PATENT SPECIFICATION

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(19)

(54) A METHOD OF AND APPARATUS FOR COLOUR REPRESENTATION

(71) We, MATSUSHITA ELECTRIC INDUSTRIAL COMPANY, LIMITED, a Japanese Body Corporate, of No. 1006, Oaza Kadoma, Kadoma City, Osaka, Japan, 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 a method of and a system for representing colored patterns on a subject for obtaining monochromes.

Several methods and sysems have been proposed for the purpose of the above mentioned color representation, but none have proven to be practically desirable in that they are complicated in structure and slow in processing and do not ensure exact representaiton.

In the following, prior to discussion of the present invention, one of the conventional methods will be discussed in connection with Figs. 1a and 1b of the accompanying drawings for better understanding of the present invention. Suitable scanning means (not shown) scans across a colored subject copy 2 along an arrow headed line 4. The subject copy 2, in this case, includes four different colors denoted by reference characters "A", "B", "C", and "D". A plurality of small circles 6 is shown, each representing an incremental element in the scan referred to herein as a picture element, of which the color is detected and represented. Light beams, which are reflected from the subject copy and include color information, are separated into bands according to wavelengths in suitable color separating means (not shown) and are employed to produce monochromes such as 8a, 8b, and 8c as shown in Fig. 1b. In the above discussed method, however, the color determination of all the picture elements is performed serially, so that much time is required since it is often the case that the number of picture elements reaches 10^7-10^8.

According to one aspect of the present invention there is provided a method of representing in electrical or data form colored patterns on a subject including the steps of: scanning the subject with a light beam; detecting borders between adjacent differently colored areas; determining the color of a scanned portion of predetermined width following each detected border and regarding the part scanned between said predetermined portion and the next detected color border in the scan as being of that color.

In another aspect the present invention provides apparatus for representing in electrical or data form colored patterns on a subject, such apparatus including: means to scan the subject with a light beam; means for detecting borders between adjacent differently colored areas; means for determining the color of a scanned portion of predetermined width following each detected border and for regarding the part scanned between said predetermined portion and the next detected color border in the scan as being of that color.

In order that the invention may be more clearly understood, the following description is given, merely by way of example, with reference to the accompanying drawings, in which:

Figs. 1a and 1b, already discussed, are schematic illustrations of the prior art;

Figs. 2a-2c illustrate a principle of a first preferred embodiment of the present invention;

Fig. 3a-5d illustrate a method of the first preferred embodiment;

Figs. 6a-6e illustrate a modification of the method of the first preferred embodiment;

Fig. 7 illustrates a system of the first preferred embodiment;

Fig. 8 is an illustration with which a second preferred embodiment of the present invention is concerned;

Figs. 9 and 10 illustrate a method of the second preferred embodiment;

Fig. 11 illustrates a system of the second preferred embodiment;

Figs. 12-14 each shows optical characteristics of a dichroic mirror used in a third preferred embodiment of the present invention;

Fig. 15 illustrates optical characteristics of a dichroic mirror for better understanding of the third preferred embodiment;

Figs. 16-18 illustrate the third preferred embodiment;

Figs. 19-20 illustrate a modification of the third preferred embodiment; and

Figs. 21-24 illustrate another modification of the third preferred embodiment.

Reference is now made to Figs. 2a through 2c inclusive, which illustrate a principle of a first preferred embodiment of the present invention. Like the scanning in Fig. 1a, a suitable scanning means (not shown) scans across the color subject copy 2 along the arrow headed line 4. Light beams including color information, which are reflected from picture elements 6 on the surface of the subject copy 2, are processed in a color analyzing or separating means (not shown) as will be referred to later, and serve for producing a train of pulses as shown in Fig. 2b. Each of the pulses in Fig. 2b represents a color border between two different colors. Therefore, if several picture elements, which follow one of the pulses in Fig. 2b, represent a specified color, that color is taken to apply to the following picture elements, until the next pulse appears. If the determination of the color is performed on the basis of a majority of the said several picture elements, its reliability increases.

It is therefore understood that, according to the above principle, the processing time can be considerably reduced in that for most of the picture elements between the adjacent color borders no color determination is made.

Reference is now made to Figs. 3a through 3f inclusive, which illustrate in more detail the principles of a preferred embodiment. Fig. 3a shows the spectral characteristics of the three colors "A", "B", and "C". On the other hand, Fig. 3b shows the color subject copy 2 which is scanned along the arrow headed line 4. Figs. 3c through 3f show the waveforms of electrical signals from suitable photoelectric converters (not shown) at wavelengths λ_1, λ_2, λ_3, and λ_n, respectively, when the color subject copy 2 is scanned along the line 4. As indicated in Fig. 3c, an output difference, for wavelength λ_1 between the colors "A" and "B" is equal to about zero, but, as seen from Fig. 3e, the output difference for wavelength λ_3 is considerable between colors "A" and "B". On the other hand, in Fig. 3f, an output difference between the colors "B" and "C" for λ_n is negligible, but, in Fig. 3c, the output difference for λ_1 is considerable for these colors. Therefore, it is concluded that if the light beams reflected from the subject copy 2 are analyzed with respect to their spectra at various different wavelengths, the various color borders can be easily detected.

The electrical signals of Figs. 3c through 3f are then differentiated, and the waveforms of the differentiated signals are shown in Figs. 4 a through 4d, respectively, Then, the differentiated signals of Figs. 4a-4d are wave shaped in such a manner as to take absolute values, the waveforms of which are shown in Figs. 4e through 4h, respectively. The thus wave shaped signals are then added as to their magnitudes and the waveform of the added signal is shown in Fig. 4i. When the added magnitudes exceed a threshold value, a pulse is generated so that an overall train of pulses is generated and the resultant waveform is shown in Fig. 4j. Consequently, it is understood that (1) each of the pulses of the train represents a color border between two different colors, and (2) even if the change in the electrical signal corresponding to any one particular wavelength is negligible or small at a border, as in Figs. 3c and 3f, the color border can still be clearly detected by adding the magnitudes of the signal for a plurality of wavelengths.

Reference is now made to Figs. 5a through 5d inclusive, which illustrate how the color information signal cen be stored in a suitable recording means 10 such as a magnetic tape, disc, or drum. The waveform in Fig. 5a corresponds to that in Figs. 4j. A pulse P_1 in Fig. 5a is used to indicate a position of the border between the two colors "A" and "B" on the line 4 and is stored as an address datum Q_1 which is a function of time. A gate pulse R_1 with a pulse width W_2 follows the pulse P_1 after an interval W_1, and contains, in this case, the information regarding three successive picture elements, BBB, which represent the colour "B". The time interval W_1 is employed for avoiding a malfunction in the determination of the color of a picture element due to overlapping of different colors in the vicinity of the border. The information regarding the three picture elements BBB is stored in recording means 10 as C_B as shown in Fig. 5c. The three data "C_B" are then abridged to be one unit of data "C_B", which is stored in a memory unit as shown in Fig. 5d. This method serves for compactly recording the information in question. Summing up, information regarding the position of a color border and the color between that border and the next can be stored as only two data units. Similarly, a pulse P_2 is used to indicate the position of the color border between the two different colors "B" and "C" on the line 4, and is stored as an address datum Q_2 which is a function of time. A gate pulse R_2 follows the pulse P_2 after an interval W_1, and contains information regarding three picture elements CCC which represent the color "C". Then, the information regarding these three picture elements is stored in the recording means 10 as shown in Fig. 5c, and is finally stored in the recording means 10 together with the address data Q_2 in the same manner as previously referred to. In the above, if, for example, the three data "C_B" in Fig. 5c differ, they are abridged into one data in Fig. 5d, on the basis of majority, so that more precise data transfer can be achieved in that faulty data can be cancelled.

It was, in the above, assumed that the color subject copy 2 does not involve, for example, nonuniformity of painting, an uneven surface, or scratches, so that electrical noises are not generated therefrom. However, in practice, such noise sources are often found in a color subject copy. As a consequence, in the following, there will be discussed, with reference to Figs. 6a-6e, a case where such undesirable noise sources are involved in the color subject copy 2′, wherein description of the steps corresponding to those in Figs. 5a through 5d will be omitted for brevity. The noise sources N_1 and N_2 cause noise pulses N_{P1} and N_{P2} as shown in Fig. 6b, resulting in the fact that fault data N_{C1} and N_{C2} are recorded on the recording means 10 as shown in Fig. 6c, wherein data Q_1' and Q_3' denote fault addresses representing positions of the noise sources N_1 and N_2, respectively, and wherein data C_X, C_B, and C_C represent a fault color and colors "B" and "C", respectively. Each of the data, which are recorded on the recording means 10, is processed in the same manner as previously referred to in connection with Figs. 5c and 5d, and then rearranged in the recording means 10 as shown in Fig. 6d, with the C_X data ignored on the basis of majority. However, since fault data N_{C3} and N_{C4} are involved in the data recorded on the recording means 10, they should be removed. To this end, the following steps are taken: (1) if two adjacent color data are equal, the latter color data is cancelled together with its associated address data, and (2) if the two adjacent color data are different from each other, the following color data is rearranged and retained on the recording means 10 as as shown in Fig. 6e. It is understood from the above that, according to this embodiment, undesirable data due to noise sources can be easily removed.

Reference is now made to Fig. 7, which illustrates an example of a system for the preceding methods. The color subject copy 2 is wrapped on a suitable drum 20, and scanned by a scanner which includes conveniently a light source 24, an optical system 26, and means (not shown) for scanning the subject copy 2. Reflected light beams enter directly a color separator 28 comprising a plurality of color filters (no numerals). The color separator 28 sends a plurality of separated color light beams to a plurality of photoelectric converters 30, 32, and 34. Electrical signals from the photoelectric converters are then fed to differentiators 36, 38, and 40, and are differentiated therein. A unit 42 receives the differentiated signals from the differentiators, treats them to obtain absolute magnitude values, and then adds the magnitudes of the signals. The added signals are fed to a next stage, viz., a circuit 44 wherein a train of pulses are generated when the magnitude of the added signals exceeds the threshold value. The pulses from the circuit 44 are then fed to an analog gate 46 to which the electrical signals from the photoelectric converters 30-34 are also applied. The gate 46 allows signals from the converters to be passed to an A-D converter 48 as shown in Fig. 5b in accordance with a train of pulses being received from the circuit 44. The A-D converter 48 converts the analog signals from the gate 46 into digital ones that is to say it gives digital color data, which are then applied to an OR gate 50. On the other hand, the pulses from the circuit 44 are applied to a circuit 52 to which picture element clock pulses are fed and which generates the address signals of digital form. The address signals are then applied to the OR gate 50. Thus, the address and color data are stored in a memory 54 such as a magnetic tape, drum, or disc, etc. The data in the memory 54 are then applied to and processed in a suitable computer 56, and being transferred to a pattern drawing means 58 such as a printing scanner, a plotter, or a cathode-ray tube, etc. The computer 56, if necessary, removes the fault data as in Figs. 6c and 6d.

Techniques for obtaining the color data will now be discussed.

In Fig. 8, there is illustrated one method of representing in electrical or data form the colors on a subject. Certain of the elements illustrated have been referred to in connection with Fig. 7 and will not be further discussed. Electrical signals x_1, x_2, ---, x_r from the photoelectric converters 30-34 and corresponding to respective wavelengths or wavelength ranges are fed to a difference detecting circuit 70. The circuit 70, although this is not shown in Fig. 8, also receives reference data concerning these wavelengths or ranges in connection with various different colors, for instance the colors A, B, and C. The data from the photoelectric converters 30-34 are directly compared with each of the reference data in order to identify the color being scanned. In practice, the identification is done by finding the minimum difference between two data being compared (reference data and subject data) after subtraction. The output, which is color data, is fed to the analog gate 46.

This method, however, has one defect: if there is nonuniformity of painting in a colored pattern, the color identification referred to above can not be exactly made because of noise resulting from the nonuniformity.

In order to reduce this difficulty, a preferred feature of the invention has been developed, this again being for use with parts already discussed in connection with Fig. 7. This preferred feature is initially discussed in connection with Fig. 9 wherein reference numbers 72 and 74 denote plotted curves indicating the magnitudes of the signals from the photoelectric converters 30-34 for a given color when the signal involves noise and no noise, respectively. The noise results from nonuniformity of painting. As seen from Fig. 9, the magnitude differences between two curves 72 and 74 are substantially constant over a range of wavelength from 420 to 720 mili-microns. Thus phenomenon has been proved by the inventor of the present invention after checking more than 4,000 picture elements. Fig. 10 shows an enlargement of a portion of the curves of Fig. 9. As shown, a magnitude difference Δx_i between signals x_i and x_{i+1} (i=1, 2, ---, r) on the curve 72 is approximately equal to the magnitude difference $\Delta x_i'$ between signals x_i' and x_{i+1}' on the curve 74. Accordingly, if it is the magnitude differences between adjacent signals which are used in the circuit 70, to identify the color, the difficulties caused by noise can be considerably reduced. Accordingly, in this embodiment as will be described below, sensed magnitude differences between adjacent wavelength signals are compared with reference data of similar type for various different colors, and the reference data also include magnitude sums for the reference colors. In case once it is found that a magnitude difference Δx_i in respect of a scanned color is equal to or resembles that of another plotted curve (not shown) with respect to another color with no noise, then, identity between the colors can be determined by comparing the magnitude sum of the signals of one with that of the other.

Fig. 11 schematically illustrates an example of apparatus in accordance with this preferred feature, which apparatus can be interposed between the photoelectric converters 30-34 and the analog gate 46 in Fig. 7. Adjacent pairs of signals x_1 and x_2, x_2 and x_3 --- x_{r-1} x_r are fed to a plurality of operational amplifiers 76, 78, 80 and 82. These amplifiers generate signals y_1, y_2, ---, y_{r-1} each of which represents a magnitude difference and is applied to the analog gate 46. The signals x_1, x_2, ---, x_r are also applied to an operational amplifier 84 which adds them for the purpose of determining lightness and determining color in the abovementioned case of received and reference signals with like magnitude differences. The signal from the amplifier 84 is also applied to the analog gate 46.

According to experiments by the inventors, faulty color discrimination can be reduced to one third by using this preferred feature.

In the following, a further preferred feature of the present invention will be described in connection with Figs. 12-24. This feature is concerned with an optical filter including a plurality of dichroic mirrors each of which has narror band transmission characteristics, and is very useful when employed in the color separator 28 in Figs. 7 and 8. Figs. 12, 13, and 14 show transmission characteristics of three dichroic mirrors with dielectric multicoated layers as a function of normalized wavelength ratio ω. The differences between the transmission characteristics of Figs. 12-14 result from differences of thickness of each of the coated layers and also differences of the number of the layers. These dichroic mirrors each have high and low refraction layers (for example, ZnS and MgF_2, respectively) alternately superimposed on a transparent substrate by, for example, vaporizing technique. As is known in the art, the absorption of light beams passing through dielectric multilayer is negligible so that a sum of the transmission and the reflection rates is substantially equal to unit. This means that a dichroic mirror with very effective optical characteristics can be obtained. Meanwhile, a main or central resonant wavelength (λ_o) of the dichroic mirror is controlled by the thickness of the coated layers, and a transmission characteristic is in turn controlled by the number of the coated layers. As a result, the resonant wavelength of a dichroic mirror, or in other words, the optical characteristic of a dichroic mirror, can be changed without a change in the number of the coated layers. By way of example, Fig. 15 shows two characteristic curves 80 and 82 having respectively different resonant wavelength 600 and 500 nm, but for the same number of the layers.

Figs. 16, 17, and 18 illustrate a first example of this preferred feature. Fig. 16 is a schematic illustration of an arrangement of an example which includes seven dichroic mirrors 501-507 and eight photoelectrical converters 508-515 in order to obtain, from a white light 57, eight outputs corresponding to light beams 518-525 having different spectra from one another. As shown, all the dichroic mirrors are positioned at an angle 45° with respect to the incoming white light 517. The dichroic mirrors 501, 502, 503, 505, 506 have central wavelengths 420, 560, 540, 660, and 620 nm, respectively, and, each of these mirrors has the same number of the layers as a mirror whose optical characteristic has been shown in Fig. 14. On the other hand, the dichroic mirrors 504 and 507 have their central wavelengths 420 and 460 nm, respectively, and, each of these mirrors has the same number of layers as a mirror whose optical characteristic has been shown in Fig. 13. Figs. 17a-17g show the seven transmission curves, 501′-507′, as a function of wavelength for the seven dichroic mirrors 501-507, respectively. As a result, the light beam 518 is reflected by the two mirrors 501 and 504, so that variations of tranmsission (percent) with wavelength with respect to light beam 518 becomes as shown by reference numeral 518′ in Fig. 18. On the other hand, the mirror 501 selectively allows the white light 517 to pass therethrough and then the mirrors 502 and 507 selectively reflect the light beam from the mirror 501. Therefore, the resultant light beam 519 has a spectrum characteristic as shown by reference numeral 519′ in Fig. 18. Similarly, other variations of transmission with wavelength with respect to light beams 520-525 are shown by reference numerals 519′-525′ in Fig. 18, respectively.

Reference is now made to Figure 19 which shows a second example of this preferred feature, which example is compactly arranged in comparison with the first one of Fig. 16. Dichroic mirrors 801-807 correspond to the mirrors 501-507, and photoelectric converters 808-815 to the converters 508-515, and light beams 817-825 to the light beams 517-525. A reference numeral 816 denotes a total reflection mirror which changes the light beam direction and serves for making this arrangement compact. As shown, eight optical interference filters 828-835 are respectively provided between the dichroic mirrors and the converters in order to remove the overlaps of the characteristic curves. The filters 828, 829, 830, 831, 832, 834, and 835 have central wavelengths 420, 460, 500, 540, 580, 620, 660, and 700, respectively, and each of the filters has a half value width of ±20 nm, as shown in Fig. 20. Reference numerals 828′-835′ show the optical characteristics of the interference filters 828-835, respectively. By means of the interference filters 828-835, although not shown, the optical characteristics of the light beams 818-825 are improved with respect to transmission and reflection bands and also separation. In the above, the interference filters 828-835 can be omitted in the case where accurate optical separation is not necessarily required. A system according to this second example is practically very useful in that the photoelectric converters 808-815 are regularly and compactly arranged in a U-shape so that this sysem is readily constructed and adjustable. Furthermore, such a compactly arranged color analyzer is very suitable for being mounted on a moving scanner as, for example, used in the system of Fig. 7 although not shown in the drawing.

Fig. 21 illustrates another example of this preferred feature of the present invention. In brief, the system of Fig. 21 separates a collimated white light 1018 into six bands by combining five dichroic mirrors 1001-1005, etc. Each dichroic mirrors 1001, 1002, and 1004 has an optical characteristic similar to that in Fig. 14, and these three mirrors have central wavelengths (λ_o) 600, 500, and 550 nm, respectively. On the other hand, the dichroic mirrors 1003 and 1005 have central wavelengths 420 and 460 nm, respectively, and each of these two mirrors has an optical characteristic similar to that in Fig. 13. Optical interference filters 1006-1011 are provided for regulating optical bands of light beams 1019-1024. The filters 1006, 1007, 1008, 1009, 1010, and 1011 have central wavelengths 420, 460, 500, 550, 600, and 650 nm, respectively, and have optical characteristics denoted by reference numerals 1008′, 1009′, 1010′, and 1011′, respectively, in Fig. 23. Fig. 22 shows optical characteristics of the filters 1001-1005 by reference numerals 1001′-1005′, respectively. In Fig. 21, the collimated white light 1018 is spectrally separated, entering, through the interference filters 1006-1011, six photoelectric converters 1012-1017, respectively. The spectrum characteristics of the light beams 1019-1024 are illustrated by reference numerals 1019′-1024′, respectively.

In the above, a filter whose optical

characteristic is similar to that in Fig. 12 is not used in the preceding three examples, however, it goes without saying that such a filter can be also available.

It is understood from foregoing that the present invention is practically useful for color printing, textile printing, or facsimile systems.

WHAT WE CLAIM IS:—

1. A method of representing in electrical or data form colored patterns on a subject including the steps of:
scanning the subject with a light beam;
detecting borders between adjacent differently colored areas;
determining the color of a scanned portion of predetermined width, following each detected border and regarding the part scanned between said predetermined portion and the next detected color border in the scan as being of that color.

2. A method according to claim 1, wherein the step of detecting comprises:
separating the light beams reflected from the subject into a plurality of bands of given wavelength or wavelengths ranges;
generating electrical signals corresponding to the bands of light;
differentiating the electrical signals;
taking the absolute magnitudes of each of the differentiated electrical signals;
adding the magnitudes; and
generating a pulse every time the added magnitude exceeds a predetermined level, which pulse indicates a color border.

3. Apparatus for representing in electrical or data form colored patterns on a subject, such apparatus including:
means to scan the subject with a light beam;
means for detecting borders between adjacent differently colored areas;
means for determining the color of a scanned portion of predetermined width following each detected border and for regarding the part scanned between said predetermined portion and the next detected color border in the scan as being of that color.

4. Apparatus according to claim 3 wherein the means for detecting borders includes:
separating means for separating the light beams reflected from the subject into a plurality of bands of given wavelength or wavelength ranges;
photoelectric means for receiving the bands of light and generating corresponding electrical signals;
means for receiving the electrical signals and differentiating them;
means for taking the absolute magnitudes of each of the differentiated electrical signals and generating a signal representative thereof;
means for adding the magnitudes and generating a signal representative of the added magnitude; and
means for generating a pulse every time the added magnitude exceeds a predetermined level, which pulse indicates a color border.

5. Apparatus according to claim 4, including:
an analog gate connected to receive the signals from the photoelectric means and connected to receive said generated pulses and to pass said signals upon receipt of a pulse;
an A-D converter connected to the analog gate and effective to convert the electrical signals passed through the analog gate into digital form; and
an OR gate connected to the A-D converters and to the eighth means *via* an address signal generator.

6. Apparatus according to claim 5, including: an adder interposed between the photoelectric means and the analog gate, for adding the magnitudes of the electrical signals, and applying the added signal to the analog gate; and
a plurality of subtractors each of which is interposed between the photoelectric means and the analog gate and generates a signal representative of a magnitude difference between two electrical signals from the photoelectric means.

7. Apparatus according to claim 4, 5 or 6, wherein the separating means includes: a plurality of optical interference filters each provided with multicoated layers, at least one of the filters having, in terms of wavelength, a main transmitting range and secondary transmitting ranges, the secondary transmitting ranges being, in terms of wavelength, on both sides or one side of the main range, and the filters being arranged in such a manner as to separate the light beams along a plurality of light paths according to wavelength by selectively transmitting and reflecting the light beams.

8. Apparatus according to claim 7, including a plurality of optical interference filters each of which is provided in the light path after a said filter for regulating the transmitted wavelength range.

9. Methods of representing in electrical or data form colored patterns on a subject,

such methods being substantially as hereinbefore described with reference to and as illustrated in Figures 2 to 24 of the accompanying drawings.

10. Apparatus for representing in electrical or data form colored patterns on a subject, such apparatus being constructed and arranged substantially as hereinbefore described with reference to and as illustrated in Figures 2 to 24 of the accompanying drawings, in particular Figures 7, 8, 11 and 16 or 19 or 21 thereof.

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28 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig. 1a

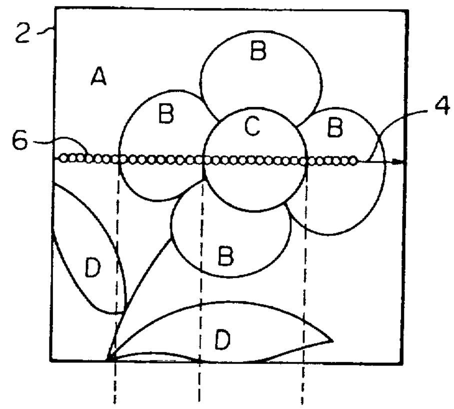
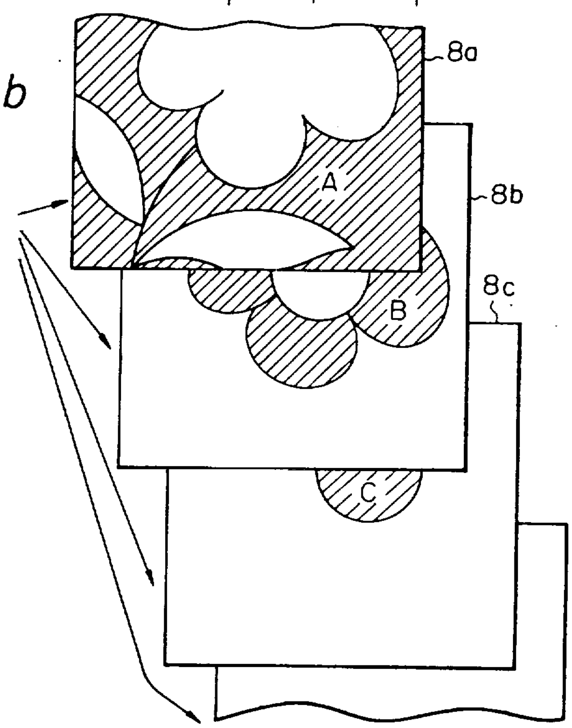


Fig. 1b



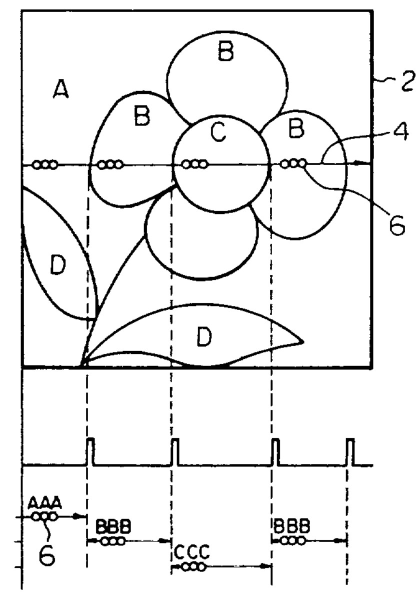


Fig 2a

Fig. 2b

Fig. 2c

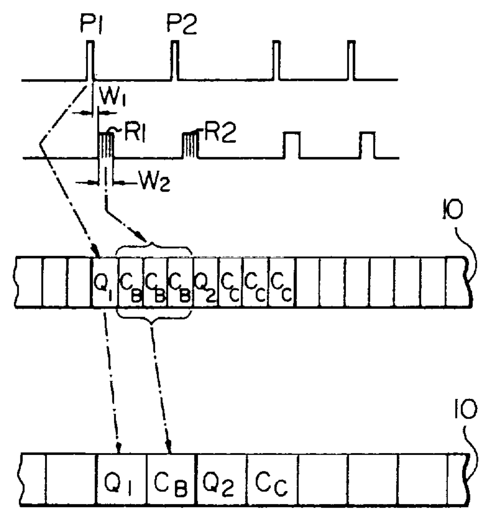


Fig. 5a

Fig. 5b

Fig. 5c

Fig. 5d

Fig. 3a

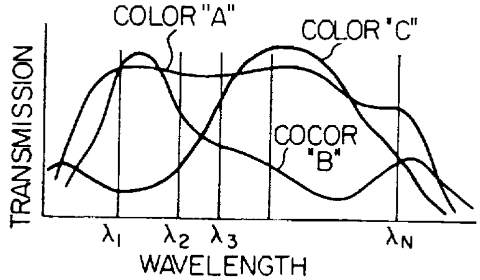


Fig. 3b

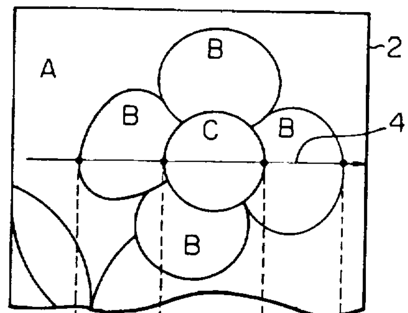


Fig. 3c

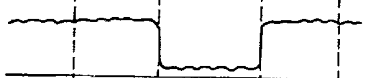


Fig. 3d

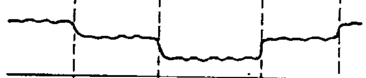


Fig. 3e

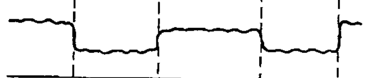
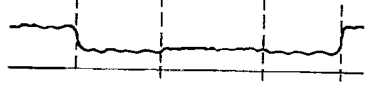


Fig. 3f



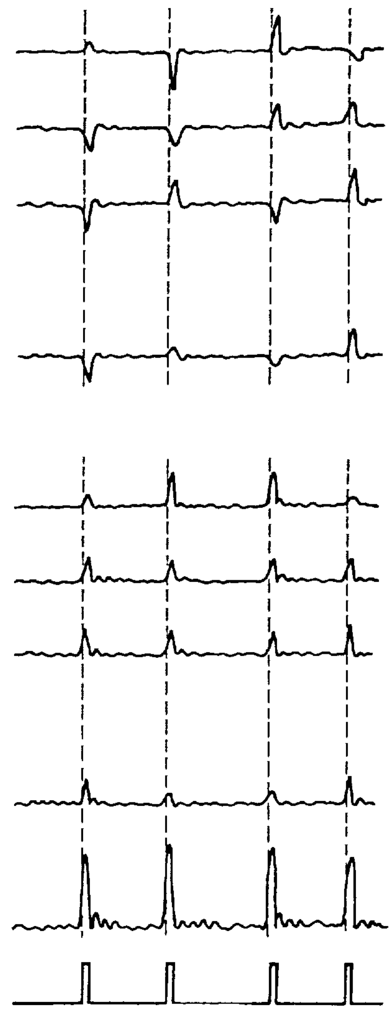


Fig. 4a
Fig. 4b
Fig. 4c
Fig. 4d
Fig. 4e
Fig. 4f
Fig. 4g
Fig. 4h
Fig. 4i
Fig. 4j

Fig. 6a

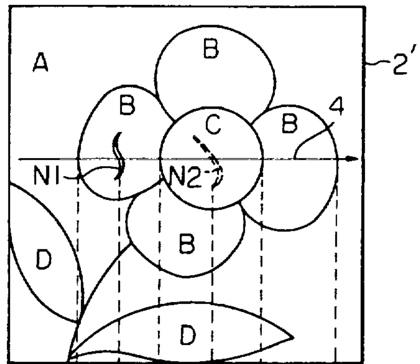


Fig. 6b

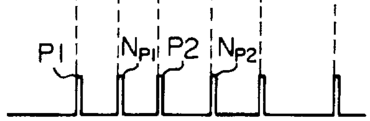


Fig. 6c

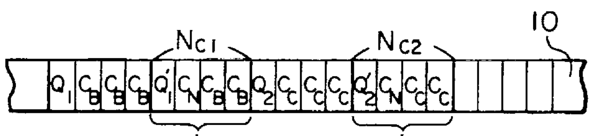


Fig. 6d

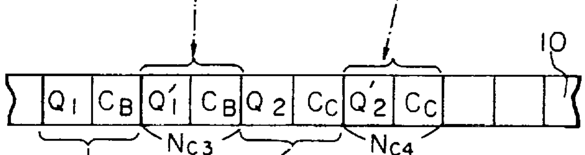


Fig. 6e

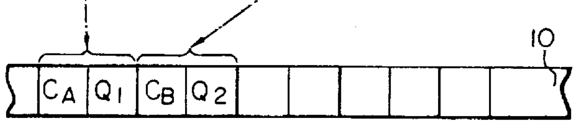


Fig. 7

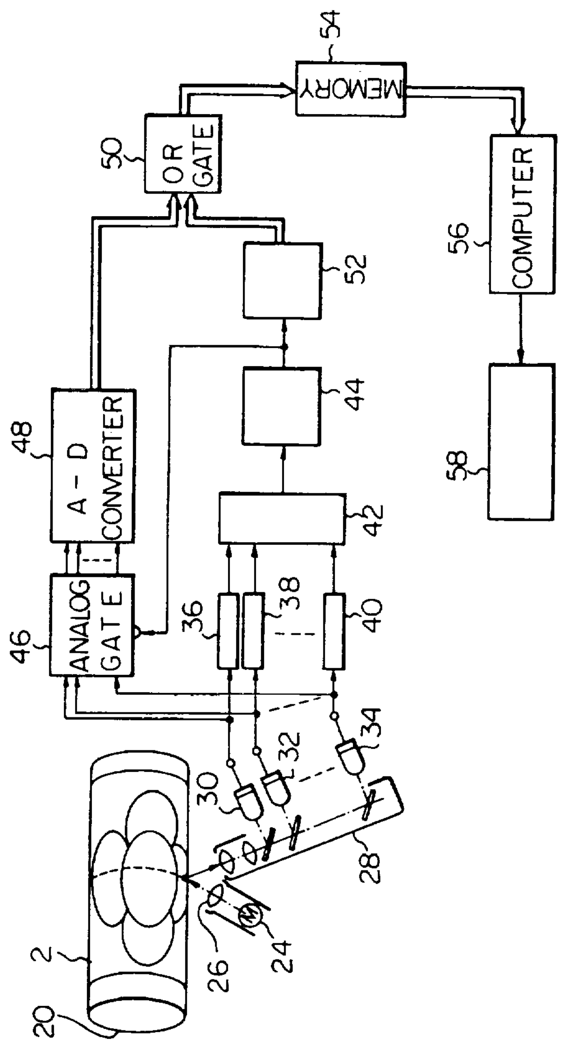

MEMORY
OR GATE
COMPUTER
A - D CONVERTER
ANALOG GATE
54
50
52
56
48
44
58
42
46
36
38
40
30
32
34
28
26
24
2
20

Fig. 8

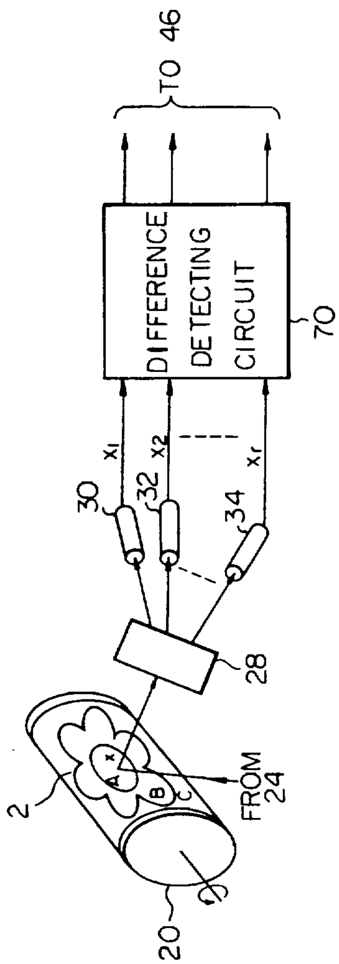

TO 46
DIFFERENCE DETECTING CIRCUIT
70
30
32
34
28
2
20
A
B
C
FROM 24

Fig. 9

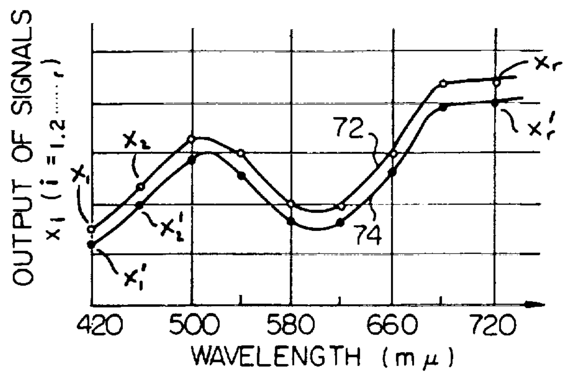

OUTPUT OF SIGNALS
x_i (i = 1,2 ...... r)
x_r
x'_r
72
x_2
x_1
x'_2
74
x'_1
420
500
580
660
720
WAVELENGTH (mμ)

Fig. 10

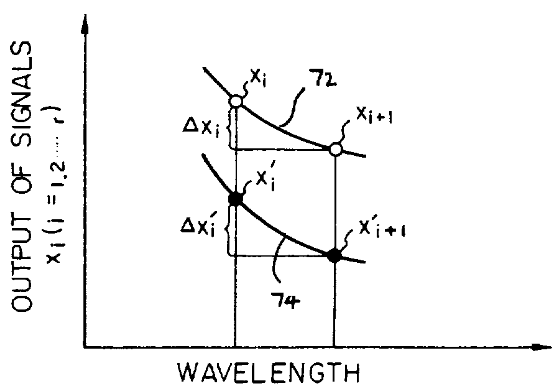

OUTPUT OF SIGNALS
x_i (i = 1,2 ..... r)
x_i
72
x_i+1
Δx_i
x'_i
Δx'_i
x'_i+1
74
WAVELENGTH

Fig. 11

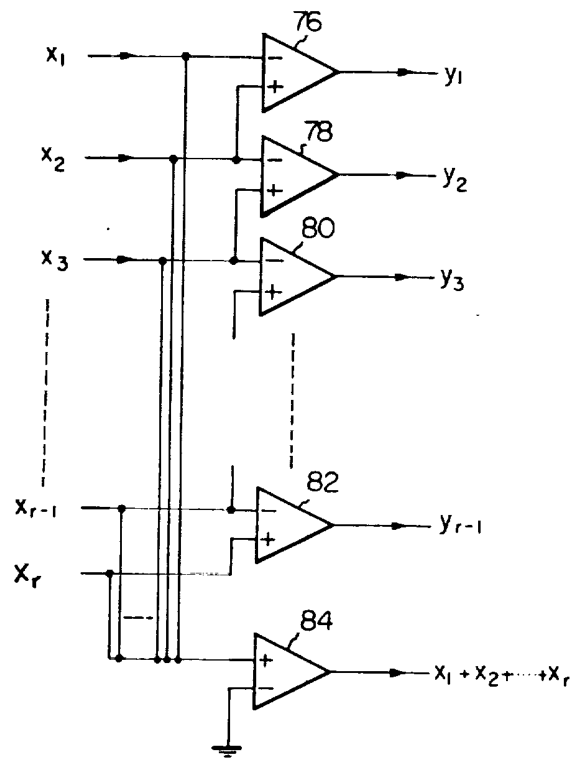


Fig. 12

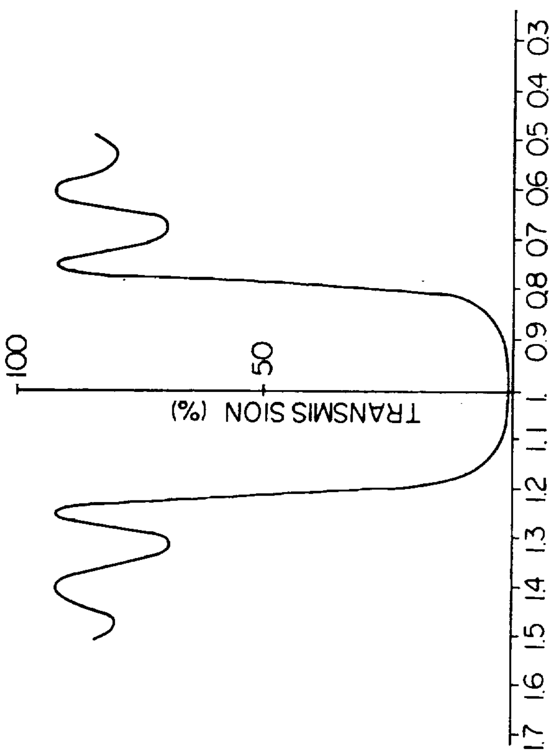

TRANSMIS SION (%)
100
50
1.7 1.6 1.5 1.4 1.3 1.2 1.1 1. 0.9 0.8 0.7 0.6 0.5 0.4 0.3
ω = λo/λ

Fig. 13

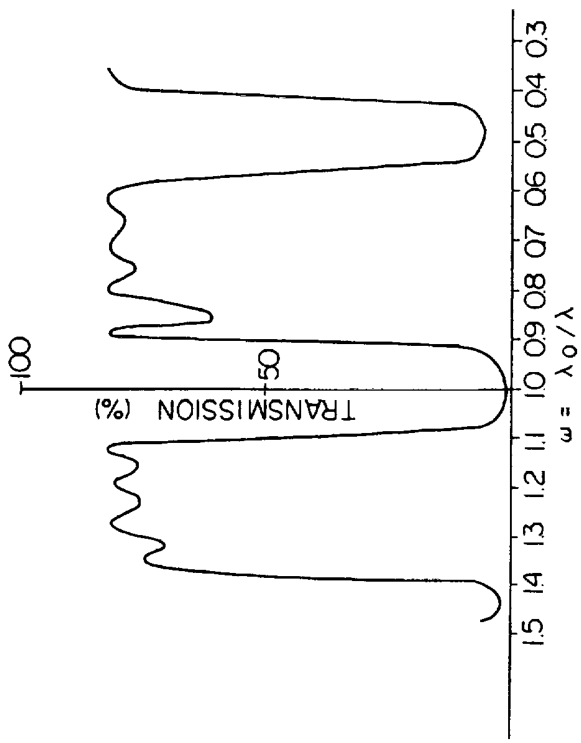


Fig. 14

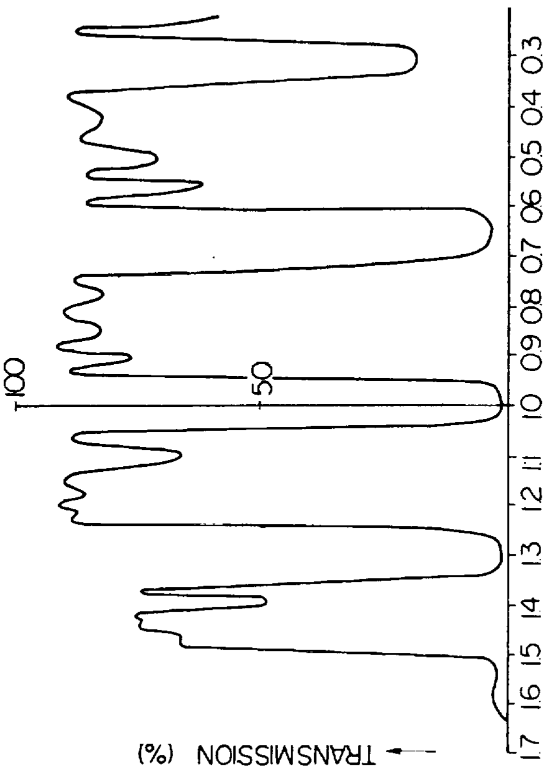

100
50
TRANSMISSION (%)
ω = λo/λ
0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7

Fig. 15

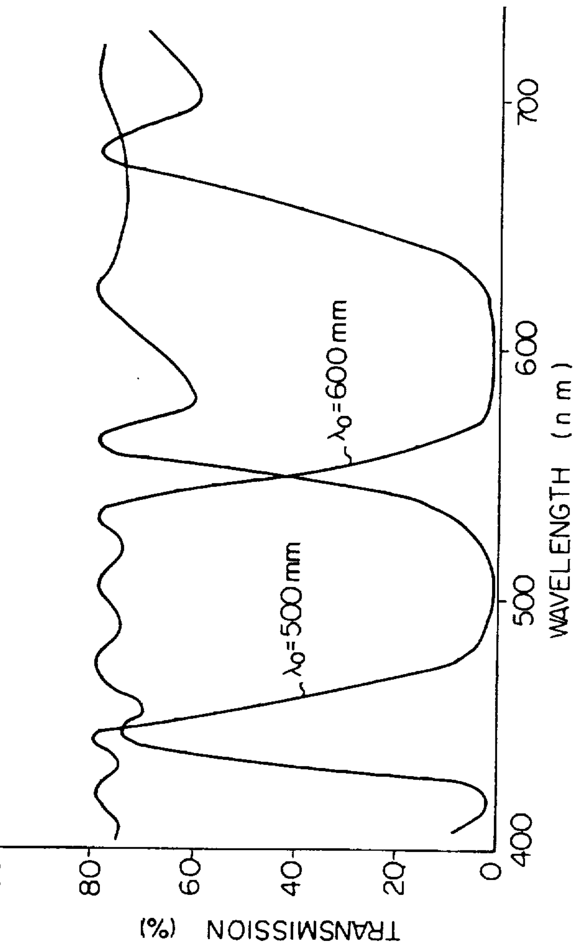
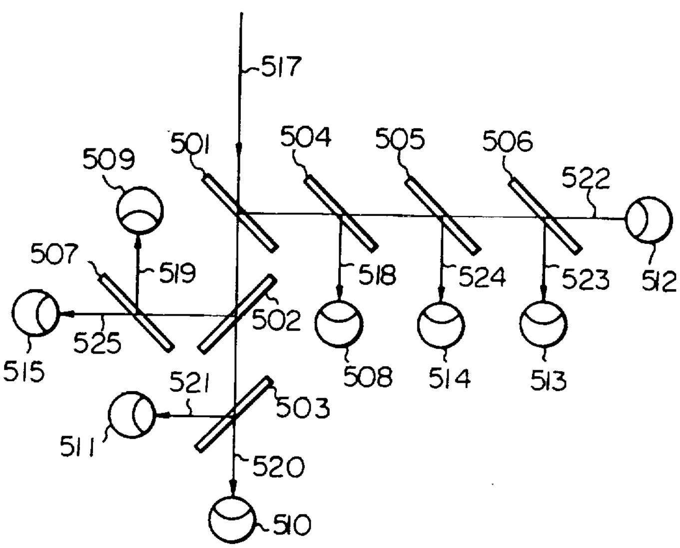

TRANSMISSION (%)
100
80
60
40
20
0
400
500
600
700
WAVELENGTH (n m)
λo=500mm
λo=600mm

Fig. 16


517
501
504
505
506
509
522
507
519
518
524
523
512
502
525
515
508
514
513
521
503
511
520
510

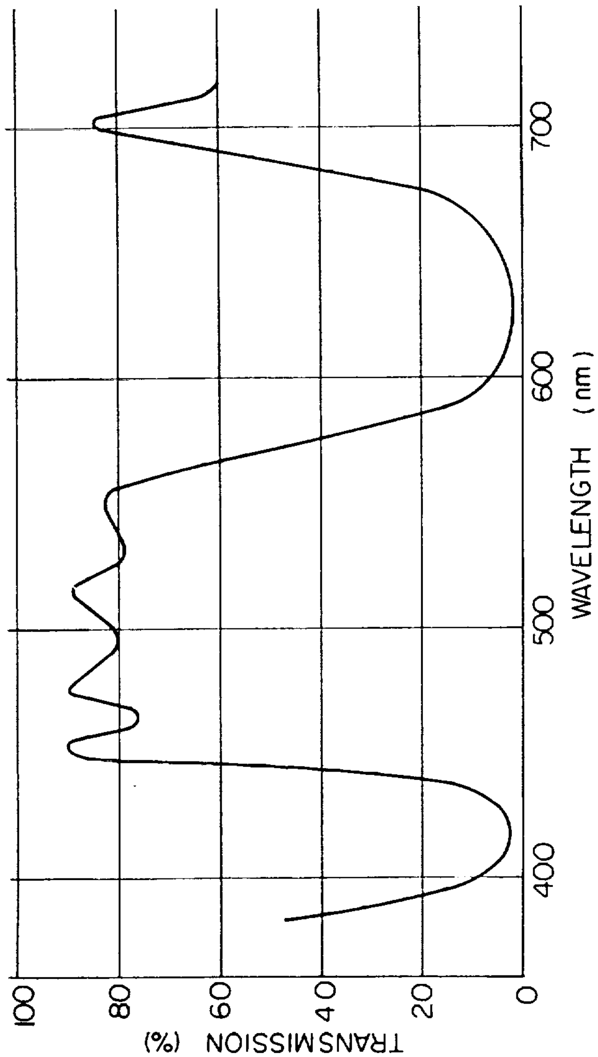


Fig. 17a

Fig. 17b

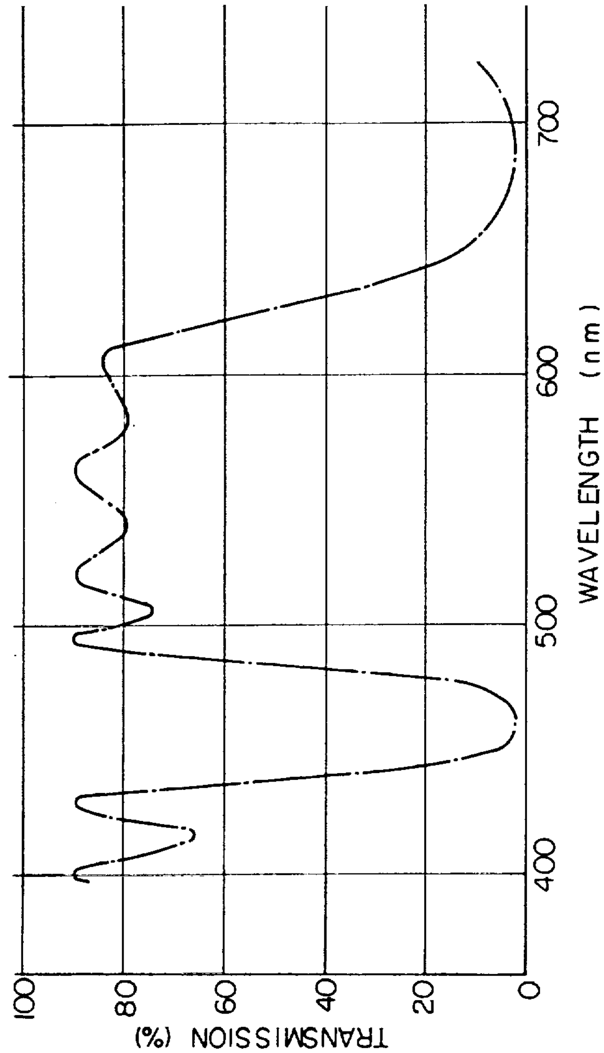


Fig. 17c

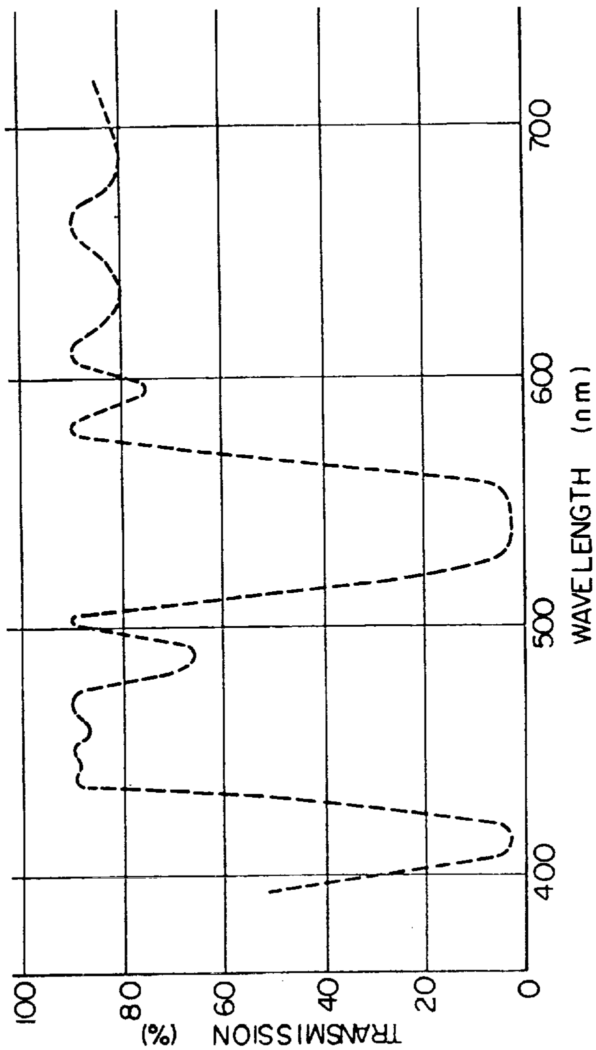
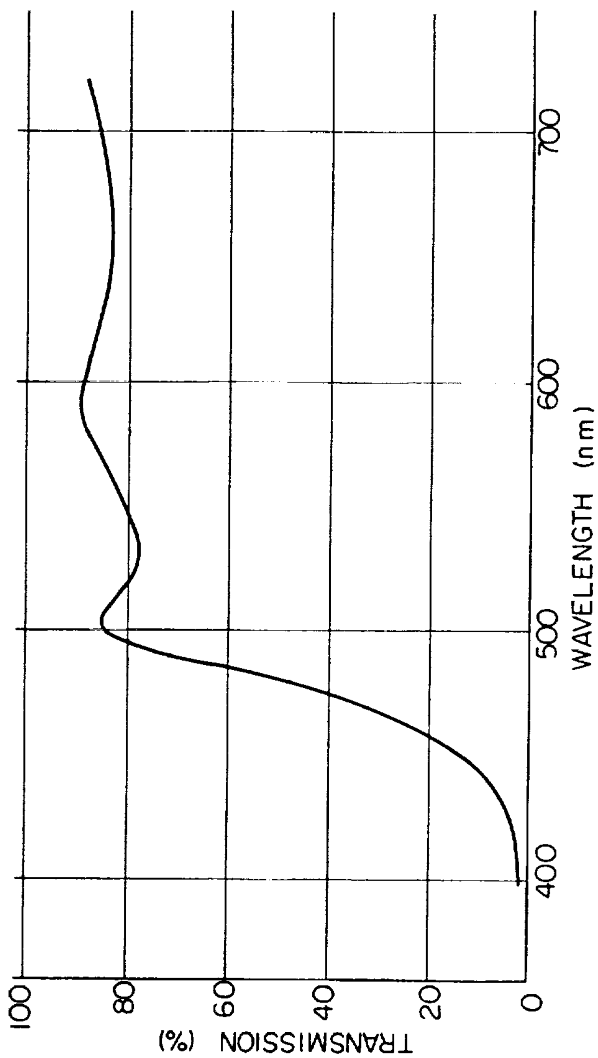


Fig. 17d



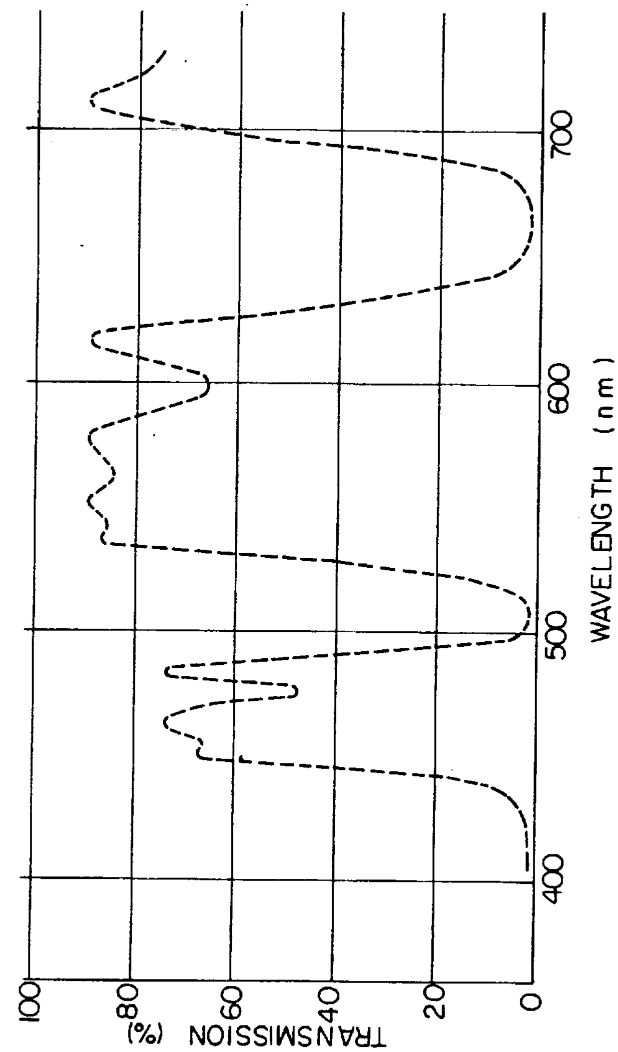


Fig. 17e

Fig. 17f

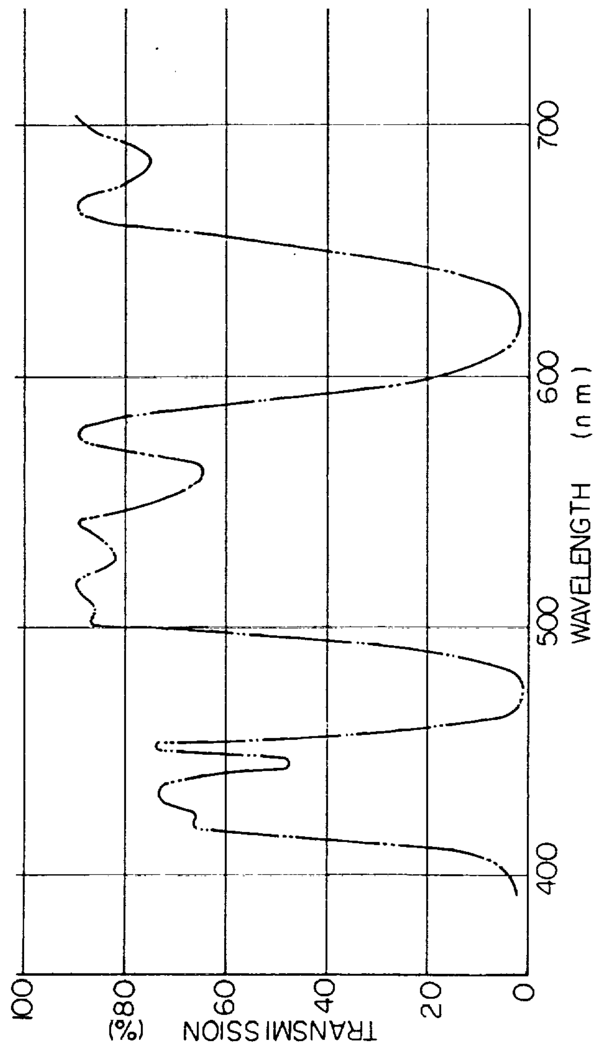


Fig. 17g

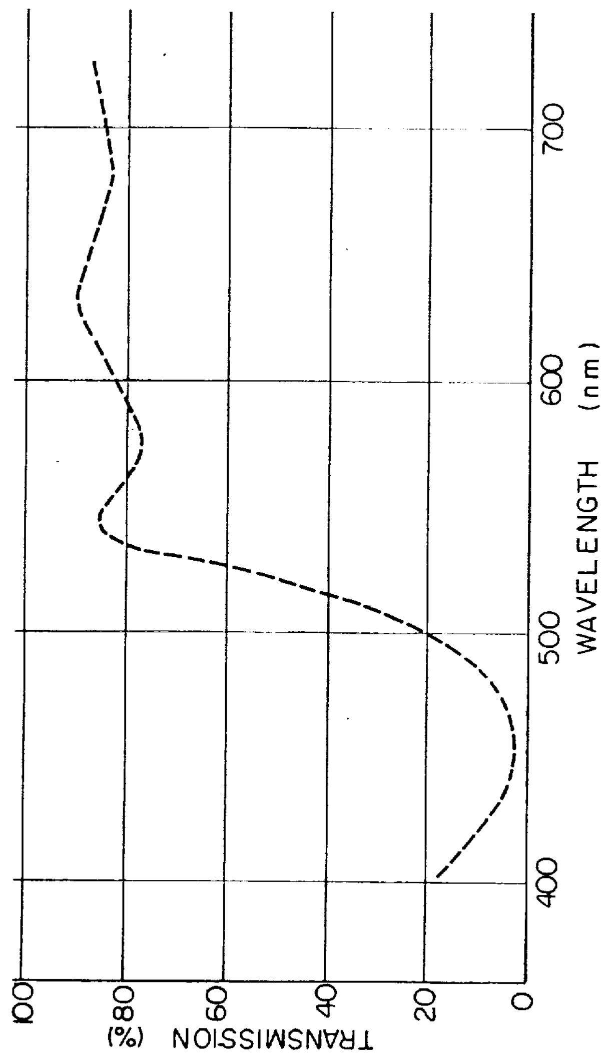


Fig. 18

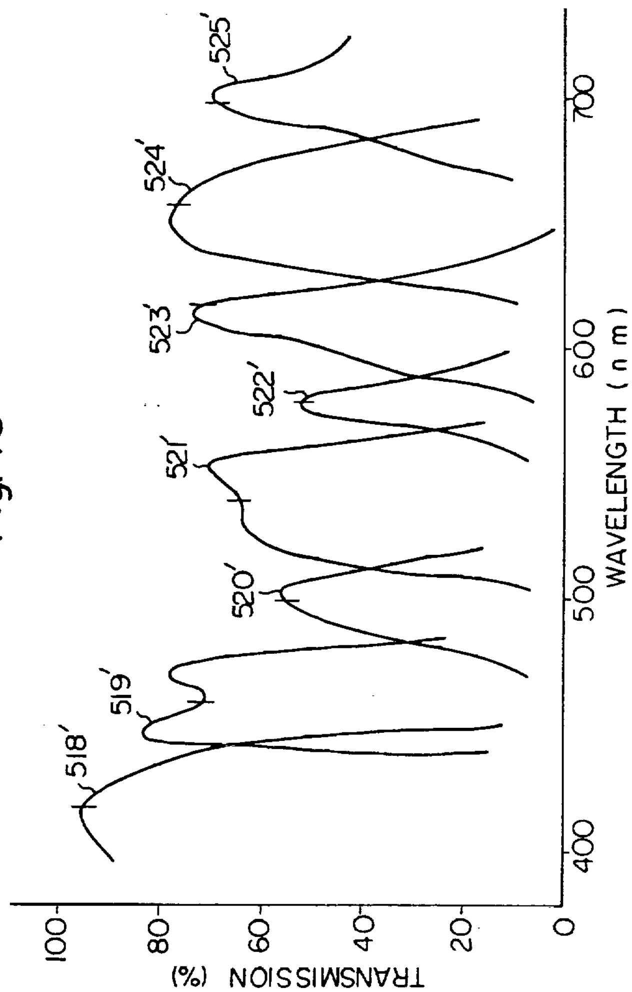

518'
519'
520'
521'
522'
523'
524'
525'
TRANSMISSION (%)
0
20
40
60
80
100
400
500
600
700
WAVELENGTH (n m)

Fig. 19

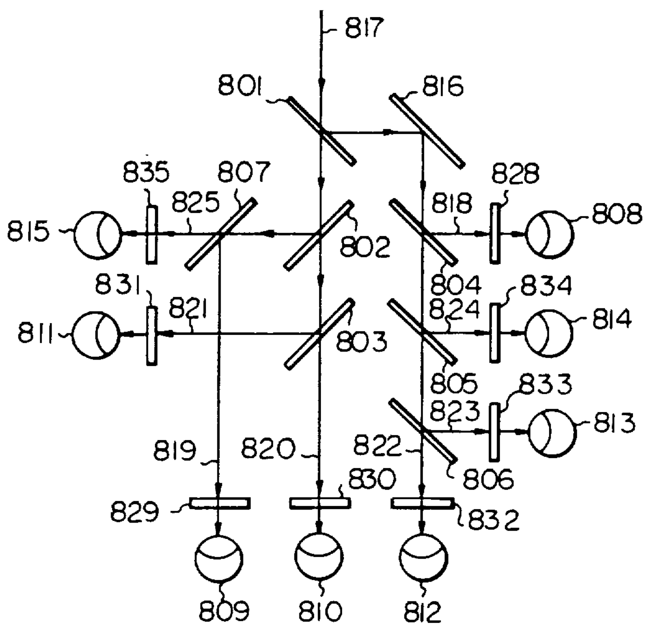

817
801
816
835
807
828
825
818
815
802
808
831
804
834
821
824
811
803
814
805
833
823
813
819
820
822
806
830
829
832
809
810
812

Fig. 20

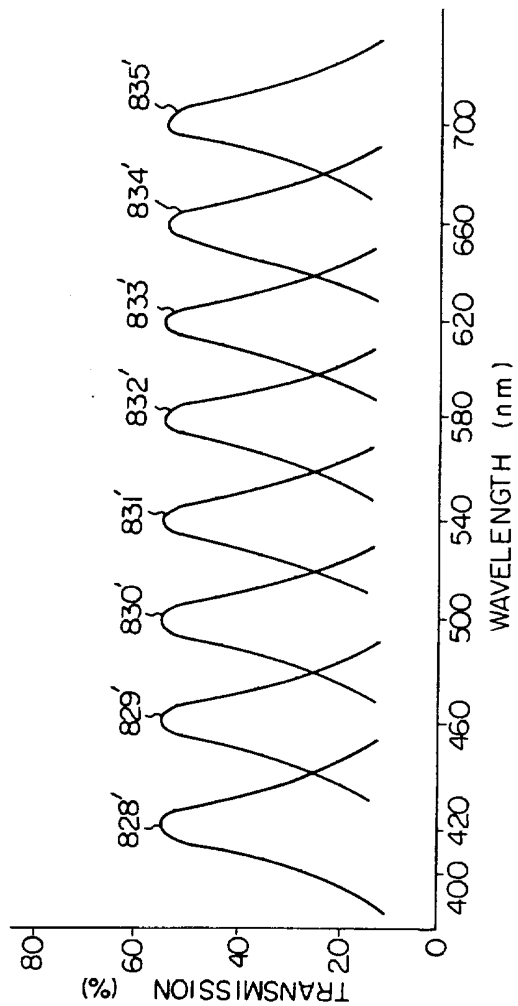

828'
829'
830'
831'
832'
833'
834'
835'
TRANSMISSION (%)
80
60
40
20
0
400
420
460
500
540
580
620
660
700
WAVELENGTH (nm)

Fig. 21

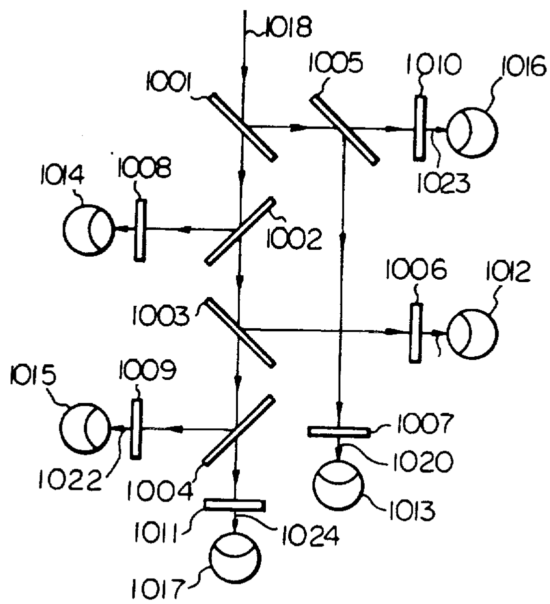

1018
1001
1005
1010
1016
1023
1014
1008
1002
1006
1012
1003
1015
1009
1007
1020
1022
1004
1013
1011
1024
1017

Fig. 22

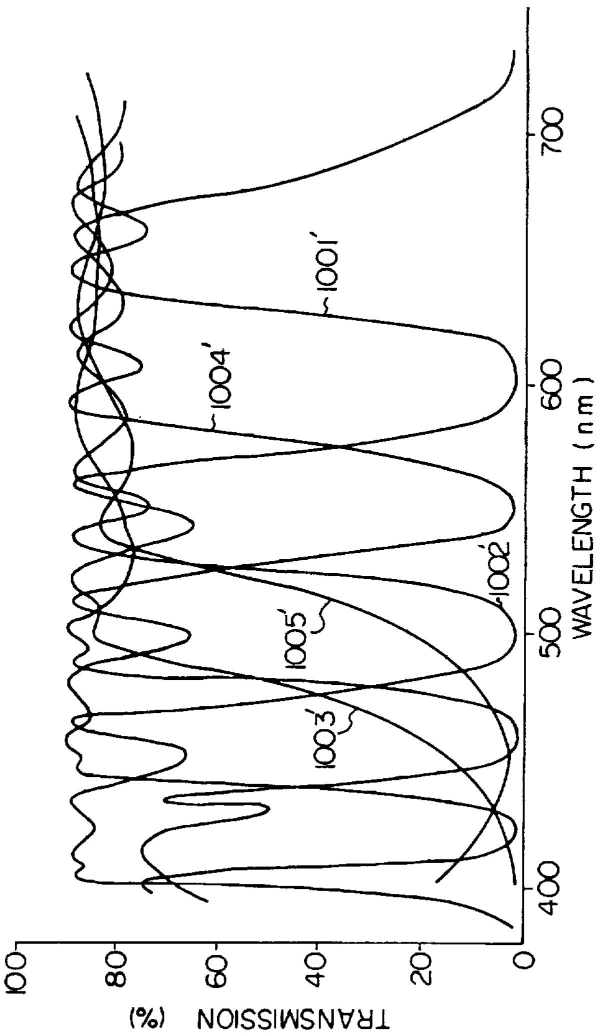

TRANSMISSION (%)
100
80
60
40
20
0
400
500
600
700
WAVELENGTH (nm)
1001'
1002'
1003'
1004'
1005'

Fig. 23

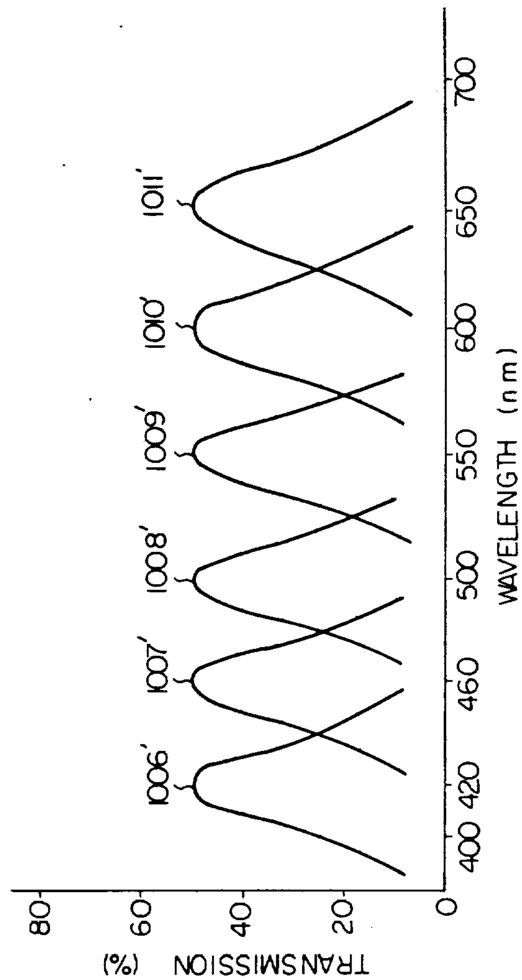
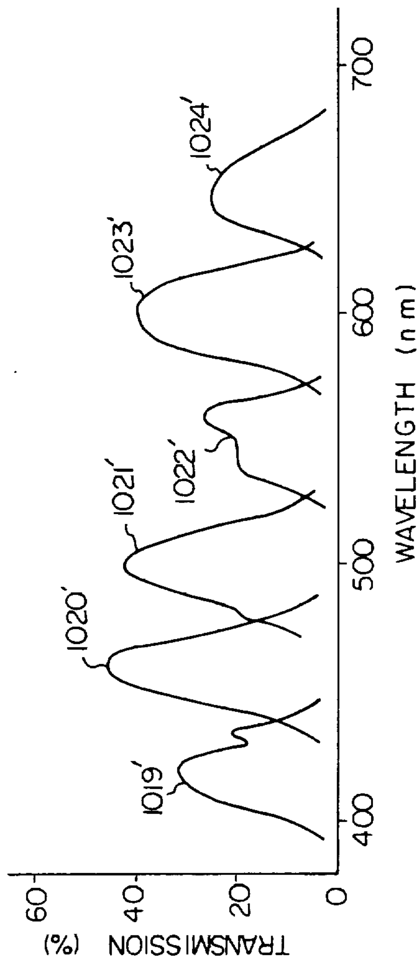

1006'
1007'
1008'
1009'
1010'
1011'
TRANSMISSION (%)
80
60
40
20
0
400
420
460
500
550
600
650
700
WAVELENGTH (nm)

Fig. 24


TRANSMISSION (%)
60
40
20
0
400
500
600
700
WAVELENGTH (nm)
1019'
1020'
1021'
1022'
1023'
1024'