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Spaulding

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[54] **MULTI-COLOR ACOUSTOOPTIC MODULATOR**

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[73] Assignee: **Eastman Kodak Company**, Rochester, N.Y.

[21] Appl. No.: **641,470**

[22] Filed: **Dec. 17, 1975**

Related U.S. Patent Documents

Reissue of:

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Issued: **Jan. 1, 1974**
Appl. No.: **221,668**
Filed: **Jan. 28, 1972**

[51] **Int. Cl.**^{2} **H04N 5/84;** H04N 9/12

[52] **U.S. Cl.** **358/4;** 358/6; 358/60; 358/63; 350/358; 350/174

[58] **Field of Search** .... 178/7.3 D, 7.5 D, 7.6, 178/6.6 R, 6.7 R, 6.7 A, DIG. 18; 358/60, 63, 4, 6; 250/199; 350/161, 169, 174; 332/7.51

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Primary Examiner—Robert L. Richardson
Attorney, Agent, or Firm—Milton S. Sales

[57] **ABSTRACT**

An apparatus and method are disclosed for acoustooptically modulating and diffracting a plurality of optical wavelengths contained in laser light impinging on an acoustooptic cell to form a composite output beam comprising intensity modulated component beams of selected wavelengths present in the impinging laser light. To accomplish this, a plurality of amplitude modulated electrical signals of different fixed frequencies are applied to an electrical-to-acoustical transducer operatively attached to the cell. Every frequency applied to the transducer produces an acoustic wave within the cell to form a diffraction spectrum of the wavelengths present in the laser light impinging or incident on the cell. The acoustic wave producing electrical frequencies are chosen such that diffracted component beams of selected wavelengths are collinear. Thus, the collinear component beams form a composite output beam comprising the selected diffracted wavelengths. Non-collinear beams of the selected wavelengths as well as unwanted diffracted wavelengths and undiffracted beams are masked or blocked from further passage through the optical system. The amplitudes of the electrical signals producing the acoustic waves within the cell are modulated independently to control the intensities of the individual component beams of selected wavelengths present in the composite output beam. The laser light impinging on the cell can comprise a single multi-wavelength beam; two collinear beams of different wavelengths and a third noncollinear beam of another wavelength; or beams of different wavelengths can be mutually noncollinear, the angles of impingement being chosen in accordance with what electrical frequencies are applied to the transducer.

29 Claims, 13 Drawing Figures

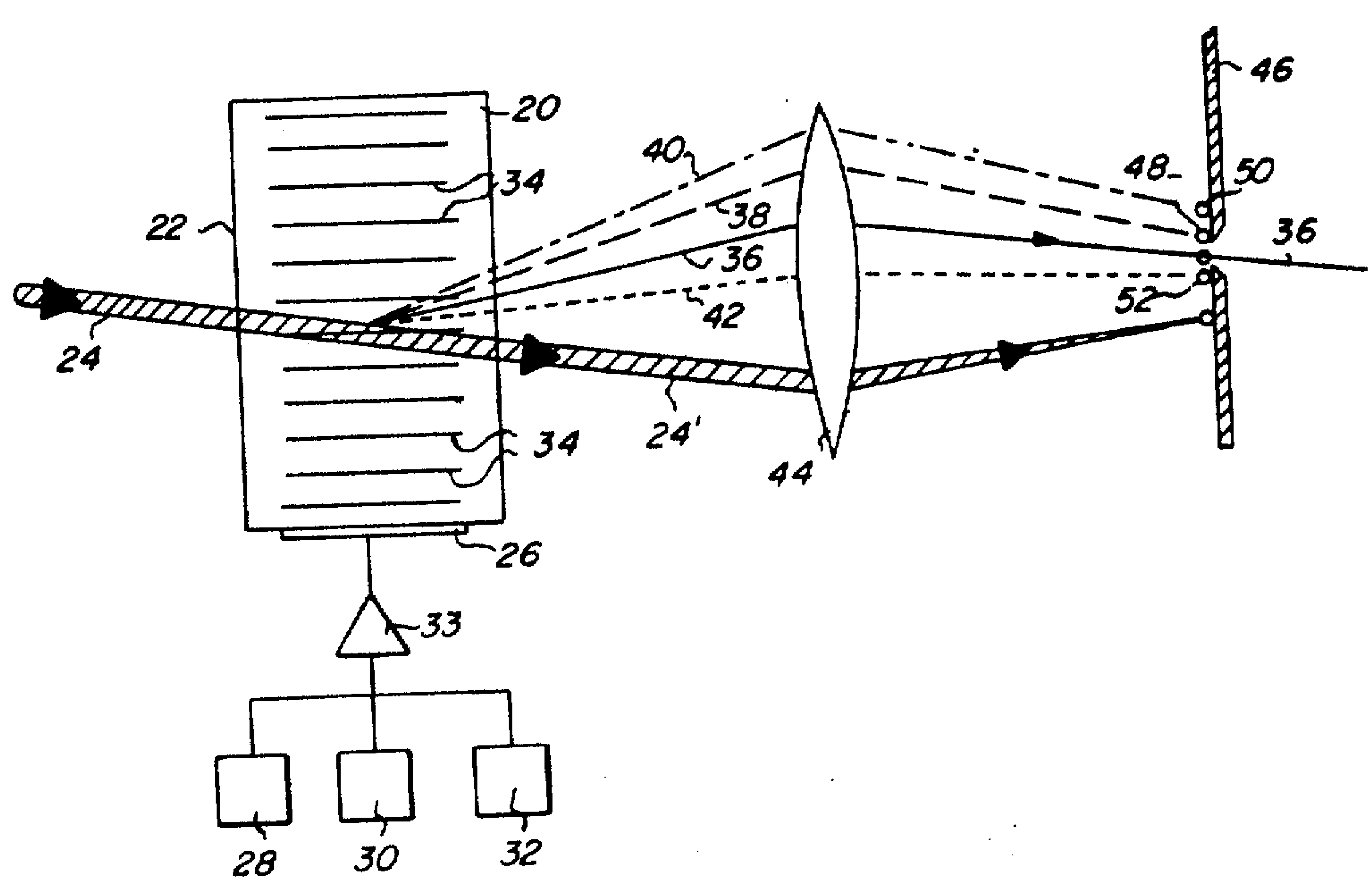

FIG. 1

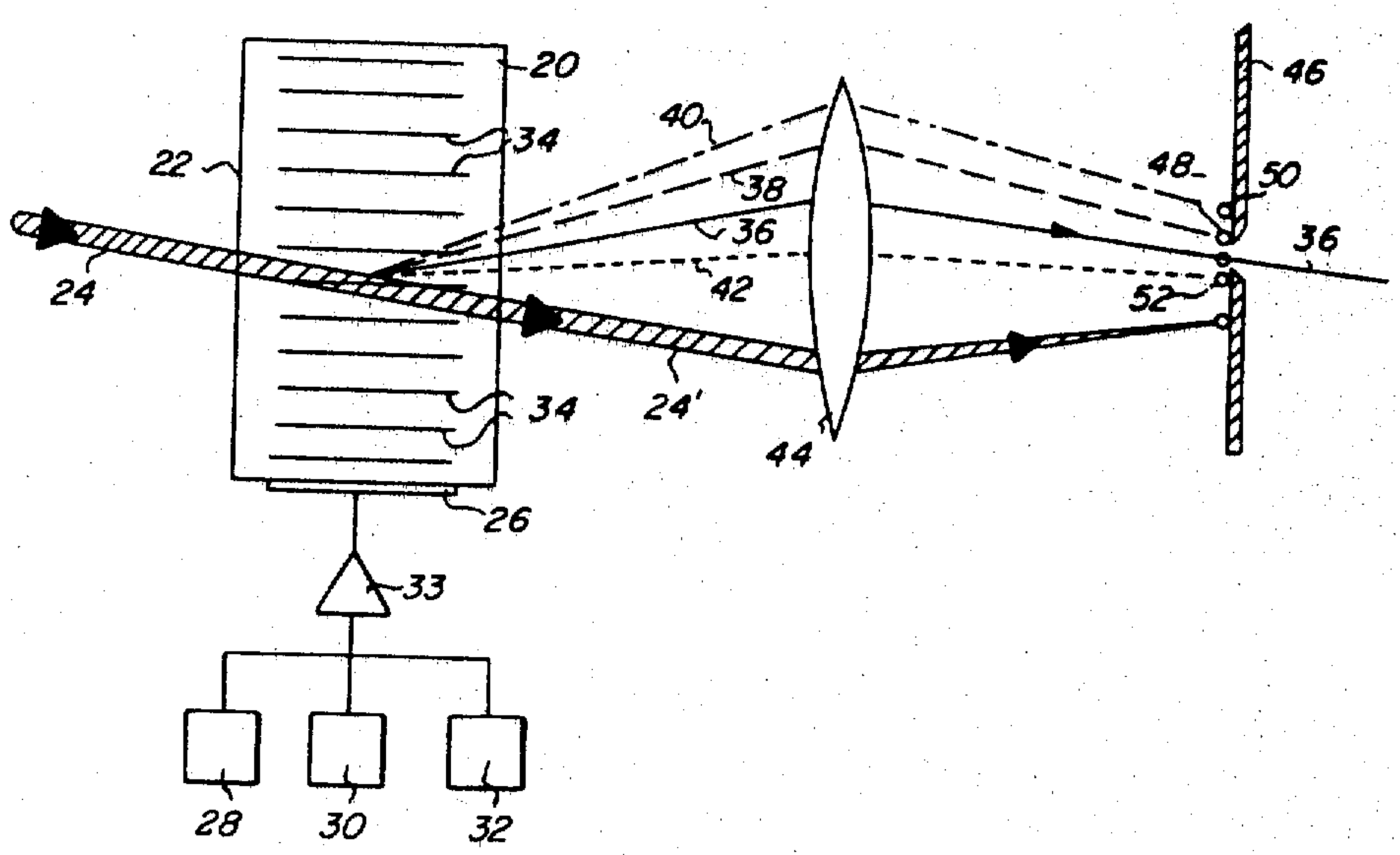
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FIG. 2

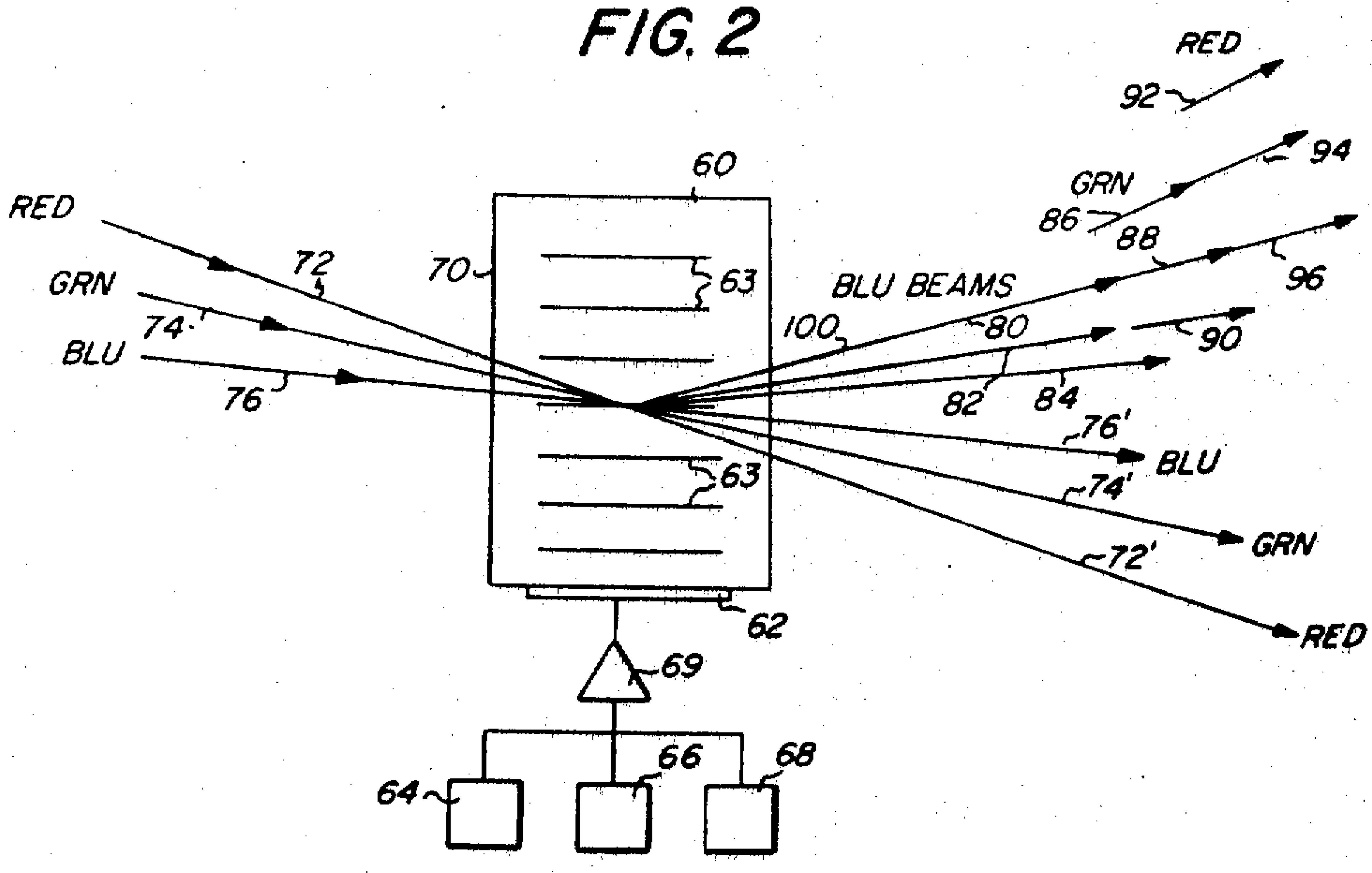
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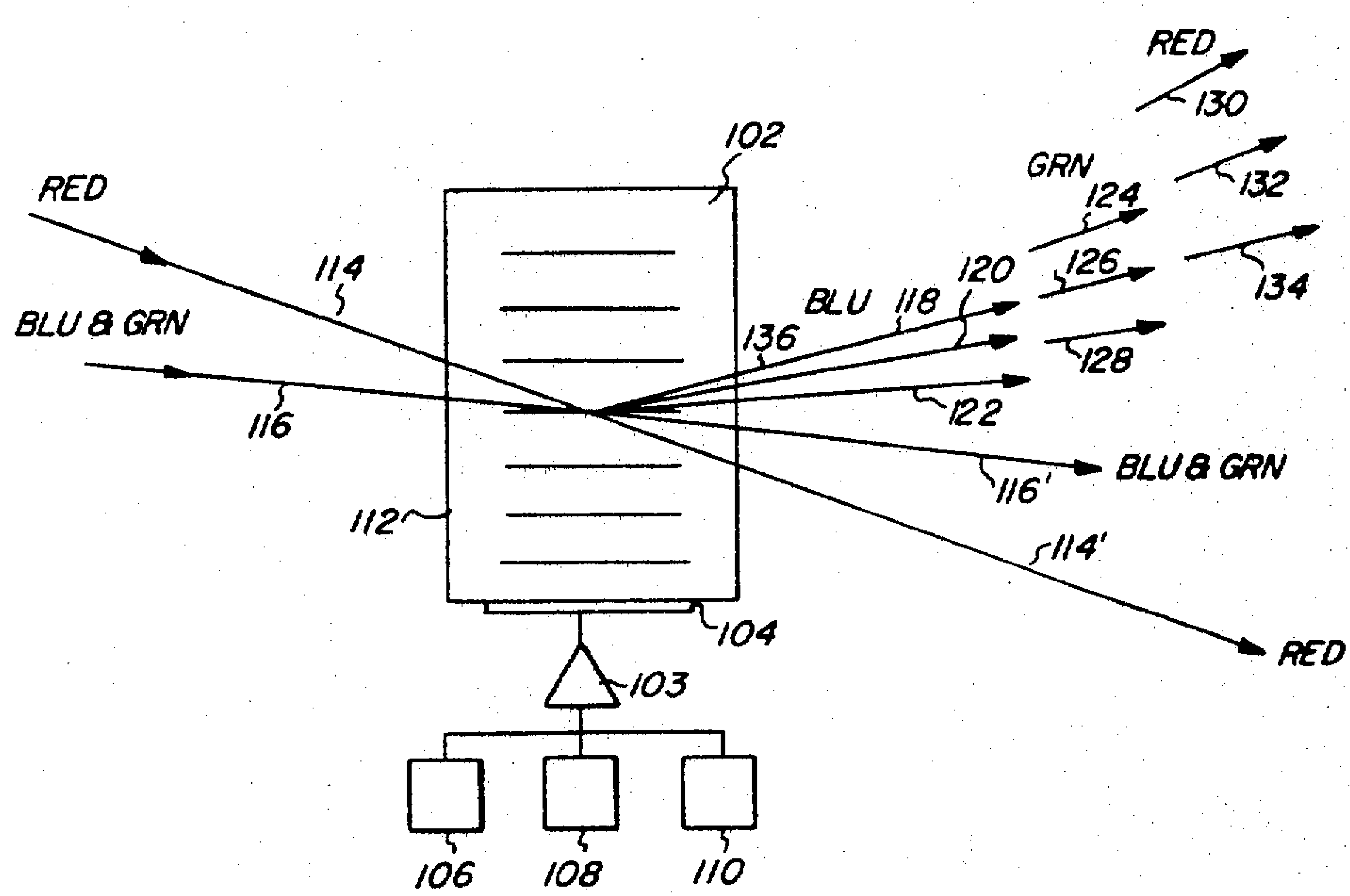
FIG. 3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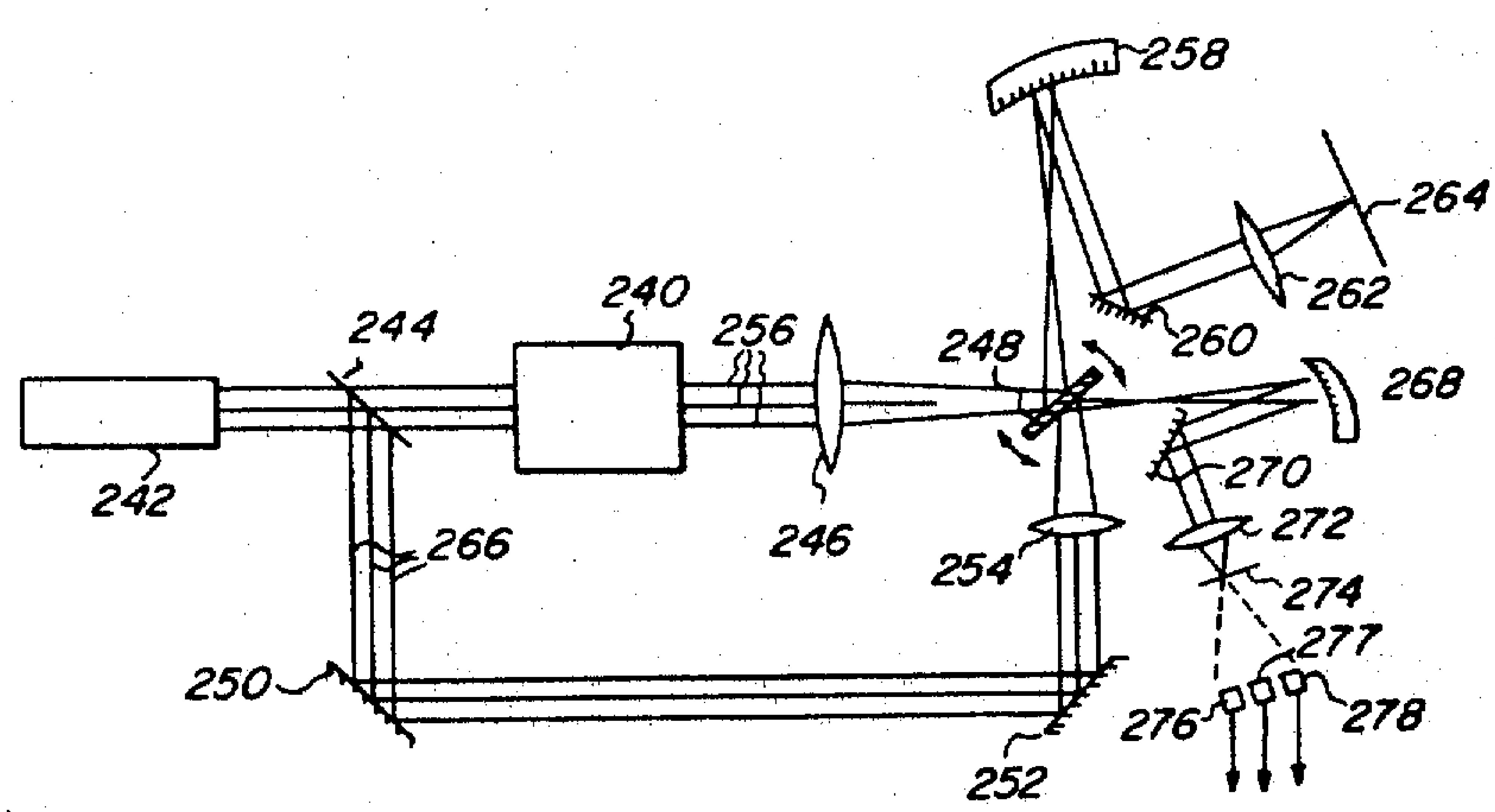
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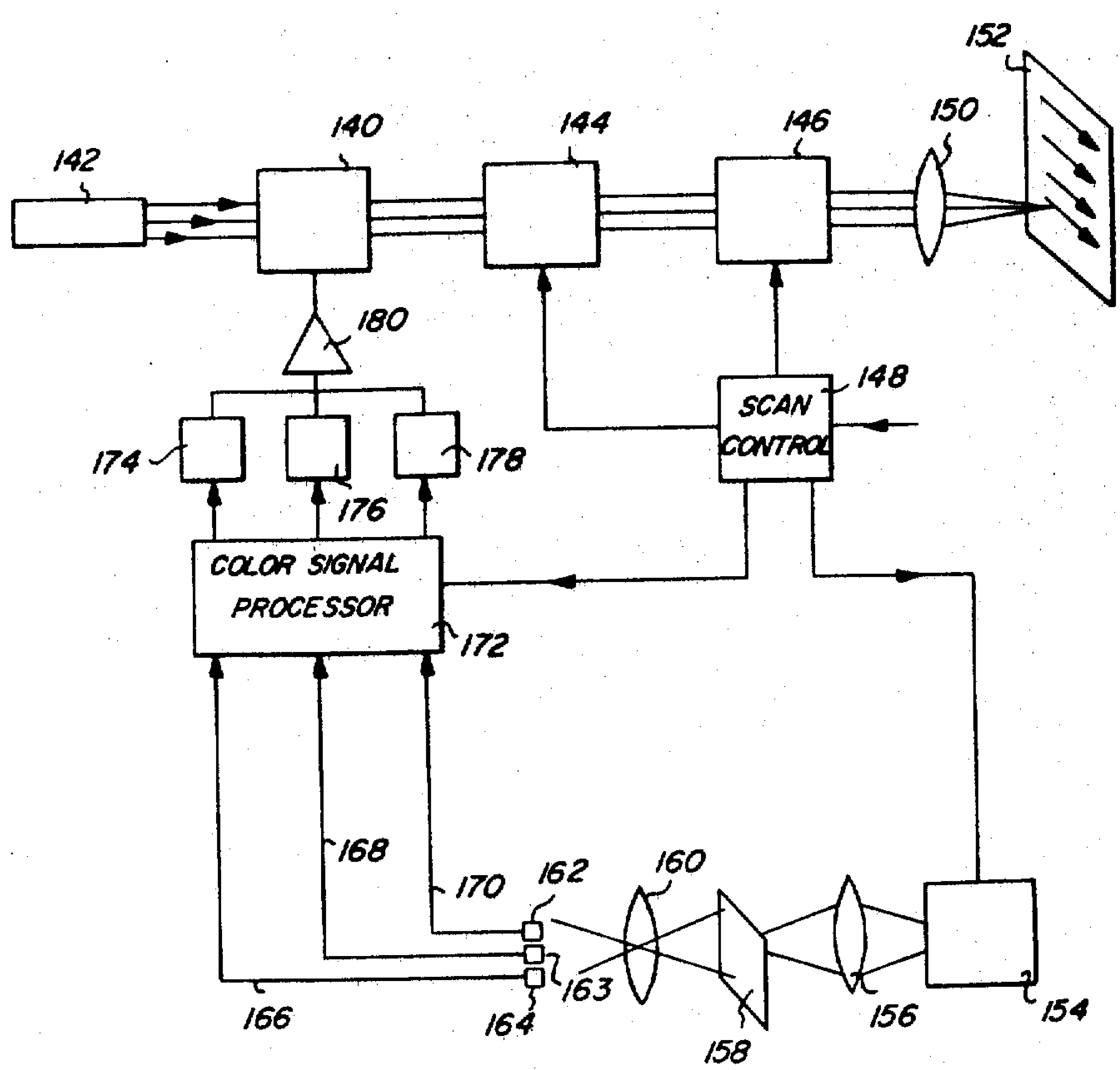
FIG. 6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SCAN CONTROL
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COLOR SIGNAL PROCESSOR
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FIG. 4

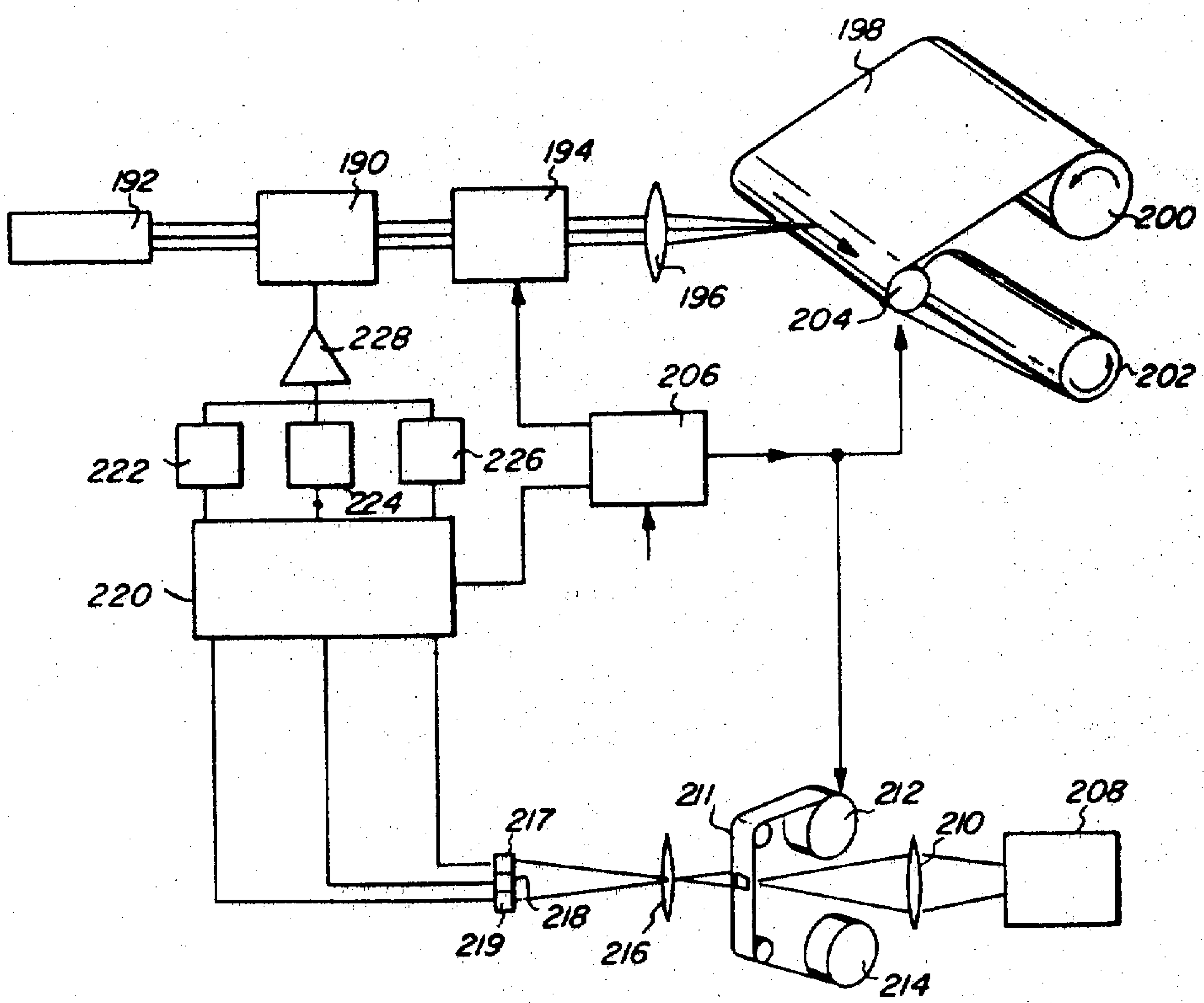
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FIG. 5

FIG. 6a

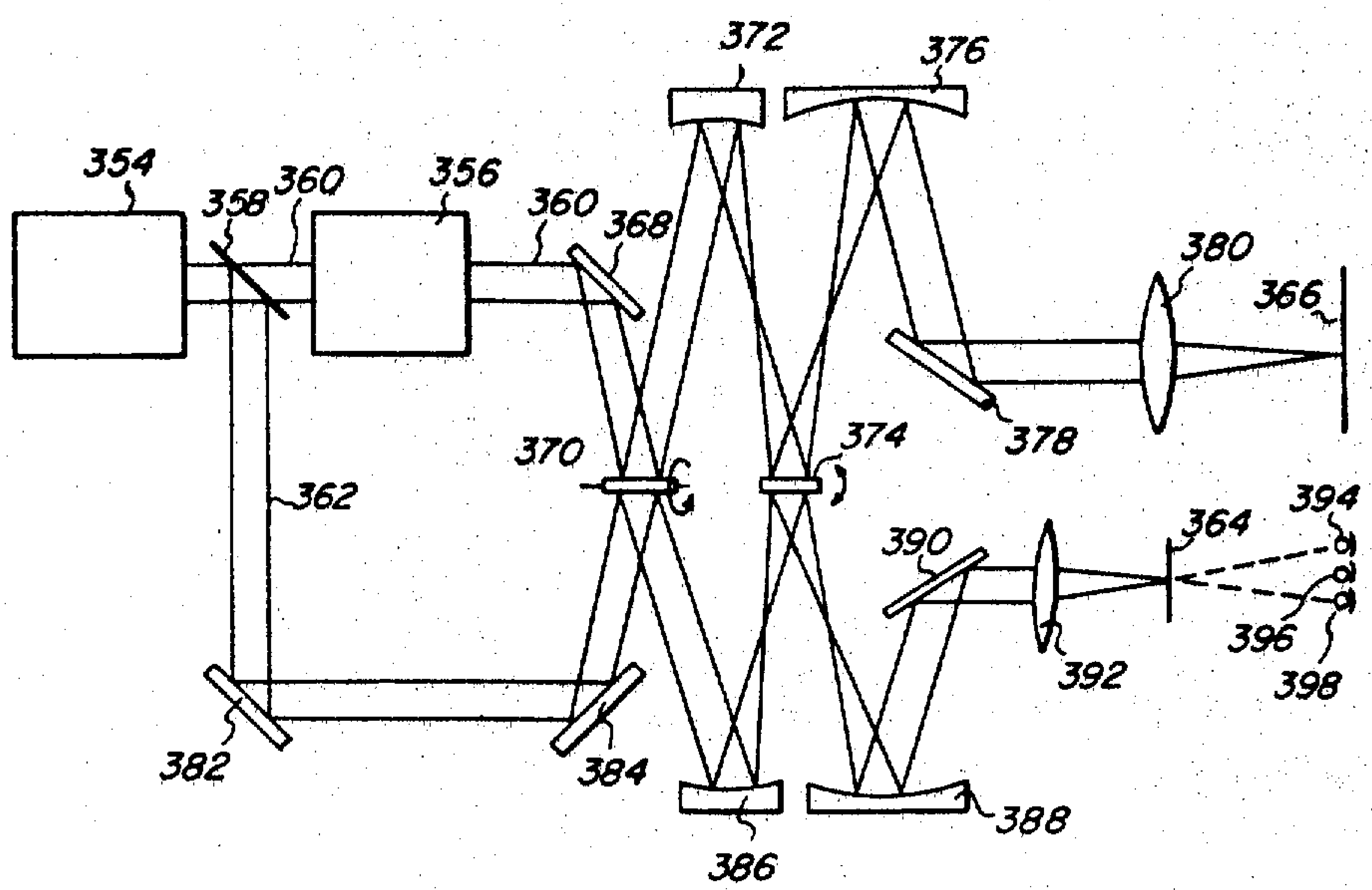
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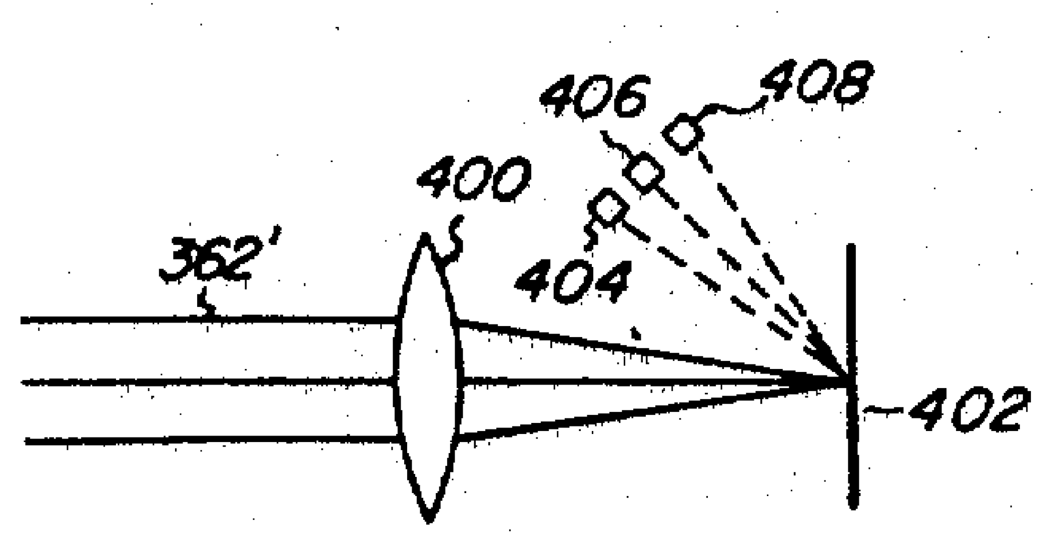
FIG. 6b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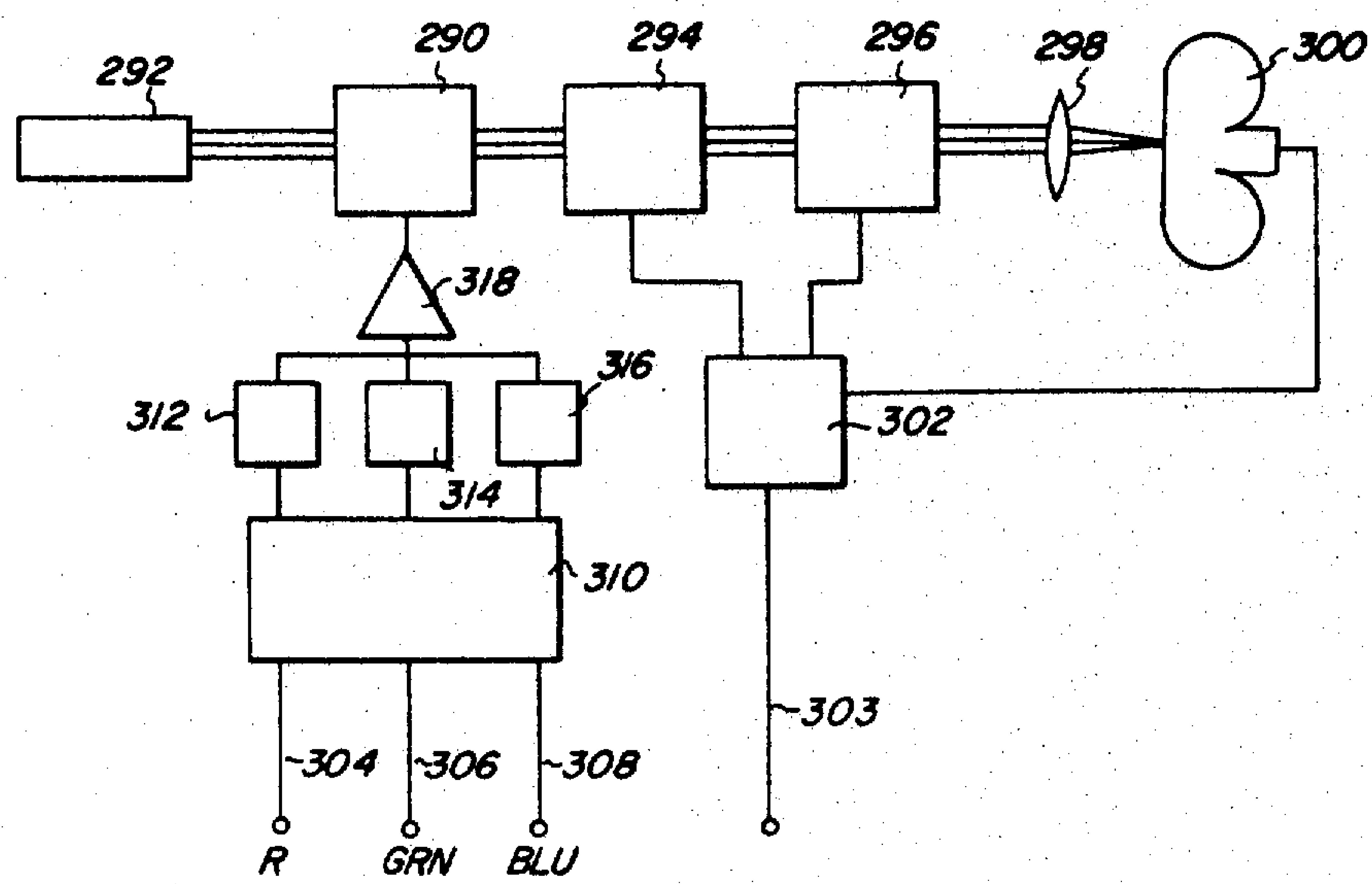
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FIG. 7

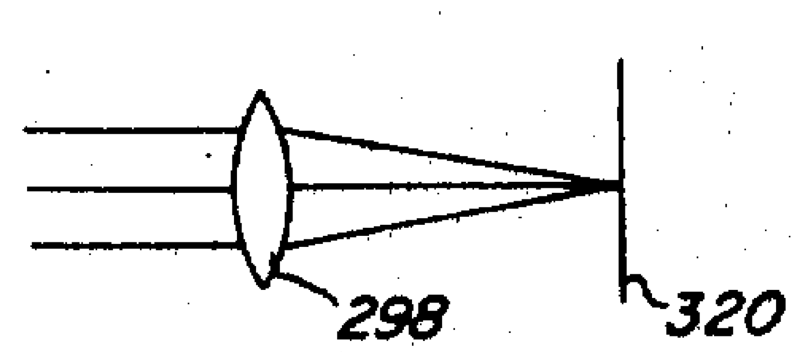
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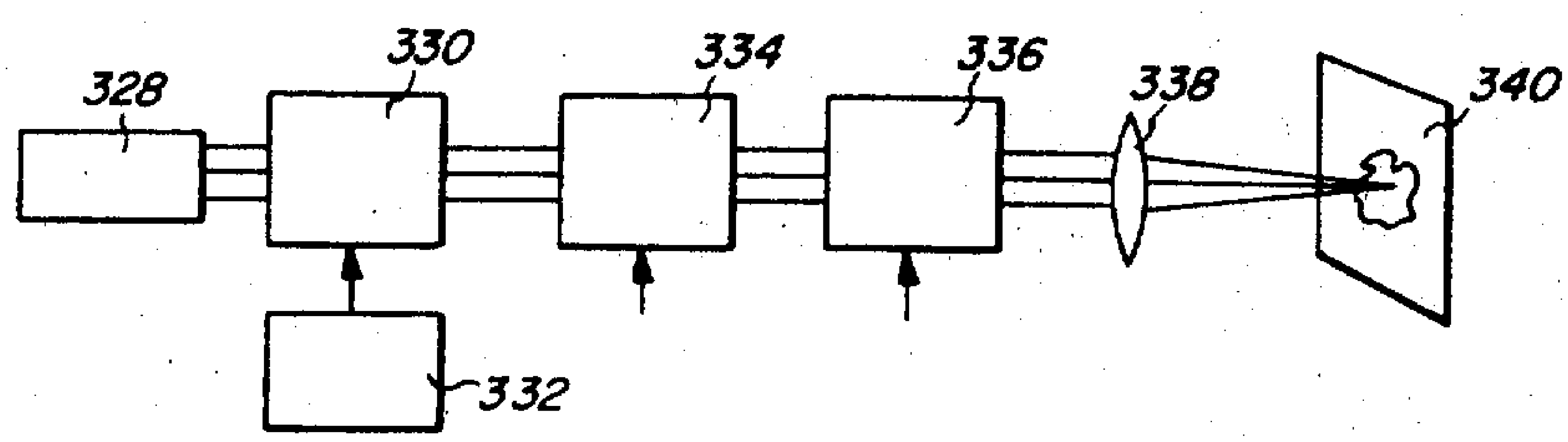
FIG. 7a

FIG. 8



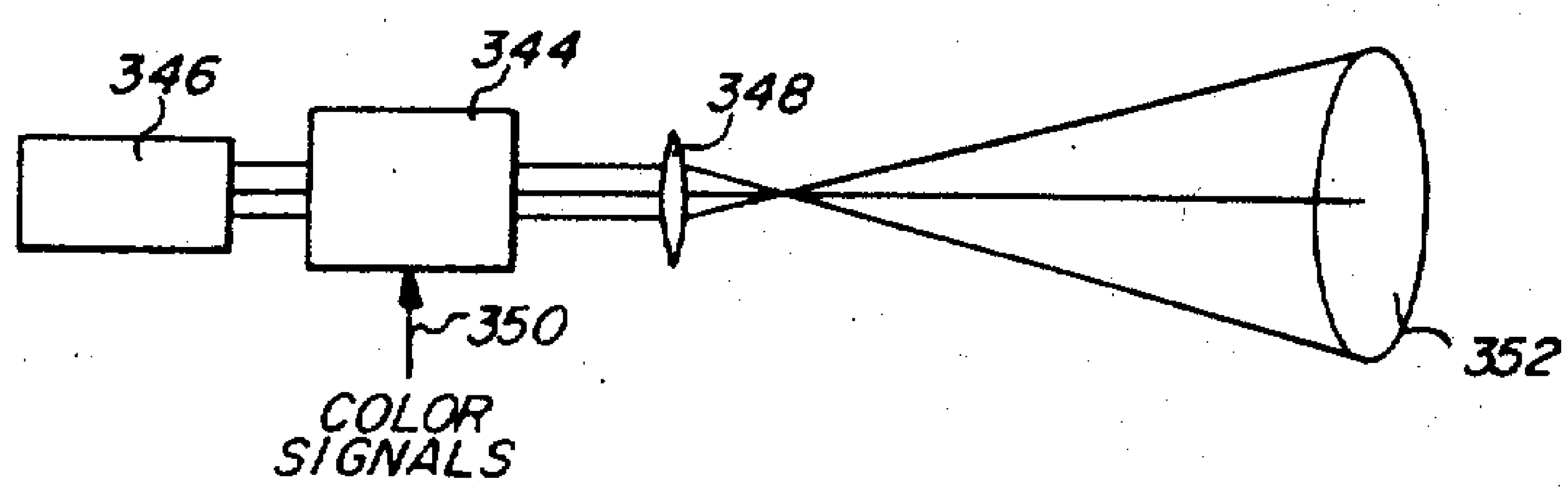


FIG. 9

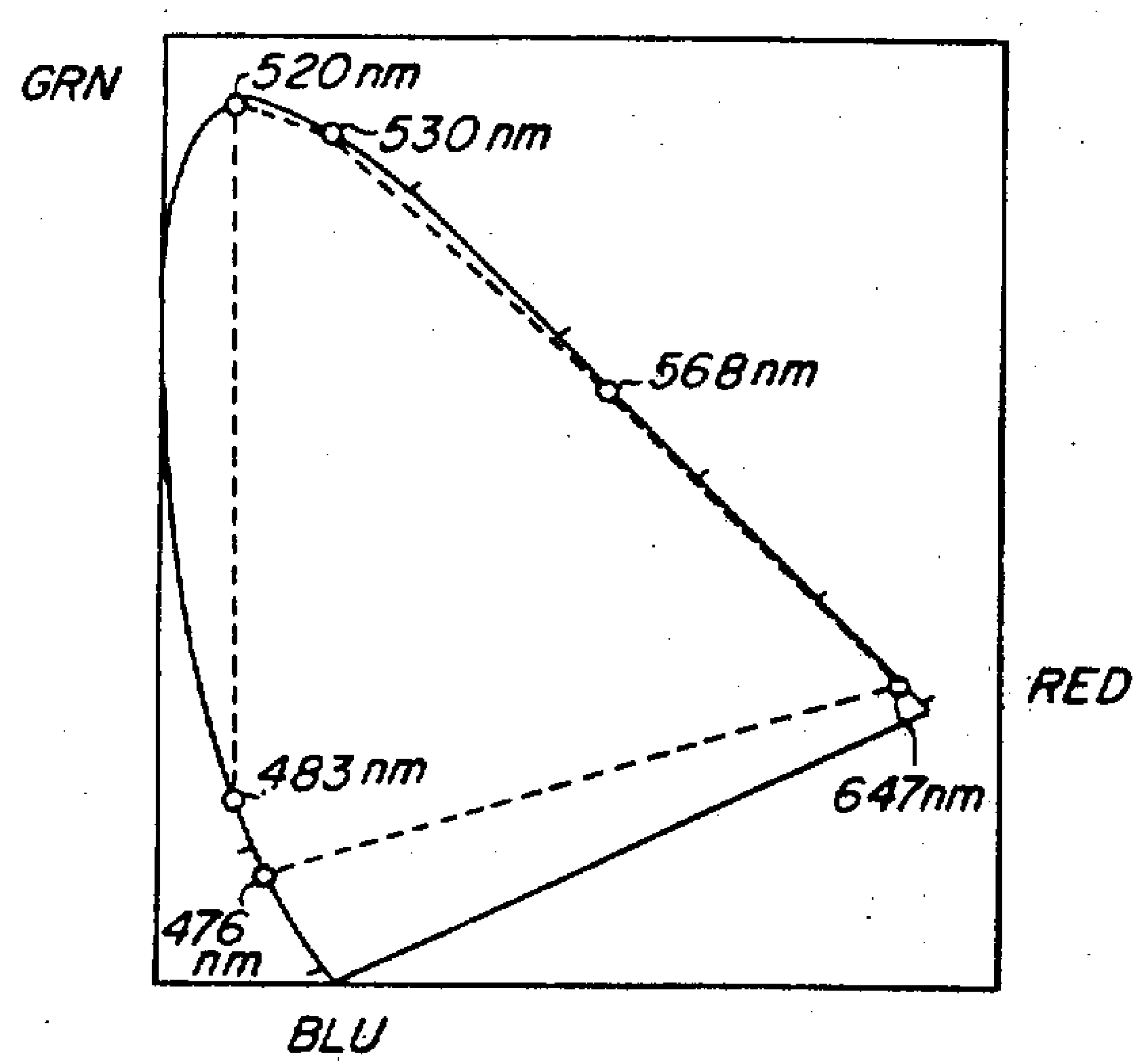


FIG. 10

MULTI-COLOR ACOUSTOOPTIC MODULATOR

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

REFERENCE TO RELATED U.S. PATENT APPLICATIONS

Reference is made to U.S. Pat. Application Ser. No. 132,955 entitled "Acoustooptic Scanner Apparatus and Method" filed Apr. 12, 1971 to Richard A. Spaulding and Royce D. Pickering and to U.S. Pat. Application Ser. No. 192,452 entitled "X-Y Optical Scanning System" to Royce D. Pickering filed Oct. 26, 1971.

FIELD OF THE INVENTION

The invention relates to acoustooptic modulators and more particularly to an acoustooptic moulator for producing an output beam comprising a plurality of collinear independently modulated component beams of selected optical wavelengths.

BACKGROUND OF THE INVENTION

To provide a modulated light beam comprising a plurality of optical wavelengths, prior art devices and methods commonly employ wavelength selective mirrors and filters to separate several selected wavelengths present in light from a source into component beams. The intensities of the component beams of selected wavelengths are separately modulated so as to control the individual intensity of each beam in accordance with, for example, signals representative of color information. The component beams are then recombined with additional optical mirrors or other such apparatus and deflected by well known scanning means or otherwise directed by mechanical optical devices to produce an information recording or display. The recordings and displays formed frequently suffer misregistration of the plurality of component beams due to physical variations in the many optical mirrors and other mechanical elements required.

Prior art devices and methods for projection or printing photographic pictures frequently use negative or positive transparencies which are illuminated so as to project the images contained therein onto photosensitive paper. The photographic materials used should be carefully matched to each other in order to provide proper color balance, contrast and color separation in the pictures printed. Sometimes the paper is exposed from the face of a cathode ray tube. The low intensity light output from the phosphors in these tubes means relatively long exposure times are needed which results in a relatively slow printing process in comparison with the printing process of the instant invention.

In accordance with the present invention, there is provided an apparatus and method of acoustooptically producing a composite output beam comprising a plurality of diffracted collinear and component beams of selected wavelengths which are each independently intensity modulated. Light containing several wavelengths is brought to operably impinge upon an acoustooptic cell. Electrical signals of different fixed frequencies are generated which correspond in number to the plurality of wavelengths selected for the output beam.

The amplitudes of these electrical signals are independently modulated in accordance with a source of color information such as a color transparency. The electrical signals are combined to form a composite signal which is applied to an electrical-to-acoustical transducer operatively attached to the cell such that acoustic waves are generated within the cell which correspond to the individual fixed frequencies present in the composite electrical signal. The acoustic waves in the cell cause the light impinging thereon to be diffracted in a plurality of spectrums containing the wavelengths present in the impinging light, the spectrums corresponding in number to the fixed frequency signals applied to the transducer. The frequencies of the electrical signals are chosen so as to produce a composite output beam comprising collinear diffracted component beams of selected wavelengths. The intensities of every component beam is modulated in accordance with the amplitude of the electrical signal responsible for that beam. Thus, there is produced a composite output beam comprising a plurality of intensity modulated component beams of selected wavelengths. The modulated output beam is scanned to record or display information. The impinging light can comprise a multiwavelength beam; two different wavelengths can be collinear and the third noncollinear to the two; or the light can comprise beams of different wavelengths all impinging at different angles on the face of the cell. The angles of impingement and electrical frequencies used are mutually dependent as will be explained hereinbelow.

Since in practicing the invention, a plurality of beams with mechanical optical elements are not separated and subsequently recombined, more light passes through the optical system of the invention than in prior art systems. This provides for greater exposure in less time of, for example, photographic material. The system of the invention virtually eliminates misregistration of the individual component output beams which is a problem in prior art systems due to variations in optical mirrors and other mechanical elements.

In accordance with one embodiment of the invention, improvements in image quality of photographic prints are realized by optically scanning photographic storage mediums point by point, electronically processing the color information contained therein, and then recording the result point by point onto photographic paper. This scanning process provides for image enhancement by electric correction of the color information which results in better and more consistent color prints, eliminating the need for as perfect as possible matching of photographic spectra sensitivity in order to produce high quality prints.

Too, in accordance with the invention, a laser light source comprising a single multiple-wavelength laser, a combination of single-wavelength and multiple-wavelength lasers or a plurality of single-wavelength lasers is utilized rather than the cathode ray tube of many prior art photographic printing scanning systems. This enables shorter exposure times because of the greater light intensity available from lasers. Therefore, the embodiment of the invention for printing pictures provides faster printing rates than had previously been possible.

One object of the present invention is to provide an apparatus and method for separately and independently modulating a plurality of wavelengths in light beams impinging upon an acoustooptic cell so as to produce an output beam comprising collinear diffracted beams of wavelengths selected from those present in the input beams.

Another object of the present invention is to provide an improved apparatus and method for color display and recording such as television and photographic color picture printing.

Yet another object of the present invention is to provide an improved television-to-film recording apparatus and method.

Still another object of the present invention is to provide an apparatus and method for photographic color printing wherein the color balance of the resultant print is manually or automatically controlled.

Yet another object of the present invention is to provide an apparatus and method for color picture recording and printing wherein color masking and contrast corrections are made while printing onto photographic paper from either positive or negative transparencies or reflection prints.

One advantage of the apparatus and method of the invention is that registration difficulties inherent in prior art devices are overcome.

Yet another advantage of the instant invention is that the apparatus and method thereof provide for higher speed color photographic printing with improved color balance control.

Still another advantage of the present invention is that the apparatus utilized in accordance therewith is less expensive than that of prior art devices.

Still other objects and advantages of the present invention will become readily apparent to those skilled in the art from the following description with reference to the drawings in which like characters denote like parts and wherein:

FIG. 1 schematically shows in accordance with one embodiment of the invention, a multi-wavelength laser beam impinging upon an acoustooptic cell;

FIG. 2 schematically shows an alternative for the embodiment of FIG. 1 wherein a plurality of laser beams of different wavelengths impinge upon the acoustic cell at different angles from one another;

FIG. 3 shows yet another alternative embodiment to that of FIGS. 1 and 2 wherein two of the impinging beams are collinear and the other is noncollinear with the two;

FIG. 4 schematically shows in accordance with the invention a laser scanning system for printing onto color sensitive photographic recording material;

FIG. 5 shows a variation of the system of FIG. 4 for printing onto color sensitive photographic recording material;

FIG. 6 shows a schematic representation of a color image recording apparatus in accordance with the invention wherein the same laser source is used to scan the color transparency and the color sensitive photographic recording material;

FIG. 6A shows a two-axis scanner for printing from color transparencies onto color sensitive photographic recording material;

FIG. 6B shows a manner of reading color information from reflection color prints;

FIGS. 7 and 7a show a video-to-film recording and display system respectively in accordance with the present invention;

FIG. 8 shows a scanning display system in accordance with the invention;

FIG.9 shows stationary display system; and

FIG. 10 shows a chromaticity curve for lasers utilized in accordance with preferred embodiments of the invention.

Before referring the FIGS., a background is best established by supporting acoustooptic theory.

The best equations pertaining to acoustooptic devices are summarized as follows:

$$\text{BRAGG ANGLE APPROXIMATION: } \theta = (\lambda f/v) \quad (1)$$

$$\text{TRANSIT TIME: } \tau = d/\nu \quad (2)$$

$$\text{SPOT SIZE, GAUSSIAN BEAM: } \alpha = (1.27\ \lambda/d) \quad (3)$$

In these equations, λ is the wavelength of light, f is the acoustic frequency, ν is the acoustic velocity, and d is the optical beam diameter. The Bragg angle θ is measured between the undiffracted and first order beams. The transit time τ is the time required for one acoustic wavefront to pass through the optical beam. The spot size α defines the full angular diameter of a focused Gaussian beam at the e^{-2} intensity points.

An acoustooptic cell with a single-frequency acoustic wave present behaves as an optical phase grating. An incident optical beam consisting of three different wavelengths (e.g. red, green and blue) will be diffracted into the first order according to equation (1). Since its wavelength is greater, the red beam is diffracted at greater angle than the blue.

At low diffraction efficiencies, the acoustooptic cell behaves as a linear device; i.e. the diffracted light intensity is linearly proportional to the input acoustic power. Thus, the superposition principle applies and multiple-frequency inputs will produce multiple diffracted beams. Applying this characteristic, when three frequencies are impressed on the acoustooptic cell, three independent arrays of red, green and blue beams are diffracted.

The three frequencies are selected such that one red, one green and one blue beam from each group are collinear. The amplitude of each frequency component thus controls the intensity of the respective wavelength in the collinear beam. This results in an effective and simple method for simultaneously intensity modulating three collinear optical beams to provide an output comprising three independently modulated collinear beams.

For the case of many wavelengths in the incident optical beam, we can rewrite equation (1) as follows:

$$\theta_{ij} = (\lambda_i\, f_j/\nu)\ i = 1,2,3\ldots m\ j = 1,2,3\ldots n \quad (4)$$

Here, each subscript i refers to a beam of a particular wavelength, and each subscript j refers to the frequency of t, the sinusoid that diffracts a desired wavelength. This equation represents an array of (m $\times$ n) diffracted beams, of which n are desired.

In the simplest case where m and n are 3, as in a three-color system, nine diffracted beams are produced. To obtain the desired condition of three collinear beams,

$$\theta_{11} = \theta_{22} = \theta_{33}, \quad (5)$$

and thus $f_1\lambda_1 = f_2\lambda_2 = f_3\mu_3$.

In practice, the middle frequency f_2 is selected first. Then, the other frequencies and angles are determined:

$$f_j = (\lambda_2\, f_2/\lambda_j) \quad (6)$$

$$\theta_{ij} = (\lambda_i/\nu\lambda_j)\,\lambda_2\, f_2 = (\lambda_i/\lambda_j)\,\theta_{22} \tag{7}$$

These relations give θ_{ij} and f_j in terms of f_2 and λ_j for a three color system.

Assuming that $f_1 < f_2 < f_3$; equivalently, the subscripts 1, 2 and 3 correspond to red, green and blue, respectively. The required acoustooptic cell bandwidth is

$$\Delta f = |\, f_3 - f_1 \,| \tag{8}$$

Since

$$f_3 = (\lambda_2\, f_2/\lambda_3) \text{ and } f_1 = (\lambda_2\, f_2/\lambda_1),$$

$$\Delta f = \lambda_2\, f_2\, |(1/\lambda_3) - (1/\lambda_1)|. \tag{9}$$

A blocking aperture is provided to eliminate unwanted diffracted and undiffracted beams. The aperture opening is positioned to pass only beams at the desired angle θ_{22}. Furthermore, a lens is used to form diffraction-limited spots at this aperture. Since adjacent spots should not overlap the aperture, there exists a minimum optical beam diameter d which will satisfy this requirement. Consider the angular differences between θ_{22} and angles immediately adjacent:

$$\delta\,\theta = |\,\theta_{22} - \theta_{22\pm 1}\,| = \lambda_2/\nu\, |\, f_2 - f_{2\pm 1}\,|. \tag{10}$$

There are two possible values for $\delta\,\theta$; the smallest value is selected and equated to the angular spot size given by equation (3). In calculating (3) for this case, the largest (red) wavelength should be used. Then, the minimum optical beam diameter is

$$d = (1.27\lambda_1/\delta\,\theta) \tag{11}$$

Note that if there are more than three wavelengths present, there will be more than two possible values for $\delta\,\theta$.

Since d has been determined, the transit time given in equation (2) has also been determined. This time is related to the modulation bandwidth possible with an acoustooptic device. It has been shown that the modulation transfer characteristic of an acoustooptic device is

$$\exp\,[-(f/f_e)^2], \tag{12}$$

where $f_e = (2\sqrt{2\nu}/\pi d) = 0.9/\tau$.
When $f = f_e$, the response is down to 36.8 percent from a maximum of 100 percent. When $f = 0.83\, f_e \approx 0.75/\tau$, the response is down to 50 percent of maximum. Denoting this 50 percent bandwidth as δ f, the maximum optical beam diameter is, from (2),

$$d = (0.75\nu/\delta\, f) \tag{13}$$

Thus, it can be seen that:

a. The modulation bandwidth required establishes the maximum optical beam diameter.
b. This diameter in turn determines the critical angular beam separation $\delta\,\theta$.
c. From $\delta\,\theta$, equations (10) and (4) determine the operating frequencies, given the acoustic velocity and optical wavelengths.
d. The required acoustooptic cell bandwidth is determined by (9).

Calculation Example

A sample calculation of operating conditions is as follows for a krypton ion laser light source with the following average wavelengths:

λ_1 = 647 nm (red)
λ_2 = 568 nm (yellow)
λ_3 = 525 nm (green)
λ_4 = 480 nm (blue)

The green and blue wavelengths shown are the average of several closely-spaced lines. The laser is used with a glass acoustooptic cell with a sound velocity of 4×10^5 cm sec^{-1} and a center frequency of 40 MHz such as the Zenith M-4OR. Since there are four wavelengths, equation (4) now becomes

$$\theta_{ij} = (\lambda_i\, f_j/\nu),\ i = 1,2,3,4.\ j = 1,2,3.$$

The angle θ_{32} is selected as the center beam, with which θ_{11} and θ_{43} must be mae coincident. θ_{32} is calculate as

$$\theta_{32} = [(5.25\times 10^{-5}\text{cm})\,(4\times 10^{7}\text{Hz})/(4\times 10^{5}\text{ cm sec}^{-1}] = 5.25 \text{ mr}.$$

The remaining angles are calculated in a manner analogous to equation (7). The results are as follows:

$\lambda_i\,\theta_{ij}$	θ_{i1}	θ_{i2}	θ_{i3}
λ_1	5.25 mr	6.47	7.07
λ_2	4.61	5.68	6.21
λ_3	4.26	5.25	5.74
λ_4	3.90	4.80	5.25

The circled values are the desired collinear output beams.

The acoustooptic cell bandwidth is calculated from equation (8) or (9) as 11.3 MHz. The three input frequencies are 32.5, 40.0 and 43.8 MHz.

From an equation analogous to (10), four possible values for $\delta\,\theta$:

$|\,\theta_{11} - \theta_{21}\,| = 0.64$ mr
$|\,\theta_{32} - \theta_{22}\,| = 0.43$
$|\,\theta_{32} - \theta_{42}\,| = 0.45$
$|\,\theta_{43} - \theta_{33}\,| = 0.49$

Of these, the smallest value is 0.43 mr.

The optical beam diameter from (11) is calculated as 1.9 mm. The transit time is calculated from (2) as 0.48 μ seconds. The modulation bandwidth to the 50 percent points is thus 1.5 MHz.

Reference is now made to FIG. **1**. Shown therein is an acoustooptic cell **20** which is a device well known to those skilled in the art. Cell **20** can comprise, for example, plastic, glass, or water where acoustic frequencies up to about 50 MHz are utilized. Lead molybdate ($PbMoO_4$) and quartz are typical materials for higher acoustic frequencies such as those within the range of 1,000 MHz. The moulation bandwidth of acoustooptic cells when utilized as color modulators is approximately proportional to the acoustic frequency. For example, with a krypton ion laser as a source, a glass acoustooptic cell operating at acoustic frequencies near 50MHz typically has a modulation bandwidth of approximately 1 MHz. A lead molybdate cell operating at about 500 MHz generally has a bandwidth of about 10 MHz. The cell **20** can comprise other substances, the acoustic properties of which are well known to those skilled in the art. Several substances are commercially available.

Incident on surface **22** of cell **20** is a multicolor laser beam **24** comprising three wavelengths. Other wavelengths can be present and other numbers of wavelengths can be selected for use in accordance with the invention. Throughout the specifications, the wavelengths or colors selected for purposes of illustration will be designated red, green and blue. It will be appreciated that other colors or wavelengths can be used in practicing the invention and the invention is not limited to the use of these illustrative wavelengths or colors or even to the use of three wavelengths or colors. Attached to cell **20** is transducer **26** which converts electrical signals produced by generators **28, 30** and **32** as passed by summing amplifier **33** into acoustic waves represented by lines **34** in cell **20**. Signal generators **28, 30** and **32** are independently modulated and controlled, either automatically or manually. Passing from cell **20** is beam **24'** which is the undiffracted portion of incident beam **24**. Diffracted by cell **20** are beams **36, 38, 40** and **42** which are representative of the diffracted beams. It will be appreciated that not all the diffracted beams are shown for purposes of clarity but that every frequency component diffracts every one of the wavelengths present in the impinging beam at a different angle. Thus, the number of diffracted beams equals the number of frequencies applied times the number of wavelengths present in the incident beam. A focusing means represented by lens **44** is also shown. A mask **46** having an aperture blocks the images formed by lens **44** which do not pass through the aperture. Such images are those from beams **38, 40** and **42** shown as spots **48, 50** and **52**, respectively. Passing through the aperture of mask **46** is composite output beam **36** which comprises collinear diffracted component beams of selected wavelengths.

Turning now to FIG. **2**, shown therein is an acoustooptic cell **60** having an acoustic transducer **62** attached thereon. Three independently controlled variable amplitude signal generators **64, 66** and **68** provide electrical signals which are summed by summing amplifier **69** and applied to transducer **62** which produces a composite acoustic wave **63** in response thereto. Incident on side **70** of cell **60** are three laser beams **72, 74** and **76** impinging upon cell **60** at three different angles. Beams **72, 74** and **76** contain, for example, red, green and blue wavelengths of light, respectively. Transmitted through cell **60** are undiffracted beams **72', 74'** and **76'**. Diffracted by cell **60** are beams for each of the applied frequencies; **80, 82** and **84** from the blue beam **76; 86, 88** and **90** from green beam **74**; and **92, 94** and **96** from the red beam **72**. Composite output beam **100** comprises beam **80** of the diffracted blue beams, beam **88** of the diffracted green beams and beam **96** of the diffracted red beams. The output angles for the diffracted beams are functions of the frequencies of the signals applied to the acoustooptic cell. These frequencies are chosen to produce the composite beam **100**. It will be appreciated that other combinations of diffracted beams can be selected. The amplitudes of the collinear component beams **96, 88** and **80** are individually controlled by amplitude modulating the outputs of the signal generators **64, 66** and **68**, respectively.

Reference is now made to FIG. **3** wherein is shown an acoustooptic cell **102** which is controlled with transducer **104** and three independently amplitude modulated fixed frequency signal generators **106, 108**, and **110** outputting through summing amplifier **103**. Incident on surface **112** of cell **102** are red laser beam **114** and a combination blue and green laser beam **116**. It will be understood that other combinations of light wavelengths in the collinear beam can be utilized in accordance with the invention. Passing through cell **102** are the undiffracted portions of the blue-green beam **116'** and the red beam **114'**. Diffracted by cell **102** are blue beams **118, 120**, and **122**; green beams **124, 126**, and **128** and red beams **130, 132**, and **134**. The frequencies of the signals produced by sources **106, 108**, and **110** are such the blue beam **118**, green beam **126**, and red beam **134** are collinear and hence from composite beam **136**. As with reference to FIGS. **1** and **2**, the amplitudes of the signals generated by **106, 108**, and **110** are modulated to control the intensities of the collinear component beams **134, 126** and **118**, respectively, in the composite output beam **136**.

In practicing the invention using the FIGS. **1–3** embodiments, three electrical signals are generated by corresponding signals generating devices. Each signal has a frequency responsible for an acoustic wave produced by the transducer attached to the cell. Separate transducers can also be used for each frequency or two transducers can be used, one handling two frequencies and the second a single frequency. Other combinations and permutations of transducer and applied frequencies will be apparent to those skilled in the art. The signal generated by each generator is amplitude modulated in accordance with the color information associated with that generator to be recorded or displayed in order to balance properly the intensities of the collinear diffracted red, green, and blue component beams. The signals are preferably electrically combined and amplified by a summing amplifier before they are applied to the acoustic transducer which converts them into acoustic waves within the cell. For a given desired angle of diffraction in the embodiment of FIG. **1**, the frequencies of the acoustic waves are selected to be inversely proportional to their corresponding component light wavelengths as specifically pointed out in the theory above appearing. More discussion of the theory in acoustooptic phenomena appears in the above-mentioned U.S. Application Ser. No. 132,955 filed April 12, 1971 to the inventor herein, Richard A. Spaulding and another, Royce D. Pickering.

Theory shows that the angle through which any beam is diffracted in dependent on the frequency of the acoustic wave causing the diffraction and not the amplitude of the acoustic wave. Thus, by modulating the amplitude of the applied electrical signal and thereby the acoustic wave, the intensity of the light diffracted can be controlled without affecting the direction the diffracted beam takes. This is because the angle of diffraction is not affected by amplitude changes in the acoustic wave.

The aperture in mask **46** of FIG. **1** is chosen to be approximately the size of the diffraction limited spot produced by the longest wavelength optical component in the impinging beam **24**. Similar masks are used to block unwanted beams in the embodiments of FIGS. **2** and **3**. Which diffracted beam of any particular wavelength is utilized in forming the composite beam is a matter of frequency selection.

Reference is now made to FIG. **4** wherein, in accordance with the invention, an apparatus and method for printing onto color sensitive photographic paper or other such color sensitive material is shown. Acoustooptic color modulator **140** receives a plurality of wavelengths, e.g., red, green and blue, from a multiwavelength laser source **142**. The laser source **142**-

acoustooptic modulator **140** combination can comprise any one of the embodiments shown in FIGS. **1, 2** and **3**. Horizontal mirror scanner **144** and vertical mirror scanner **146** are controlled by a scan control unit **148**. The scan control unit **148** can be any one of several well known devices, the complexity of which runs from simple mechanical gear drives to complex digital computer controlled systems. The choice for a particular application will depend upon the complexity of the task and upon whether or not color compensation (discussed hereinbelow) is desired in the finished product and other such factors. Lens **150** schematically represents a focusing system which focuses the scanning beam onto the photographic paper **152** for recording an image thereon. Other optical elements such as lenses and mirrors optically coupling elements **140, 142, 144, 146** and **150** are not shown for purposes of clarity, but are well known to those skilled in the art. Scan control **148** also controls a scanning light source **154** which images a beam through an optical system represented schematically by lens **156** through a negative or a positive transparency **15**. The light beam modulated by negative or positive transparency **158** is focused by an optical system represented by lens **160** onto photosensors **162, 163**, and **164** which are each photosensitive to a different one of the selected wavelengths, e.g., red, green, or blue. The red, green, and blue wavelengths present in the light falling onto photosensors **162, 163**, and **164** active these photosensors to produce electrical signals representative of the red, green, and blue information in the transparency **158**. Electrical signals produced by the photosensors are carried by lines **166, 168**, and **170** to a color signal processor **172** which is synchronized with the scanning of the negative or positive transparency and the acoustooptic modulator **140** by scan control unit **148**. Color signal processor **172** controls the amplitudes of the output of signal generators or oscillators **174, 176**, and **178**. The amplitudes of the signals generated by oscillators **174, 176**, and **178** are therefore varied by color signal processor **172** in accordance with the relative intensities of the color components of the point being scanned on transparency **158** at any one point in time. The processor output is adapted to whether a negative or positive transparency **158** is being used. The outputs of oscillators **174, 176**, and **178** are fed to a summing amplifier **180** which applies the signals amplified thereby to the transducer(s) mounted on the acoustooptic cell of acoustooptic modulator **140**.

In operation, scan control unit **148** is activated so as to control the scan of the light source **154**, mirrors **144** and **146**, and color signal processor **172** by a control information input. Scanning light source **154** which is preferably a laser source, can be a separate source of light or can utilize part of the light from source **142** as will be discussed hereinbelow with reference to FIG. **6**. In any event, light from source **154** scans negative or positive transparency **158**. Transparency **158** modulates the selected wavelengths in the beam in accordance with the colors within the spot being scanned on the transparency. Photosensors **162, 163** and **164** pick up the amount of any color component in the spot being scanned in transparency **158** and transmit electrical signals representative thereof through lines **166, 168** and **170** to color signal processor **172**. Color signal processor **172** is adapted for use with negative or positive transparencies and controls the amplitudes of the signals generated by the oscillators **174, 176** and **178** in accordance with the transmittance for each color component in the spot being scanned in the transparency at that point in time. The oscillators **174, 176** and **178** as amplitude modulated by processor **172** output through summing amplifier **180** to acoustooptic modulator **140** to control the intensities of the red, green and blue diffracted collinear component beams produced by the acoustooptic modulator. The composite output beam comprising the collinear intensity modulated component beams is scanned by horizontal mirror scanner **144** and vertical mirror scanner **146** and imaged by lens **150** onto photographic paper **152** to record an image representative of the image in the positive transparency **158**, or of the positive of the negative transparency image if a negative transparency is utilized. The scanning source **154** can be a cathode ray tube, i.e., a flying spot scanner, as well as the preferred laser source. Transparency **158** can also be scanned utilizing the same mirrors which effect the horizontal and vertical scan of the photographic paper **152**, i.e., **144** and **146**, as seen with reference to FIG. **6**.

Turning now to FIG. **5**, shown therein is another embodiment of a laser printing apparatus and method, this one using roll photographic recording paper. Acoustooptic modulator **190** processes the beam from a multi-wavelength laser source **192** which preferably comprises any of the embodiments of FIGS. **1, 2** or **3**. Horizontal scanning mirror **194** scans the diffracted composite output beam of modulator **190** through an optical system schematically represented by lens **196** onto constant-speed roller driven photographic paper **198**. Supply reel **200** and take-up reel **202** in combination with constant speed drive roller **204** provide a constant speed past the scanning beam for the continuous belt of photograhic paper **198**. Drive and scan control unit **206** controls horizontal scanning mirror **194** and constant speed drive roller **204**. An optical scanner **208** through an optical system schematically represented by lens **210** scans positive or negative transparencies in roll form **211** mounted on supply reel **212** and take-up reel **214**. Drive and scanning control **206** controls the drive and take-up reels **212** and **214** so as to synchronize the movement of the transparencies on roll **211** with the movement of the photographic paper **198**. An output optical system schematically represented by lens **216** focuses the light from the transparencies as scanned onto red, green, and blue photosensors **217, 218** and **219**. Electrical signals produced by red, green and blue photosensors **217, 218** and **219** are fed to color signal processor **220** wherein they are used to control signal generators **222, 224** and **226**. As passed through summing amplifier **228**, the signal provided by generators **222, 224** and **226** are fed to acoustooptic modulator **190** which intensity modulates the selected wavelengths in the composite beam transmitted therefrom. This is accomplished by drive and scan control **206** synchronizing the color signal processor **220** to amplitude modulate fixed-frequency oscillators **222, 224** and **226** with the scans of the transparencies on roll **211** and photographic paper **198**.

It will be appreciated that the operation of the printing system of FIG. **5** is similar to that of FIG. **4** except that the FIG. **5** embodiment uses no vertical mirror scanner. The paper motion provides a constant presentation of fresh photographic paper synchronized with the movement of the transparencies in roll form.

Reference is now made to FIG. **6**. Shown therein is an apparatus and method for utilizing the same scanning mirror for reading the transparency and printing on the photographic paper. Acoustooptic modulator **240** receives input light from a multi-wavelength laser beam generated by laser source **242**. The laser-modulator combination preferably comprises one of the embodiments shown in FIGS. **1**, **2** and **3**. Between laser source **242** and modulator **240** is disposed a beam splitter, **244**, which splits the beam from source **242** into two multi-wavelength components. One of the multi-wavelengths component beams, **256**, passes through the beam splitter **244** and goes through acoustooptic modulator **240**. Modulated beam **256** then passes through an optical focusing arrangement represented schematically by lens **246** to a rotating two-sided scanning mirror **248**. Bean **256** is reflected from mirror **248**, being given scanning motion thereby, onto mirror **258** and then onto a mirror **260**. It then passes through lens **262** to arrive at photographic paper **264**. The other portion of the beam from laser source **242**, designated **266**, is reflected from mirror **250** onto mirror **252** and then through an optical system represented by lens **254** onto rotating mirror **248**. Beam **266** is reflected and given scanning motion by rotating mirror **248** which reflects the beam onto mirror **268**, from where it is reflected onto mirror **270**. From mirror **270**, the beam is passed through an optical system schematically represented by lens **272** and then through transparency **274** where the beam is modulated by the image contained therein. Light beam **266**, now modulated by transparency **274** impinges upon photosensors **276**, **277** and **278** which are reponsive to the red, green and blue component portions thereof, respectively. Electrical signals produced by photosensors **276**, **277** and **278** are representative of the intensities of the component colors of light impinging thereon and are sent to a color signal processor such as **220** shown in FIG. **5**.

In the arrangement shown by FIG. **6**, light from the same source **242** is used to scan both the transparency **274** and the photographic paper **264**. Synchronization is inherent in such a system since mirror **248** supplies the rate of scan for both the image scanned from the transparency and the image recorded on the paper. Prisms or other light deflecting elements can be substituted for any or all mirrors **250**, **252**, **260** and **270** to more efficiently utilize the light available. This system provides 1-dimensionsal scanning motion, while paper motion provides the other scan dimension as in the embodiment shown in FIG. **5**.

Alternatively, the transparency can be replaced by a color reflection print, and the red, green and blue signals sensed by reflection instead of transmission.

FIG. **6a** shows a 2-axis mirror sensor using the same mirror for horizontal and vertical scanning of transparency and paper.

The multi-wavelength light source **354**-acoustooptic modulator **356** combination can once again be any of the embodiments shown in FIGS. **1–3**. Disposed between source **354** and modulator **356** is beam splitter **358** which divides the beam from source **354** into two portions. One portion, **360**, is optically processed by modulator **356** whereas portion **362** is not. Beam portion **360** is used to record onto photographic paper **366** and beam portion **362** is used to read the image within transparency **364**. Mirror **368** reflects beam **360** onto two-sided mirror **370** which rotates in a first direction shown herein to be about an axis in the plane of the paper. The mirror **370** gives the beam **360** a first of "X" direction of scanning motion and reflects it onto mirror **372** which reflects it onto two-sided mirror **374** rotating in a "Y" direction about an axis substantially perpendicular or otherwise disposed in relation to the axis of rotation of mirror **370** and shown herein as an axis perpendicular to the plane of the paper. Bean **360**, now having "X" and "Y" scanning motion is reflected from mirrors **376** and **378** and passed through an optical focusing device schematically represented by lens **380** which focuses beam **360** onto photographic paper **366** to record the image from transparency **364** thereon. At the same time, beam **362** is reflected from mirrors **382** and **384** onto rotating mirror **370**, mirror **386** and rotating mirror **374** to give it an "X-Y" scanning motion inherently synchronized with the scan of beam **360**. Beam **362** is additionally routed by mirrors **388** and **390** through a focusing device schematically represented by lens **392**. Lens **392** focuses beam **362** onto transparency **364**, the beam passing therethrough and modulated thereby impinging on photosensors **394**, **396** and **398** which are each sensitive to a different component color. Photosensors **394**, **396** and **398** produce electrical signals representative of the color information in the transparency. The signals are processed in a fashion similar to that shown in FIG. **4** to reproduce the image of transparency **364** on paper **366**.

Reflectance prints can also be used when the embodiments of the invention shown in FIGS. **4–6** are adapted thereto. Such an adaption is illustrated in FIG. **6b** wherein a beam such as **362'** corresponding to beam **362** of FIG. **6a** is passed through lens **400** onto reflectance print **402** which reflects light modulated according to the color information thereon. Some of the reflected light is received by photosensors **404**, **406**, **408** which produce electrical signals in accordance therewith to be processed as disclosed with reference to FIGS. **4–6a**.

Turning now to FIG. **7**, a video-to-film recorder in accordance with the invention is shown. The acoustooptic modulator **290**-multi-wavelength laser source **292** combination preferably comprises any one of the embodiments shown in FIGS. **1**, **2**, and **3**. The composite intensity modulated output beam of modulator **290** is passed through horizontal mirror scanner **294** and vertical mirror scanner **296**. The scanned beam is transmitted by an optical system represented by lens **298** onto the input of a television-film recording camera **300**. Such cameras are well known to those skilled in the art and no detailed disclosure thereof is made herein. It is well known that frame rate conversion from television which has a rate of 30 frames per second to conventional motion pictures which have frame rates of 24 frames per second is accomplished with such standard television film recording cameras. Scan control **302** synchronizes horizontal mirror scanner **294**, vertical mirror scanner **296** and camera **300** from a picture synchronization signal input **303**. Decoded color video signals from magnetic or video tape, broadcast television, closed circuit television, or other such source are passed through red, green and blue signal input lines **304**, **306**, and **308** to color signal processor **310** which controls the acoustooptic modulator **290**. The conversion takes place in processor **310** in a manner similar to those of the aforementioned embodiments of FIGS. **4** and **5** with the color signal processor **310** controlling the intensities of the selected wavelength component beams in the composite beam produced by modulator **290**. This is accomplished by modulating the amplitudes of the outputs of fixed frequency oscillators **312**, **314**, and **316** which are passed by summing amplifier **318** to the transducer (not shown) of the acoustooptic modulator **20**. The decoded red, green, and blue video information coming in on lines **304**, **306**, and **308** is preferably adjusted by processor **310** to compensate for film characteristics, color balance, and color masking. Typically in this embodiment, the acoustooptic modulator **290** comprises lead molybdate as the interaction medium in combination with a 500 MHz. thin-film transducer which yields a video modulation bandwidth of about 10 MHz. Horizontal scanner **294** is preferably a high speed rotating mirror synchronized to the horizontal synchronization signal in the video waveform although other scanning means can be employed as scanner **294**. Vertical mirror scanner **296** is preferably a galvanometer driven mirror synchronzied to the vertical synchronization signal. In this manner, selected forms of the television picture are recorded frame by frame on the motion picture film in camera **300**.

The television recording system described with reference to FIG. **7** can be also used as a television projection display by substituting a projection screen **320** as seen in FIG. 7a for camera **300**, screen **320** receiving light from lens **298**. The high light intensities available from lasers make possible a projection display of high brightness. The color purity from laser light enables highly saturated colors to be reproduced which result in improved visual color balance and contrast of the projected image. Speckle effects which are caused by the inherent coherence of laser light can be eliminated by moving or vibrating the projection screen **320**.

FIG. **8** shows a display system comprising a laser source **328**-acoustooptic color modulator **330** combination such as that shown in FIGS. **1—3**. The color modulation signals are produced by modulated oscillators and a control device combination collectively represented by block **332**. The output of source **328** impinges upon acoustooptic modulator **330**. The output of the acoustooptic modulator **330** passes through horizontal mirror scanner **334** and vertical mirror scanner **336** into an optical focusing system represented schematically by lens **338** and from there onto a display screen **340** where the display appears. This is a very convenient, simple, and efficient as well as inexpensive way to display color visual information and patterns. The color display can be manually or automatically controlled depending on the control device **322** incorporated into the system to provide a wide range of visual colors projected on the screen **340**.

A stationary display is seen with reference to FIG. **9**. Acoustooptic modulator **344** receives incident light from laser source **346** and transmits the beams diffracted thereby through an optical system schematically represented by lens **348**. The composite output beam from acoustooptic modulator **344** is controlled in color and intensity by the electrical signals applied through line **350**. Such a control is similar to those discussed in regard to other embodiments heretofore disclosed. The stationary display is focused on screen **352**. One application of the dislay of FIG. **9** is a device known as a color stimulus generator in which various color sensations are produced to study human color visual response. The laser sources described herein in FIGS. **1-3** are capable of a much greater range of colors then present instruments using optical filters and white light from nonlaser sources. A vibrating projection screen can be used to reduce the speckle effect.

With reference to FIG. **10**, a C.I.E. standard chromaticity curve is shown having dotted lines enclosing the areas of colors possible with a Krypton-ion laser as the multi color cource. Reference is made to "Principles of

Color Photography", by Evans, Hanson and Brewer, Wylie, 1953, page 62 transducers.

Another application of displays such as those of FIGS. **8** and **9** is in the measuring of the response to photographic materials to various combinations of laser wavelengths. The multi-color acoustooptic modulator offers a simple and reliable means for controlling the relative intensities as well as the durations of exposures due to each of the wavelengths present in the composite beam emerging from the acoustooptic modulator as imaged onto photographic material.

Although the embodiments shown herein were directed to three colors — red, green, and blue; other three-color combinations and, indeed, any number of colors in combination can be utilized in practicing the invention. Too, acoustic waves in the acoustooptic modulators hereinabove described are produced simultaneously by an acoustic transducer in response to three simultaneously applied electric signals from generating sources. Alternatively, three separate acoustic transducers can be used, each having a signal of different frequency applied. The three transducers can be arranged such that their acoustic waves are coincident at the region which interaction with the light beams takes place, or they can sequentially interact with the incident light beam. Too, the acoustic wave can be a standing wave within the interaction material rather than a traveling wave as disclosed with reference to the embodiment shown herein. Combinations of one transducer handling two or more frequencies with other transducers handling one or more frequencies can also be used.

It will be appreciated that the application of signals of several frequencies into the acoustic transducer to obtain independent diffracted component beams utilizes the linear property of the acoustooptic cell. This linearity is strictly valid for low diffraction efficiencies. When higher amounts of diffracted light are utilized, there may be some interaction between the different frequency components. This can result in a variation of optical intensity or power of one diffracted beam when the intensity of another is varied. Since this amount of error is known to be a function of the intensity of the light diffracted, the error can be corrected by the use of nonlinear electronic circuitry within the color signal processors such as those of FIGS. **4**, **5**, **7**, and **8**. Thus, the color signal processors can be adapted to correct for the problem and the acoustooptic cell can be operated at larger diffraction efficiencies to increase the exposure or printing rate for printing on photographic materials or other uses.

Too, the relative diffraction efficiencies vary for the frequencies and wavelengths utilized. In practicing the invention, any desired combination of efficiencies suitable for obtaining sufficient light intensity for each of the components of the composite beam can be utilized. An advantage is realized when one wavelength is diffracted with greater efficiency than the others. For example, greater light intensity of the red beam is possible before nonlinear interactions become apparent. The correction for nonlinear effects can also be implemented by the use of negative feedback techniques, sampling the diffracted light, and correcting the signal produced by the color signal processor to produce an optical intensity which substantially reproduces the input electrical signal.

Many existing scanners can be used to perform in accordance with the schematic representations of FIGS. **4-8**, but a particularly well-suited scanner is that disclosed in U.S. Application entitled, "X-Y Optical Scanning System" having Ser. No. 192,452 to Pickering filed October 26, 1971.

The signal generators are also controlled so as to produce types of information other than color scenes with outputs in color code in analog or digital form.

Two or more noncollinear output beams can be produced in accordance with the invention. For example, for interlace scanning or other use a red output beam and a composite output beam consisting collinear blue and green component beams can be formed. Other combinations and permutations will be apparent to those skilled in the art.

The colors scanned from the color information media can be totally different colors than those used to record the scanned information onto the color sensitive photographic recording medium. Also, one or more of the colors for scanning out can be the same as the recording colors and the remaining color(s) can be different.

Although FIGS. 1–3 show laser light beams representative of one, two and three wavelengths, it will be understood that laser sources usually emit more than one wavelength. In accordance with invention, laser sources are utilized which will, together, produce a composite output beam comprising collinear component beams of selected wavelengths such that significant amounts of overlapping of undesired wavelengths is eliminated. This is done by using lasers strongly emitting at wavelengths which are adequately separated from other strongly emitted wavelengths such that unwanted sufficiently strong wavelengths can be masked.

This invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

I claim:

1. An apparatus **[**including an acoustooptic cell**]** for **[**modulating and**]** diffracting *source* light of different wavelengths **[**impinging on said cell**]** into a composite, collinear output beam of light comprising a selected number of the different wavelengths present in said **[**impinging**]** *source* light, the **[**combination**]** *apparatus* comprising:

- an acoustooptic cell **[**having**]** *locatable in the path of such source light;*
- electrical-to-acoustical transducer means operatively attached **[**thereto**]** *to said cell*;
- **[**means for impinging multi-wavelength light upon said cell;**]**
- means for generating a **[**plurality**]** *number* of electrical signals **[**in accordance with a**]** *corresponding to the* selected number of *wavelengths in the* collinear output **[**beams**]** *beam*, each signal being of a *predetermined* different fixed frequency *selected to cause diffraction of at least a portion of light of each of the selected wavelengths along a common output axis;* and
- means for applying said electrical signals to said transducer means to form acoustic waves in said cell which diffract said *source* light **[**impinging on said cell**]** to form said composite, collinear output beam of light of said selected number of different wavelengths.

2. The invention of claim **1** **[**including means for modulating**]** *wherein:*

- *said selected number of the different wavelengths are fixed wavelengths of $\lambda_1, \lambda_2, \lambda ..., \lambda_n$;*
- said *plurality* of electrical signals *are* of different fixed **[**frequency**]** *frequencies $f_1, f_2, f ..., f_n$ selected such that $f_1\lambda_1 = f_2\lambda_2 = f_n\lambda_n$.*

3. The invention of claim **1** *including means for modulating said electrical signals* wherein said modulating means comprises means for independently controlling the amplitudes of said signals of different fixed frequencies.

4. The invention of claim **1** wherein said **[**impinging means**]** *source light* comprises a multi-wavelength laser light beam.

5. The invention of claim **1** wherein:

- said **[**impinging means**]** *source light* comprises at least two collinear laser light beams of different wavelengths and at least one other laser light beam of another wavelength, *said collinear beams impinging upon said cell at one incident angle and said other beam impinging upon said cell at another incident angle; and*
- *said fixed frequencies are chosen in accordance with said incident angles to form said composite, collinear output beam.*

6. An apparatus for recording a color image corresponding to a color image on a storage medium onto color sensitive photographic recording material, said apparatus comprising:

- means for scanning said medium with multi-wavelength light that is modulated in accordance with the color image on said medium;
- photoelectric means for receiving the modulated light and for generating a number of electrical signals, each of which is representative of a different selected wavelength within the modulated light;
- means responsive to said photoelectric means for modulating said electrical signals;
- an acoustooptic cell having electrical-to-acoustical transducer means operatively attached thereto;
- means for impinging multi-wavelength laser light upon said cell;
- means for applying said modulated signals to said transducer means to produce acoustic waves in said cell which diffract said laser light into at least one composite, collinear output beam of said different selected wavelengths; and
- means for scanning said photographic recording material with said composite, collinear output beam of light to record a color image thereon corresponding to the color image on said medium.

7. The invention of claim **6** further comprising means for synchronizing said photographic recording material scanning means with said medium scanning means.

8. An apparatus for recording a color image corresponding to a color image on a positive transparency onto color sensitive photographic recording material, said apparatus comprising:

- means for scanning said transparency with multi-wavelength light that is modulated in accordance with the color image on said transparency;
- photoelectric means for receiving said modulated light and for generating a number of electrical signals of different fixed frequencies, the signals corresponding in number to a selected number of different wavelengths of modulated light;
- means responsive to said photoelectric means for modulating said electrical signals;

an acoustooptic cell having electrical-to-acoustical transducer means operatively attached thereto;

means for impinging multi-wavelength laser light upon said cell;

means for applying said modulated electrical signals to said transducer means to produce acoustic waves in said cell which diffract said laser light to form at least one composite, collinear output beam of said different selected wavelengths; and

means for scanning said photographic recording material with said composite, collinear output beam to record a color image thereon corresponding to the color image on said transparency.

9. The invention of claim 8 further comprising means for synchronizing said photographic recording material scanning means with said transparency scanning means.

10. An apparatus for recording a color image corresponding to the positive of a negative image on a color transparency onto color sensitive photographic material, said apparatus comprising:

means for scanning said negative transparency with a multi-wavelength beam of light to modulate the wavelengths thereof in accordance with the image on said negative transparency;

photoelectric means for receiving said modulated beam of light for generating electrical signals of different fixed frequencies in accordance with a number of different selected wavelengths in the modulated beam;

means responsive to said photoelectric means for amplitude modulating said electrical signals;

an acoustooptic cell having electrical-to-acoustical transducer means attached thereto;

means for impinging multi-wavelength laser light upon said cell;

means for applying said modulated electrical signals to said transducer means to produce acoustic waves in said cell which diffract said laser light to form at least one composite, collinear output beam of said different selected wavelengths; and

means for scanning said photographic recording material with said composite, collinear output beam to record a color image thereon corresponding to the positive of the negative image on the transparency.

11. An apparatus for recording a color image corresponding to a color image on an opaque support onto color sensitive photographic recording material, said apparatus comprising:

means for scanning the color image on said support with a multi-wavelength beam of light the light of different wavelengths being reflected by and modulated in accordance with the color image;

photoelectric means for receiving the modulated wavelengths of light for generating electrical signals of different fixed frequencies in accordance with a number of different selected wavelengths present in the reflected light;

means responsive to said photoelectric means for modulating said electrical signals;

an acoustooptic cell having electrical-to-acoustical transducer means operatively attached thereto;

means for impinging multi-color laser light upon said cell;

means for applying said modulated electrical signals to said transducer means to produce acoustic waves in said cell which diffract said laser light to form at least one composite, collinear beam of said different selected wavelengths; and

means for scanning said photographic recording material with said composite, collinear output beam to record a color image thereon corresponding to the color image on said support.

12. An apparatus for recording an image on a color sensitive photographic recording material from color information in a storage medium, said apparatus comprising:

means for directing a multi-wavelength beam of light onto said storage medium to produce a first X-Y scanning beam;

means for receiving the wavelengths of light as modulated by the color information and for converting a number of different selected modulated wavelengths of said light into electrical signals, each of which is modulated by a signal of different fixed frequency;

means responsive to said multi-wavelength beam of light and to said electrical signals for producing a second X-Y scanning beam comprising a group of different selected wavelengths of light corresponding in number to the number of different selected wavelengths;

means for synchronizing the second X-Y scanning beam with the first X-Y scanning beam; and

means for exposing said photographic recording material with said second X-Y scanning beam to record an image thereon representative of the color information derived from said storage medium.

13. The invention of claim 12 wherein said producing means for said second X-Y scanning beam comprises:

an acoustooptic cell having electrical-to-acoustical transducer means operably attached thereto;

means for impinging a multi-wavelength beam of laser light upon said cell; and

means comprising a summing amplifier responsive to said modulated electrical signals and interconnected to said transducer means for producing acoustic waves within the cell which diffract the light beams impinging upon the cell to form a composite, collinear output beam comprising wavelengths of light corresponding to said group of different selected wavelengths.

14. The invention of claim 12 wherein said first and second scanning beams are derived from a common laser source and are coupled to a common synchronizing means.

15. An apparatus for recording a color image corresponding to color information on a color storage medium onto color sensitive photographic recording material, said apparatus comprising:

means for scanning said storage medium with a multi-wavelength beam of light in a single dimension of scan;

means for moving said storage medium in a direction substantially perpendicular to said dimension of scan to produce an effective X-Y scan of the medium;

means responsive to a number of different selected wavelengths of the scanning beam as modulated by said medium for generating a corresponding number of electrical signals, each of said signals being modulated by a signal of different fixed frequency;

an acoustooptic cell having electrical-to-acoustical transducer means operably attached thereto;

means for impinging a plurality of laser produced light beams of different wavelengths upon said cell;

means responsive to said modulated electrical signals and interconnected to said transducer means for diffracting said multi-wavelength beam of light to produce a composite, collinear output beam of light comprising said different selected wavelengths;

means for moving said collinear output beam in scanning synchronism with the medium scanning means; and

means for exposing said photographic recording material with said collinear output beam to record color images thereon corresponding to the color information on said storage medium.

16. The invention of claim **15** wherein said collinear output beam has a scanning direction corresponding to and synchronized with the scanning direction of said medium scanning beam and the photographic recording material is moved in a direction corresponding to and synchronized with that of said medium.

17. The invention of claim **16** wherein said collinear output beam and medium scanning beams are derived from the same laser source and are responsive to a common synchronizing means.

18. The invention of claim **15** wherein said diffracting means includes:

means for summing the plurality of modulated electrical signals of different fixed frequencies to produce said composite, collinear output beam; and

means for varying the amplitudes of said electrical signals of fixed frequencies to control the intensity of said composite, collinear output beam.

19. An apparatus for recording color images corresponding to color information carrying video signals onto motion picture film, said apparatus comprising:

laser source means for producing multi-wavelength light;

means for converting video signals carrying color information to electrical signals of different fixed frequencies which are modulated in accordance with the color information carried by said video signals;

means responsive to said electrical signals for diffracting light from said source means into a composite, collinear output beam comprising a number of different selected wavelengths present in said light;

means for moving said collinear output beam so as to produce an X-Y scanning motion of said beam;

means for synchronizing said X-Y scanning motion with said video signals; and

means for exposing motion picture film to said collinear output beam to record images on said film corresponding to said color information.

20. An apparatus for producing a color display comprising:

laser source means for producing multi-wavelength light;

means for generating a selected number of electrical signals of different fixed frequencies and for modulating the signals generated thereby;

acoustooptic means optically coupled with said laser means and responsive to said electrical signals for producing a composite, collinear output beam containing a number of different selected ones of the wavelengths present in the light from said laser means; and

means for directing said composite, collinear output beam onto a screen to produce said color display.

21. The invention of claim **20** wherein said beam directing means includes means for scanning said screen with said composite, collinear output beam.

22. A method of producing a composite, collinear beam of light comprising a plurality of different selected wavelengths derived from the wavelengths in one or more laser light sources; the method comprising the steps of:

propagating multi-wavelength laser light;

generating a number of electrical signals of different fixed frequencies;

modulating said signals to provide signals of predetermined intensities; and

acoustooptically diffracting said propagated laser light in accordance with said electrical signals to form a composite, collinear output beam comprising a number of different selected wavelengths corresponding in number to said number of electrical signals.

23. The invention of claim **22** wherein propagating laser light comprises propagating a multi-wavelength beam of laser light.

24. The invention of claim **22** wherein propagating laser light comprises propagating at least two wavelengths of laser light.

25. A method for recording a color image corresponding to a color image on a positive transparency onto a color sensitive photographic recording material comprising the steps of:

propagating a beam of multi-wavelength laser light;

scanning the transparency with said multi-wavelength beam of light;

receiving the beam as modulated by the transparency;

generating a number of electrical signals of different fixed frequencies, each of which is modulated in accordance with the intensity of a respective one of a corresponding number of different selected wavelengths present in the received modulated beam;

acoustooptically diffracting said propagated laser light in accordance with said modulated electrical signals to form a composite, collinear output beam including said selected wavelengths; and

scanning said photographic recording material with said composite, collinear output beam to form a color image thereon corresponding to the image in the transparency.

26. A method of recording a color image corresponding to a color image in a negative transparency onto a color sensitive photographic recording material comprising the steps of:

propagating a beam of multi-wavelength laser light;

scanning the transparency with said multi-wavelength beam of light;

receiving the beam as modulated by the transparency;

generating a number of electrical signals of different fixed frequencies, each of which is modulated in accordance with the intensity of a respective one of a corresponding number of different selected wavelengths present in the received modulated beam;

acoustooptically diffracting said propagated laser light in accordance with said modulated electrical signals to form a composite, collinear output beam including said selected wavelengths; and

scanning said photographic recording material with said composite, collinear output beam to form a color image thereon corresponding to the image in the negative transparency.

27. A method of recording a color image corresponding to a color print onto a color sensitive recording material comprising the steps of:

propagating a beam of multi-wavelength laser light;

scanning the color print with said multi-wavelength beam of light;

receiving light reflected from and modulated by the color print;

generating a number of electrical signals of different fixed frequencies, each of which is modulated in accordance with the intensity of a respective one of a corresponding number of different selected wavelengths presented in the reflected modulated light;

acoustooptically diffracting said propagated laser light in accordance with said modulated electrical signals to form a composite, collinear output beam including said selected wavelengths; and

scanning said color sensitive photographic recording material with said composite, collinear output beam to form a color image thereon corresponding to that of the color print.

28. A method of recording color information carried by television signals on color sensitive motion picture film comprising the steps of:

propagating a beam of multi-wavelength laser light;

generating a number of electrical signals of different fixed frequencies, each of which is modulated in accordance with the color information carried by the television signals;

acoustooptically diffracting said propagated laser light to form a composite, collinear output beam including a number of different selected wavelengths corresponding in number to said electrical signals; and

scanning the color sensitive motion picture film with said composite, collinear output beam to record a color image on said film in accordance with the color information carried by the television signals.

29. The invention of claim 1 wherein:

said source light comprises at least three input light beams of different wavelengths, each of said input light beams impinging upon said cell at an incident angle different from that of the other input light beams; and

said fixed frequencies are chosen in accordance with said incident angles to form said composite, collinear output beams.

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