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(54) HIGH-FIDELITY PRINTED ANAGLYPHS AND VIEWING FILTERS

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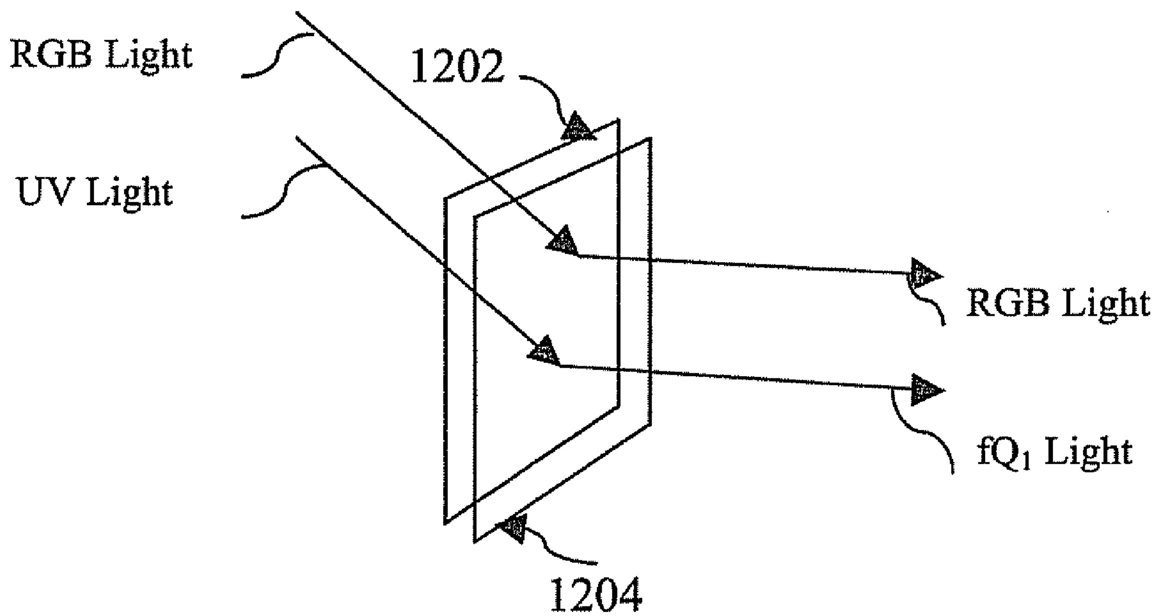
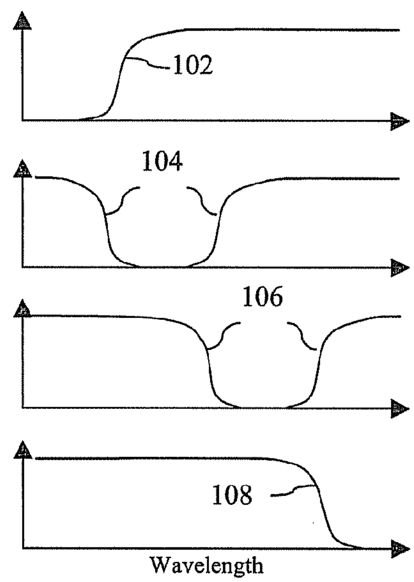
(57) **ABSTRACT**

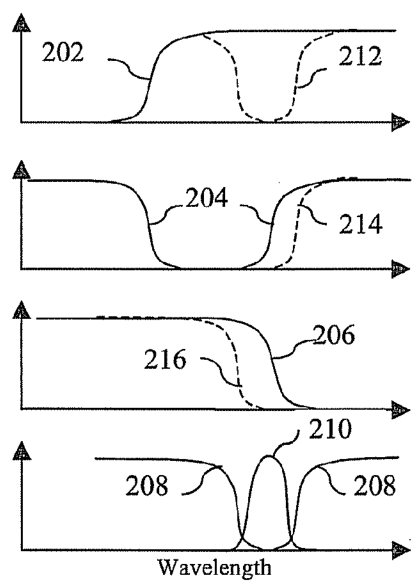
Four primary colors provide a wide color gamut in the anaglyph images. Primary colors with narrow spectral distributions allow the first and second images in an anaglyph to be viewed using colored filter glasses. In print media, primary colors with narrow spectral distributions are provided by fluorescent inks and incident light with narrow spectral distributions. Incident light with narrow spectral distributions may cooperate with broad adsorption spectra of inks to produce reflected light with narrow spectral distributions from printed anaglyphs. Viewing filters for anaglyphs comprised of narrow spectral distributions may have broad, overlapping transmission spectra and utilize adsorption dyes or pigments.





102
104
106
108
Wavelength

Fig. 1



202
212
204
214
216
206
210
208
208
Wavelength

Fig. 2

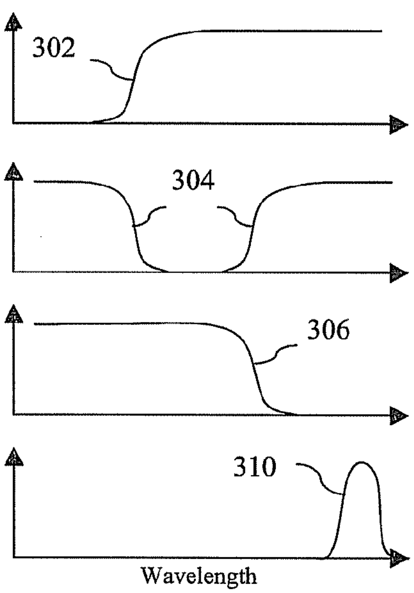


Fig. 3

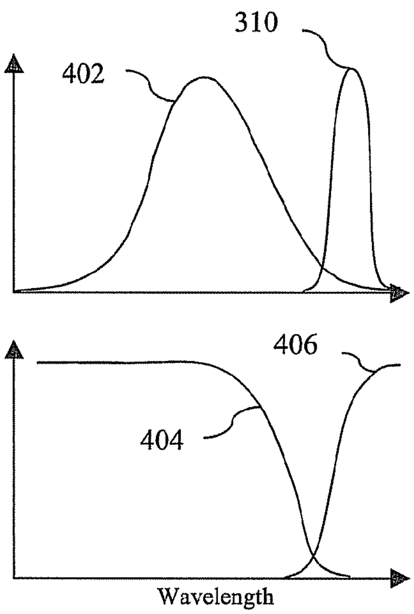


Fig. 4

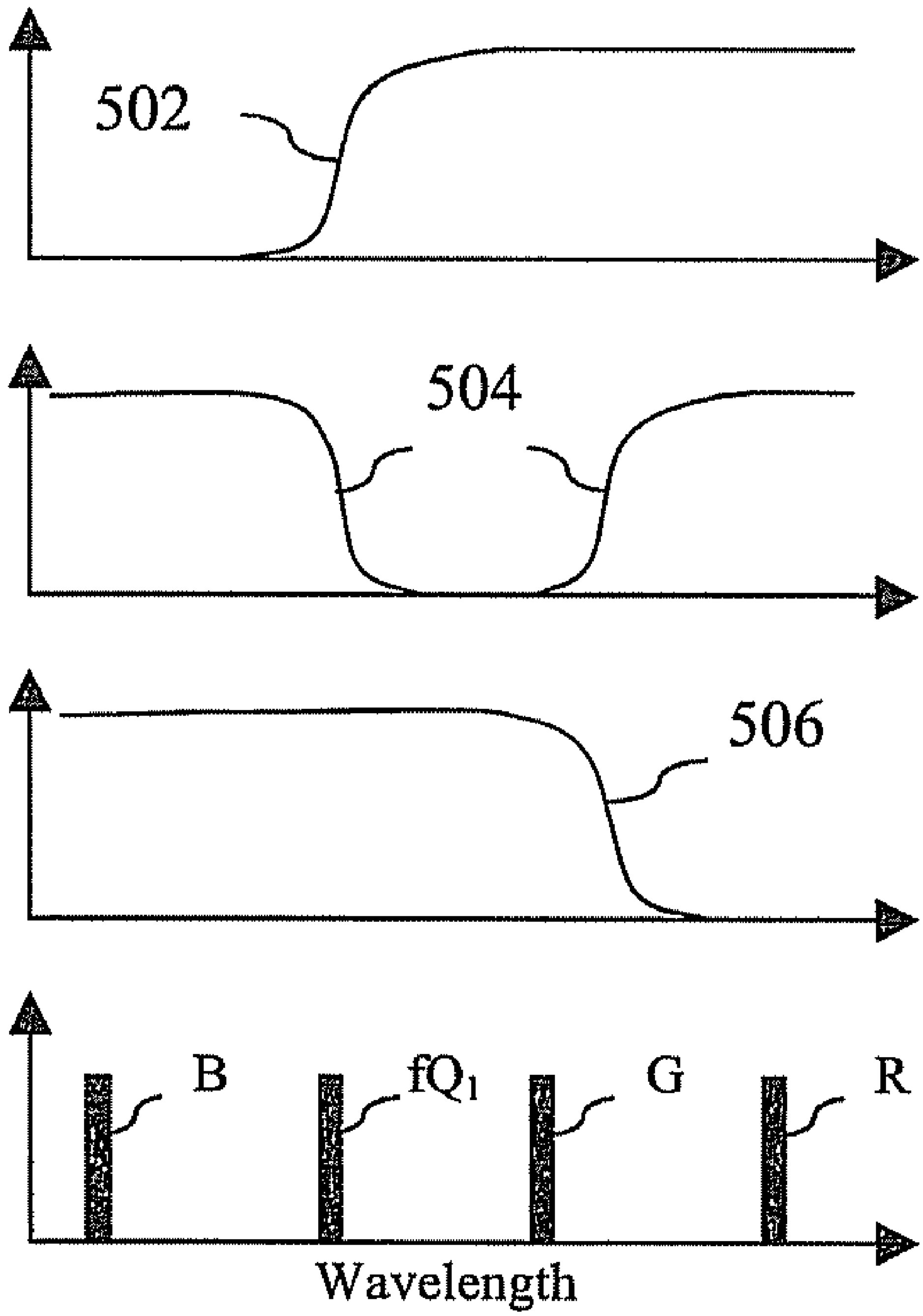


Fig. 5

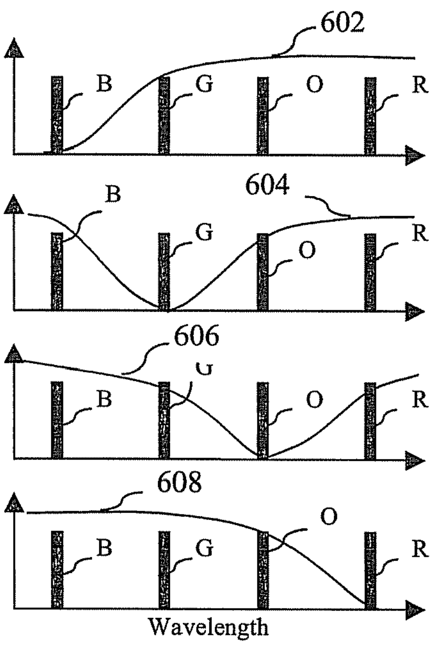

602
B
G
O
R
604
B
G
O
R
606
B
O
R
608
B
G
O
R
Wavelength

Fig. 6

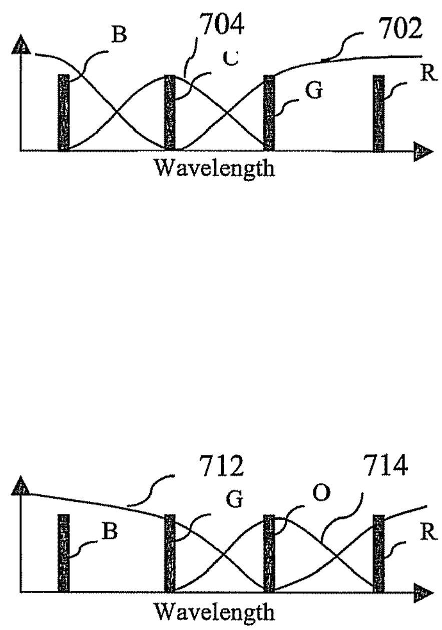

B
704
702
G
R
Wavelength
712
G
O
714
B
R
Wavelength

Fig. 7

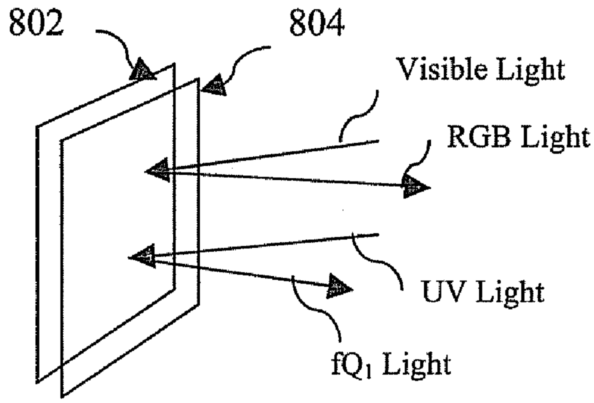

802
804
Visible Light
RGB Light
UV Light
fQ_1 Light

Fig. 8

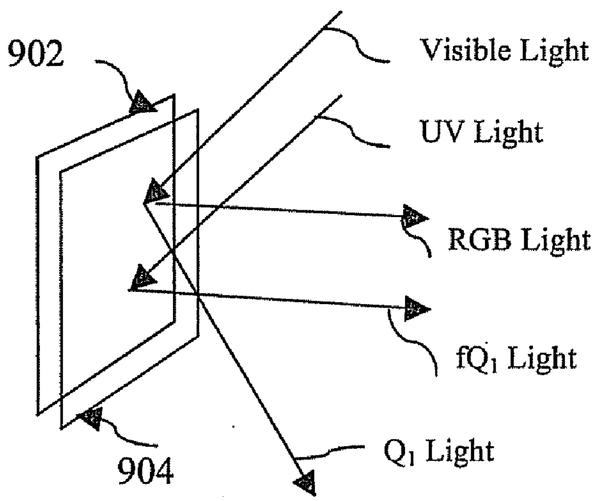

902
Visible Light
UV Light
RGB Light
fQ_1 Light
904
Q_1 Light

Fig. 9

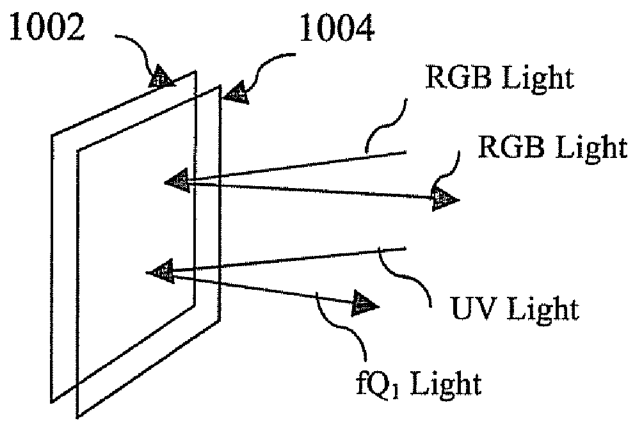

1002
1004
RGB Light
RGB Light
UV Light
fQ1 Light

Fig. 10

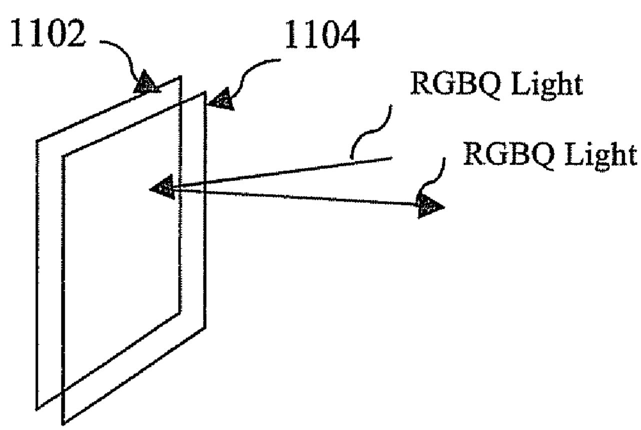

1102
1104
RGBQ Light
RGBQ Light

Fig. 11

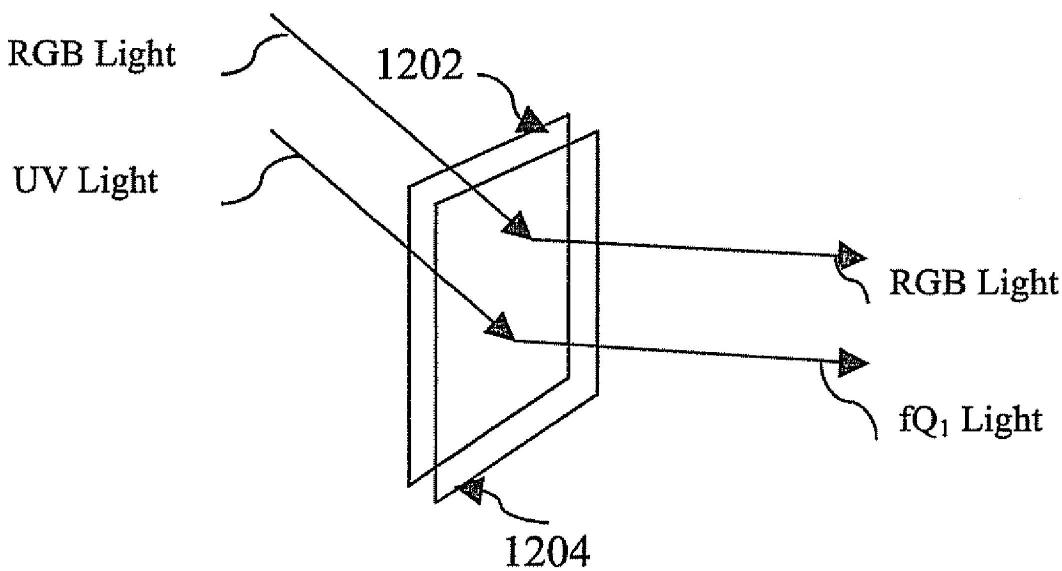


Fig. 12

HIGH-FIDELITY PRINTED ANAGLYPHS AND VIEWING FILTERS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of PCT/US2008/000841 filed Jan. 23, 2008, which claims priority to U.S. Ser. No. 60/881,863 filed Jan. 23, 2007, which applications are hereby incorporated by reference herein.

TECHNICAL FIELD

[0002] The technical field relates to imaging and viewing in three dimensions.

BACKGROUND

[0003] Stereoscopic images generally consist of two images which are related by a small change in the lateral perspective. When viewed through an enabling apparatus, stereoscopic images may provide the perception of stereoscopic depth. Anaglyphs are stereoscopic images wherein different sets of primary colors are used to render the first and second images of the stereo pair. Usually, the spectra of the first and second images do not overlap significantly. Then the first and second images may be viewed selectively using two complementary color viewing filters. The first viewing filter F_1 may be used to view the first image while the second viewing filter F_2 may be used to view the second image. The first filter substantially transmits the primary colors of the first image and blocks the primary colors of the second image. The second filter substantially transmits the primary colors of the second image and blocks the primary colors of the first image.

[0004] Anaglyphs are often rendered in three primary colors where the first image is rendered in two primary colors while the second image is rendered in one primary color. In red/cyan anaglyphs, the first image is rendered in green and blue primary colors while the second image is rendered in a red primary color. Other types of anaglyphs include blue/yellow and green/magenta anaglyphs. Herein these anaglyphs are called three-color anaglyphs.

[0005] Anaglyphs are often used to display stereoscopic images due to their relatively low cost and wide compatibility with display devices. However, conventional anaglyphs have some well known disadvantages. Firstly, conventional anaglyphs generally exhibit a reduced color gamut when viewed through the colored viewing filters. Secondly, conventional anaglyphs generally exhibit retinal rivalry which may cause user discomfort. The prior art contains many methods to improve the color gamut of anaglyphs. The prior art also contains many methods to reduce the retinal rivalry in anaglyphs. However, these anaglyphs still have reduced color gamuts and exhibit retinal rivalry.

[0006] It is commonly known that viewing a subject through colored filters may reduce the observed color gamut of the subject. In general, a color filter which transmits only a single primary color may not allow any color hue to be fully perceived through the filter. For example, an image rendered in a pure red primary color may appear to be nearly a grayscale image when viewed through the red filter.

[0007] On the other hand, a filter which transmits two primary colors may allow only the hues associated with the two primary colors to be perceived through the filter. The hue consisting of both primary colors may appear to be nearly a gray color through the filter. For example, a cyan filter (which transmits green and blue light) may allow only blue and green hues or blue and greenish-yellow hues to be perceived through the filter depending on how close the green primary color is to yellow. An image rendered in pure cyan hues may appear to be nearly a grayscale image when viewed through a cyan filter. These phenomena may be confirmed by viewing a digital color spectrum through pure cyan and pure red filters. Software programs for editing digital images often provide a suitable digital color spectrum in their color selection tools.

[0008] Since the second image in an anaglyph is generally perceived as a grayscale image, the color gamut observed in a stereo view of an anaglyph is generally similar to the color gamut of the first image rendered in two primary colors. The first image in an anaglyph generally contributes more to color perception than the second image.

[0009] Methods exist in the prior art to increase the color gamut of anaglyph images by using leaky viewing filters. It is widely known that the range of perceived hues in anaglyphs may be expanded to some degree by allowing one or both of the viewing filters to partially transmit or leak a small amount of additional primary colors through the filters. For example, a red filter which also transmits a small amount of green light may allow a dark green hue and an unsaturated red hue to be perceived through the red filter. Or a cyan filter which also transmits a small amount of red light may allow a dark red hue and an unsaturated cyan hue to be perceived through the filter.

[0010] Transmitting part of the primary colors of the opposite image through the viewing filters may cause the user to see ghost images or double images in the stereo view. The double images may reduce the ability of the user to fuse the stereo pair and may reduce the perceived stereoscopic depth in the stereo view. Therefore, when using leaky filters, the benefit of the extra hues created by the leak must be balanced against the disadvantage of perceiving less stereoscopic depth.

[0011] Conventional cyan filters for viewing red/cyan anaglyphs are often designed to leak a small amount of a red primary color through the filter. This allows a weak reddish hue to be perceived through the cyan filter. However the leaked red primary color creates a ghost of the second image in the view of the first image. Furthermore since the second image is often offset from the first image due to stereoscopic parallax, the red light from the second image is not always at the proper location to contribute correctly to the color of the first image. Similar disadvantages occur when using leaky filters with blue/yellow and green/magenta anaglyphs.

[0012] Stereoscopic images may be displayed on print media using several techniques. Some well known methods for printing stereoscopic images include: (1) printing the first and second images next to each other in a side-by-side format; (2) printing the first and second images superimposed in an anaglyph format; and (3) printing methods using polarized inks such described in Scarpetti, U.S. Pat. No. 5,764,248, in which the first and second images are superimposed on a surface. The side-by-side format provides good color, but requires special viewing apparatus which usually restricts the viewing distance or image size. The anaglyph format allows variable viewing distances and image sizes. However, conventional anaglyphs have a limited color gamut and often cause retinal rivalry whereby the images are uncomfortable to view. The polarized ink format allows variable viewing distances and image sizes, and provides good color. However, the polarized ink format requires special polarized printing substrates which are difficult to manufacture.

BRIEF SUMMARY OF THE INVENTION

[0013] One embodiment of the present invention describes a method of displaying anaglyphs comprising an anaglyph including a first image and a second image and printing the first image in three or more subtractive primary colors $\{mP_1, \ldots, mP_m\}$ and printing a second image in a fluorescent primary color fQ_1 and illuminating the printed anaglyph with visible incident light and ultraviolet light.

[0014] An alternative embodiment of the present invention describes a method of displaying anaglyphs comprising an anaglyph including a first image and a second image and a light source providing three or more distributions of visible light $\{P_1, \ldots, P_m\}$ and a distribution of visible light Q_1 and distributions of light $\{P_1, \ldots, P_m\}$ mutually non-overlapping and distributions of light $\{P_1, \ldots, P_m\}$ and Q_1 mutually non-overlapping and subtractive primary colors $\{mP_1, \ldots, mP_m\}$ preferentially absorbing the distributions of light $\{P_1, \ldots, P_m\}$ respectively and subtractive primary color mQ_1 preferentially absorbing the distribution of light Q_1 and printing a first image of an anaglyph in subtractive primary colors $\{mP_1, \ldots, mP_m\}$ and printing a second image of the anaglyph in subtractive primary color mQ_1 and illuminating the printed anaglyph with incident distributions of light $\{P_1, \ldots, P_m\}$ and Q_1.

[0015] An alternative embodiment of the present invention describes an apparatus for viewing anaglyph images comprising a first filter F_1 substantially transmitting light with wavelengths in regions $\{P_1, P_2, P_3\}$ of visible light and blocking light with wavelengths in a region Q_1 of visible light and a second filter F_2 substantially transmitting light with wavelengths in the region Q_1 and blocking light with wavelengths in the regions $\{P_1, P_2, P_3\}$ and the regions $\{P_1, P_2, P_3\}$ excluding a region of visible light with a range of about 60 nm to 90 nm and the excluded region substantially including the region Q_1 and the region Q_1 with a range of about 30 nm and the transmission spectra of the first filter substantially overlapping the transmission spectra of the second filter in the excluded region.

[0016] An alternative embodiment of the present invention describes a method of displaying anaglyphs comprising and an anaglyph including a first image and a second image and printing the first image in three or more subtractive primary colors $\{mP_1, \ldots, mP_m\}$ and printing a second image in three of more fluorescent primary colors $\{fQ_1, \ldots, fQ_n\}$ and illuminating the printed anaglyph with visible incident light with narrow distributions of light $\{P_1, \ldots, P_m\}$ and with ultraviolet light and the spectra of the distributions of light $\{P_1, \ldots, P_m\}$ not overlapping the spectra of the fluorescent primary colors $\{fQ_1, \ldots, fQ_n\}$.

[0017] The present invention is directed to the use of fluorescent inks, adsorption inks, light sources and special viewing filters for displaying and viewing digital anaglyphs with wide color gamuts.

[0018] One aspect of the present invention provides methods to expand the color gamut of anaglyph images by using additional primary colors to render the first image of an anaglyph image. In order for the additional primary colors to expand the color gamut, the spectrum of the primary colors should be substantially independent of the other primary colors. For certain displays technologies such as digital projection, methods of providing more than three primary colors are well known.

[0019] In the case of print media, creating many substantially independent primary colors may be difficult due to the reliance on absorption dyes or pigments in inks to form subtractive primary colors. The subtractive primary colors typically have broad spectra due to the broad absorption spectra of most dyes and pigments. Ink sets which include four or more independent adsorption spectra are often called high fidelity inks. Herein a conventional black ink is not considered to have an independent spectrum since a black ink spectrum is usually nearly identical to a combination of the other inks' spectra such as yellow plus cyan plus magenta spectra. One example of a high fidelity ink set is called hexachrome inks and is described in Herbert, U.S. Pat. No. 5,734,800.

[0020] Fluorescent inks have the property of absorbing light with one wavelength and emitting the light at a longer wavelength. A spectrum of wavelengths may be absorbed and a spectrum of wavelengths may be emitted. The emission spectrum of fluorescent inks may be narrower than the typical absorption spectra of conventional ink pigments or dyes. One aspect of the present invention concerns the use of fluorescent inks to create sharp independent primary colors for printing anaglyphs with wide color gamuts.

[0021] Several types of light sources may provide narrow distributions of spectral intensity. These narrow distributions may interact with conventional inks to produce images comprised of narrow spectral distributions. One aspect of the present invention concerns the use of narrow spectral distributions of incident light to display anaglyphs with wide color gamuts.

[0022] Some embodiments of the present invention provide methods and apparatus for displaying and viewing anaglyph images rendered in four primary colors including a fluorescent or high-fidelity primary inks. Some embodiments of the present invention concern the use of viewing filters for viewing anaglyphs with narrow spectral distributions of light.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0023] FIG. **1** depicts the spectra of four nearly ideal subtractive primary colors. The spectra may represent minus blue, minus green, minus orange, and minus red primary colors.

[0024] FIG. **2** depicts the spectra of conventional yellow, magenta, and cyan subtractive primary colors; a subtractive primary color mQ_1, and a fluorescent primary color fQ_1. The dotted lines show the combined spectra of the primary color mQ_1 with the yellow, the magenta, and cyan primary colors.

[0025] FIG. **3** depicts the spectra of conventional yellow, magenta, and cyan subtractive primary colors; and a far-red fluorescent primary color fQ_1.

[0026] FIG. **4** depicts the spectra of a far-red fluorescent primary color fQ_1 and the photopic response function of the human visual system. Also depicted are the transmission spectra of a first viewing filter and the transmission spectra of a second viewing filter.

[0027] FIG. **5** depicts sharp spectral distributions of blue B, green G, red R light from a light source and a sharp spectral distribution of a fluorescent primary color fQ_1. Also depicted are the spectra of subtractive primary inks: minus blue mB, minus green mG, and minus red mR.

[0028] FIG. 6 depicts sharp spectral distributions of blue B, green G, orange O, and red R light which may illuminate an anaglyph. Also depicted are the spectra of subtractive primary inks: minus blue mB, minus green mG, minus orange mO, and minus red mR.

[0029] FIG. 7 depicts the spectra of a first viewing filter and the spectra of a second viewing filter in relation to blue B, cyan C, green G, and red R sharp spectral distributions of light. Also depicted are the spectra of a first viewing filter and the spectra of a second viewing filter in relation to blue B, green G, orange O and red R sharp spectral distributions of light.

[0030] FIG. 8 depicts the interaction of a first image printed on an opaque medium and a layer of a subtractive primary color mQ_1 (not shown) with incident visible light where a primary color Q_1 is absorbed by the primary color mQ_1. Also depicted is the interaction of the second image printed in fluorescent ink on a transparent medium with incident UV light which produces a fluorescent primary color fQ_1.

[0031] FIG. 9 depicts the interaction of a first image printed on an opaque medium and a dichroic sheet (not shown) with incident visible light where Q_1 light is reflected by the dichroic sheet in a spectral reflection. Also depicted is the interaction of the second image with incident UV light which produces a fluorescent primary color fQ_1.

[0032] FIG. 10 depicts the interaction of a first image printed on an opaque medium with sharp distributions of red, green, and blue incident light (RGB light). Also depicted is the interaction of the second image printed in fluorescent ink on a transparent medium with incident UV light which produces a fluorescent primary color fQ_1.

[0033] FIG. 11 depicts the interaction of a first image and a second image printed on an opaque substrate with incident light which comprises sharp distributions of red, green, blue, and Q_1 light (RGBQ light).

[0034] FIG. 12 depicts a back lit embodiment of the present invention where the first and second images are printed on transparent media; and the interaction of the first image with incident light with sharp distributions of red, green, and blue light (RGB light). Also depicted is the interaction of the second image printed in fluorescent ink with incident UV light which produces a fluorescent primary color fQ_1.

DETAILED DESCRIPTION OF THE INVENTION

[0035] Digital subtractive primary color values may usually be transformed into a set of additive primary colors values. For clarity, some aspects of the present invention will be described in terms of additive primary colors. These aspects are applicable to subtractive primary colors in a straight forward way.

[0036] The color gamut observed in a stereo view of an anaglyph may be generally similar to the color gamut of the first image rendered in two primary colors. Therefore, expanding the color gamut of the first image in an anaglyph may expand the color gamut observed in the anaglyph. Herein the color gamut of an image is considered to be the color gamut of the set of primary colors used to render the image. The color gamut of a set of primary colors is the set of colors which may be rendered using the set of primary colors. The color gamut of a set of primary colors may be depicted by plotting the xy chromacity coordinates of the primary colors on a CIE chromacity diagram. A property of a CIE chromacity diagram is that the color gamut of a set of primary colors can be depicted by connecting the points representing the primary colors with line segments in the chromacity diagram. The color gamut includes the area bounded by the line segments.

[0037] Conventional anaglyphs have a small color gamut because only two primary colors $\{P_2, P_3\}$ are used to render the first image of the stereo pair where the first image substantially determines the color gamut of the anaglyph. In the present invention, anaglyphs with wide color gamuts may be produced on print media by using three (or more) primary colors $\{P_1, P_2, P_3\}$ to render the first image and a fourth primary color Q_1 to render the second image.

[0038] One embodiment of the present invention provides a method to print anaglyphs using four primary colors. FIG. 1 depicts the spectra of four independent subtractive primary colors $\{mP_1, mP_2, mP_3, mQ_1\}$ where mP_1 108 is a minus red, mP_2 104 is a minus green, mP_3 is a minus blue 102, and mQ_1 is a minus yellow 106. These spectra have rounded profiles in order to indicate the difficulty in producing sharp or narrow subtractive primary colors. Nevertheless, these spectra represent a nearly ideal case where the subtractive primary colors may be transformed into additive primary colors $\{P_1, \ldots P_m\}$ where the spectra of each additive primary color overlaps the other additive primary colors' spectra by only a small amount.

[0039] Since the spectra of subtractive printing primary colors are generally broad, it is generally difficult to create a fourth primary color Q_1 whose spectra does not overlap the $\{P_1, P_2, P_3\}$ primary colors significantly. It is important that the spectra of the Q_1 primary color not overlap the spectra of the $\{P_1, P_2, P_3\}$ primary colors in order that the first and second images may be selectively viewed through colored viewing filters. Some embodiments of the present invention provide methods of producing sharp primary colors in printed media in order to display anaglyphs with wide color gamuts wherein the first and second images may be selectively viewed through color viewing filters.

Subtractive Plus Fluorescent Primary Colors

[0040] Another embodiment of the present invention provides methods to print anaglyphs with wide color gamuts using conventional inks, a subtractive primary color mQ_1 (minus Q_1), and a fluorescent ink fQ_1 (additive Q_1). The first image may be printed in conventional inks using conventional methods. The second image may be printed in a fluorescent ink. A uniform layer of the mQ_1 primary color may be used to absorb reflected light in the region of wavelengths of the fluorescent fQ_1 light. The second image and the mQ_1 layer may be printed using conventional methods utilizing special inks. The first image may be made visible by illumination using conventional lighting whereas the second image may be made visible by illumination using ultraviolet lighting. Preferably, the fluorescent light may be either red, orange, yellow, or cyan light. Preferably, the fluorescent ink may be chosen to be excited by ultraviolet light which is invisible to both eyes. However, in some embodiments, the fluorescent ink may be excited by visible light. In practice, the conventional printing inks may be optimized for use with the mQ_1 primary color of the present invention.

[0041] The first image may be viewed through a first viewing filter F_1 which substantially transmits red, green and blue components of the first image and blocks the fQ_1 primary color. The second image may be viewed through a second viewing filter F_2 which substantially transmits the fQ_1 primary color and blocks the other regions of the visible spectra.

The mQ_1 primary color may prevent the first image from being visible through the second viewing filter.

[0042] The second image may become visible under ultraviolet (UV) light. Under normal light (free of UV light), the second image may be nearly invisible. Therefore under normal light, the image may appear substantially 2D or monoscopic. Under combined UV and visible light, the image may appear 3D or stereoscopic when viewed through first and second viewing filters F_1 and F_2.

[0043] FIG. **2** depicts representative emission spectra **210** of a fluorescent ink which provides a fluorescent primary color fQ_1 having yellow or orange wavelengths. Also depicted is representative spectra **208** of a subtractive mQ_1 primary color which may adsorb light with wavelengths in the region of the fluorescent emission. FIG. **2** also depicts representative spectra of yellow Y **202**, magenta M **204**, and cyan C **206** primary inks. The dotted lines show the combined spectra of the mQ_1 primary color with the yellow primary spectra **212**; the magenta primary spectra **214**; and the cyan primary spectra **216**. Similarly in another embodiment, the mQ_1 and fQ_1 bands may be located in the cyan region of wavelengths near about 480-500 nm or in a red region of light.

[0044] Another embodiment of the present invention is represented in FIG. **8**, wherein an anaglyph may be produced as follows: (1) the first image of the anaglyph may be printed using the conventional inks; (2) the mQ_1 primary color may be printed uniformly over the whole of the first image; and (3) the second image may be printed or superimposed on the first image using a fluorescent fQ_1 ink. The anaglyph may be illuminated with visible and UV light. The order of steps 1 and 2 and 3 may be varied to minimize the spectral interactions between the primary colors.

[0045] FIG. **8** depicts an alternative embodiment of the present invention wherein the first image may be printed in a first layer **802** using conventional inks. The second image may be printed in a second layer **804** using a fluorescent ink. The first layer may printed on a first medium that may be opaque and generally reflecting of white light such as white paper. The mQ_1 primary layer (not shown) may be near the first layer **802** or between first **802** and second **804** layers. The visible light incident on the anaglyph may pass through the second layer and may be partially absorbed by the first image layer and the mQ_1 primary layer. The reflected visible light may comprise red, green and blue components of the first image (RGB light) with little reflected light in the fQ_1 region of the visible spectrum. The first image may modulate the reflected RGB light. The UV light incident on the anaglyph may be partially absorbed and re-emitted as fQ_1 primary color light by the second image. The user (not shown) may view the anaglyph through viewing filters F_1 and F_2 (not shown) from the incident side of the anaglyph. The second image layer **804** may be printed on a second medium which is distinct from the first medium and maybe attachable to the first medium.

[0046] The second image may be printed on the same medium as the first image. Or, the second image may be printed on a second transparent medium. The transparent medium of the second image may be overlaid on the first image in order to produce a stereoscopic image.

[0047] In another embodiment of the present invention, the first or second medium may have a mQ primary color as an integral component. In other words, a medium may be produced with a mQ_1 primary color pre-applied. For example, a layer containing neodymium or other adsorbing material may be used to obtain a uniform mQ_1 primary color in a substrate. Then the first image may be printed on the first medium. The second image may be printed either on the first medium or on a second transparent medium.

[0048] In another embodiment of the present invention, the transparent medium may be comprised of interference layers which selectively reflects light with wavelengths of the Q_1 primary color. Then the specular reflection of the Q_1 primary color may be used to direct the Q_1 light away from the user's eyes. For example, the transparent media lit from above may reflect the Q_1 primary color downward which is an unlikely vantage point to view the anaglyph. The anaglyph may be illuminated with visible and UV light.

[0049] FIG. **9** depicts another embodiment of the present invention. The first image may be printed in a first layer **902** using conventional inks. The second image may be printed in a second layer **904** using a fluorescent ink. The first layer may be printed on a first medium that may be opaque and generally reflecting of white light such as white paper. The second layer may be printed on a second medium composed of interference layers (such as provided in a dichroic filter sheet) which may selectively reflect light with wavelengths in the region of the Q_1 primary color. The visible light incident on the anaglyph lit from above may be partially reflected by the interference layers and partially reflected by the first opaque medium of the first layer. The interference layers may reflect the light with wavelengths in the Q_1 primary color downward in a specular reflection. The opaque medium may reflect the red, green, and blue light (RGB light) of the first image in a broad distribution of directions. The first image may modulate the reflected RGB light. The UV light incident on the anaglyph may be partially absorbed and re-emitted as fQ_1 primary color light by the second image. The user (not shown) may view the anaglyph through viewing filters F_1 and F_2 (not shown) from the incident side of the anaglyph.

Far-Red Fluorescent Primary Colors

[0050] Another embodiment of the present invention provides methods to print anaglyph images with wide color gamuts using conventional inks and a far-red fluorescent ink. The first image may be printed in conventional inks using conventional methods. The second image may be printed in a far-red fluorescent ink. The first image may be made visible by illumination using conventional lighting whereas the second image may be made visible by illumination using ultraviolet lighting. Preferably, the fluorescent ink may be chosen to be excited by ultraviolet light which is invisible to both eyes. However, in some embodiments, the fluorescent ink may be excited by visible light.

[0051] The first image may be viewed through a first filter F_1 which substantially transmits light with wavelengths shorter than the fluorescent spectra and blocks light of the fluorescent spectra. The second image may be viewed through a second filter F_2 which substantially transmits the fluorescent spectra and blocks light with shorter wavelengths.

[0052] The second image may become visible under ultraviolet (UV) light. Under normal light (free of UV light), the second image may be nearly invisible. Therefore under normal light, the image may appear substantially 2D or monoscopic. Under combined UV and visible light, the image may appear 3D or stereoscopic when viewed through first and second viewing filters F_1 and F_2.

[0053] FIG. **3** depicts representative emission spectra **310** of a fluorescent ink which provides a fluorescent primary color fQ_1 having far-red wavelengths. Also depicted are the representative spectra of conventional yellow **302**, magenta **304**, and cyan **306** inks. FIG. **4** depicts representative transmission spectra **404** of the first viewing filter F_1 and representative transmission spectra **406** of the second viewing filter F_2.

[0054] FIGS. **3** and **4** show that the conventional inks generally may have substantial transmission in the far-red region of the visible spectrum overlapping the transmission spectrum of the second viewing filter. Therefore, while the first filter may transmit red, green and blue spectral components of the first image and may block the fluorescent light of the second image, the second filter may transmit the fluorescent light of the second image and may also transmit a far-red component of the first image. However, the far-red component of the first image may have low luminance viewed through the second filter due to the reduced sensitivity of human vision to far-red light.

[0055] FIG. **4** depicts the emission spectra of a far-red fluorescent ink **310** and the International Commission on Illumination (CIE) human photopic response function **402**. Since the human photopic response function has low values for far-red wavelengths, the luminance of first image may naturally be low in the far-red region for typical lighting conditions. Therefore, the luminance of the far-red component of the first image which is transmitted by the second filter may be low for typical lighting conditions.

[0056] Preferably, the luminance of the first image viewed through the second viewing filter may be less than 2% of the luminance of the second image viewed through the second viewing filter. Also in order to optimize the color gamut of the anaglyph, the luminance of the second image viewed through the second viewing filter may be about 10-30% of the luminance of the first image viewed through the first viewing filter. Note that red/cyan anaglyphs usually satisfy the second condition naturally by the red primary color being about 30% of the luminance of the green and blue primary colors. The two above conditions may be satisfied if the luminance of the first image in the far-red region is less than about 0.2-0.6 percent of the total luminance of the first image.

[0057] The luminance of the second image viewed through the second filter depends on the intensity of the ultraviolet light source. The intensity of ultraviolet light may be adjusted or set to cause the luminance of the second to greatly exceed the luminance of the first image in the far-red wavelengths.

[0058] The fraction of the luminance of the first image in the far-red region may be adjusted by selecting the specific cut-off or edge wavelength λ which generally separates the far-red light of the second image from the near-red light of the first image. As the edge wavelength λ increases, the fraction of the luminance of the first image in the far-red region decreases. Therefore, by using a long edge wavelength, the luminance of the first image may be much smaller than the luminance of the second image when viewed through the second filter while the luminance of the second image may be about 10-30% of the total luminance of the first image. For natural lighting, preferably the edgewavelength λ may be longer than about 640-650 nm. Then the portion of the luminance of the first image contained in wavelengths longer than λ may be small compared to the total luminance of the first image.

[0059] The fraction of the luminance of the first image in the far-red region may also be affected by the visible light source used to illuminate the first image. Some light sources such as metal halide and fluorescent lights have relatively low intensity of far-red light compared to near-red, green, and blue light. Therefore, by using specific visible lighting sources, the luminance of the first image viewed through the second filter may be much smaller than the luminance of the second image viewed through the second filter for edge wavelengths λ in the region of about 630-650 nm. In other words, the fraction of the first image leaked through the second filter may be made small by choosing an appropriate visible light source to illuminate the first image.

[0060] Typical filters of the prior art for viewing red/cyan anaglyph images have edge wavelengths λ near about 580-590 nm. These filters may transmit or block light with wavelengths shorter than or longer than about 580-590 nm. Some embodiments of the present invention may use filters with edge wavelengths λ in the range of about 610 nm to 650 nm. Visible light sources may be selected which produce low light intensity in wavelengths longer than the edge wavelength. In some embodiments, filters may be used with some light sources to remove light with wavelengths longer than the edge wavelength. Anaglyphs of the present invention with edge wavelengths near the shorter end of the range 610 nm to 650 nm may have smaller color gamuts than anaglyphs with longer edge wavelengths, however, they both may have wider color gamuts than anaglyphs of the prior art.

[0061] One aspect of the present image is a pair of viewing filters for viewing anaglyphs wherein the first image is rendered in red, green and blue primary colors and the second image is rendered in a far-red primary color. The first viewing filter may substantially transmit light with wavelengths shorter than an edge wavelength λ in the range of about 610-650 nm and substantially block light with wavelengths longer than the edge wavelength λ. The second viewing filter may substantially transmit light with wavelengths longer than the edge wavelength λ in the range of about 610-650 nm and substantially block light with wavelengths shorter than the edge wavelength λ.

[0062] Another embodiment of the present invention includes the use of a source of fluorescent light which substantially lacks emitted light with wavelengths in the far-red region of the visible spectrum. These fluorescent light sources may lack the phosphors which fluoresce substantially in the far-red wavelengths. This type of fluorescent lighting may be combined with ultraviolet lighting to illuminate the printed anaglyphs of the present invention. The fluorescent lighting and conventional inks may form the first image of an anaglyph while ultraviolet lighting and fluorescent inks may form the second image of the anaglyph. In the absence of the ultraviolet light, the anaglyph may appear as a conventional 2D image.

[0063] Other types of light sources which may be deficient of light in the far-red region may also be used to illuminate the anaglyphs of the present invention such as LED, laser, xenon-mercury arc-lamps, and metal halide lamps and other light sources. Filters may also be combined with conventional light sources to remove the far-red light from the spectrum of visible light incident on an anaglyph image of the present invention.

Narrow Incident Primary Colors

[0064] Some embodiments of the present invention use the fact that incident light that has narrow spectral distributions may be reflected from printed media with similar narrow spectral distributions. This allows sharp primary colors to be produced in printed media using conventional inks and light sources with narrow spectral distributions. Herein the narrow distributions of light incident on an anaglyph image are called incident primary colors. Several types of light sources may produce narrow spectral distributions including: fluorescent lighting, mercury arc lamps, low pressure metal halide lights, LED and laser light sources.

[0065] In another embodiment of the present invention, incident light with three (or more) narrow spectral distributions may be used to provide three (or more) incident primary colors for displaying the first image of an anaglyph with a wide color gamut. The first image may be printed in convention inks using conventional methods. The second image may be printed in a fluorescent ink providing an fQ_1 primary color. The anaglyph may be illuminated with incident primary colors and UV light. The incident primary colors may include red, green, and blue incident primary colors. Herein, light with red, green and blue components but, lacking a Q_1 component is called RGB light. The reflected spectra of RGB light from the first image may have narrow primary color spectra similar to the incident RGB spectra. The first image may modulate the reflected RGB light. The second image may emit fluorescent light fQ_1 with a narrow spectral distribution.

[0066] The RGB light spectra may have regions of low intensity between the narrow primary colors. These regions may coincide with the wavelengths of the fluorescent primary color fQ_1. The incident primary colors illuminating the first image printed in the conventional inks may reflect very little light with wavelengths of the fQ_1 primary color. The second image may emit fluorescent fQ_1 light and little light with wavelengths in the regions of the incident primary colors. Therefore, the first and second images may be selectively viewed through color viewing filters. Preferably, the fluorescent light may be either red, orange, yellow, or cyan. Preferably, the fluorescent ink may be chosen to be excited by ultraviolet light which is invisible to both eyes. However, in some embodiments, the fluorescent ink may be excited by visible light.

[0067] The first image may be viewed through a first viewing filter F_1 which substantially transmits the RGB light and blocks the fluorescent fQ_1 light. The second image may be viewed through a second viewing filter F_2 which substantially transmits the fluorescent fQ_1 light and blocks the RGB light. By viewing the anaglyph through the F_1 and F_2 filters, a stereoscopic view with a wide color gamut may be perceived.

[0068] The second image may become visible under ultraviolet (UV) light. Under normal light (free of UV light), the second image may be nearly invisible. Therefore under normal light, the image may appear substantially 2D or monoscopic. Under combined UV and RGB light, the image may appear 3D or stereoscopic when viewed through the first and second viewing filters F_1 and F_2. The RGB light spectra may have regions of low intensity between the sharp primary colors. These regions may coincide with the wavelengths of the fluorescent fQ_1 primary color.

[0069] FIG. **5** depicts representative narrow incident primary colors from a light source including a blue B, a green G, and a red R incident primary color. Also depicted is the narrow spectrum of a fQ_1 fluorescent primary color. FIG. **5** depicts representative transmission spectra of conventional yellow **502**, magenta **504**, and cyan **506** inks. The transmission spectra of the conventional inks generally may overlap the spectrum of fluorescent primary color fQ_1.

[0070] In another embodiment of the present invention represented in FIG. **10**, an anaglyph may be produced as follows: (1) the first image of the anaglyph may be printed using conventional inks; and (2) the second image may be printed or superimposed on the first image using a fluorescent fQ_1 ink. The anaglyph may be illuminated with RGB light and UV light.

[0071] FIG. **10** depicts another embodiment of the present invention. The first image may be printed in a first layer **1002** using conventional inks. The second image may be printed in a second layer **1004** using a fluorescent ink. The first layer may be printed on a first medium that may be opaque and generally reflecting of white light such as white paper. RGB light incident on the anaglyph may pass through the second layer and may be partially absorbed and partially reflected by the first opaque medium. The first image may modulate the reflected RGB light. The UV light incident on the anaglyph may be partially absorbed and re-emitted as light of the primary color fQ_1 by the second image. The user (not shown) may view the anaglyph through F_1 and F_2 viewing filters (not shown) from the incident side of the anaglyph. The second image layer **1004** may have a second substrate which is distinct from the first substrate and may be attachable to the first substrate.

[0072] The second image may be printed on the same medium as the first image. Or, the second image may be printed on a second transparent medium. The transparent medium may be overlaid on the first image in order to produce a stereoscopic image.

Narrow Incident Primary Colors and High Fidelity Inks

[0073] In another embodiment of the present invention, four independent subtractive primary colors and special light sources with sharp spectral distributions may be used to display anaglyphs with a wide color gamut. Herein the narrow distributions of light incident on an anaglyph are called incident primary colors. The first image of an anaglyph may be printed in three independent subtractive primary colors $\{mP_1, \ldots, mP_m\}$ while the second image of the anaglyph may be printed in one independent subtractive primary color mQ_1. The anaglyph may be illuminated with a light source comprising four incident primary colors $\{P_1, \ldots, P_m\}$ and Q_1. The three subtractive primary colors $\{mP_1, \ldots, mP_m\}$ may preferentially absorb the distributions of light $\{P_1, \ldots, P_m\}$ respectively. The subtractive primary color mQ_1 may preferentially absorb the distribution of light Q_1. The first image may modulate the incident primary colors $\{P_1, \ldots, P_m\}$ while the second image may modulate the incident primary color Q_1.

[0074] The incident primary colors may include red R, green G, blue B, and a fourth Q_1 incident primary colors. Herein light comprising red, green, blue, and Q_1 components may be called RGBQ light. Herein, light with red, green and blue components but, lacking a Q_1 component is called RGB light. The anaglyph may be illuminated with RGBQ light where the spectra of the Q_1 primary color does not overlap the spectra of the incident R, G, and B primary colors. The reflected spectra of RGB light from the anaglyph may have narrow distributions similar to the incident RGB spectra. The first image may modulate the reflected RGB light. The reflected spectra of Q_1 light from the anaglyph may have a narrow distribution similar to the incident Q_1 spectra. The second image may modulate the reflected Q_1 light. Preferably, the Q_1 incident primary color may be comprised of either red, orange, yellow, or cyan light.

[0075] The first image may be viewed through a first viewing filter F_1 which substantially transmits the RGB light and blocks light with wavelengths of the Q_1 incident primary color. The second image may be viewed through a second viewing filter F_2 which substantially transmits light with wavelengths of the Q_1 incident primary color and blocks the RGB light. By viewing the anaglyph through the F_1 and F_2 filters a stereoscopic view with a wide color gamut may be perceived.

[0076] Since reflected light may not change wavelength when reflected from an image, the incident primary colors reflected from a printed anaglyph may have narrow spectral distributions similar to the spectra of the incident primary colors. Subtractive primary inks may be used to modulate the incident primary colors in order to create the first and second images. The subtractive primary colors may have any spectral shape in the regions of wavelength between the incident primary colors. This allows more flexibility in the spectral shape of subtractive primary colors modulating the incident primary colors than if the incident light is comprised of a broad spectrum of light. Generally, the absorption spectra of subtractive inks do not need to be as sharp when using light sources with narrow distributions of light.

[0077] FIG. **6** depicts the spectra of four incident primary colors and four subtractive ink spectra. The incident primary colors include blue B, green G, red R, and a fourth Q_1 incident primary colors. The incident primary color Q_1 may be a cyan, yellow, orange or red incident primary color. If the Q_1 incident primary color is a cyan incident primary color, the Q_1 and G incident primary color may be drawn in reversed positions in FIG. **6**. The blue primary color may be modulated by a minus blue mB ink. The spectra of a mB ink **602** is depicted in FIG. **6**. The green primary color may be modulated by a minus green mG ink. The spectra of a mG ink **604** is depicted in FIG. **6**. The Q_1 primary color may be modulated by a mQ_1 ink (minus Q_1). The spectra of a mQ_1 ink **606** is depicted in FIG. **6**. The red primary color may be modulated by a minus red mR ink. The spectra of the mR ink **608** is depicted in FIG. **6**. The spectra of the subtractive inks depicted in FIG. **6** may be much broader than the spectra of the ideal subtractive inks depicted in FIG. **1**. Therefore, the inks of the present embodiment may be achieved more readily with inexpensive dyes and pigments than the ideal inks of FIG. **1**.

[0078] In another embodiment of the present invention represented in FIG. **11**, an anaglyph may be produced as follows: (1) the first image of the anaglyph may be printed using the high fidelity RGBQ inks. The anaglyph may be illuminated with RGBQ light comprised of incident primary colors.

[0079] FIG. **11** depicts an alternative embodiment of the present invention. The first image may be printed in a first layer **1002** using the mR, mG, and mB inks of the present invention. The second image may be printed in a second layer **1004** using a mQ_1 ink of the present invention. The first layer may be printed on a first medium that may be opaque and generally reflecting of white light such as white paper. The RGB light incident on the anaglyph may pass through the second layer and may be partially absorbed and partially reflected by the first opaque medium. The first image may modulate the reflected RGB light. The Q_1 light incident of the anaglyph may be partially absorbed and partially reflected. The second image may modulate the reflected Q_1 light. The user (not shown) may view the anaglyph through F_1 and F_2 viewing filters (not shown) from the incident side of the anaglyph. The second image layer **1104** may be printed on a second medium which is distinct from the first medium and may be attachable to the first substrate.

[0080] The second image may be printed on the same medium as the first image. Or, the second image may be printed on a second transparent medium. The transparent medium may be overlaid on the first image in order to produce a stereoscopic image.

[0081] Incident primary colors may be provided by some common types of light sources. Fluorescent light sources, low pressure arc-lamps, LED light sources, and laser light sources are examples of light sources which may produce sharp spectra of emitted light. These light sources may provides incident primary colors in various regions of the visible spectrum. For example fluorescent lights often emit narrow distributions of blue, cyan, green, yellow, and red light. An LED or laser light source may emit narrow distributions in several regions of the visible spectrum including red, green, and blue regions. Also low pressure arc lamps may produce narrow distributions of light. For example a mercury-xenon arc lamp may have sharp spectral peaks near 433 nm (blue), 543 nm (green) and 772 nm (yellow) 580 nm (yellow) and 613 nm (red). These light sources may be used to illuminate a printed anaglyph so that the spectra of reflected light may have narrow distributions.

Backlit Embodiments

[0082] In some embodiments of the present invention, both the first and second images may be printed on transparent media. In this case, a backlight may the used to provide the incident light on the printed media. The backlit aspect of the present invention may be combined with many of embodiments of the present invention including embodiments comprising an adsorption mQ_1 layer; a Q_1 reflection filter; the RGB light sources; UV light sources; and RGBQ light sources.

[0083] FIG. **12** depicts a backlit embodiment of the present invention combined with an RGB and UV light sources. The first image may be printed with conventional inks on a first layer **1202**. The second image may be printed with a fluorescent fQ_1 ink: on a second layer **1204**. The RGB light illuminates the first image as it passes through the first layer. The UV light illuminates the second image as it passes through the second layer. The first image may modulate the transmitted RGB light while the second image may emit fluorescent fQ_1 light. The user may view the first and second images from the side opposite from the incident light through first and second color viewing filters F_1 and F_2 respectively. In the present embodiment, the medium of the first and/or second images may be transparent to UV light. FIG. **12** depicts the layer of the second image closer to the UV light source than the layer of the first image in order that the UV light need not travel through a substrate medium.

Viewing Filters for Narrow-Band Anaglyphs

[0084] Displaying anaglyphs in four or more primary colors may provide stereoscopic views with wide color gamuts. However, the viewing filters typically require sharp spectral features which may be difficult to achieve using adsorption dyes. Therefore, the viewing filters may typically comprise dichroic filters which may be expensive. The following aspect of the present invention provides a method to view anaglyphs with wide color gamuts using viewing filters comprised of adsorption dyes.

[0085] Some methods of displaying anaglyphs of the present invention include the use of primary colors with narrow spectral distributions. Narrow spectral distributions of light may be used to illuminate anaglyphs printed in conventional inks and a fluorescent ink, or to illuminate anaglyphs printed in the high fidelity inks of the present invention. Other display methods may also provide primary colors with narrow spectral distributions. For example, digital projectors may use LED or laser light sources which have narrow spectral distributions. LCD flat panel displays may provide narrow spectral distributions by using backlights that have narrow spectral distributions such as fluorescent lights, LED lights or other types of backlights. Also plasma displays may provide primary colors with narrow spectral distributions by using phosphors which emit narrow spectral distributions of light.

[0086] Another embodiment of the present invention provides viewing filters for viewing anaglyph images displayed in four or more primary colors with narrow spectral distributions. The first and second viewing filters of the present invention may have overlapping transmission spectra while not leaking a significant amount of the opposite images through the filters. The relatively broad adsorption spectra of the first and second viewing filters allow the spectra to be achieved using adsorption dyes whereby the viewing filters may be relatively inexpensive to produce.

[0087] FIG. **7** depicts narrow spectral distributions **700** of four primary colors which may include a blue B, cyan C, green G, and red R primary colors where the Q_1 primary color may be the cyan primary color. The first image of an anaglyph may be rendered in the B, G, and R primary colors while the second image may be rendered in the Q_1 primary color. Also depicted are the transmission spectra of the first **702** and second **704** viewing filters of the present embodiment. The first viewing filter may transmit the B, G, and R primary colors and may block the Q_1 primary color. The second viewing filter may transmit the Q_1 primary color and may block the B, G, and R primary colors. Therefore, the first and second viewing filters may be used to selectively view the first and second images of an anaglyph.

[0088] In order to selectively filter images rendered in light with narrow spectra distributions, the adsorption spectra of the viewing filters may be broad. The first and second viewing filters may have overlapping transmission spectra in the regions where the primary colors have small intensity. For example, the blue primary color may have a spectrum centered near about 430 nm to 460 nm. The green primary color may have a spectrum centered near 530 nm to 560 nm. This provides at least about 80-100 nm between for example a blue primary at 430 nm and a green primary near 550 nm for the second viewing filter to transmit a band of wavelengths including the Q_1 primary color, and for the first viewing filter to block a band of wavelengths including the Q_1 primary color. These broad spectral requirements may be provided by common adsorption dyes.

[0089] FIG. **7** depicts narrow spectral distributions of four primary colors which may include a blue B, green G, orange O, and red R primary colors where the Q_1 primary color may be the orange primary color. The O primary color may also be a yellow primary color. The first image of an anaglyph may be rendered in the B, G, and R primary colors while the second image may be rendered in the Q_1 primary color. Also depicted are the transmission spectra of the first **712** and second **714** viewing filters of the present embodiment. The first viewing filter may transmit the B, G, and R primary colors and may block the Q_1 primary color. The second viewing filter may transmit the Q_1 primary color and may block the B, G, and R primary colors. Therefore, the first and second viewing filters may be used to selectively view the first and second image of an anaglyph.

[0090] In order to selectively filter images rendered in light with narrow spectra distributions, the adsorption spectra of the viewing filters may be broad. The viewing filters may have overlapping transmission spectra in the regions where the primary colors have small intensity. For example, the green primary color may have a spectrum centered near about 530 nm to 560 nm. The red primary color may have a spectrum centered near 620 nm to 660 nm. This provides at least about 80-1000 nm between for example a green primary at 530 nm and a red primary near 640 nm for the second viewing filter to transmit a band of wavelengths including the Q_1 primary color, and for the first viewing filter to block a band of wavelengths including the Q_1 primary color. These broad spectral requirements may be provided by common adsorption dyes.

[0091] Thereby the present invention provides inexpensive viewing filters for viewing anaglyphs with wide color gamuts displayed with primary colors with narrow spectra using various display technologies.

[0092] In one embodiment of the present invention, the first image may be rendered in three or more primary colors $\{P_1, \ldots, P_m\}$ with narrow spectral distributions. The second image may be rendered in three or more fluorescent primary colors $\{fQ_1, \ldots, fQ_n\}$ with narrow spectral distributions. The anaglyph may be illuminated with visible incident light with narrow distributions of light $\{P_1, \ldots, P_m\}$ and with ultraviolet light where the spectra of the narrow distributions of light $\{P_1, \ldots, P_m\}$ do not overlap the spectra of the fluorescent primary colors $\{fQ_1, \ldots, fQ_n\}$. The first image of the anaglyph may be viewed through a first filter which transmits the distributions of light $\{P_1, \ldots, P_m\}$ and blocks the fluorescent primary colors $\{fQ_1, \ldots, fQ_n\}$. The second image of the anaglyph may be viewed through a second filter which transmits the fluorescent primary colors $\{fQ_1, \ldots, fQ_n\}$ and blocks the distributions of light $\{P_1, \ldots, P_m\}$.

[0093] For example the first image may be printed in conventional inks and illuminated with three incident primary colors including red R_1, green G_1, and blue B_1 primary colors while the second image may be printed in three fluorescent primary colors including red R_2, green G_2, and blue B_2 fluorescent primary colors where the spectra of the $\{R_1, G_1, B_1\}$ primary colors do not overlap the $\{R_2, G_2, B_2\}$ primary colors significantly.

[0094] As noted above, the present invention is applicable to primary colors and inks, special light sources and special filters and is believed to be particularly useful for displaying and viewing anaglyph images with wide color gamuts. The present invention should not be considered limited to the particular examples described above, but rather should be understood to cover all aspects of the invention as fairly set out in the attached claims. Various modifications, equivalent processes, as well as numerous structures to which the present invention may be applicable will be readily apparent to those of skill in the art to which the present invention is directed upon review of the present specification. The claims are intended to cover such modifications and devices.

I claim:

1. A method of displaying anaglyphs comprising:
an anaglyph including a first image and a second image;
printing the first image in three or more subtractive primary colors $\{mP_1, \ldots, mP_m\}$;
printing a second image in a fluorescent primary color fQ_1; and
illuminating the printed anaglyph with visible incident light.

2. The method of claim 1 further comprising illuminating the printed anaglyph image with ultraviolet incident light.

3. The method of claim 1 further comprising a medium which substantially adsorbs incident light with wavelengths in the region of significant emitted fluorescent light of the primary color fQ_1.

4. The method of claim 1 further comprising printing a layer of a subtractive primary color mQ_1 which substantially adsorbs incident light with wavelengths in the region of significant emitted fluorescent light of the primary color fQ_1.

5. The method of claim 1 further comprising a medium which substantially specularly reflects incident light with wavelengths in the region of significant emitted fluorescent light of the primary color fQ_1.

6. The method of claim 1 wherein the primary color fQ_1 is far-red, red, orange, yellow, or cyan.

7. The method of claim 1 further comprising printing a layer of a subtractive primary color mQ_1 which substantially adsorbs incident light with wavelengths in the region of significant emitted fluorescent light of the primary color fQ_1.

8. The method of claim 1 further comprising:
a first filter F_1 substantially transmitting a region visible light which does not substantially overlap the spectra of the primary color fQ_1 and blocking the primary color fQ_1;
a second filter F_2 substantially transmitting the primary color fQ_1 and blocking a region of visible light which does not substantially overlap the spectra of the primary color fQ_1;
the first image viewable through the first filter F_1; and
the second image viewable through the second filter F_2 whereby the first image may have a two-dimensional color gamut.

9. The method of claim 1 wherein the spectrum of the visible incident light does not substantially overlap the spectrum of the primary color fQ_1.

10. A method of displaying anaglyphs comprising:
an anaglyph including a first image and a second image;
a light source providing three or more distributions of visible light $\{P_1, \ldots, P_m\}$ and
a distribution of visible light Q_1;
distributions of light $\{P_1, \ldots, P_m\}$ mutually non-overlapping;
distributions of light $\{P_1, \ldots, P_m\}$ and Q_1 mutually non-overlapping;
subtractive primary colors $\{mP_1, \ldots, mP_m\}$ preferentially absorbing the distributions of light $\{P_1, \ldots, P_m\}$ respectively;
subtractive primary color mQ_1 preferentially absorbing the distribution of light Q_1;
printing a first image of an anaglyph in subtractive primary colors $\{mP_1, \ldots, mP_m\}$;
printing a second image of the anaglyph in subtractive primary color mQ_1; and
illuminating the printed anaglyph with incident distributions of light $\{P_1, \ldots, P_m\}$ and Q_1.

11. The method of claim 10 further comprising:
a first filter F_1 transmitting the distributions of light $\{P_1, \ldots, P_m\}$ and blocking the distribution of light Q_1;
a second filter F_2 blocking the distribution of light Q_1 and blocking the distributions of light $\{P_1, \ldots, P_m\}$;
the first image of the anaglyph viewable through the first filter F_1; and
the second image of the anaglyph viewable through the second filter F_2.

12. The method of claim 10 wherein primary color Q_1 is far-red, red, orange, yellow, or cyan.

13. An apparatus for viewing anaglyphs comprising:
a first filter F_1 substantially transmitting light with wavelengths in regions $\{P_1, P_2, P_3\}$ of visible light and blocking light with wavelengths in a region Q_1 of visible light;
a second filter F_2 substantially transmitting light with wavelengths in the region Q_1 and blocking light with wavelengths in the regions $\{P_1, P_2, P_3\}$;
the regions $\{P_1, P_2, P_3\}$ excluding a region of visible light with a range of about 60 nm to 90 nm;
the excluded region substantially including the region Q_1
the region Q_1 with a range of about 30 nm; and
the transmission spectra of the first filter substantially overlapping the transmission spectra of the second filter in the excluded region.

14. The apparatus of claim 13 wherein region Q_1 includes wavelengths from about 480 nm to about 510 nm and the excluded region includes wavelengths from about 460 nm to about 555 nm.

15. The apparatus of claim 13 wherein region Q_1 includes wavelengths from about 570 nm to about 600 nm and the excluded region includes wavelengths from about 550 nm to about 620 nm.

16. The apparatus of claim 13 wherein region Q_1 includes wavelengths from about 640 nm to about 670 nm and the excluded region includes wavelengths longer than about 630 nm.

17. A method of displaying anaglyphs comprising:
an anaglyph including a first image and a second image;
printing the first image in three or more subtractive primary colors $\{mP_1, \ldots, mP_m\}$;
printing a second image in three of more fluorescent primary colors $\{fQ_1, \ldots, fQ_n\}$;
illuminating the printed anaglyph with visible incident light with narrow distributions of light $\{P_1, \ldots, P_m\}$ and with ultraviolet light; and
the spectra of the distributions of light $\{P_1, \ldots, P_m\}$ not overlapping the spectra of the fluorescent primary colors $\{fQ_1, \ldots, fQ_n\}$.

18. The method of claim 17 further comprising:
a first filter which transmits the distributions of light $\{P_1, \ldots, P_m\}$ and blocks the fluorescent primary colors $\{fQ_1, \ldots, fQ_n\}$;
a second filter which transmits the fluorescent primary colors $\{fQ_1, \ldots, fQ_n\}$ and blocks the distributions of light $\{P_1, \ldots, P_m\}$;
the first image viewable through the first filter; and
the second image viewable through the second filter.

* * * * *