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(54) COLOUR PHOTOGRAPHY

(71) We, EASTMAN KODAK COMPANY, a Company organized under the Laws of the State of New Jersey, United States of America of 343 State Street, Rochester, New York 14650, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to colour photography.

A method for recording three colour images on single layer, monochrome panchromatic film has been proposed by exposing a colored scene through three crossed grating patterns, one grating consisting of cyan coloured (by transmittance) lines and uncoloured transparent spaces, a second grating consisting of magenta coloured lines and uncoloured spaces and the third grating consisting of yellow coloured lines and uncoloured spaces. The three gratings are superposed in the plane of a panchromatic film emulsion for exposure to the scene. When the light from the scene falls on the gratings, the red component of the scene is modulated by the cyan grating, the green component is modulated by the magenta grating and the blue component is modulated by the yellow grating thereby encoding the colour information recording on the panchromatic film. The luminance information is represented by the sum of the three colour modulations.

After the colour gratings have been removed and the film processed to form a transparency, the colour and luminance information can be retrieved by projecting the processed film as a spatial filtering system using red, green and blue colour filters.

The present invention provides a method of recording multicolour images on photographic materials in which no colour gratings are required when the colour scene is being photographed, this allows the use of conventional cameras and the loss of effective film speed because of the absorption of the grating filters is eliminated.

According to the present invention there is provided a method of recording two or more colour images on a photographic material having portions separately sensitive to the colours, comprising the steps of exposing each sensitive portion to a diffraction grating pattern having a higher spatial frequency than the finest image detail to be recorded and previously or subsequently exposing each sensitive portion to an image containing the colours.

There is further provided a method of making a colour recording material comprising exposing a sensitive material having portions separately sensitive to at least two different colours to at least two diffraction grating patterns, each pattern being exposed using radiation which is recorded by one sensitive portion only.

Colour reproductions can be obtained in accordance with this invention using the various embodiments described below.

1) A three layer film having superposed a blue sensitive layer, a green sensitive layer and a red sensitive layer is exposed with blue light to a grating pattern angularly oriented in a first direction, with green light to a grating angularly oriented in the first or a second direction and with red light to a grating pattern angularly oriented in a first, the second, or a third direction. If the gratings have the same alignment they must have different spatial frequencies from one another. The angular orientations of the gratings, used when the gratings have the same spatial frequency, can be any angles which will adequately separate the spectra that are to be separated by spatial filtering during projection. The grating exposures produce latent images of the gratings angularly oriented in the predetermined directions in the layers. The spacing of the grating lines should be one that can be well resolved by the sensitive layers being used and which will produce first order spectra that are adequately separated from the zero order in a spatial filtering system. Furthermore, the spatial frequency of every grating must be at least twice the maximum spatial frequency to

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be recorded from its corresponding scene component to ensure separation of the diffracted order from the zero order upon projection. The preferred range of frequencies for gratings lies in the range from 10 to 500 lines per millimetre with the above restrictions based on scene frequency; i.e. scene frequencies can be recorded from 5 to 250 lines/mm. It will be appreciated that grating frequencies outside this range may be used depending on film and lens resolution and other optical system limitations. It will also be appreciated that every one of the gratings must have a fixed period, i.e., a repetitive interference cycle. The pre-exposed film is subsequently used as a camera film at which time the scene exposure modulates each latent image grating in accordance with the luminance and colour of the scene components. The film is then processed to a negative and the silver images bleached out.

A complementary colour negative image of the scene can then be produced by projecting white light through the processed film in a spatial filtering system in which the first order spectra produced by the gratings are separated. The first order spectra from the blue sensitive layer are passed through a blue filter, the first order spectra produced by the grating in the green sensitive layer are passed through a green filter and the first order spectra produced by the grating in the red sensitive layer are passed through a red filter. The second order, cross-product and zero order spectra are blocked. The colour filtered and separated first order spectra are then combined and form a resultant complementary colour negative image that can be recorded on a negative working colour print material, such as that sold under the registered Trade Marks KODAK 'Ektacolor' paper or projected on a television camera tube or viewing screen, to obtain a positive tone, real colour reproduction of the original scene photographed.

2) A mixed grain, single photosensitive layer film may be used in which the emulsion layer is of the multigrain type which consists of a mixture of blue sensitive grains, green sensitive grains and red sensitive grains. This film is exposed, processed and treated in all other respects as the three layer film.

3) The same type of three layer film used in the procedure described in paragraph (1) is pre-exposed to grating patterns and subsequently to a colour scene as described in paragraph (1), but the film is then reversal processed to a silver density image. A real colour, positive tone image of the scene can then be produced by projecting the processed film in a spatial filtering system using white light in which the zero order and the first order spectra are blocked and the cross-product spectra produced by the gratings in the green sensitive layer and the red sensitive layer are passed through a blue filter, the cross-product spectra produced by the gratings in the blue sensitive

layer and the red sensitive layer are passed through a green filter, and the cross-product spectra produced by the gratings in the blue sensitive layer and the green sensitive layer are passed through a red filter. The projected image can be recorded on a reversal type photosensitive colour product such as that sold under the registered Trade Marks Kodak 'Ektachrome' film, or projected on a television camera tube face or viewing screen.

4) The same type of three layer film used in paragraph (1) is pre-exposed to grating patterns as described in paragraph (1). The film is then developed to a negative, bleached washed and dried in total darkness. Then the pre-treated film is exposed to a visual colour scene. The film is then developed to a negative silver image, projected in a spatial filtering system using white light and the cross-product spectra passed through colour filters as in paragraph (3), the zero order and first order spectra being blocked as in paragraph (3). A negative, complementary colour image of the scene is produced on the projection screen. The complementary colour image can be printed on a negative working colour print material. (Note: a set of emulsions are required in this embodiment which do not lose their spectral sensitization while the grating exposures are processed.)

The operation of the invention will be described with the aid of the following drawings in which:

Fig. 1 is a schematic diagram showing how two colour scene information may be retrieved from the storage medium of the present invention.

Fig. 2 is a schematic diagram showing the first order image positions formed upon projection of light through a two colour storage medium of the present invention.

Fig. 3 is a schematic diagram of a three colour embodiment of the storage medium of the invention disposed in a projection apparatus;

Fig. 4 is a greatly enlarged representation of a set of gratings having constant width stripes and spaces in the three colour storage medium;

Fig. 5 is a representation of the images of the source 44 as formed at the plane 46 in the configuration of Fig. 3;

Fig. 6 is a second representation of images of the source 44 as formed at the plane 46 of Fig. 3; and

Fig. 7 is a schematic representation of a projection apparatus for reproducing a colour representation of a visual scene using the storage medium of the present invention.

The general method of making the sensitive storage medium comprises providing a photosensitive storage media of the multilayer or multigrain type pre-exposed to form therein latent image gratings as described in paragraphs 1 to 4.

After the pre-exposure to form the image

gratings, the media is exposed to a visual scene such that component scenes which represent colour components of the visual scene are recorded on the media.

5 The media is then processed to produce a photostorage element which, when light is passed therethrough, produces a number of first order spectra representative of the encoded colour compounds of the visual scene.

10 Two exemplary mutually aligned layers 12 and 14, see Figure 1, with pre-exposed gratings or grids recorded thereon as 18 and 20. The layers 12 and 14 are very thin with the grating structure 18 existing in layer 12 and
15 grating 20 in layer 14. The gratings are shown as density variations however in the case of relief image, grating structures are present as irregularities on the surface. Scene image components are recorded on the emulsion layers in addition to the gratings, but the image components are not shown for the purposes of clarity. The preparation of the storage medium will be discussed by way of example to follow:

25 For purposes of simplicity a two grating embodiment is shown in Figure 1 although it will be appreciated that for full colour image reconstruction a three grating embodiment is preferred. A point light source 10 such as an
30 arc-lamp, illuminates emulsion layers 12 and 14 each containing a scene image component, through a lens system 16 which collimates the light from the source 10. The gratings 18 and 20 within the layers 12 and 14 respectively
35 have different spatial frequencies and are mutually aligned i.e. superposed with parallel diffracting gratings. Diffracted rays 22 are formed by each grating and focused by a convergent lens system 17 so that the first order
40 images of the light source 10, represented by circles 24 and 26, fall on a light source image plane shown as the rectangle 28 at fixed areas 30 and 32, respectively. Grating frequencies are chosen so that the first order image produced by one grating does not overlap with
45 any first or higher order images produced by the other grating and such that Moiré effects and crosstalk are minimized. Naturally, any first order image overlap with a zero order image shown by circle 34 is avoided by proper grating selection. A lens system 33 forms an image of the layers 12 and 14 in a transparency image plane 35.

55 Alternative embodiments such as shown in Figures 2 and 4 may use gratings of the same or differing frequencies superposed but rotated at relative angles to one another. As shown in Figures 2 and 4, angular separations in the 30—90° range are preferable for two or three
60 grating systems since upon projection, image overlap problems are minimized. As can be seen in perspective in Figure 2, a point source 37 illuminates superposed gratings 36 and 38 which are oriented at 90° to one another,
65 through a collimating lens system 47. The first

order source images shown by circles 40 and 42 are formed by the converging lens system 49 in the plane 28' and are located on axes at 90° to one another on the plane 28'. From this, it can readily be seen and appreciated that grating frequency selection may be made independently of concern for image overlap between corresponding images 40 and 42 produced by the gratings 36 and 38 at 90° to one another, so long as the grating frequencies are high enough to separate the first order images from the zero order image 43. Observable Moiré effects are also minimized if the gratings are angularly oriented. Zero order images are blocked and for reasons of simplicity other order images are not shown but they should not overlap the first order images.

Figure 4 indicates in accordance with the preferred embodiment, a three layer storage media where Moiré patterns are minimized by disposing a grating 45 at 90° from a grating 41 and a grating 47 at 45° to the grating 41. It is immaterial which layer contains which grating.

If a set of three gratings hereinafter to be described be used, a cross-product spectrum of two of the gratings may fall in the same relative angular position as the first or second order of the third grating. Separation is achieved by changing the grating frequencies or orientations to avoid this. It should be noted that if relative grating angles are small the filtering problem is difficult due to image overlap.

The mathematical theory behind the method of recording images according to the invention is described in an article 'Color Television from Monochrome Transparencies using Modulated Latent Image Gratings' published in *Photographic Science and Engineering* 15, pages 343 to 355 Sept/Oct 1971.

It will be seen that in Figure 3 of the drawings, a light source 44 is imaged in a plane 46 by successive lens systems 48 and 50. A transparency 52 is imaged in plane 54 by successive lens systems 50 and 56. Amplitude gratings 58, 60 and 62 superposed in the transparency 52 may have the same frequency which may be represented substantially by the form, $\cos wx$, and gratings 60 and 62 are oriented at 45° and 90° respectively with respect to grating 58. Figure 5 shows the pattern generated at the plane 46 of Figure 3 using this arrangement and linearly processed. Figure 5 shows an intersection 64 of the axes of the gratings 58, 60, 62 i.e. axes 66, 68 and 70 in Figure 5, the latter two intersecting at 90° and 45° respectively to the axis 66. Crosses 72 and 74 represent first order images from the cross modulation of the images associated with grating 58 and 60, crosses 76 and 78 similarly represent those from 58 and 62 and crosses 80 and 82 represent those for 60 and 62. It is to be understood that for purposes of clarity only half the cross-points are shown.

12
Colour filters are placed according to which component scene information is desired at the cross-points and the remaining orders of images are blocked. From the selected first order images, a colour image is produced at the plane 54.

5
Using non-linear processing three colour signals, i.e. the red, blue and green components of the scene are multiplied by their respective cosine gratings so that the pattern in plane 10 of Figure 3 is that shown in Figure 6. Point 64 is the intersection at which the zero order images coincide and is blocked. To obtain a colour image, the first order images 85, denoted by the crosses, in plane 46 are passed through colour filters (not shown). The signal on the red axis is denoted by the crosses 85 and 66', the blue by those on 68' and the green by those on 70'. It is to be understood that higher order terms are present at the plane 46 but transmission is blocked at the plane by an appropriately perforated aperture plate. It will be appreciated that the choice of which axis carries a given colour component is arbitrary.

25 Illustrative examples follow for the further understanding of the invention:
Colour pictures were obtained by the additive modulation technique using the following photographic equipment.

30 A 35mm 'Nikon' camera with a Micro-'Nikkor' Auto f/3.5, 55mm focal length lens was used to photograph test objects at 5X reduction. 'Nikon' and 'Nikkor' are registered Trade Marks. Test objects were mounted on a 'Kodak' Deluxe Transparency Illuminator, Model 2, using a 100 watt frosted bulb controlled by a variable transformer and a 0.125 inch thick piece of 'Plexiglas' W 2447, Type C70 as a diffuser. 'Plexiglas' is a Trade Mark.

40 In the following first three examples, exposures were made on 'Recordak' Micro-File AHU Film, Type 5459. 'Recordak' is a Trade Mark. This film is a single photosensitive layer panchromatic film having a fine grain and an extremely high resolution. The grating latent images were obtained by photographing a glass plate containing a 10 line per millimetre (equal line and space widths) grating pattern. At the 45 5X reduction this gave 50 lines per millimetre pattern on the film. Picture test objects were then placed on the same illuminator and photographed at the same reduction.

50 The spatial filtering projection apparatus used to produce the colour pictures from the processed films is schematically shown by Fig. 7 which operates as follows:

55 A quarter inch diameter aperture 90, located in a mask 92 passes light from a source 94 which is a 25 watt 'Sylvania' Concentrated Arc lamp through a collimating lens 96 having a 2 inch focal length and a 1 inch aperture. 'Sylvania' is a registered Trade Mark. The collimated light then passes through a plane 98 containing the gridded scene and from there through a lens 100 having a 12

inch focal length and 1 inch aperture. If greater scene magnification is desired the gridded scene may be placed in plane 102. Passing through spatial filtering elements in the form of a perforated plate at plane 104, the light goes through lens 106, a 12 inch, f/4.5 Kodak Anastigmat Lens, which images the plane 98 or 102 on the projection plane 108 containing a projection screen.

Formation of Phase Images using simulated Three Layer Film

The above mentioned 10 line per millimetre grating was photographed on 3 frames of Recordak Micro-File AHU Film. Frame number 1 had the grating lines oriented at about +45° from the horizontal, frame number 2 had the grating lines oriented at about -15° from the horizontal, and frame number 3 had the grating lines oriented about +105° from the horizontal. The exposure used to photograph the grating was 10 seconds at f/5.6 through a 'Wratten' 99 filter a narrow pass band green filter having a peak transmission at 550 nm with the 100 watt bulb in the illuminator operated through a variable transformer set at 65 Volts. It will be appreciated that the 'Wratten' 99 filter is not necessary for colour separation in these exposures and in those of the following examples, but it was used in order to get sharper grating images on the film. 'Wratten' is a Trade Mark and 'Wratten' filter characteristics are set out in the book Kodak Wratten Filters.

After the grating exposure was made on each frame, a picture exposure was added. On frame No. 1, a monochrome negative representing the green component of a scene was photographed. On frame No. 2, a monochrome negative representing the red component of the same scene was photographed and on frame No. 3, a monochrome negative representing the blue component of the same scene was photographed. The exposure used for the picture was 10 seconds at f/5.6 through the 'Wratten' 99 filter with the variable transformer set at 82.5 Volts.

The three exposed frames were then processed as follows:

- 1) 3 min. Development in 'Kodak' D-19, 21°C (dip agitation)
- 2) 10 sec. rinse
- 3) 1 min. 'Kodak' Rapid Fixer with Hardener
- 4) 2 min. wash
- 5) 1 min. 'Kodak' R-9 bleach
- 6) 1/2 min. wash
- 7) 1 min. 'Kodak' CB-6 clear
- 8) 2 min. wash
- 9) dry

The formulae D-19, R-9 and CB-6 are set out hereinafter. 'Kodak' Rapid Fixer with Hardener is obtainable from Kodak Ltd.

The processed film showed faint brownish images upon visual examination. In this example, the only image remaining was a phase image in the gelatin itself. When any of the three frames was projected in the apparatus shown in figure 7 with no spatial filtering, practically no image was formed in the picture plane 108. However, when the zero order was blocked out at the spatial filtering plane 104, a positive picture was formed in the picture plane 108 because of the optical path differences introduced by the phase modulating bleached transparency.

The three frames were superimposed in register and placed in the plane 102 shown in figure 7. In the spatial filtering plane 104 apertures and colour filters were placed so that only the first order spectra were passed and coloured as follows:

The first order spectra produced by the grating to which the picture representing the green component had been added was passed through a green filter, 'Wratten' 57; the spectra produced by the grating to which the picture representing the red component had been added was passed through a red filter 'Wratten' 24; and the spectra produced by the grating to which the picture representing the blue component had been added was passed through a blue filter 'Wratten' 38A. The spectra were combined to form an image in plane 108 which was a positive tone image in the correct colours enlarged about three times.

The projected image was then recorded on Kodak 'Ektachrome' R paper, a photographic colour paper giving reflection prints from positive colour transparencies with an exposure time of 15 seconds. Upon standard processing a full colour picture was produced. It will be appreciated that a three photosensitive layer film behaves the same as three sections of superimposed single photosensitive layer film for projection.

Formation of Reversal Processed Silver Images using Cross Product Spectra

The 10 line per millimeter grating was photographed on three frames of 'Recordak' Micro-File AHU Film with the grating rotational orientations similar to those in Example 1. The exposure used was 10 seconds at f/5.6 through the 'Wratten' 99 filter with the variable transformer set at 75 Volts. After the grating exposure was made on each frame, a picture exposure was added. On frame No. 1 a positive picture representing the green component of a visual scene was photographed, on frame No. 2, a positive picture representing the red component of the same scene was photographed, and on frame No. 3 a positive picture representing the blue component was photographed. The exposure used for each picture was 10 seconds, f/5.6 through the 'Wratten' 99 filter with the variable transformer

set at 110 Volts. The exposed film was then reversal processed as follows:

- 1) 4 min., Kodak Developer DK-50 (1:1), 21°C (dip agitation)
- 2) 1 min. wash
- 3) 1 min. Kodak R-9 bleach
- 4) 1/2 min. wash
- 5) 1 min. Kodak CB-6 clear
- 6) 2 min. wash
- 7) re-exposure: 30 sec., 6 inches from 100 watt bulb
- 8) 4 min., Kodak Developer DK-50 (1:1), 21°C
- 9) 1 min., Kodak Rapid Fix with Hardener
- 10) 3 min., wash
- 11) dry

Formula DK-50 is set out hereinafter.

After processing, each frame had a positive black and white image visible by diffuse transillumination. When a single frame was projected in the apparatus described in figure 7, no picture was produced at the projection plane 108 when the zero order was blocked out. This is evidence that linearity has been met and indicates that the scene for any layer does not modulate the carrier in that layer.

The three frames were then superimposed in register and placed in plane 98. Colour filters and apertures were placed in the spatial filtering plane 104 so that the cross-product spectra were passed and coloured as follows: Cross-product spectra No. 1 were passed through a green filter, 'Wratten' 52. Cross-product spectra No. 1 were produced by the grating to which the red component picture had been added and the grating to which the blue component picture had been added. Cross-product spectra No. 2 were passed through a red filter 'Wratten' 24. Cross-product spectra No. 2 were produced by the gratings to which the blue component picture had been added and the grating to which the green component picture had been added. Cross-product spectra No. 3 were passed through a blue filter, two layers of 'Wratten' 38. Cross-product spectra No. 3 were produced by the grating to which the green component picture had been added and the grating to which the red component picture had been added.

The cross-product spectra were located at angles half way between the angles between the first order spectra of the contributing gratings and at a distance from the optical axis approximately $1.7\times$ the distance of the first order from the optical axis. Only the cross-product spectra within the 60 degree angles were used; the cross-product spectra within the 120 degree angles were not used. If the orientations and spacings of the gratings were such that all of the cross-product spectra were adequately isolated, both sets could be colour filtered and used.

- The image produced in plane 108 was a positive tone image in the correct colours, enlarged about two times. The projected colour image was recorded on Kodak 'Ektachrome'
- 5 Daylight Sheet Film with an exposure of about 2 minutes, and with the standard E-3 processing procedure recommended for the material a full colour picture was obtained.
- 10 Formation of Bleached Grid, Negative Processed Picture using Cross-Product Spectra
- The 10 line per millimeter grating was photographed on three frames of Recordak 'Micro-File' AIIU Film. The grating lines for frame No. 1 were at +90 degrees from the horizontal, for frame No. 2, +45 degrees from the horizontal, and for frame No. 3, +135 degrees from the horizontal. These orientations were chosen to eliminate unwanted line patterns produced by the Moiré effect. The exposure used was 10 seconds, f/5.6 through the 'Wratten' 99 filter with the variable transformer set at 75 Volts. The film with the grating exposures was treated as follows, all in total darkness:
- 25
- 1) develop 4 min., Kodak developer DK-50 (1:1), 70F (dip agitation)
 - 2) wash 1 min.
 - 3) bleach 1 min. Kodak R-9 bleach
 - 4) wash 1/2 min.
 - 5) clear 1 min. Kodak CB-6 cleaning bath
 - 6) wash 2 min.
 - 7) dry
- 30
- The dried film was placed back in the camera. The negative representing the green component of a picture was photographed on frame No. 1, the negative representing the red component of the same picture was photographed on frame No. 2, and the negative representing the blue component of the same picture was photographed on frame No. 3. The picture exposures were 10 seconds at f/5.6 with the variable transformer set at 110 Volts. No filter was used.
- 35
- The picture-exposed films were developed 4 minutes in Kodak developer DK-50 (1:1) at 21°C, fixed, washed, and dried.
- 40
- Because negatives were photographed and negative processed, each frame of the processed film showed a positive tone, black and white image when examined by diffuse transillumination. When a single frame was projected by the apparatus described in Figure 7, no picture was produced in plane 108 when the zero order was blocked.
- 45
- The three frames were then superimposed in register. The composite was placed in the plane 98 of the apparatus shown in Figure 7 for projection. Colour filters and apertures were placed in the spatial filtering plane such that the cross product spectra were passed and coloured the same as they were for Example
2. A positive tone colour image was obtained in the plane 108 at about two times enlargement.
- 65
- Example 1
- Phase Image-Multilayer Film
- A multilayer film comprising the following sensitive layers in the order in which they were coated on a clear film base was utilized:
- 70
- 1) red sensitive emulsion
 - 2) separating layer
 - 3) green sensitive emulsion
 - 4) yellow filter layer
 - 5) blue sensitive emulsion
 - 6) overcoat layer
- 75
- This film was exposed in the 'Nikon' camera using the system above described. Exposures were made on the same frame and in the order listed:
- 80
- 1) 10 line per millimeter grating oriented at -15° from horizontal: 10 seconds, f/5.6, 'Wratten' No. 70 filter (red) transformer at 55 Volts (exposed through base).
 - 2) 10 line per millimeter grating oriented at +45° from horizontal: 10 seconds, f/5.6, 'Wratten' No. 99 filter (green), transformer at 55 Volts.
 - 3) 10 line per millimeter grating oriented at +105° from horizontal: 20 seconds, f/5.6, 'Wratten' No. 47B (blue) filter, transformer at 120 Volts.
 - 4) Negative representing red component of a scene 10 seconds f/5.6, 'Wratten' No. 70 filter, transformer at 75 Volts.
 - 5) Negative representing red component at the same scene: 10 seconds, f/5.6, 'Wratten' No. 99 filter, transformer at 65 Volts.
 - 6) Negative representing blue component of the same scene: 10 seconds, f/5.6, 'Wratten' No. 47B filter, transformer at 120 Volts.
- 85
- 90
- 95
- 100
- The film was then processed as follows:
- 105
- 1) 5 min., 'Kodak' developer D-19, 21°C
 - 2) 1 min. wash
 - 3) 1 min. 'Kodak' R-9 bleach
 - 4) 2 min. wash
 - 5) dry
- 110
- Since the 'Kodak' R-9 bleach changes the developed silver to a water soluble silver salt, the bleached images are removed, leaving only the unexposed silver halide, thus forming a positive phase image.
- 115
- The processed film was projected in the spatial filtering apparatus shown in figure 7. The first order spectra produced by the grating in the blue sensitive layer was passed through a blue filter 'Wratten' 38A; the first
- 120

order spectra produced by the grating in the green sensitive layer were passed through a green filter 'Wratten' 99 and the first order spectra produced by the grating in the red sensitive layer were passed through a red filter 'Wratten' 24. Upon projection, a positive tone, full colour image was formed on a viewing screen located in picture plane 108.

Example 2

10 Modulated Grating Exposures on a Single Layer Mixed Grain Film

A gelatino-silver bromiodide emulsion coating of the type described in U.S. Patent 2,592,243 contains a blend of red and green sensitized grains. This example demonstrates that the image resulting from an exposure made with red light can be separated from the image resulting from an exposure made with green light when the image exposures additively modulate two separate pre-exposed grating patterns and the processed image is projected in a spatial filtering apparatus such as shown by figure 7.

25 A 35mm 'Nikon' Camera with a Micro-'Nikkor' auto f/3.5 55mm focal length lens was used to photograph test objects at 5X reduction, mounted on a 'Kodak' Deluxe Transparency Illuminator, Model 2, using a 100 watt frosted bulb and a 0.125 inch thick piece of 'Plexiglas' W2447, Type C70, as a diffuser.

30 A 10 line per millimeter grating having equal line and space widths and a black-and-white transparency negative picture test object were sequentially photographed onto a single frame of the emulsion as follows: 1) Grating lines at +45° from horizontal: 'Wratten' No. 93 filter (green), 5 seconds exposure time, lens at f/8, illuminator lamp operated through a variable transformer set at 75 Volts. 2) Picture test object, right-side-up; 'Wratten' No. 93 filter (green), 5 seconds, f/8, variable transformer at 85 Volts. 3) Grating lines at 135° from horizontal; 'Wratten' No. 70 filter (red), 5 seconds, f/8, variable transformer at 32 Volts; and 4) Picture test object, up-side-down; 'Wratten' No. 70 filter (red), 5 seconds f/8, variable transformer at 37 Volts.

The exposed film was processed as follows:

- 50 1) 5 min., 'Kodak' Developer D-19, 21°C
- 2) 10 sec. rinse
- 3) 1 min. fix in 'Kodak' F-5 hypo
- 4) 2 min. wash
- 55 5) 1 min. In-4 bleach (1:5) (Bleach from 'Kodak' Chromium Intensifier In-4)
- 6) 1 1/2 min. wash
- 7) 1/2 min. F-5 hypo
- 8) 2 min. wash
- 9) dry

60 Formulae F-5 and In-4 are set out hereinafter.

The processed film was then projected in

the spatial filtering apparatus described in figure 7. When the first order spectra produced by the grating made with green light were passed, a positive right-side-up picture was projected on the screen. When the spectra produced by the grating made with red light were passed, a positive up-side-down picture was projected on the screen. No cross-talk contamination was noticeable in either picture, thus indicating that in a mixed grain emulsion an image resulting from an exposure made with red light can be separated from an image resulting from an exposure made with green light when the image exposures additively modulate two separate pre-exposed grating patterns and the processed image is projected in a spatial filtering apparatus.

Example 3

Phase Image, Multilayer Film-One Shot Camera Exposure 80

A multilayer film of the type described in Example 1 was used. An 83 line per millimetre master grating was contact printed three times on a single frame of the film, once through a 'Wratten' 99 (green) filter, once through a 'Wratten' 98 (blue) filter and once through a 'Wratten' 70 (red) filter. The grating lines were oriented at 0 degrees for the red exposure, 45 degrees for the blue exposure and 90 degrees for the green exposure. The grating exposed film was loaded into a 'Nikon' X camera and an outdoor sunlight scene was photographed at 1/60 second with the lens set at an aperture of f/4.

The film was processed as follows:

- 1) 5 min., 'Kodak' D-19 developer, 21°C
- 2) 10 sec. rinse
- 3) 2 min. F5 fixer
- 4) 2 min. wash
- 5) 1 min. In-4 bleach (1:5)
- 6) 5 min. wash
- 7) dry

A glass cover was sealed to the emulsion surface of the processed film with an index matching oil so that only index of refraction effects contributed to the image. The frame was placed in the spatial filtering system. The first order spectra produced by the grating in the blue sensitive layer were passed through a 'Wratten' 98 (blue) filter, the first order spectra produced by the grating in the green sensitive layer were passed through a 'Wratten' 99 (green) filter and the first order spectra produced by the grating in the red sensitive layer were passed through a 'Wratten' 26 (red) filter. The zero order image and spectral orders higher than the first order were blocked. A negative tone, complimentary colour reproduction of the scene photographed was formed on the projected image plane at about 7X enlargement. This image was recorded on Kodak 'Ektacolor' Professional Paper with an expo-

sure of 10 seconds to produce, after processing, a positive tone, real colour picture.

Example 4

Subtractive Primary Originals

- 5 Cyan, magenta and yellow colour separation positive transparencies of a visual scene and a 10 line per millimetre opaque and clear line grating overlay were separately photographed at 5× reduction on Kodak 'Panatomic-X'
- 10 Film in a 'Nikon' camera using a Micro-'Nikkor' f/3.5 lens. The word 'Panatomic' is a registered Trade Mark. The transparencies were transilluminated by a 'Kodak' Deluxe Transparency Illuminator Model 2 with a 100 watt bulb controlled by a variable transformer. Each exposure was made through a 'Wratten' 99 filter for 10 seconds at f/5.6 with the variable transformer set at 40 Volts, and all three separations were recorded on the same frame of film. The picture exposures were superimposed in register but the grating was rotated 60° between exposures. The grating over the cyan separation positive was at -15°, the grating over the yellow separation positive was at 105° to a horizontal reference axis.
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- The exposed film was developed for 7 minutes in 'Kodak' developer D-76 (1:1) at 21°C, rinsed for 10 seconds, fixed for 1 minute in 'Kodak' Rapid Fixer with hardener, washed for 2 minutes, bleached for 2 minutes in the bleach from 'Kodak' Chromium Intensifier In-4 (working dilution), washed for 2 minutes and dried to produce the transparency. The processed film was then almost completely transparent when viewed by diffuse transillumination.
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- The processed transparency was projected with white light in a spatial filtering apparatus such as shown in figure 7. A white light source was used in projection but it will be appreciated that other kinds of light sources may be used with equal facility and would provide a similar result. For example, laser and sources containing only portions of the spectrum may be used. The first order spectra from the grating associated with the cyan separation were passed through a 'Wratten' 24 (red) filter. The first order spectra from the grating associated with the magenta separation were passed through a 'Wratten' 57 (green) filter. The first order spectra from the grating associated with the yellow separation were passed through 'Wratten' 38A (blue) filter. When an aperture plate having three apertures passing these first order spectra was suspended in the image plane, a projected image positive in tone and in real colours was produced.
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Example 5

Additive Primary Originals

- 60 Red, green and blue colour separation positive transparencies of a pictorial scene and a 10 line per millimeter opaque and clear line grating overlap were photographed at 5×

reduction on a single frame of a multilayer film having a red sensitive layer, a green sensitive layer and a blue sensitive layer. The film was medium speed, crucible form, bromiodide emulsion coated at 50 milligrams silver and 100 milligrams of gel per square foot per layer. The green and red layers were sensitized with a spectral sensitizing dye. A 'Nikon' Camera was used with a Micro-'Nikkor' f/3.5 lens as follows:

Blue separation positive with grating orientation 90° to horizontal: 'Wratten' filter No. 47B (blue), 50 seconds, f/4, transformer at 120 Volts.

Green separation positive with grating orientation 135° to horizontal: 'Wratten' filter No. 99 (green), 10 seconds, f/5.6 transformer at 65 Volts.

Red separation positive with grating orientation 45° to horizontal: 'Wratten' filter No. 70, (red), 10 seconds, f5.6, transformer at 80 Volts.

The exposed film was processed as follows:

- 1) 5 min. 'Kodak' Developer D-19 21°C
- 2) 10 sec. rinse
- 3) 1 min. Rapid Fix with Hardener
- 4) 2 min. wash
- 5) 2 min. 'Kodak' In-4 bleach solution
- 6) 2 min. wash
- 7) dry

The processed transparency was projected in the same spatial filtering apparatus as the transparencies of Example 1. The first order spectra from the grating in the green sensitive layer were passed through a green filter 'Wratten' No. 61; the first order spectra from the grating in the red sensitive layer were passed through a red filter 'Wratten' No. 24; and the first order spectra from the grating in the blue sensitive layer were passed through a blue filter 'Wratten' No. 47. The three first order spectra were superimposed to form a projected image on the screen. The image corresponded to the combined colour components of the visual scene. The image was positive in tone, real in colours, and in an upright position.

The photosensitive layer or layer of photographic films can be exposed to the grating patterns sequentially or all at once during the manufacture, for example, by the Clayden pre-screening process disclosed in U.S. Patent 3,110,593 so that a user may obtain a film ready to use with the pre-exposure already on it.

There are several photographic silver halide emulsion systems that can be used in this invention. One is a standard multilayer system, similar to that used for Kodak 'Kodachrome' colour film, in which the silver in any colour filter layer or layers is bleached or removed in processing. The word 'Kodachrome' is a registered Trade Mark. Another possible photographic element is the mixed grain emul-

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sion described in U.S. Patent 2,592,243. This emulsion uses a mixture of differently sensitized silver halide grains in a single layer to record a scene. One system for a colour forming element is the mixed packet system of U.S. Patent 2,698,794, but this is less satisfactory than those mentioned above for use in accordance with the present invention for reasons of resolution, cost, and being limited to printing materials. Yet another possible system using a resulting dye image instead of silver is the dye bleach system such as that described in U.S. Patent 2,612,448, where only the on-image dye remains after processing.

It is to be understood that the three colour and two colour embodiments shown are merely representative and that four or more colours may be used. Too, the invention is not limited to the best mode optical system shown and the use of equivalent or reflective optical systems will be readily apparent. Furthermore, a film consisting of a multilayer combination of single grain type layer or layers and mixed grain type layer or layers may be used.

The formulae used to process the exposed material are set out below:

'Kodak' Developer D-19

	Metol	2	g
	Sodium sulphite (anhydrous)	90	g
30	Hydroquinone	8	g
	Sodium Carbonate (anhydrous)	45	g
	Potassium Bromide	5	g
	Water to one litre		

'Kodak' Developer DK-50

35	Metol	2.5	g
	Sodium Sulphite (anhydrous)	30	g
	Hydroquinone	2.5	g
	Sodium metaborate	10	g
	Potassium Bromide	0.5	g
40	Water to one litre		

'Kodak' Bleach Bath R-9

	Potassium Dichromate	9.5	g
	Sulphuric acid (conc)	12	ml
	Water to one litre		

'Kodak Clearing Bath CB-6

45	'Kodak' Anti-Calcium No. 3	0.5	g
	Sodium Metabisulphite	15	g
	Water to one litre		

'Kodak' Intensifier In-4

50	Potassium dichromate	90	g
	Hydrochloric acid (conc solution)	64	ml
	Water to one litre		
	Use diluted 1 to 10 parts water.		

'Kodak' Fixer F-5

55	Sodium thiosulphate crystals	240	g
	Sodium Sulphite anhydrous	15	g
	Acetic acid (80% aqueous)	17	ml
	Boric acid (cryst)	7.5	g
60	Potassium Alum	15	g
	Water to one litre		

'Kodak' Developer D-76

	Metol	2	g	
	Sodium Sulphite (anhydrous)	100	g	
	Hydroquinone	5	g	
	Borax	2	g	65
	Water to one litre			

WHAT WE CLAIM IS:—

1. A method of recording two or more colour images on a photographic material having portions separately sensitive to the colours, comprising the steps of exposing each sensitive portion to a diffraction grating pattern having a higher spatial frequency than the finest image detail to be recorded and previously or subsequently exposing each sensitive portion to an image containing the colours. 70
2. The method as claimed in Claim 1 wherein the photographic material comprises two or more superposed layers each sensitive to a different colour. 75
3. The method as claimed in Claim 1 wherein the photographic material comprises a single layer in which the photographic material comprises a single sensitive layer containing two or more sets of discrete particles each sensitive to a different colour. 80
4. The method as claimed in any of the preceding Claims in which all the sensitive portions have a grating pattern of the same spatial frequency but the orientation differs between each portion. 85
5. The method as claimed in Claim 4 wherein there are three gratings at 90°, 45° and 135° to a reference axis. 90
6. The method as claimed in any of the Claims 1 to 3 wherein all the sensitive portions have grating patterns at different spatial frequencies from one another. 95
7. The method as claimed in any of the preceding Claims in which the sensitive portions are exposed to grating patterns before exposure to the coloured image. 100
8. The method as claimed in any of the preceding Claims in which the sensitive portions are sensitive silver halide emulsion grains. 105
9. The method of recording two or more colour images as claimed in Claim 8 wherein the exposed silver halide emulsion containing latent images of the gratings and colour images is developed to provide a series of silver images. 110
10. The method as claimed in Claim 9 wherein the silver images are bleached to leave a series of phase images in the binding colloid. 115
11. The method of making a colour recording material comprising exposing a sensitive material having portions separately sensitive to at least two different colours to at least two diffraction grating patterns, each pattern being exposed using radiation which is recorded on one sensitive portion only. 120
12. The method as claimed in Claim 11 wherein the colour recording material com-



- sion described in U.S. Patent 2,592,243. This emulsion uses a mixture of differently sensitized silver halide grains in a single layer to record a scene. One system for a colour forming element is the mixed packet system of U.S. Patent 2,698,794, but this is less satisfactory than those mentioned above for use in accordance with the present invention for reasons of resolution, cost, and being limited to printing materials. Yet another possible system using a resulting dye image instead of silver is the dye bleach system such as that described in U.S. Patent 2,612,448, where only the on-image dye remains after processing.
- It is to be understood that the three colour and two colour embodiments shown are merely representative and that four or more colours may be used. Too, the invention is not limited to the best mode optical system shown and the use of equivalent or reflective optical systems will be readily apparent. Furthermore, a film consisting of a multilayer combination of single grain type layer or layers and mixed grain type layer or layers may be used.
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	Sodium Sulphite (anhydrous)	30	g
	Hydroquinone	2.5	g
	Sodium metaborate	10	g
	Potassium Bromide	0.5	g
40	Water to one litre		

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	Hydroquinone	5	g	65
	Borax	2	g	
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12. The method as claimed in Claim 11 wherein the colour recording material com-

- prises two or more superposed layers each sensitive to a different colour.
13. The method as claimed in Claim 11 wherein the recording material comprises a single layer in which the sensitive material comprises two or more sets of discrete particles each sensitive to a different colour.
14. The method as claimed in any of the Claims 11 to 13 in which all the sensitive portions are exposed to grating patterns having the same spatial frequency but the orientation of the grating pattern differs between each portion.
15. The method as claimed in Claim 14 wherein there are three grating patterns at 90° , 45° and 135° to a reference axis which are exposed respectively on three sensitive portions.
16. The method as claimed in any of the Claims 11 to 13, wherein all the sensitive portions are exposed to grating patterns having different spatial frequencies from one another.
17. The method as claimed in any of the Claims 11 to 16 in which the sensitive portions are sensitized silver halide emulsions.
18. Methods of making colour recording materials as claimed in Claim 11 and as herein described.
19. Colour recording materials whenever made by the method of any of the Claims 11 to 18.
20. Methods of recording colour images as claimed in Claim 1 and as herein described.
21. Records of coloured scenes whenever made by the method of any of the Claims 1 to 10 or 20.
- L. A. TRANGMAR, B.Sc., C.P.A.,
Agent for the Applicants.

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