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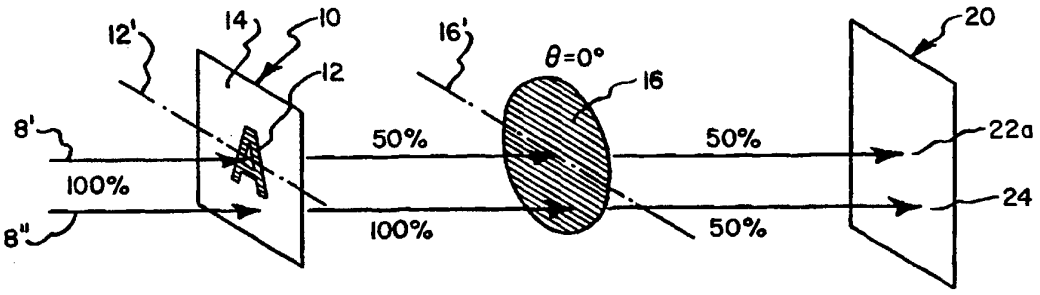
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(54) Title: CONTRAST SENSITIVITY TESTER



(57) Abstract

A device for testing visual contrast sensitivity is disclosed whereby the contrast between a vectographically polarized test symbol (12, 22a) and a reference background (24) may be continuously varied by changing the direction of polarization (16') of a polarization analyzer (16) situated along the test axis (8'). The invention is practised by providing a chart projector or a conventional refractor with a rotatable analyzer (16).

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CONTRAST SENSITIVITY TESTER

BACKGROUND OF THE INVENTION

The present invention relates to contrast sensitivity testers and, more particularly, to contrast sensitivity testers using projected images produced by vectographic slides or vectographic near-point cards.

Vectographic slides have been used for many years to test for monocular acuity under binocular conditions, axis of astigmatism of each eye under binocular conditions, acuity and accommodative balance between the right and left eyes, binocular instability, parity between monocular and binocular acuity, muscle balance, fixation disparity, and stereo acuity. One early report on the use of such slides was published in the New England Journal of Optometry, May 1966, Vol. XVII, No. 5. The unique feature of these slides is the presence of polarized symbols against an unpolarized background portion; typically, some symbols are polarized in one direction and other symbols are polarized in the orthogonal direction. The traditional tests noted above are conducted using a pair of orthogonal polarization analyzers, one in front of each eye, to make each symbol visible to one eye and invisible to the other eye. Positioning of the analyzers at exactly 90° is not required, since unwanted ghost images do not appear until the analyzers are fully 20° out of alignment. Most subjective refractors are offered to practitioners with orthogonal analyzers mounted in the accessory wheels.

Since most practitioners already use vectographic slides and near-point cards, the adaptation of a refractor to provide rotatable analyzers instead of, or in addition to, the fixed analyzers offers a simple means for contrast sensitivity testing in addition to the conventional vectographic tests. Alternatively, a rotatable analyzer can be added to a chart projector. Vectographic slides and vectographic near-point cards, which may include slides and near-point cards having test symbols polarized in one direction only, may be used in conjunction with rotatable

analyzers for testing contrast sensitivity. One advantage of a refractor containing rotatable analyzers is that contrast sensitivity under reading conditions can be tested using vectographic near-point reading cards. Vectographic near-point reading cards for use in binocular refraction, and a process for making them, are disclosed in U.S. Patent No. 3,572,911 issued March 30, 1971; it will be understood by those skilled in the art that the disclosed process may be easily modified to produce near-point cards having a symbol or symbols polarized in one direction only.

Heretofore, contrast sensitivity testing has been conducted using special charts containing symbols having different contrast levels relative to the chart background or slides that project symbols of different contrast levels. Such devices have the inherent disadvantage that there is necessarily a predetermined finite step between each contrast level, whereby the precision with which contrast sensitivity may be determined is limited.

Thus, it is an object of the present invention to provide an improved means of testing contrast sensitivity whereby the relative contrast of a test symbol in relation to a reference background may be continuously, rather than discretely, varied by the practitioner.

It is a further object of the present invention to provide a means of testing contrast sensitivity using vectographic slides or vectographic near-point cards rather than specialized contrast-level type charts or slides.

Another object is to enable practitioners to conduct an improved test for contrast sensitivity through simple modification of a conventional refractor or chart projector.

Other objects, advantages, and features of the present invention will become apparent from the following description and taken in connection with the accompanying figures.

SUMMARY OF THE INVENTION AND DRAWINGS

The present invention is directed to devices for varying the contrast between a vectographically polarized test symbol and the background surrounding the symbol. The variation can be achieved by including a rotatable analyzer in each bank of a conventional subjective refractor through which a vectographic slide or vectographic near-point card is viewed, or by including a rotatable analyzer in a chart projector used to project a vectographic slide.

Figs. 1a, 1b and 1c are graphical representations of a vectographically polarized projected image illustrating the effect of varying the orientation of the analyzer with respect to a horizontally polarized test symbol;

Fig. 1d is a graph indicating relative contrast as a function of analyzer orientation for the system illustrated in Figs 1a-1c;

Fig. 2 is an optical schematic diagram of a chart projector in accordance with an embodiment of the present invention;

Fig. 3 is a rear view of a modifier slide having a rotatable analyzer;

Fig. 4 illustrates an indicator scale for reporting analyzer orientation and relative contrast;

Fig. 5 is a front view of a portion of a rotatable slide disc having a rotatable analyzer; and

Fig. 6 illustrates one bank of a refractor, partly in section, having external means to rotate a mounted

analyzer.

DETAILED DESCRIPTION

The principle of continuous contrast variation with regard to vectographic test symbols is illustrated in Figures 1a through 1c. In the simplest contrast situation, concern is solely for two luminance levels: a higher level L_h, and a lower level L_l. The relative contrast C_{rel} between the two luminance levels may be expressed as the ratio of the difference between the two levels to the higher level:

$$C_{rel} = (L_h - L_l) / L_h$$

where L_h is greater than or equal to L_l.

In accordance with the present invention, the lower luminance level L_l is the light transmittance corresponding to the projected test symbol expressed as a percentage of source light, while the higher luminance level L_h is the light transmittance corresponding to the surrounding reference background, also expressed as a percentage of source light. Thus, relative contrast may be expressed by the following relation:

$$C_{rel} = (B - S) / B$$

where S is the light transmittance corresponding to the projected test symbol and B is the light transmittance corresponding to the surrounding reference background. Consequently, a relative contrast value of 0 indicates an absence of contrast between the projected test symbol and the reference background; conversely, a value of 1

indicates maximum contrast between the projected test symbol and the reference background.

Referring to Figure 1a, projected unpolarized source light, represented by light paths 8′ and 8′′, is intersected by vectographic slide 10, which is orthogonally situated with respect to the incident light. Vectographic slide 10 includes polarized test symbol 12 printed on transparent film 14. Test symbol 12, in the form of uppercase letter A, has a direction of polarization or polarization axis 12′ and intersects light path 8′. Direction of polarization 12′, shown in Figs. 1a through 1c as being horizontal for explanatory purposes, may be arbitrarily chosen. The transparent portion of slide 10, which functions to produce a reference background for the projected image of test symbol 12, intersects light path 8′′. Since unpolarized source light along path 8′ can be considered as being half horizontally polarized and half vertically polarized, polarized test symbol 12 transmits only the horizontally polarized portion of the light; consequently, the transmittance through the test symbol is 50 percent and the transmitted light along path 8′ becomes horizontally polarized. The transparent portion 14 of vectographic slide 10 transmits 100 percent of unpolarized incident source light along path 8′′, and the light remains unpolarized.

The light is then intercepted by rotatable polarization analyzer 16, which is orthogonally situated

with respect to the incident light. In Figure 1a, analyzer **16** has a horizontal direction of polarization or polarization axis **16'**, hence the included angle θ between test symbol polarization axis **12'** and analyzer polarization axis **16'** is 0 degrees. At this angle of rotation, analyzer **16** transmits 50 percent of the unpolarized light along path **8''** which had been completely transmitted by the transparent reference background **14**. The light along path **8'** which was horizontally polarized by test symbol **12** is completely transmitted by analyzer **16** where the analyzer polarization axis **16'** substantially matches the direction of polarization of the incident light, as shown in Figure 1a. Consequently, all of the light which has passed through analyzer **16** is of homogeneous intensity corresponding to a 50 percent transmittance of source light.

The light then illuminates display screen **20**. Because the transmittance of light for test symbol **12** is equal to the transmittance of light for reference background **14**, the relative contrast is zero and projected test symbol image **22a** is indistinguishable from projected background **24**.

Figure 1b illustrates the effect of rotating analyzer **16** through an angle of rotation θ equal to 45 degrees. The reference background transmittance along path **8''** remains at 50 percent, while the test symbol transmittance along path **8'** varies continuously as a function of the angle of rotation θ according to the equation $S_2 = S_1\cos^2\theta$, where S_2

is the test symbol transmittance through analyzer **16** and S_1 is the test symbol transmittance through vectographic slide **10**, both as a percentage of source light. For θ equal to 45 degrees, the test symbol transmittance S_2 is reduced to 25 percent, resulting in a darkened test symbol image **22b** at display screen **20** in relation to projected reference background **24**, and the relative contrast becomes 0.5.

If analyzer **16** is further rotated such that θ equals 90 degrees, as shown in Figure 1c, a condition of maximum relative contrast is reached. Where analyzer polarization axis **16'** is perpendicular to test symbol polarization axis **12'**, test symbol transmittance along path **8'** is eliminated and the relative contrast value is 1 for test symbol image **22c** in relation to reference background **24**.

The graph in Fig. 1d represents the continuous variation of relative contrast as included angle θ is varied from 0 through 90 degrees.

Referring now to Figure 2, a schematic representation of a chart projector system in accordance with a preferred embodiment of the present invention is shown. Light source **32**, such as the filament of a projection lamp, condensing lens **34**, and filter system **36** combine in a known manner to generate light path **30** along projection axis **28**. A vectographic slide **38** is orthogonally aligned to intersect light path **30** at film plane **40**. Light along light path **30** which is transmitted by vectographic slide **38** is then caused to intersect modifier **42** selectively positioned and

oriented orthogonal to the light path. Conventional projection lens **44** is provided to project the resultant image transmitted by the modifier onto screen **46**.

Modifier **42** is shown more fully at Fig. 3 and includes rotatable polarization analyzer **54** fixed within cell **52**, which is rotatably mounted within counterbored seat **50**. A conventional rack and pinion assembly is provided to permit rotation of analyzer **54** by a user. Drive knob **58**, which is rotatably mounted to modifier **42**, drives a concentrically attached pinion gear **60** engaged with rack **62**, resulting in linear motion of rack **62** relative to cell **52**; teeth on rack **62** mate with peripheral gear teeth on cell **52**, causing the cell and analyzer to rotate. The linear motion of rack **62** is limited by limit stops **64a** and **64b** such that the rotational motion of analyzer **54** is correspondingly restricted to an included angle of 90 degrees. Alternative systems (not shown) are contemplated for rotating the analyzer, such as a drive gear internally mounted on the projector to engage one side of a two-sided rack when the modifier is slid into position and the other side of the rack engaging teeth on the cell, or a lead screw system whereby threads on a knobbed lead screw directly engage worm gear teeth on the periphery of the cell. By varying factors of a particular rotational system, such as gear ratios and/or pitch, suitable speed and precision for rotating analyzer **54** may be achieved. It is also within the scope of the present invention to provide tandem

rotatable analyzers on modifier 42 by adding a second cell and analyzer proximate the first cell and analyzer whereby both analyzers may be rotated by the same drive mechanism.

The orientation of the analyzer is preferably indicated as part of the projected image appearing on the screen, thereby enabling the practitioner to easily view a quantitative measure of the patient's contrast sensitivity while administering an examination in a darkened room. Referring to a preferred arrangement illustrated in Figure 4, the angle of analyzer rotation is generally indicated by a scale marker 74 which is fixed relative to analyzer 70 and which moves relative to stationary radial reference scale 72 as the analyzer is rotated, thereby marking a point on reference scale 72 corresponding to the angular rotation of analyzer 70; a rotation of approximately 38 degrees is shown in Figure 4. Reference scale 72 is preferably printed on the vectographic chart slide or, in the alternative, on a separate transparency. Projection of scale marker 74 is preferably achieved by providing a shaped cutout in analyzer 70 suitably located with respect to reference scale 72 whereby a relatively bright region will be projected onto the screen at the appropriate reference scale line, or a miniature short focal length lens may be inserted into a circular cutout in analyzer 70 and cemented in place to project a relatively bright spot onto the screen image. In the alternative, a shaped opaque overlay may be encorporated on the analyzer to produce a

shadow on the projected image at the appropriate scale line.

An additional scale is preferably provided to allow the examining practitioner to directly obtain a measure of relative contrast that is not expressed in degrees. A contrast scale **76** calibrated in accordance with $\cos^2\theta$ is shown in Figure 4, with readings ranging from 0 through 10; other suitable scales, such as linear scales (not shown) ranging from 0 through 10 with each unit equal to 9 degrees of rotation, or one-tenth of the contrast range, may also be employed. Like scale marker **74**, calibrated contrast scale **76** is preferably fixed relative to analyzer **70** and moves relative to reference scale **72** as the analyzer is rotated; a reading may be obtained by comparing the contrast scale position in radial alignment with a zero setting **78** on reference scale **72**. In the alternative, a calibrated contrast scale may be printed bi-ocularly, and in registry, thereby achieving high optical density.

An alternative embodiment of the present invention is illustrated by Figure 5 with reference to prior U.S. Patent No. 3,655,276 issued on April 11, 1972 to Wilkinson, the specification and drawings of which are incorporated herein. U.S. Patent No. 3,655,276 relates to an ophthalmic refracting chart projector in which slides are mounted peripherally around discs which are rotatable relative to the projector light path such that an operator may selectively place desired slides in the light path by

remote control. As described at column 1, line 73 through column 2, line 3, slide apertures disposed around the periphery of a first disc may be equipped, as desired, with rotatable cells for holding certain test slides, for instance a paraboline chart slide. A form of the present invention is carried out by locating a polarization analyzer within a rotatable cell on the first disc and mounting a vectographic slide on a second disc located between the projector light source and the first disc. When the vectographic slide and analyzer are aligned along the projector light path, the analyzer may be rotated to vary the contrast of the projected chart image.

Fig. 5 herein shows a portion of a disc **80** with peripheral apertures **82**. A rotatable cell **86** is set into aperture **84** and polarization analyzer **88** is secured within cell **86** to rotate therewith. Rotation of cell **86** is effected by a motor-driven gear train as described in the above-referenced patent at column 2, lines 8-26 and 53-54, and at column 3, lines 21-23.

A further embodiment of the present invention is practiced by rotatably supporting a polarization analyzer in a conventional ophthalmic refractor. A practitioner may then rotate the analyzer to vary the relative contrast of a projected vectographic slide image or a vectographic near-point card as viewed by a test subject.

A conventional refractor is disclosed in prior U.S. Patent No. 3,498,699 issued March 3, 1970 to Wilkinson, the

specification and drawings of which are incorporated herein. The refractor has right and left batteries for enabling the practitioner to position various corrective lenses on a test axis in viewing alignment with the test subject's eyes and a viewing tube, with each battery having a sphere lens assembly and a cylinder lens assembly. As described at column 5, lines 61-76, the practitioner may control the orientation of the cylinder lenses by rotating a cylinder axis control knob.

Figure 6 herein shows a conventional refractor in cross-section. A polarization analyzer is rotatably mounted in either disc **94a** or **94b** where a cylinder lens typically resides, at either **90a** or **90b**, by cell **92a** or **92b**, respectively. Rotatable control knob **96** acts through a gear train to effect rotation of the analyzer, as disclosed in the above-incorporated patent for the case of a cylinder lens. Suitable visual indication of the analyzer's orientation may be provided as described at column 6, lines 29-42 of referenced U.S. Patent No. 3,498,699.

What is claimed is:

1. A visual acuity chart projector which comprises, a projection axis, a test slide positioned on said axis, said test slide being transparent and having a polarized test symbol and an unpolarized reference background surrounding said test symbol, means for positioning said test slide on said axis, a polarization analyzer positioned on said axis, said analyzer having a direction of polarization, means for positioning said analyzer on said axis, and means for changing the direction of polarization of said analyzer, whereby the contrast between a projected image of said test symbol and a projected image of said reference background is varied by changing the direction of polarization.

2. A chart projector according to claim 1, wherein said test slide further includes a reference scale and said analyzer further includes a reference scale marker coacting with said reference scale, said reference scale and reference scale marker being projected with said test symbol, whereby said direction of polarization is indicated.

3. A visual acuity test system which comprises, a test axis, a corrective lens positioned on said test axis, first support means for positioning said corrective lens on said test axis, a polarization analyzer positioned on said test axis, said analyzer having a direction of polarization, a second support means for positioning said analyzer on said test axis, means for varying the direction of polarization of said analyzer and means for providing a polarized test symbol having a surrounding unpolarized reference background on said test axis, whereby the contrast between said polarized test symbol and said surrounding reference background therefor is varied by changing the direction of polarization of said analyzer for testing visual acuity under varying contrast conditions.

4. A visual acuity test system according to claim 3, wherein said test symbol is a projected image.

5. A visual acuity test system according to claim 3, wherein said means for providing a polarized test symbol includes a vectographic near-point card.

6. A refractor comprising a pair of batteries, each said battery including:

a test axis;

a viewing tube aligned on said test axis;

a sphere lens assembly comprising a plurality of corrective lenses and means for selectively aligning at least one of said corrective lenses with said viewing tube;

a cylinder lens assembly comprising at least one disc, said disc having a plurality of cells for mounting optical elements therein;

means for rotating said disc for selectively aligning any one of said optical elements with said viewing tube;

a polarization analyzer mounted in one of said cells, said analyzer having a direction of polarization; and

means for rotating said analyzer to change the direction of polarization when said analyzer is aligned with said viewing tube;

whereby the contrast between a polarized test symbol and an unpolarized reference background therefor is varied by changing the direction of polarization of said analyzer.

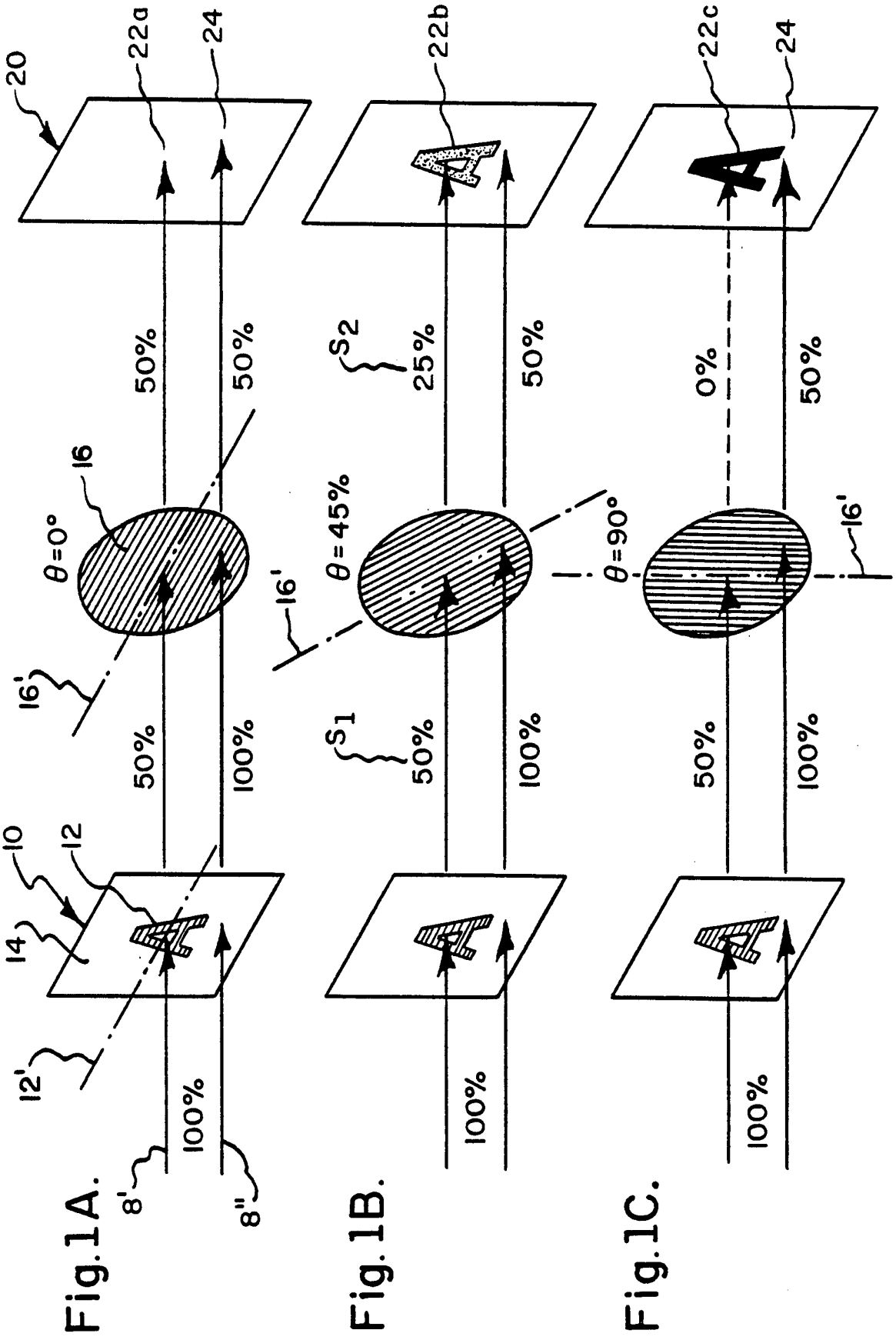

20
22a
24
50%
50%
16
θ=0°
16'
50%
100%
10
12
14
12'
100%
8'
8"
Fig.1A.
22b
S2
25%
50%
θ=45°
16'
S1
50%
100%
100%
Fig.1B.
22c
24
0%
50%
θ=90°
16'
50%
100%
100%
Fig.1C.

Fig. 1D

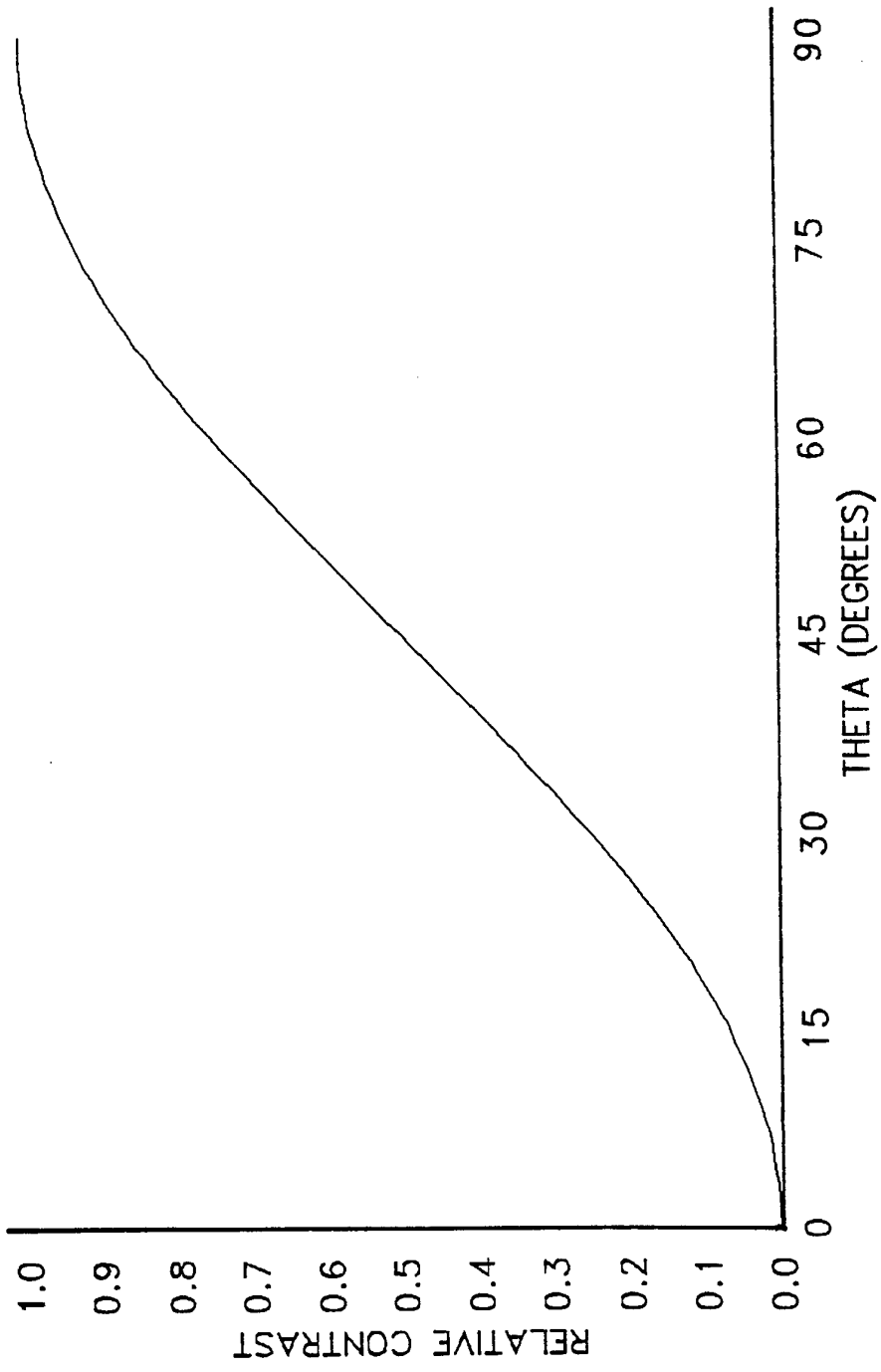

RELATIVE CONTRAST AS A FUNCTION OF INCLUDED POLARIZATION ANGLE THETA
RELATIVE CONTRAST
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
15
30
45
60
75
90
THETA (DEGREES)

Fig. 2.

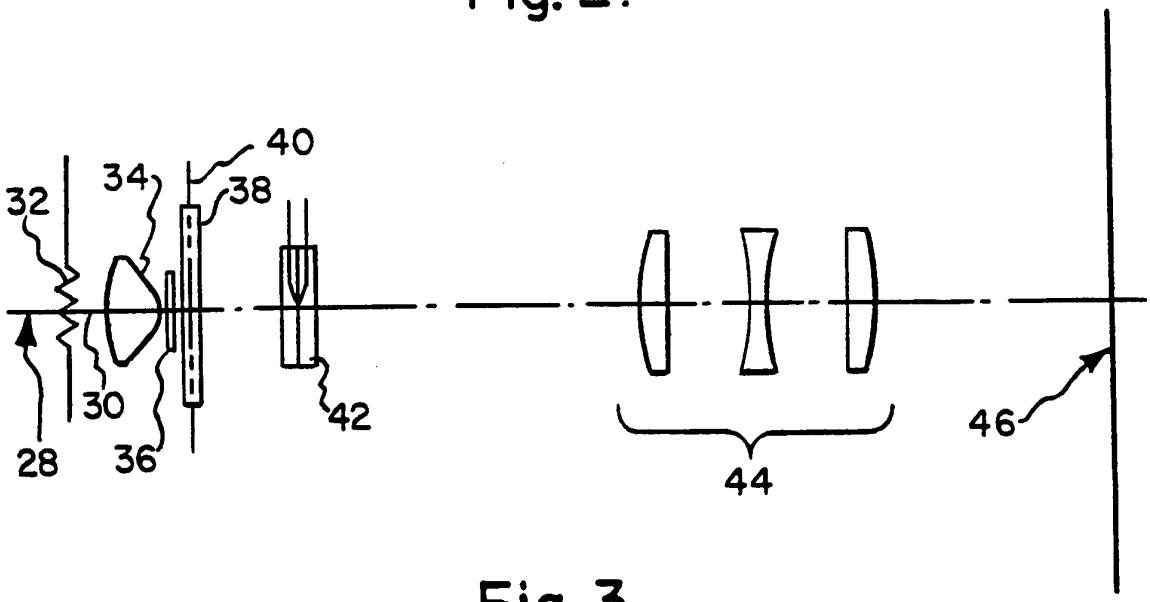


Fig. 3.

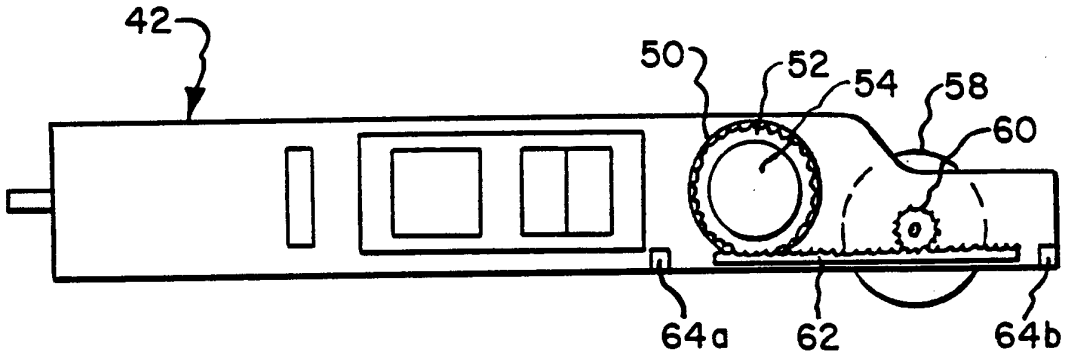


Fig. 5.

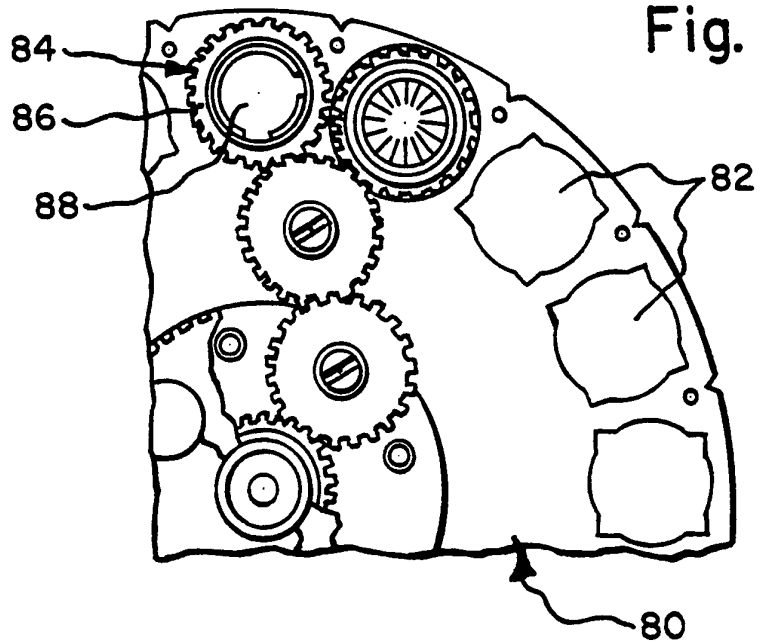


Fig. 4.

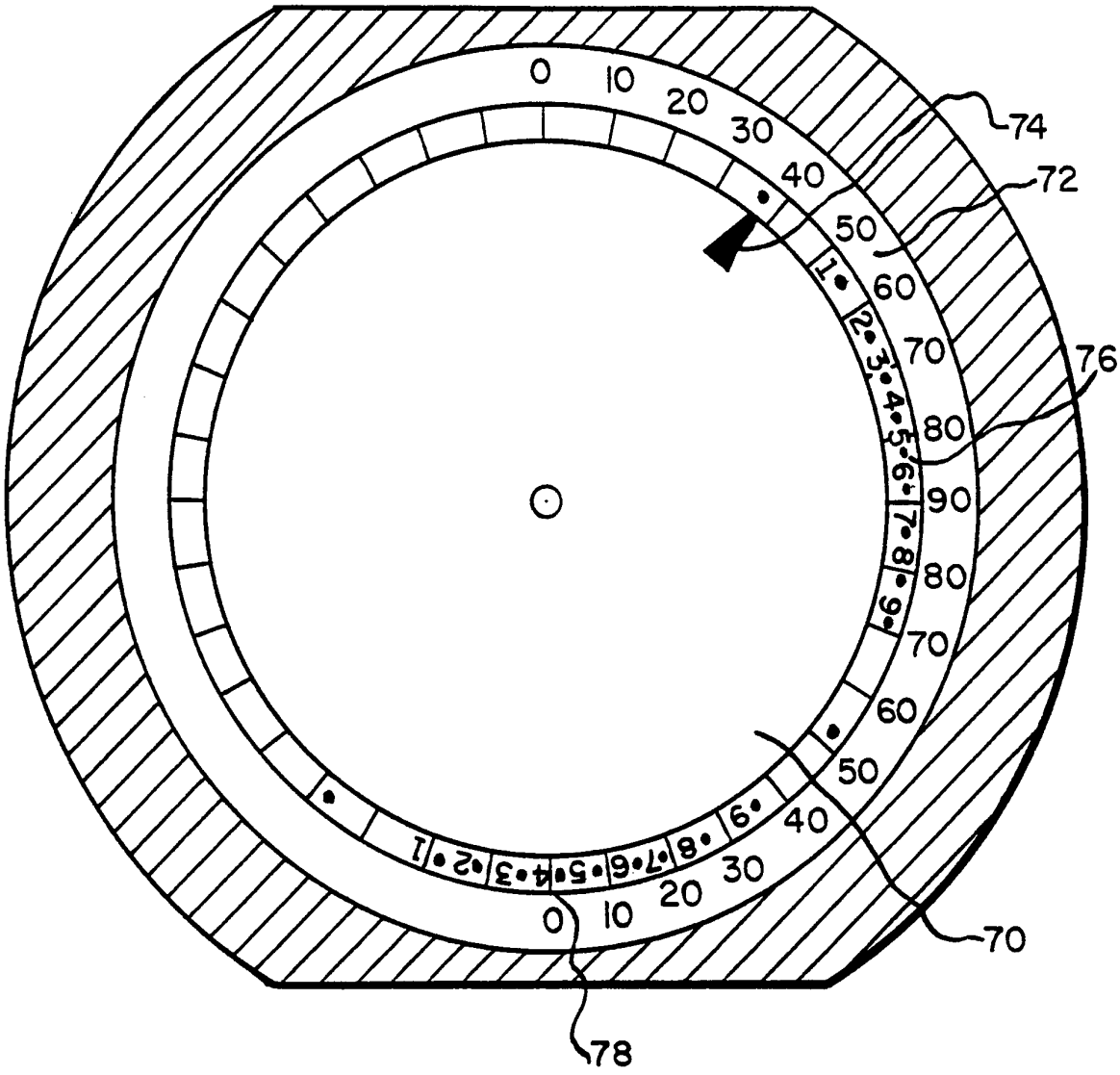
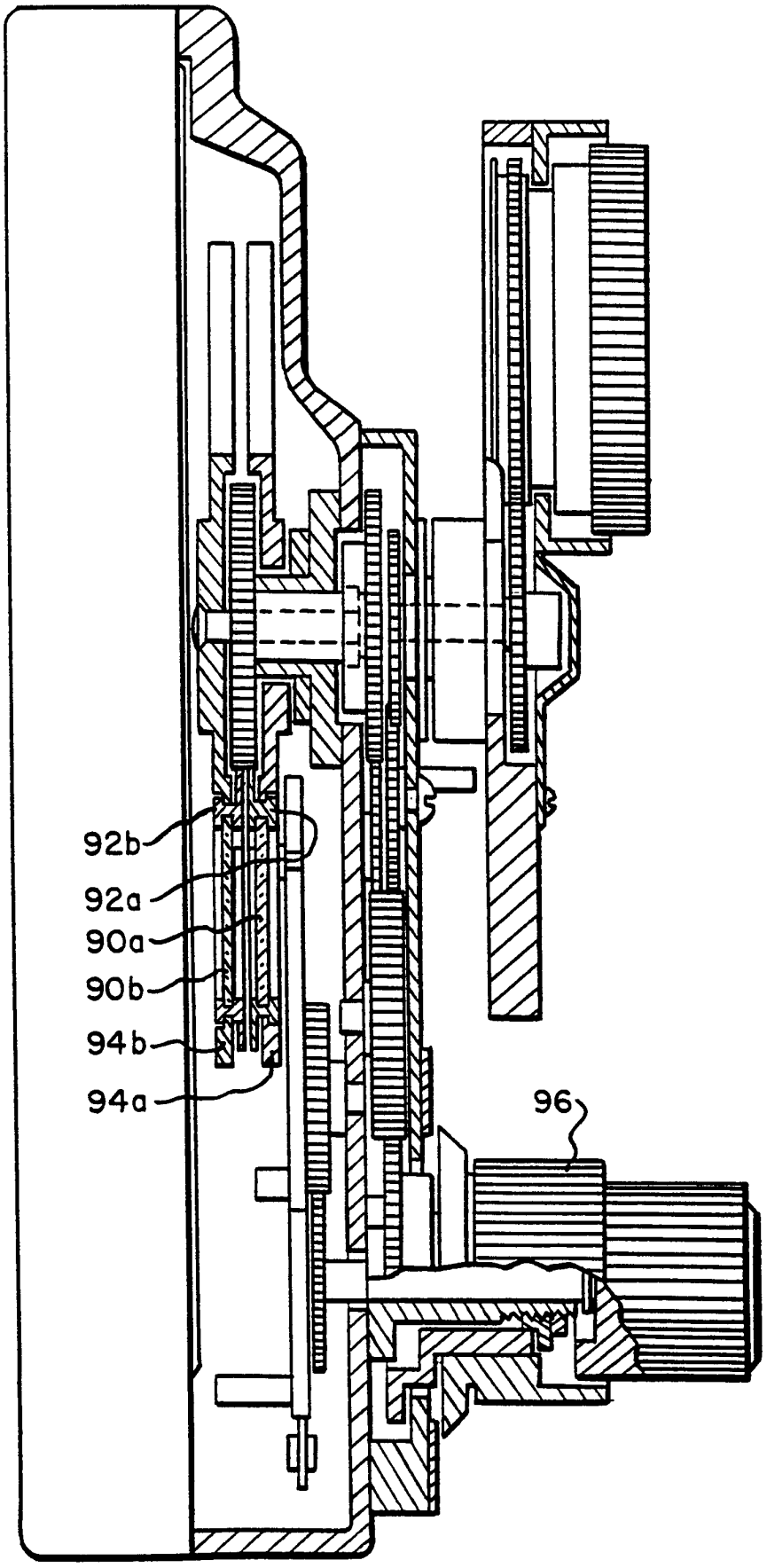

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4
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6
7
8
9
74
72
76
70
78

Fig. 6.



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/06623

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :A61B 3/02, 3/032

US CL : 351/232, 234, 237, 239, 243

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 351/222, 232, 233, 234, 237, 239, 243; 359/485, 501

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, JPOABS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 5,216,458 (Andera et al) 01 June 1993. See entire document.	1-6
A	US, A, 2,933,977 (Landis) 26 April 1960. See entire document.	1-6
A	US, A, 2,280,297 (Neumueller et al) 21 April 1942. See entire document.	1-6
A	US, A, 2,206,303 (Neumueller et al) 02 July 1940. See entire document.	1-6

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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