Oct. 13, 1931. H. NYQUIST 1,826,812

ELECTROOPTICAL TRANSMISSION

Filed May 26, 1927 2 Sheets-Sheet 1

FIG. 1

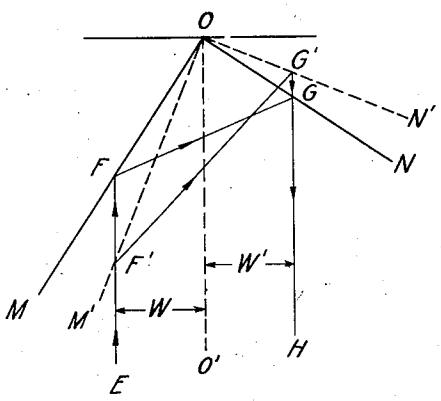


FIG. 2.

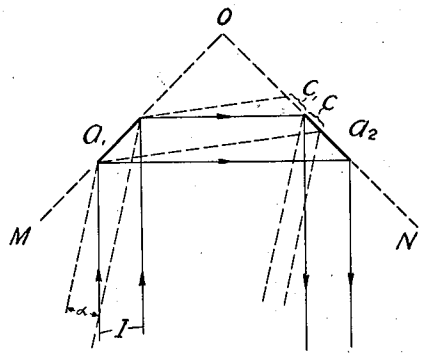


FIG. 3.

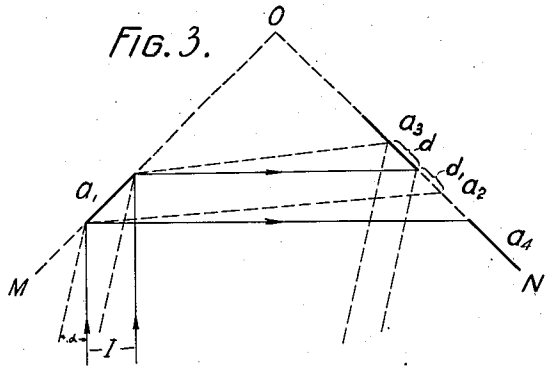
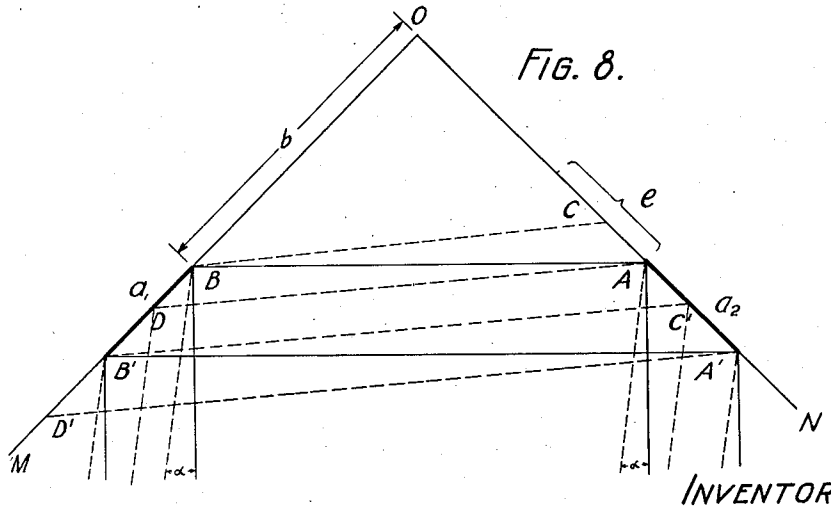


FIG. 8.



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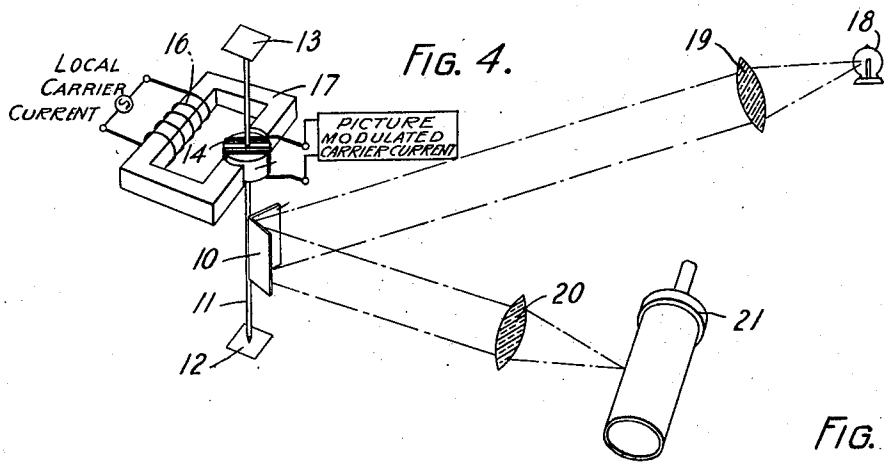


FIG. 4.

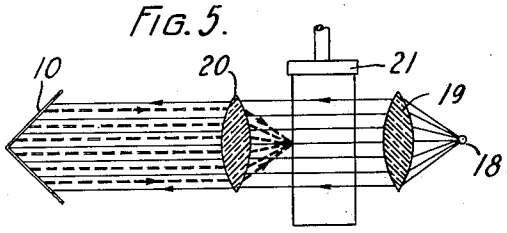


FIG. 5.

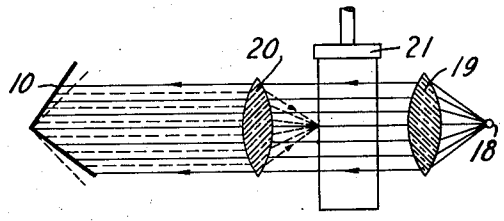


FIG. 6.

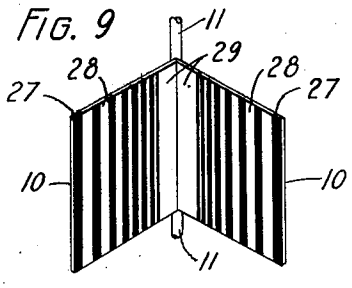


FIG. 9

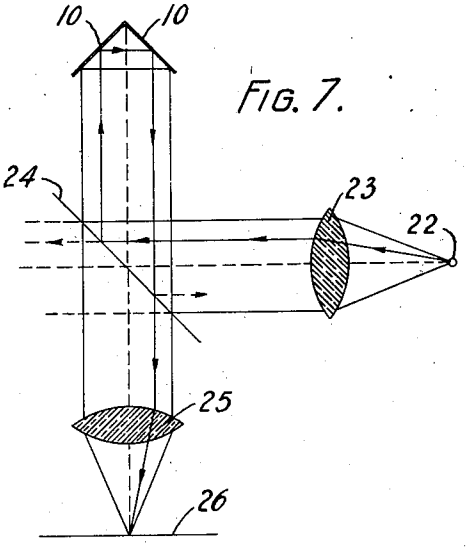


FIG. 7.

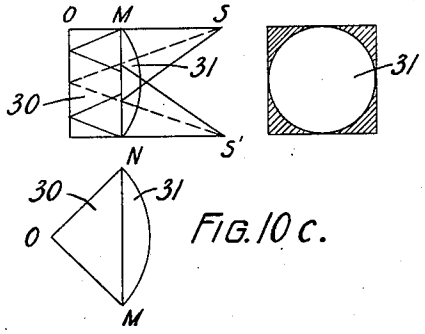


FIG. 10a. FIG. 10b. FIG. 10c.

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UNITED STATES PATENT OFFICE

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ELECTROOPTICAL TRANSMISSION

Application filed May 26, 1927. Serial No. 194,381.

This invention relates to translating variable energy of one form into variable energy of another form, and more particularly to the translation of electric energy into light of varying intensity for producing an image or picture at the receiver of a picture transmission system.

Heretofore, it has been customary in the electrical transmission of pictures to transmit picture currents, corresponding to the tone values of a picture, from a sending station to a receiving station, a light valve being actuated by the received picture currents to control the amount of light, to which a sensitive film is exposed. A more complete disclosure of a picture transmission system of this type may be found in Patent No. 1,606 227, issued to Horton, Ives and Long, November 9, 1926.

A specific embodiment of the present invention, herein chosen for purpose of illustration, comprises two plane mirrors having their planes intersecting at right angles and controlled by incoming picture current at the receiving station, which mirrors take the place of the light valve used in the system above described. The term "90 degree mirror" is used hereinafter to designate such an arrangement of plane mirrors. This "90 degree mirror" rotates about an axis at the line of intersection. The surfaces consist of alternately reflecting and non-reflecting strips of gradually increasing width from the line of intersection. The rotation of the 90 degree mirror is controlled jointly by picture currents received from a transmission line, which currents pass through a movable coil attached to the 90 degree mirror, and by current from a local source which passes through a stationary coil, the position of the 90 degree mirror varying in accordance with the amount of current received from the line. A constant light source is arranged to project a beam of substantially parallel rays of light toward the surfaces, the axis of the beam being directed toward the axis, or intersection line, of the surfaces and at an angle thereto. The reflected beam from these surfaces is directed to a focal point on a light sensitive surface, such as a photographic film. The amount of light reflected by the surfaces and, therefore, the intensity of the light at the focal point will vary directly with the angular change in position of the surfaces as controlled by the picture currents received from the sending station. The reflecting strips on the surfaces may be so designed as to give a non-linear relation between the light intensity and the received current strength.

The invention will be more fully explained in the following detailed description having reference to the accompanying drawings.

Figures 1, 2 and 3 are various diagrams used for explaining the principles on which the invention is based;

Fig. 4 is a perspective view of one embodiment of the invention in a receiver or an electro-optical system illustrating an arrangement of the 90 degree mirror with respect to an incident beam from a light source and a reflected beam directed to a sensitive surface, the axis of the incident beam being at an angle of inclination less than 90 degrees to the axis of the 90 degree mirror;

Fig. 5 is a diagrammatic plan view of Fig. 4 showing the intensity of the reflected light obtained when the 90 degree mirror is in normal position;

Fig. 6 shows the change in intensity of reflected light when the 90 degree mirror is moved to another angular position with respect to the light source;

Fig. 7 shows diagrammatically a modified arrangement of the invention in which a semi-transparent mirror is positioned at an angle of 45 degrees with respect to the axes of the incident beam and the reflected beam;

Fig. 8 is an enlarged diagram of the 90 degree mirror used in explaining the construc-

tion of a mirror in accordance with this invention;

Fig. 9 is a perspective view of a 90 degree mirror embodying this invention with alternate reflecting and non-reflecting parallel strips on the surfaces; and

Figs. 10*a*, 10*b* and 10*c*, respectively, show side, front and plan views of a modified arrangement of a combined lens and 90 degree mirror according to this invention.

The principles on which the invention is based may be better understood by referring to Figs. 1, 2 and 3. In Fig. 1 there are represented two plane mirrors OM and ON perpendicular to the plane of the drawings and intersecting at right angles as shown at O. A ray of light EF is projected on the mirror OM and reflected from point F on the mirror OM to point G on the mirror ON, the reflected ray being again reflected to a point H. Considering the two mirrors as a unit, EF may be called the incident ray and GH the reflected ray. These rays are parallel and if a line O—O′ is drawn from the intersection O of the mirror unit parallel to the rays EF and GH, it will be seen that $\omega' = \omega$ where ω and ω' are perpendicular to O—O′. It, therefore, follows that if the mirror unit is rotated about an axis through O, the line of intersection of the mirror surfaces, to the position OM′ and ON′ so that the incident ray strikes the mirror OM′ at point F′ and is reflected to point G′ on the mirror ON′, then the second reflected ray G′H coincides with the first reflected ray GH, i. e., the reflected ray is unaltered in location and direction by the rotation of the mirror unit, provided the angle between the surfaces OM and ON is maintained at 90 degrees. Consequently, if a beam of light is so directed at the mirror unit that the axis of the beam passes through the axis O, the beam will be reflected without inversion and the axis of the reflected beam will also pass through the intersection O, regardless of the angular position of the 90 degree mirror. The effect of the 90 degree mirror is to reverse exactly the direction of the beam.

In Fig. 2, the plane surfaces OM and ON are altered so that only the strips a_1 on the plane OM and a_2 on the plane ON reflect light. These strips are equal in size and equi-distant from the axis O. Now if a beam of light I is directed to the 90 degree mirror and the mirror is rotated to a position so that the angle of incidence of the beam is 45 degrees (this position will be called the normal position), that portion of the beam which falls on a_1 will be completely reflected from a_2 and vice versa. If the axis of the beam is rotated through an angle α, which is the same as rotating the mirror through the same angle, only a portion of the beam directed to the reflecting strip a_1 on the plane OM will be reflected to the reflecting strip a_2 on the plane ON, as indicated by *c*. The portion *c* will again be reflected parallel to the axis of the incident beam. The portion c_1 falling outside of a_2 will not be reflected. In a similar manner a portion of the incident beam reflected from a_2 which is totally reflected by a_1 with the 90 degree mirror in normal position, will now fall outside of a_1 and not be reflected. It is evident, then, that the amount of light reflected by the reflecting strips a_1 and a_2 depends on the position of the 90 degree mirror with respect to the light source and is less the greater the value of α up to the point where no light is reflected.

In Fig. 3, the conditions are varied by making the portion a_2 on the plane ON non-reflecting and providing reflecting strips a_3 and a_4 on either side of the non-reflecting strip a_2. In this case, the incident beam I directed to the reflecting strip a_1 on the plane OM is not reflected when the 90 degree mirror is in normal position, i. e., when the 90 degree mirror is at an angle of 45 degrees with respect to the axis of the light beam. However, if the axis of the beam is rotated through an angle α as described in connection with Fig. 2, a portion of the incident beam reflected by a_1 will fall on a_3, as indicated by *d*, and be reflected and the portion d_1 will not be reflected. Likewise, a part of the incident beam reflected by a_3 will fall on a_1 and be reflected. It is obvious, then, that in this case the amount of light reflected by the reflecting strips will also depend on the position of the 90 degree mirrors but here will be greater the greater the value of α, varying from zero to a point where all the incident light directed to a_1 and a_3 will be reflected.

The arrangement of a 90 degree mirror in a receiver of an electro-optical system is shown in Fig. 4, in which a pair of rectangular plane surfaces 10, are arranged at right angles to each other and are attached to a common shaft 11 at the line of intersection. These surfaces are provided with alternate reflecting and non-reflecting strips. The shaft is mounted between jeweled bearings 12 and 13 to form an assembly which can be rotated about its axis. The movement of the 90 degree mirror is controlled by current from a source of picture modulated carrier current 40 transmitted from a sending station which passes through a movable coil comprising a winding 14 surrounding an armature 15 attached to the shaft 11 intermediate the bearing 13 and the rectangular surfaces 10. A system for producing picture modulated carrier current is disclosed in detail in the patent to Horton, Ives and Long referred to hereinbefore. A source of local carrier current 41 exactly synchronized with the carrier component of the current received from the sending station is passed through a fixed coil comprising a winding 16 surrounding an arm of the core 17 which is provided with inwardly projecting legs

positioned at either side of the armature 15. The arrangement of the movable coil and the fixed coil is similar to that employed in the ordinary dynamometer. A source of light 18 is placed at the principal focus of a projecting lens 19 which is used to produce a beam of light having its axis directed to the axis, or intersection line, of the 90 degree mirror at an angle of inclination less than 90 degrees, with respect to the vertical axis of the 90 degree mirror, so that the reflected beam from the 90 degree mirror is directed to a focal point, through a lens 20, on a sensitive surface such as a photographic film surrounding a rotatable carrier 21. The axis of the reflected beam is at an opposite angle of inclination with respect to the axis of the incident beam. The angle of inclination of the incident and reflected beams should, however, be no smaller than is necessary to obtain the desired separation of the incident and reflected beams. Furthermore, in this simple arrangement of the light source with respect to the 90 degree mirror, it is desirable to have the axes of the incident and reflected beams in the same vertical plane. This is more clearly shown in Figs. 5 and 6 in which Fig. 5 indicates the maximum value of the intensity of the reflected beam in dotted lines when the 90 degree mirror is in normal position; and Fig. 6 indicates a reflected beam of lesser intensity, due to the rotation of the 90 degree mirror so that the incident rays of light are only partially reflected. It is evident that rotation of the 90 degree mirror will cause no displacement of the reflected beam in a horizontal plane and since the path of the ray remains constant in length for all positions of the 90 degree mirror, there will be no displacement of the reflected beam in a vertical plane. Thus, the reflected beam remains stationary for all the angular positions of the 90 degree mirror with respect to the constant light source, but the intensity of the reflected beam varies with the deflection of the 90 degree mirror.

A modified arrangement of the light source with respect to the movable 90 degree mirror is shown in Fig. 7 in which a source of light 22 is placed at the principal focus of a projecting lens 23 which is used to produce a beam as shown with its axis in the plane of the drawings. This beam encounters a half-silvered or semi-transparent mirror 24 arranged at an angle of 45 degrees. Part of the beam directed to the mirror 24 passes through the mirror and is lost and the remainder of the beam is reflected to the 90 degree mirror with the axis of the incident beam directed at the axis, or intersection line, of the 90 degree mirror. The light reflected by the 90 degree mirror has the same axis as the incident beam and will also encounter the semi-transparent mirror 24. Here again a portion of the light is reflected and lost but the remainder passes through the mirror 24 to a lens 25 which brings the reflected beam to a focus at a point on the surface 26. The amount of light reflected by the 90 degree mirror 10 and, therefore, the intensity of the light at the focal point on the surface 26 will vary in accordance with the position of the 90 degree mirror 10 as controlled by the received current, the same as hereinbefore described in connection with Fig. 4.

This invention will find embodiment in a great variety of forms. Probably the most usual form will be that in which the change in intensity of the reflected light from the normal intensity will vary directly with the angular change in position of the 90 degree mirror from its normal position. For this to be so, certain conditions must exist and these will now be determined having special reference to Fig. 8. In this figure strips a_1 and a_2 are two reflecting surfaces, each having the width a.

A beam of light is projected on the surfaces MON of sufficient width to cover the surfaces. It is assumed that the amount of light incident to the strips a_1 and a_2 is the same for all positions of the surfaces MON. This is approximately true only when the deflection of the surfaces from their normal position is small. b is the distance of a_1 and a_2 from the axis O measured to the inner edge of the reflecting surfaces. In the normal position of the surfaces MON all the incident light reflected by a_1 and a_2 is again reflected by a_2 and a_1, respectively. If the light beam is rotated through an angle α, which is the same as rotating the surfaces MON about the axis O through the same angle, the beam reflected from a_1 to the surface ON falls on CC′ instead of being wholly reflected to a_2, and only that portion of the beam which falls on a_2 is reflected for useful purposes.

Now

$$OC=b\tan\left(\frac{\pi}{4}-\alpha\right)$$

and

$$AC=b-OC=b\left[1-\tan\left(\frac{\pi}{4}-\right)\right]=\frac{2b\tan\alpha}{1+\tan\alpha}=2bK,$$

where

$$K=\frac{\tan\alpha}{1+\tan\alpha}.$$

Similarly,

$$A'C'=2\ (a+b)K.$$

Therefore

$$R_1=\frac{\text{amount of light reflected by } a_2}{\text{amount of light incident to } a_1}=\frac{AC'}{CC'}=\frac{a-2(a+b)K}{a-2(a+b)K+2bK}=\frac{a-2aK-2bK}{a-2aK}=1-\frac{2bK}{a-2aK}$$

In like manner, the incident light reflected from a_2 to the surface OM falls on DD′ instead of a_1 and only that portion of this beam which falls on a_1 is reflected for use. In this case

$$BD=2bK' \text{ and } B'D'=2(a+b)K',$$

where

$$K'=\frac{\tan\alpha}{1-\tan\alpha}.$$

$$R_2=\frac{\text{amount of light reflected by } a_1}{\text{amount of light incident to } a_2}=\frac{a-2bK'}{a-2bK'+2(a+b)K'}=$$

$$\frac{a+2aK'-2(a+b)K'}{a+2aK'}=1-\frac{2(a+b)K'}{a+2aK'}.$$

$$\frac{R_1+R_2}{2}=\frac{\text{intensity of reflected beam}}{\text{normal intensity of reflected beam}}=1-\frac{bK}{a-2aK}-\frac{(a+b)K'}{a+2aK'},$$

and

$$\frac{\text{change in intensity}}{\text{normal intensity}}=\frac{bK}{a-2aK}+\frac{(a+b)K'}{a+2aK'}.$$

Assuming that the rotation of the 90 degree mirror from the normal position is sufficiently small so that $\tan\alpha=\alpha$ then

$$K=\frac{\alpha}{1+\alpha} \text{ and } K'=\frac{\alpha}{1-\alpha};$$

from which

$$\frac{\text{change in intensity}}{\text{normal intensity}}=\frac{b\alpha}{a(1-\alpha)}+\frac{(a+b)\alpha}{a(1+\alpha)}.$$

This has been shown to be true for one pair of reflecting surfaces but is equally true for any number of such pairs provided they are sufficiently separated to avoid diffraction. In order that as many strips as possible may be placed on the surfaces OM and ON without interference, the width of the strip (non-reflecting) adjacent to and inside of a_1 and a_2 should be equal to CC′, when $A'C'=a$; i. e., when

$$K=\frac{a}{2(a+b)}.$$

For this case, the width of the strip is

$$e=\frac{ab}{a+b}.$$

From this,

$$\frac{e}{b}=\frac{a}{a+b};$$

and it is evident that the width of any strip is proportional to the distance of the outside edge of the strip from the point O.

Considering now the case in which no light is reflected for the normal position of the mirrors, a_1 and e are reflecting surfaces and a_2 is non-reflecting. Using the same notation as before, it can be shown that

$$R_1=\frac{\text{amount of light reflected by } e}{\text{amount of light incident to } a_1}=\frac{2bK}{a-2aK},$$

$$R_2=\frac{\text{amount of light reflected by } a_1}{\text{amount of light incident to } e}=\frac{2bK'}{e+2eK'},$$

and

$$\frac{aR_1+eR_2}{a+e}=\frac{\text{intensity of reflected beam}}{\text{intensity of incident beam}}.$$

Now, this is equally true for a number of pairs of such strips and as before for the greatest number of strips without interference

$$e=\frac{ab}{a+b};$$

and if a is small compared with b, $e=a$ (approximately). In this case

$$\frac{aR_1+eR_2}{a+e}=\frac{R_1+R_2}{2}$$

and

$$\frac{\text{intensity of reflected beam}}{\text{intensity of incident beam}}=\frac{bK}{a-2aK}+\frac{(a+b)K'}{a+2aK'}$$

Assuming as before that $\tan\alpha=\alpha$,

$$\frac{\text{change in intensity}}{\text{intensity of incident light}}=\frac{b\alpha}{a(1-\alpha)}+\frac{(a+b)\alpha}{a(1+\alpha)}$$

This is the same result as obtained for the preceding case.

In either case, then, provided $\tan\alpha=\alpha$, the change in intensity of the reflected beam is proportional to the quantity

$$\frac{b\alpha}{a(1-\alpha)}+\frac{(a+b)\alpha}{a(1+\alpha)}$$

or

$$\frac{\alpha(2b+a-a\alpha)}{a(1-\alpha 2)}.$$

For this quantity to vary as α,

α^2 must be small compared to 1,

and

$a\alpha$ must be small compared to $2b+a$.

As α has already been assumed small, these conditions will ordinarily be satisfied. If we assume further that a is small compared with b, the conditions are more easily satisfied. Therefore, the device described above will give a linear variation in intensity with deflection if the deflection is always small.

It has been assumed above that $\tan\alpha=\alpha$; i. e., α can not be much greater than 3° for maximum deflection. For maximum deflection and $\alpha=3°$,

$$e=\frac{2b\tan 3°}{1+\tan 3°}=0.0995b;$$

i. e., the width of a strip should not be greater than one-tenth of its distance from the apex

O. However, it will be better to use a narrower strip than this, say, one the width of which is one-thirtieth or possibly one one-hundredth of its distance from the apex. The strips should not, of course, be made so narrow that interference effects will result.

Fig. 9 illustrates one form of 90 degree mirror mounted on a shaft 11 in which each surface 10 is provided with alternate parallel reflecting strips 27 and non-reflecting strips 28 of width gradually decreasing from the outer edge of the surfaces to the axis or intersection line of the 90 degree mirror in accordance with the foregoing formulæ. A portion 29 of each surface adjacent to the axis is not used for reflecting purposes due to the effects of light interference and manufacturing limitations. It is understood that the edges of the reflecting and non-reflecting strips on the plane surfaces 10 are parallel to each other and the conditions have been found for a linear variation of light in accordance with the deflection of the 90 degree mirror. In order to compensate for any non-linearity in other parts of the electro-optical system using this device, or if for any reason it is desirable to obtain a non-linear relationship, this can be accomplished by using strips with non-parallel edges, the particular pattern being determined by the case under consideration.

In a telephotographic system such as is disclosed in Patent No. 1,691,071, to H. E. Ives and M. B. Long, November 13, 1928, the operation is such that zero light intensity is received on the film when the line current is a minimum but not necessarily zero. For all values of line current from zero to this allowable minimum, the light intensity on the receiving film remains zero. If the 90 degree mirror of this invention is to be used in such a system the type of mirror should be that which gives zero light intensity for the normal position of the 90 degree mirror; and in order that the intensity will remain zero until the line current exceeds some value, the reflecting strips should be made narrower and the non-reflecting strips wider than those specified above. The amount of change in width of the strips depends on the value assumed for the line current beyond which the light intensity will increase with the current.

The manner of making the surfaces consisting of alternately reflecting and non-reflecting strips may be accomplished by a method similar to that used for diffraction gratings by ruling lines or strips on speculum metal or plate glass. However, for the proper operation of the 90 degree mirror, it is essential that the corresponding strips on the surfaces OM and ON be exact duplicates of each other. Instead of making these surfaces independently, it is recommended that the second surface be laid out photographically from the first surface using a process similar to that employed in photoengraving. After one surface has been laid out with alternate reflecting and non-reflecting parallel strips of graduated widths, the second surface is covered with gelatin mixed with potassium bichromate, or some similar mixture, and then mounted at 90 degrees inclination. By directing a beam of light on the completed surface, the second or prepared surface will be exposed to the light reflected from the first. The unexposed gelatin can then be washed off, the exposed material being insoluble, and the surfaces etched in the usual manner. The second surface will be an exact duplicate of the first surface so that the maximum reflected intensity of light is obtainable when the 90 degree mirror is in normal position.

An alternative arrangement of the rotatable 90 degree mirror and lens system is shown in Figs. 10*a*, 10*b* and 10*c*. In this arrangement, the 90 degree mirror is formed by the narrow sides of a 90 degree prism 30 on the face of which is a lens 31 for projecting the incident beam and focusing the reflected beam. As shown in the side view of Fig. 10*a*, the axes of the incident beam from S and the reflected beam to S_1 are at an angle of inclination less than 90 degrees with respect to the axis O of the prism 30. The outer surfaces OM and ON of the prism 30 may be etched in a manner similar to that described above to form the alternate reflecting and non-reflecting strips on the surfaces. Canada balsam or "frosting" may also be used to produce the non-reflecting strips on the surfaces. The results obtained with this structure are the same as described hereinbefore in connection with Fig. 4, in which, change in intensity of reflected light varies with the change in angular position of the 90 degree mirror with respect to the light source.

This invention has been described above with special reference to its application to picture transmission. It is also applicable to other electro-optical systems such a television, and in general to any system in which variable energy such as variable electric or sound waves, for example, are utilized to vary a beam of radiant energy.

What is claimed is:

1. In combination, a source of varying energy, a source of radiant energy and means to vary the intensity of a beam of radiant energy from said source in accordance with the variations of said varying energy which means comprises a plurality of elements for successively reflecting said beam, the surfaces of said elements being in fixed angular relation, and means for moving said elements in accordance with said energy variations.

2. A combination in accordance with claim 1 in which said reflecting surfaces are plane.

3. A device for utilizing variable energy to vary a beam of radiant energy in accordance with claim 1 in which each of said elements

has a plurality of reflection surfaces separated by a non-reflecting medium.

4. An electro-optical system comprising means for producing a beam of light, a source of varying current and means for utilizing said electric current variations to vary the intensity of said light beam which means comprises a plurality of elements for successively reflecting said beam, the surfaces of said elements being in fixed angular relation, and means for moving said elements in accordance with said current variations.

5. In combination, a source of radiant energy, and means for varying the intensities of radiant impulses from said source, which comprises a pair of planary elements arranged in intersecting planes and rotatable about a common axis, each of said elements having a plurality of reflecting surfaces separated by non-reflecting surfaces and being positioned to reflect energy from said source to the other of said elements.

6. In an electro-optical system, a source of light, a source of varying electrical energy, and means for modifying light from said source in accordance with the variations of the electrical energy from said source, which means comprises a pair of planary elements arranged in intersecting planes and rotatable about a common axis, each of said elements having alternate reflecting and non-reflecting surfaces.

7. A device for translating electrical impulses into light impulses of varying intensities, which comprises a pair of planary elements arranged in intersecting planes and rotatable about a common axis, each of said elements having reflecting surfaces separated by non-reflecting surfaces, said reflecting surfaces being of gradually increasing width from the intersection line of said intersecting planes.

8. In combination, a source of light, and means for varying the intensity of a beam of light from said source, which means comprises a pair of elements, one element being positioned in a plane 90 degrees from the plane of the other element, said pair of elements being rotatable on a common axis, and each element having a plurality of separated reflecting surfaces and so positioned that light from said source is reflected thereby to the other of said elements.

9. A device for varying the intensity of light, which comprises a pair of reflecting surfaces located in planes intersecting at right angles, a lens positioned across the outer edges of said surfaces, and means to rotate said surfaces and lens about the intersection of said planes as an axis.

10. In an optical system for varying the intensity of light waves, a pair of surfaces arranged in intersecting planes at right angles to each other and rotatable about a common axis, a constant light source projecting a beam of light on said surfaces, means on said surfaces for varying the intensity of the reflected light from said constant light source in proportion to the position of said surfaces with respect to said light source, and variable pulsating means for controlling the rotation of said surfaces.

11. In an optical system for varying the intensity of light waves, a pair of surfaces arranged in intersecting planes and rotatable about a common axis, a constant light source projecting a beam of light rays on said surfaces, reflecting strips of varying width on said surfaces parallel with said axis, said beam of light being projected on said strips of either surface and being reflected therefrom, and means for changing the position of said surfaces with respect to said light source, whereby the intensity of the reflected light from said surfaces is directly proportional to the angular position of said reflecting strips with respect to the axis of said beam of constant light.

12. In an electrical picture transmission system, an oscillatory element having surfaces intersecting at right angles, said surfaces having symmetrical reflecting and non-reflecting strips parallel to the axis thereof, means for producing a light beam of constant intensity having its axis directed to the axis of said element, said reflecting strips in normal position producing maximum reflected light from said light beam, and means for controlling the oscillations of said element, said means being energized by current waves, whereby variations in reflected light are produced in accordance with various positions of said strips with respect to said light beam.

13. In an optical system for varying the intensity of light waves, an element having plane surfaces intersecting at right angles and rotatable about a common axis, a source of light projecting a constant beam on said surfaces, means on said surfaces for causing a reflected beam to be projected to an objective, the axes of said beams being at divergent angles less than 90 degrees and inclined to the intersection of said surfaces, and means for causing the rotation of said surfaces to vary the intensity of said reflected beam.

14. In an optical system for varying the intensity of light waves, an element having plane surfaces intersecting at right angles and rotatable about a common axis, a source of constant light, a beam of incident light from said source being projected on said surfaces, means on said surfaces for causing a reflected beam to be projected to an objective, semi-transparent reflecting means in the path of said incident and reflected beams, and means for causing the rotation of said surfaces to vary the intensity of said reflected beam passing through said semi-transparent reflecting means.

15. The method of changing a beam of ra-

diant energy of constant intensity to a beam of varying intensity by means of a 90 degree mirror having multiple reflecting portions, which method comprises projecting said beam upon said mirror, and changing the angular position of said mirror with respect to said beam so that the intensity of the reflected beam from said mirror is a function of the instantaneous position of said mirror.

16. The method of changing a light beam of constant intensity to a light beam of varying intensity by means of a combination of alternate reflecting and non-reflecting surfaces intersecting at right angles, which method comprises projecting said beam to the intersecting axis of said surfaces, and vibrating said surfaces so that the incident light projected on some of the reflecting surfaces is reflected to the opposite reflecting surfaces and the resultant reflected light is proportional to the position of said surfaces with respect to said constant light beam.

17. In combination, a source of signaling current, a source of radiant energy and means to vary the intensity of a beam of radiant energy from said source in accordance with the variations of the signaling current from said source of signaling current, which means comprises two elements having plane surfaces intersecting at right angles for successively reflecting said beam of radiant energy and means for moving said elements in accordance with the variations of said signaling current.

In testimony whereof, I have signed my name to this specification this 25th day of May, 1927.

HARRY NYQUIST.