right images in synchronisation with a signal from a controller 44. Controller 44 also determines the setting of a spectrally selective filter 46, representing one embodiment of a colour encoding filter, and a switchable polarisation rotator 48, representing one embodiment of a polarisation encoding filter. In a first phase, the left eye image is produced, the light is spectrally filtered by the filter 46 and the polarisation output determined by the switchable polarisation rotator 48. The light is projected onto a projection screen 50 which has polarisation preservation properties. The reflected light is directed towards the eyewear comprising left eye filter 52 and right eye filter 54. The elements 46, 48, 52 and 54 will now be described in more detail.

The filter 46 may comprise a spectrally selective filter such as an isotropic interference filter. The filter may have two regions on a single disk, and is rotated in the illumination path of the projector so as to provide sequential spectrally selective operation of the device. Alternatively, the filter 46 may be of the polarisation (birefringent) interference type.

The filter 48 may comprise a polarisation rotator. Such a filter may be an achromatic push-pull polarisation rotator as shown in Fig. 7. An input linear polariser 62 is followed by a half wave rotator 62, a residual retardance compensation stack 68, a first zero twist nematic liquid crystal cell 74, a second zero twist nematic liquid crystal cell 88, arranged to operate substantially in anti-phase to the first cell 74, and a residual retardance compensation stack 90. The optical function of the residual retardance compensation retarder can further be divided either side of each cell 74, 88. The retarder 62 may comprise half wave retarder films 64, 66 with angles set so as to provide low dispersion characteristics to match the dispersion of the retardance of the remainder of the stack during operation. Further retarders (not shown) may be included in the stack 62 to further improve the chromaticity of the system. The cell 74 is arranged so as to provide a high retardance mode (low voltage) in a first state, and a low retardance mode (high voltage) in a second state. The cell 88 is correspondingly arranged so as to provide a low retardance mode (high voltage) in a first state, and a high retardance mode (low voltage) in a second state. The stacks 68, 90 respectively comprise orthogonal retarder sets 70, 72 and 92, 94 aligned to the cells 74, 90 with retardances set to compensate for the residual retardance of the mode in the high voltage state. The compensation retarders can also be positioned to
each side of the cells 74,88 such that stacks 68 and 76 (comprising half wave retarders 78,80) and 
stacks 82 and 90 (comprising half wave retarders 84,86) cooperate to provide improved viewing angle 
performance.

An example output for providing substantially +/-45 degree rotation of the input polarisation 
state using representative waveplate and liquid crystal dispersions is achieved with a polariser axis of 0 
degrees, a low dispersion half waveplate retarder stack 62 axis direction aligned to rotate the input 
polarisation close to 111.5 degrees, and cells having axes aligned at 158.5 degrees and 111.5 degrees 
respectively. The cells 74,88 are operated in anti-phase so that one cell is relaxing while the other is 
driven.

The on-axis spectral output is shown in Fig.9. The extinction levels 102,104 of each state is 
shown, indicating the cross talk level that can be achieved across the visible spectrum. If required, a 
further broadband quarter waveplate stack 96 comprising for example retarders 98,100 can be inserted 
at the output to provide achromatic circular output polarisation states with similar chromatic 
performance.

The degradation in polarisation contrast at the partially polarisation preserving screen 50 is 
compensated by the operation of the eyewear 52,54 as described below. Fig 10a shows one 
embodiment of one of the eyewear filters 52. An input polariser 106 receives light from the projection 
screen with polariser transmission axis aligned to the output polarisation axis from the shutter 48 for 
the particular eye. An output polariser 108 analyses the final output polarisation state and is set 
 orthogonal to the input polarisation state. The retarder stack comprises identical retarders 110, 114 
aligned at 45 degrees to the input polariser 106, with a third retarder 112 sandwiched between them 
with a quarter wave less retardation and aligned parallel to the input polariser. With appropriate 
retardances, the stack produces an on-axis eyewear transmission spectrum 135 (representing the third 
spectrum of the invention) as shown in Fig 11a. Optional retarders (not shown) can be positioned at 
the input side of the polarisers 106, 116 such that the system is tolerant to head tilt by operating with 
circularly polarised light. In this case, the output of the display apparatus is also encoded with the 
corresponding orthogonal circular polarisation states.

It can be seen that this simple stack comprises a low order ripple filter, with significant ripple 
side-bands to the main spectral maxima (a high ripple factor). The input spectra from the filter 46 
comprising blue 126, green 128 and red 130 spectral regions are marked and for maximum 
transmission, there is substantial overlap between the spectrum 135 and the spectrum 126,128,130. 
Note that the simplicity of the low order ripple filter means that there are additional spectral maxima 
129, 131 and 133 in which the light from the spectrum 135 falls outside the regions 126, 128 and 130. 
In particular, these additional maxima have a peak which is greater than 5% of the maximum peak of 
the spectrum 135. There may be at least four such maxima in each eyewear, and typically there will be 
six or more in such low order ripple factor across the visible spectrum.
The second eyewear filter 54 is shown in Fig.10b and uses an input polariser 116. In one embodiment, the stack of retarders 120,122,124 can be identical to the retarders 110,112,114, and the output polariser 118 parallel to the polariser 108. In this case, the spectrum 137 of the filter is shown in Fig.11b. It can be seen that substantially the light falls in the regions 132,134 and 136 (representing the second spectrum of the invention) but that there is also significant overlap with the first spectral filter spectrum 126, 128 and 130.

In isolation, this creates cross talk above the crosstalk threshold, but the crossed input polarisation state of polarisers 106, 116 mean that the device cross talk can be reduced below the cross talk threshold.

In a different embodiment, the polariser 118 is orthogonal to the polariser 116 and the thickness of the retarders 110,112 and 114 is adjusted so that the output spectrum with spectrum 139 (representing the fourth spectrum of the invention) is as shown in Fig.11c. Again, the light from spectrum 139 substantially overlaps the second spectrum 132,134 and 136, but there is significant overlap of the band 139 with the first spectral filter band 126,128,130. Thus the second eyewear transmits a significant portion of the second visible coding spectrum(132,134,136) and a lesser, but non-zero, portion of the first visible coding spectrum (126,128,130) Similarly the first eyewear transmits a significant portion of the first visible coding spectrum(126,128,130) and a lesser, but non-zero, portion of the second visible coding spectrum (132,134,136). The first blue channel spectral cross talk is contributed by light around wavelength maximum 129, and around maxima 131 and 133 green and red respectively. The luminance of the first image in the blue colour channel can be calculated for example by the overlap of the spectrum 135 with the coding spectrum 126.

This significant transmission of a lesser proportion of the opposite coding spectrum would provide unacceptable cross talk levels in isolation, but the polarisation coding of the image means that cross talk below the cross talk threshold is achieved using low cost eyewear.

A colour channel is defined as the combination of the bands 132,126 for blue, 128,134 for green and 130,136 for red.

In one illustrative example, a vacuum deposition four cavity filter has an on-axis channel separation of 1000:1 between left and right eye filters. An achromatised push-pull linear polarisation rotator modifies the output polarisation state as shown in Fig.9. The output polarisation is incident on a partially polarisation preserving screen with a reflected contrast ratio of 20:1. Thus, the cross talk seen by each eye for vertically aligned polarisers will be 5%. In one filter design as shown in Figs 11a and 11c, using representative retarder dispersion, the average colour spectral cross talk in each eye is 6% and 12% respectively. The average system cross talk is thus 0.3% and 0.6%. If the cross talk threshold is 1% then, the colour overlap ratio is above the threshold, while the system cross talk is close to the cross talk visibility level. Such a display can thus provide high quality stereoscopic images with low cost eyewear.
Clearly, some further enhancement of the filter performance can reduce the filter overlap further, but at the expense of significant additional retarder layers and therefore expense of glasses. In an alternative embodiment, the spectral width of the filters 126, 128, 130, 132, 134 and 136 can be reduced to boost cross talk further by removing peaks of the overlapping eyewear spectra from the transmitted light. It may be desirable to use an additional blue cut-off filter or retardance stack modification to remove residual blue light in one of the filters, thus improving blue cross talk in that eyewear filter. For example, as shown in Fig.10c, a further retarder 107 and polariser 109 may be inserted into the first eyewear filter and in Fig.10d, a further retarder 111 and polariser 115 may be inserted. The retarders responsible for defining the spectral characteristics of the transmission may be referred to as spectral retarders, while the additional retarders inserted to enhance the field of view of the stack may be referred to as wide-field retarders. The function of such retarders may be combined to provide overall enhancement of performance.

Thus, the present invention advantageously uses a simple retarder stack in a polarisation interference low order ripple filter in combination with orthogonal polarisers to produce a low cross talk system at low cost for the glasses.

In a further embodiment of the invention as shown in Fig.6, the single projector of fig.5 is replaced by two projectors 2,4. Mixed spectral colour filters 46 and 58 and fixed polarisers 56 and 60 replace the dynamic filters 46,48. Advantageously such a system has high brightness than the projector of fig.5, and the spectral performance of the polarisers 52, 54 is greater. Such a system requires robust alignment and projector matching characteristics. Further, as each eye sees the respective image continuously, the display is less sensitive to flicker artefacts in the stereoscopic image. The filters 46,56 may be incorporated within the light engine optical path, and the filters 56, 60 may comprise the output polarisation state of the image engine of the respective projector.

Fig.7a shows another embodiment of the invention in which the projector 16 is replaced by a direct view display. A backlight 140 comprises first 142 and second 144 filtered light sources for respective colour spectra. The light sources may comprise LEDs, polarisers and retarder stacks to achieve polarisation interference selectivity, or alternatively may be tuned laser sources. A fast response transmissive display 146, such as an Optically Compensated Bend Liquid Crystal Display receives light from the backlight 140 with image data presented in synchronisation with the output of the light sources 142, 144 respectively. A polarisation switcher 148 is placed in front of the output polariser 147 of the display 146, and operates in synchronisation with the output of the panel 146 and light sources 142, 144. The eyewear 150,152 comprises orthogonal polarisation filters and overlapping spectrally selective filters as described above. The shutter 148 may be arranged in horizontal stripe regions 154-162 to switch the output of the display in synchronisation with the addressed image data on the panel 146 as well known in the art. Such an apparatus increases the separation of the stereoscopic view data channels. In this manner, the cost of the components in the display can be
minimised by reducing the number of films used, while allowing the use of low cost glasses to achieve a low cross talk level.

Alternatively, as shown in Fig. 7b, the display may comprise an emissive display 164. Light from the display is incident on a switchable colour selective filter 168, formed for example by means of a retarder stack, polarisation switch and input and output polarisers. A further polarisation switcher 148 is attached to the output of the display to modify the output polarisation accordingly. The two elements combine to produce a sequence of colour and polarisation alternating images which are observed by the glasses in the manner described above.

In a further embodiment of the present invention, eyewear for a multi-view 3D display system is shown in Fig. 12. In Fig 12a, a first set of eyewear comprises a polarisation interference filter comprising a polariser 170, a first retarder stack 172 and a polariser 174. Such a filter cooperates to transmit light of a first polarisation with a first spectrum. A second set of eyewear comprises filter comprising a second polariser 176 with a transmission axis orthogonal to the first polariser 170, a second retarder stack 178 and a polariser 180. The retarder stack 178 is the same as the retarder stack 172, but oriented orthogonally. Thus, each eye sees light of orthogonal polarisations, but with the same spectral characteristics. Fig. 12b shows a second set of eyewear comprising third filter 170, 172 and 174 for one eye, identical to the first filter. The second filter of the second eyewear comprises a polariser 182, retarder stack 184 and polariser 186. Polariser 182 is orthogonal to polariser 170, but the stack 182, 184, 186 has different spectral transmission characteristics to the stack 176, 178 and 180 of the first eyewear.

The image display apparatus (not shown) is capable of producing three images. A first image has a first spectrum and polarisation state that is passed through the eyewear 170, 172 and 174. A second image has the orthogonal polarisation state and the same spectrum as the first image so that it is passed through the second eyewear 176, 178 and 180. A third image has the orthogonal polarisation to the first image and a second spectrum so that it is passed through the third eyewear 182, 184, 186. In such a way, at least three images can be directed towards a viewing audience. Advantageously, the audience can select whether they would like high depth or low depth range 3D images. For example adults may preferably view high depth images, while children (with a lower interocular separation) are encouraged to view lower depth images. Alternatively, experienced users may prefer high depth images, while less experienced users may prefer lower depth ranges for increased comfort. The first image can be a common image, while the second and third images may present different amounts of disparity to the audience. Advantageously, the disparity difference between the second and third image may be low so that higher levels of cross talk may be acceptable between these two image channels. In this way, the spectral filter design may have a high ripple factor, reducing device cost.

If observers wish to view a 2D image, then they wear the same filter in each eye. Alternatively, the transmission spectra of the first and second filters in each eye and between different eyewear may be different allowing two different sets of stereoscopic image to be shown.
Claims

1. A stereoscopic image display apparatus comprising:
   an image display apparatus capable of providing at least first and second images;
   at least one colour encoding filter which encodes the colour output of the first and second images with respectively first and second different visible coding spectra;
   at least one polarisation encoding filter which encodes the polarisation output of the first image substantially with a first polarisation state and encodes the polarisation output of the second image substantially with a second polarisation state;
   first eyewear comprising a first polarisation interference filter comprising a first eyewear input polariser which substantially extinguishes light with the second polarisation state, at least one retarder stack and at least a further polariser, which cooperate to provide a first eyewear transmission spectrum;
   second eyewear comprising a second polarisation interference filter comprising a second eyewear input polariser which substantially extinguishes light with the first polarisation state, at least one retarder stack and at least a further polariser, which cooperate to provide a second eyewear transmission spectrum;
   in which the first eyewear transmits a portion of the first visible coding spectrum and a lesser portion of the second visible coding spectrum;
   in which the second eyewear transmits a portion of the second visible coding spectrum and a lesser portion of the first visible coding spectrum.

2. An apparatus according to the above claims in which the first and second polarisation states are orthogonal.

3. An apparatus according to the above claims in which the first and second polarisation states are linear polarisation states.

4. An apparatus according to the claims 1-2 in which the first and second polarisation states are circular polarisation states.

5. An apparatus according to the above claims in which the first and second eyewear comprise low order ripple polarisation interference filters in which each of the first and second transmission spectra each comprise at least four visible transmission maxima.

6. An apparatus according to claim 5 in which each of the transmission maxima are greater than 5% of the peak transmission across the visible spectrum for the respective eyewear.
7. An apparatus according to the above claims in which the total spectral cross talk of the first and second eyewear is greater than the cross talk threshold value.

8. An apparatus according to the above claims in which the channel spectral cross talk of the first and second eyewear is greater than the cross talk threshold value.

9. An apparatus according to claim 7-8 in which the cross talk threshold value is 0.5%-5%.

10. An apparatus according to claim 9 in which the cross talk threshold value is 1%.

11. An apparatus according to claim 5 in which the first and second polarisation interference filters each comprises a retarder stack with two polarisers.

12. An apparatus according to claim 11 in which the retarder stack has three retarders.

12. An apparatus according to claim 11 in which the retarder stack has spectral retarders and wide field retarders.

14. An apparatus according to claim 5 in which the first and second polarisation interference filters each comprise two retarder stacks and three polarisers.

15. An apparatus according to the above claims in which the image display apparatus produces a sequence of left and right eye images.

16. An apparatus according to the above claims in which the image display apparatus produces at least two separate images in parallel.

17. An apparatus according to the above claims in which the colour encoding filter is at least one of:
   - an isotropic interference filter.
   - a birefringent interference filter

18. An apparatus according to claim 17 in combination with claim 15 in which the filter is a filter wheel arranged to sequentially modify the transmitted spectrum of light to provide at least first and second coding spectra.
19. An apparatus according to the above claims in which the colour encoding filter is a birefringent polarisation filter.

20. An apparatus according to claim 15 in which the polarisation encoding filter is a switchable polarisation rotator.

21. An apparatus according to claim 20 in which the polarisation encoding filter comprises a polariser, at least one retarder stack and two zero twist nematic liquid crystal modulators.

22. An apparatus according to claim 21 in which the liquid crystal modulators are arranged to operate in anti-phase.

22. An apparatus according to claim 20 in which the polarisation encoding filter comprises a polariser, at least one retarder stack and a ferroelectric liquid crystal modulator.

23. An apparatus according to the above claims comprising a control apparatus arranged to synchronise the image, polarisation and colour spectrum of the output of the display apparatus.

24. An apparatus according to the above claims further comprising a partially polarisation preserving projection screen where the display apparatus is a projection display apparatus.

25. An apparatus according to the above claims where the display apparatus is a direct view display apparatus.

26. A multi-view stereoscopic display apparatus comprising
   image display apparatus arranged to provide at least three images;
   at least one colour encoding filter arranged to encode respective images with one of at least two different visible coding spectra;
   at least one polarisation encoding filter arranged to encode respective images with first or second polarisation states,
   eyewear each comprising spectral and polarisation decoding filters;
   where the spectral and polarisation decoding filters comprise polarisation interference filters.

27. An apparatus according to the claim 26 in which the first and second polarisation states are orthogonal.
28. An apparatus according to the claims 26-27 in which the first and second polarisation states are linear polarisation states.

29. An apparatus according to the claims 26-27 in which the first and second polarisation states are circular polarisation states.

30. An apparatus according to the claims 26-29 in which the first and second eyewear comprise low order ripple polarisation interference filters in which each of the first and second transmission spectra each comprise at least four visible transmission maxima.

31. An apparatus according to claim 30 in which the first and second polarisation interference filters each comprises a retarder stack with two polarisers.

32. An apparatus according to claim 31 in which the retarder stack has three retarders.

33. An apparatus according to claim 31 in which the retarder stack has spectral retarders and wide field retarders.

34. An apparatus according to claim 30 in which the first and second polarisation interference filters each comprise two retarder stacks and three polarisers.

35. An apparatus according to claims 26-34 in which the image display apparatus produces a sequence of at least first, second and third images.

36. An apparatus according to claims 26-34 in which the image display apparatus produces at least two separate images in parallel.

37. An apparatus according to the above claims in which the colour encoding filter is at least one
   - isotropic interference filter.
   - birefringent interference filter

38. An apparatus according to claims 26-37 comprising a control apparatus arranged to synchronise the image, polarisation and colour spectrum of the output of the display apparatus.

39. An apparatus according to claims 26-38 further comprising a partially polarisation preserving projection screen where the display apparatus is a projection display apparatus.
40. An apparatus according to the above claims where the display apparatus is a direct view display apparatus.

41. An apparatus according to claims 26-40 in which first eyewear decodes first and second images, and second eyewear decodes first and third images.

42. An apparatus according to claim 41 in which the second and third image comprise image data with different disparity information.

43. An apparatus according to claims 26-40 in which first eyewear decodes first and second images, and second eyewear decodes third and fourth images.
**Patents Act 1977: Search Report under Section 17**

**Documents considered to be relevant:**

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<th>Category</th>
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<td>US 2008/0151193 A1 (REDER)</td>
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<td>-</td>
<td>EP 0237283 A2 (TEKTRONIX) See abstract</td>
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- **X**: Document indicating lack of novelty or inventive step
- **Y**: Document indicating lack of inventive step if combined with one or more other documents of same category
- **&**: Member of the same patent family
- **A**: Document indicating technological background and/or state of the art.
- **P**: Document published on or after the declared priority date but before the filing date of this invention.
- **I**: Patent document published on or after, but with priority date earlier than, the filing date of this application.

**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKPC:

Worldwide search of patent documents classified in the following areas of the IPC

G02B: H04N

The following online and other databases have been used in the preparation of this search report

Online: WPI, EPDOC

**International Classification:**

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Application No: GB0720282.3
Examiner: Iwan Thomas
Date of search: 22 January 2009
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