April 21, 1959 S. W. LEVINE 2,882,792

LUMINOUS OUTPUT TRANSDUCER

Filed Sept. 10, 1954 2 Sheets-Sheet 1

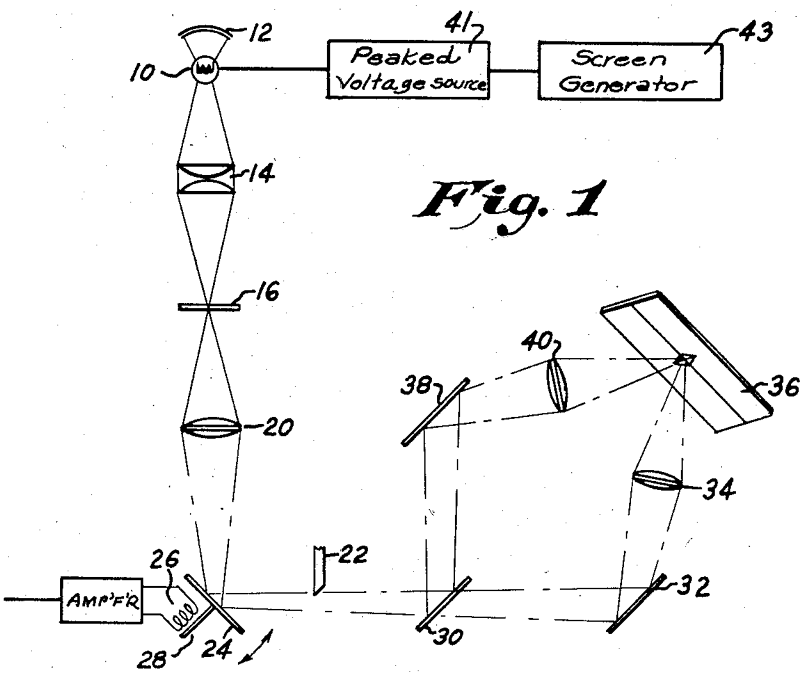

Fig. 1

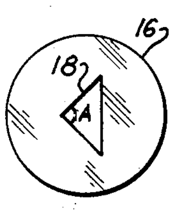

Fig. 2

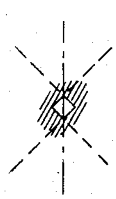

Fig. 3

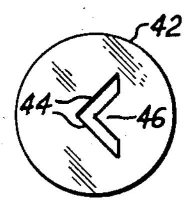

Fig. 4

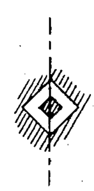

Fig. 5

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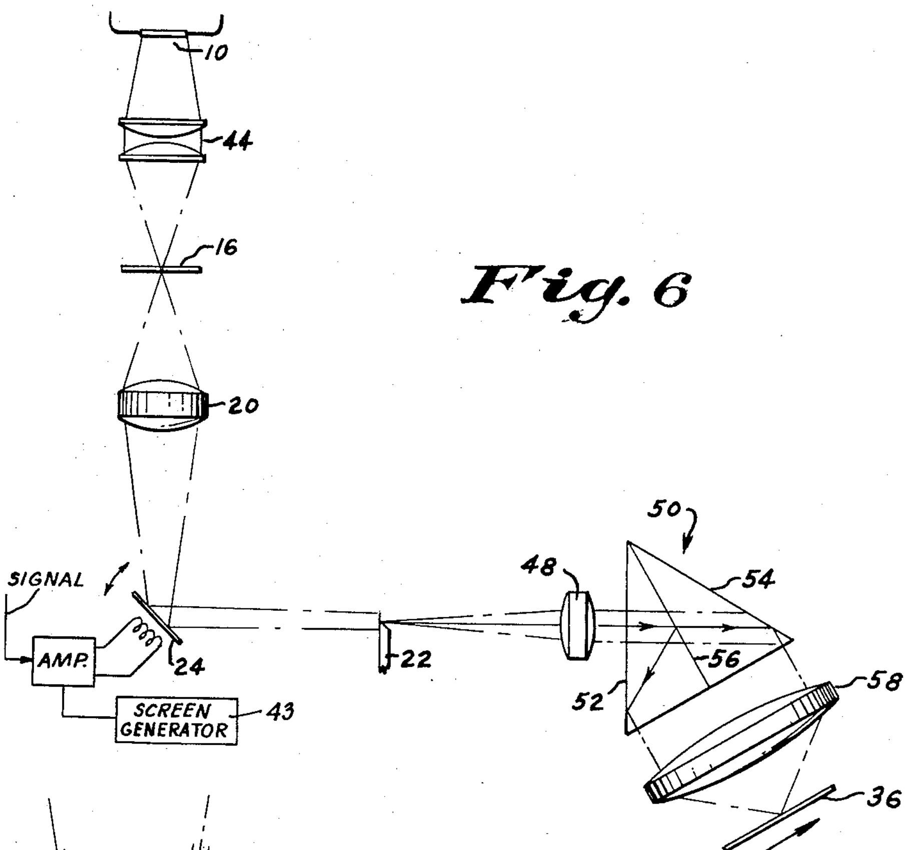

Fig. 6

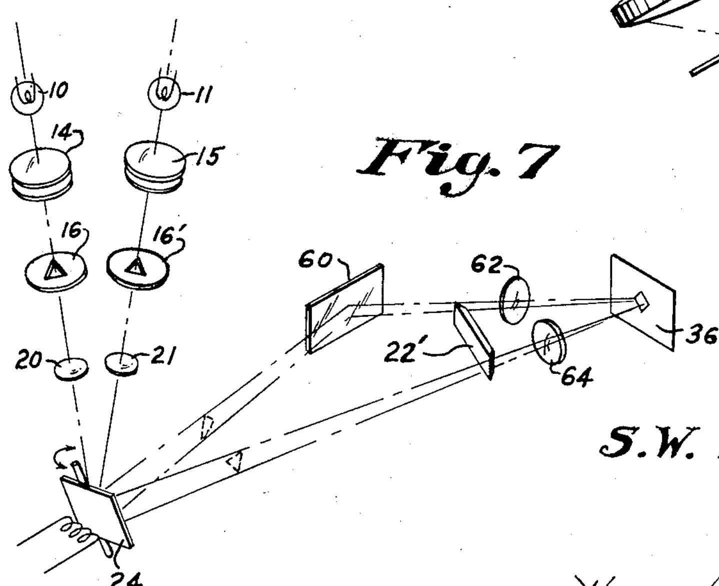

Fig. 7

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LUMINOUS OUTPUT TRANSDUCER

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7 Claims. (Cl. 88—61)

This invention pertains to transducers, and more particularly to a transducer capable of producing a luminous output in the form of a dot or spot of light having a predetermined shape but whose size is a function of a varying electrical input applied to the transducer.

So-called "light valves" of a large variety of designs are well known in the optical and electro-optical arts, finding particular application in modulating light beams in response to input signals of electrical or acoustic origin. In general, the varying luminous output of such light valves consists of changes in the intensity of a beam, for example in variable density sound recording or photographic film. However, light valves have also been devised in which the luminous output is constituted by a focussed line or strip of light, one of whose dimensions is varied in response to the input signal. Such types are employed for variable-area sound recording, and when used for push-pull recording, one dimension of the luminous line or strip is altered by equal amounts on opposite sides of a central ray. The present invention aims to provide an optical system comparable to a light valve, but whose luminous output takes the pattern of a focussed geometrical shape (specifically, a square) whose dimensions as to both length and width will vary simultaneously in accordance with an input signal. In other words, the luminous output may consist of a square "dot" of light whose size will be controlled by the input signal to the transducer, but whose shape factor will remain a geometrical square regardless of the variations in said signal. However, the dot may equally well take other geometrical shapes, as will appear hereinafter.

The invention has a particular important application in graphic arts, since it is ideally and peculiarly adapted to the production of successive dots of varying sizes which, when laid down in a regular pattern upon a photographic or other photosensitive material, will produce directly a halftone representation of the information constituting the signal input to the transducer. Of course, such signal information must be of proper form and periodicity so that separate discrete dots are produced in regular order, rather than a continuous line whose width only varies with the picture information.

It is a further important object of the invention to provide a transducer of the above type in which the luminous flux of the output beam is substantially constant, when integrated over the time of exposure of one dot, to produce the effect of a beam of substantially constant intensity whether the dot size called for is large or small. This is necessary to minimize the density variations in the final product or picture, which would otherwise result because of the finite speed with which the light "valve" opens and closes.

Without intending to limit the invention thereby, a better understanding of the purposes of the new device may be had from consideration of one successful application thereof. In the making of halftone printing plates by automatic photoelectric engraving apparatus, it is necessary to engrave the proper dot structure upon a suitable

sheet, the dots being represented by indentations or the like in the sheet material. Such a procedure is well disclosed in U. S. Patent No. 2,575,546, issued November 20, 1951, to J. A. Boyajean. In that particular process, the engraving results from the periodic contact of a hot stylus with a plastic blank, the size of the dot or cavity produced at each point on the plate being determined by the depth to which the hot stylus enters such plate. While that procedure, and the apparatus covered by the patent, has gone into wide and successful use, the necessity for utilizing a hot stylus imposes limitations which are undesirable in many cases. Similarly, in other engraving techniques where the product is a representation by discrete dots, the necessity for physical movement of the cutter or stylus, especially at reasonably high repetition frequencies, requires the precise control of a substantial amount of electromechanical energy.

Considered as a substitute for a mechanically moving tool or stylus, the present invention may be used in connection with a photosensitive plate to produce the desired dot structure in various ways. Thus, if the sheet being "engraved" is a suitable plastic which can be locally hardened by luminous energy, the same may have the desired pictorial representation developed thereon by known processes familiar to those skilled in the photomechanical aspects of the graphic arts field; e. g., by the use of light-hardenable materials or the like. Likewise, if the sheet being treated is photographically sensitive, a direct halftone picture will be produced, after exposure of the entire surface to the dot pattern produced by the invention, by the ordinary processes of photographic development.

In general, then, the invention provides a transducer which produces a recurrent dot pattern as a luminous output, rather than as the result of the physical action of a tool. Inasmuch as halftone reproduction techniques require the use of discrete dots whose order of size is quite small (individual dots being not normally resolvable at the intended viewing distance), the ability to produce dots in a size range whose lower limit may be of the order of 0.001 inch is desired. On one hand, the solution of the problem is complicated by diffraction effects which result when it is attempted to define a small light beam by physical apertures. Also, the design is made difficult by the fact that successive dots, even though of different sizes, must have their centers spaced with great precision; in other words, changes in size of the dot produced must not involve changes in the centered positions of successive dots, nor changes in the geometrical shape of the dots, nor noticeable changes in the time integral of luminous flux comprising each dot when divided by the area of said dot. The invention satisfactorily accomplishes all of these aims, and does so by devices which are relatively inexpensive to manufacture and sufficiently compact so that they may be substituted directly, in many cases, for purely electromechanical transducers formerly used.

The invention will best be understood by referring now to the following detailed specification of certain preferred embodiments thereof, given by way of example, and taken in connection with the appended drawings, in which:

Fig. 1 is a schematic view, principally in side elevation, of one preferred form of transducer incorporating the invention,

Fig. 2 is a view in plan showing the shape of an opaque aperture mask used in Fig. 1,

Fig. 3 is a diagram illustrating the shape of the luminous output beam of the Fig. 1 device,

Fig. 4 is a view similar to Fig. 2 of a modified aperture mask,

Fig. 5 is a diagram similar to Fig. 3 illustrating the instantaneous output when using the Fig. 4 mask,

Fig. 6 is a view similar to Fig. 1 but showing a modified arrangement of the parts, and

Fig. 7 is a view in perspective of still another modified form of transducer.

For reasons which have in part been discussed above, the use of a physical aperture of variable size is prohibited; such components, including iris diaphragm structures and the like, would produce substantial diffraction effects especially when at their lower limits of size, and in addition require multiple moving parts whose masses must be accelerated at high rates if signals of frequencies ordinarily encountered are to be reproduced. The mass and friction effects both involve high power requirements which should be avoided. The arrangement shown in Fig. 1 of the drawings requires only a simple stationary aperture mask, and a single moving part which takes the form of a tiltable mirror, but nevertheless satisfies the requirements for variable dot size and precise centering of all dots. As shown in that figure, a light source of suitable and constant intensity is indicated by numeral **10**, together with a reflector **12** and a condensing lens system **14** to produce a concentrated beam of light directed towards the aperture mask **16**, and of sufficient size to cover completely the aperture therein. This aperture, as better shown at **18** in Fig. 2, is of isoscles triangular shape, with an apex angle A of 90° if square dots are to be produced.

An objective lens **20** is positioned to image the aperture **18** at a knife edge **22** whose sharp edge protrudes partly into the beam representing the aperture image shape. However, between lens **20** and knife edge **22**, a reflector **24** is positioned, preferably constituted by a front-surface reflector mounted for tilting through a limited angle about an axis perpendicular to the plane of the drawing and lying in the reflecting surface of the element **24**; the tilt axis should pass through the point of the reflecting surface at which the central ray of the impinging beam strikes the same, so that tilting movements of the reflector **24** will permit more or less of the aperture's image at knife edge **22** to be occluded thereby, without any sidewise shifting of the shadow edge produced by the knife edge.

Suitable means are provided for tilting of reflector **24** in response to electrical control or input signals. As shown, such means may include a coil **26** energized by the signals and operating to move an armature **28** or the like attached securely to the reflector **24**. The reflector may be freely pivoted and provided with restraining springs to return it to its proper zero-deflection position, or the tilt may result from torsion or bending of the reflector support. Such mechanical details may be widely varied without departing from the spirit of the invention. Actually, it is quite feasible to mount the reflector **24** upon the stylus-carrying part of the electromechanical transducer shown in the Boyajean patent, although the power capabilities of the latter are greater than necessary for the purpose of tilting the reflector, which may be an extremely light structure.

From the above, it follows that the beam shape leaving the knife edge **22** constitutes a triangle whose base is defined by the knife edge, and whose altitude line bisects the 90 degree angle opposite to the base. The base (knife edge) being stationary, the position of the center of the base line is also stationary. The desired square output dot shape is obtained by combining, along their common base lines, two such triangles, as best indicated in Fig. 3, which diagrams the shape of the final output beam. In the latter figure, the vertical dot and dash line indicates the imaged position of the knife edge with reference to the beam, and the triangle to the left of that line represents the beam shape leaving the physical knife edge **22**. The complementary triangle to the right of the center line is produced optically in a manner now to be described.

Returning now to Fig. 1, the beam leaving knife edge **22** proceeds to a beam-splitter or semi-reflector **30** disposed at an angle (preferably at 45°) to the beam direction. One half of the beam proceeds by transmission through **30** to a full reflector **32** and is reflected through a focussing lens **34** onto the surface **36**, which may be the photosensitive surface to be engraved or upon which the succession of dots is to be imaged. This surface is shown in perspective for clarity, but it will normally be perpendicular to the plane of the drawing. The other half of the beam proceeds from beam splitter **30**, by reflection, to a further full reflector **38** and is focussed by lens **40** upon surface **36** in a position adjacent to the spot produced by the first half of the beam. Since the common base line of the two triangular spots is fixed with respect to the optical axis at the knife edge, and hence with respect to the two axes arriving at the surface **36**, it follows that tilting mirror **24** will produce the variable size symmetrical square shape desired, and that the center of the square will always fall on the same spot with reference to the fixed parts of the optical system. This results from the fact that one half of the beam arriving at surface **36** undergoes a single reflection (at reflector **32** after leaving the mirror **24**), while the other half undergoes two such reflections, one at beam splitter **30** and one at reflector **38**. Each reflection reverses the sense or direction of effective beam deflection due to tilting of **24**, whence the use of a number of reflections differing by one, for the two halves, produces opposite movement of the two triangular halves of the output dot.

The desired succession of such dots is, of course, produced by proper relative movement between the surface **36** and the body of the transducer, in the usual manner exemplified for instance by the Boyajean patent. The production of individual discrete dots in the desired regular succession will require some on-off modulation of the light beam producing the dots, e.g., by modulation of the light source **10** or by chopping the beam itself at a regular rate. The on-off modulation may also be incorporated in the electrical signals applied to coil **26**, if the zero-input position of the reflector is made to correspond to a dot of zero size or less, i.e., to the existence of no light output whatever or to a finite signal for zero light.

Since the principal purpose of the invention is ultimately to provide screen plates made up of discrete dots of predetermined shape and variable size, it is desirable to insure that the exposure which produces each such dot is fairly brief as compared with the rate of motion of surface **36** relative to the exposure beam; otherwise, blurring of the dot shape will result. Thus, the light source **10** may be of a type which can be flashed briefly by peaks or pulses derived from the energizing voltage source **41**, in Fig. 1. Alternatively, a steady light source may be employed, and the on-off modulation obtained by a light-chopper or sector disc to give a brief exposure which will have the same effect; that is, to produce the exposure on surface **36** in a time interval which will not produce substantial blurring or elongation of the dot shape in the direction of film travel.

It is also possible to obtain the desired brief exposure by superimposing an on-off pulse upon the signals controlling the movement of reflector **24**, as by known wave-shaping circuits. The dot repetition rate will in general be determined by a screen frequency generator such as is shown in the Boyajean patent, or equivalent source, and the on-off modulation will be controlled from such generator. The screen generator is indicated schematically in Fig. 1 at **43**, controlling the peaked voltage source **41** as to frequency, but it will be understood that such a screen generator would also provide the necessary frequency control if on-off modulation is accomplished by a light-chopper or by modulating the signal energy applied to coil **26**.

If the beam arriving at the aperture mask is homogeneous as to intensity, the mask shown in Fig. 2 will allow the central portion of a large dot to be over-exposed as compared with a small dot. The reason for this is that in forming a dot, the device commences with the aperture in effect closed, and then allows the "aperture" to open as reflector **24** is tilted, the maximum tilt corresponding to the size of the dot being produced. Since the reflector **24** has a finite speed of movement, a longer time will be required for the effective aperture to open to a large size than is required for it to open to a smaller size. Thus in forming a large dot, the central portion will be exposed for a longer time than the total exposure time involved in making a small dot. To prevent this, it is possible to provide a decrease in the central light flux which occurs progressively as the dot size increases, by employing a special shape of mask shown at **42** in Fig. 4. The left profile **44** there corresponds to the aperture **18** of mask **16**, but the right-hand profile, instead of being a straight line, is the edge of a smaller triangle indicated at **46**. Obviously, for dot sizes above a certain value, the projecting point of this opaque triangle will obtrude upon the beam passing through the mask, and more will obtrude as the dot size increases. However, below said value, the full intensity of the original beam will be passed. In effect, the instantaneous shape of the dot when of moderate size will then be as shown in Fig. 5, in which the light is passed only in a marginal strip around the square beam cross-section at the surface on which it is focussed.

While the arrangement of Fig. 1, with or without the modification as to aperture shape of Fig. 3, performs quite well, and permits the production of square output dots as small as a thousandth of an inch on the side, a preferred embodiment shown in Fig. 6 permits simplification of the optical parts, is generally easier to maintain in proper adjustment, and has a much greater depth of focus. Like reference characters in this figure denote the same or equivalent parts as those shown in Fig. 1. Thus, numeral **10** again denotes a light source, here shown as a ribbon filament lamp, and a condenser **44** concentrates the light upon an aperture disc or mask **16**, opaque except for the aperture which may be of the shapes as shown in Fig. 2 or Fig. 4. An objective lens **20** images the light from the aperture, after reflection from tiltable mirror **24**, in the plane of the knife edge **22**. Tiltable mirror **24** is provided with drive means as in the previous form of the invention.

From knife edge **22**, a collimating lens **48** converts the rays to a parallel beam, which beam enters a prismatic beam splitter generally designated by numeral **50**. This is formed of two right-angle prisms **52** and **54**, contacting along one common face as at **56**, which interface is provided with a half-silvered or other beam-splitting layer. The layer may be coated on one or both prism faces or otherwise provided in ways well known to those skilled in optics. The prism **50** is disposed so that the beam enters it normally to one face (of prism **52**), and since the beam is collimated, aberrations that would otherwise be introduced by the prism are avoided. One half of the entering beam is thus reflected at layer **56**, then totally internally reflected at the outer surface of prism **52**, and passes to the focussing lens **58**, which in this case may be a single lens receiving both components of the spot beam. The other half beam, transmitted by layer **56**, is reflected only once, namely by total internal reflection at the outer surface of prism **54**, and is also focussed by lens **58** upon the receiving surface **36**. Inasmuch as prism assembly **50** is in effect a single integral structure, the alignment of the various reflectors, including the beam splitting surface, is readily maintained. Also, the manufacture of this component involves less cost than the separate manufacture and assembly of the three reflectors of Fig. 1, and the arrangement gives a much greater effective depth of focus for such a system.

Operationally, the embodiment of Fig. 6 is no different from that earlier described, so that further elaboration as to this form is believed to be unnecessary. The screen generator **43** is here shown applying on-off modulation to the input signals applied to the drive coil of mirror **24**, as already described.

Both of the forms of the invention described above have employed a common illuminating system, a common mask and knife-edge and output beams which suffer respectively a single reflection, and a pair of reflections, after leaving the knife edge. A form of the invention will now be described in which separate illuminating systems are employed, a double knife edge element, and output arrangements in which only a single reflector is needed. Bearing in mind that the symmetrical dot shape results from combining beams which have suffered a difference in number of reflections of "one" it is apparent that the result can be obtained by reflecting one component beam once only, and the other not at all.

Referring now to Fig. 7 of the drawings, a pair of light sources are indicated at **10** and **11**, these being identical with the sources previously described. Each source has the condensing system **14, 15**, and each has an aperture mask **16, 16′**. These masks are oriented so that their triangular apertures have the bases parallel to one another. Separate lenses **20** and **21** focus the beams at knife edge device **22′**, which differs from that previously described in having its opposite ends both sharpened to intersect partly each of the two beams from tilting reflector **24**. The beam from aperture **16** is focussed at one edge of knife edge **22′**, and the resulting image is projected to the photosensitive surface **36** by lens **64**. The beam from aperture **16′** is focussed at the other edge of knife edge **22′** after reflection from the front surface mirror **60** to reverse the angular sense of rotation of the beam passing from mirror **60** through lens **62** with respect to the angular rotation of the beam passing through beam **64**. Thus, for example, as the mirror rotates counter-clockwise, a greater portion of the projected aperture **16** is intercepted by the knife edge and one-half of the resulting square is decreased in size. This same counter-clockwise rotation of mirror **24** decreases the effective size of the projected aperture **16′** because of the reversal in angular direction produced by the reflection by mirror **60**.

The optics are arranged so that the base lines of the variable size triangles projected on to surface **36** are coincident, so that these two images combine to form a single dot or spot of square shape and variable size just as in the previous forms of the invention.

One advantage of this form of the invention lies in the fact that since no splitting of the original beam occurs, a given light source intensity and optical components permits about twice as much light to be directed into the resulting spot, because light is transmitted throughout the system from each of the two sources. Fundamentally, however, the same optical principle (differential number of reflections) is employed. While the double knife edge element **22′** is shown as an integral element, it is obvious that separate knife edges could be used so long as they are located in fixed positions corresponding to the knife edges at the opposite ends of the single element **22′**, or in other fixed positions which will produce the same optical effect.

While the invention has been described in connection with certain preferred examples in accordance with the patent statutes, the details can be varied in many respects without departing from the spirit of the invention. Thus, whereas the aperture masks shown herein comprise opaque elements with triangular apertures or transparent parts, combined to provide a truly square output shape, other output shapes of symmetrical configuration can be obtained by using different masks. A slight deviation from true square shape may be desired, for example, where relative movement between the transducer output axis and the surface **36** would tend to elongate the dot in the direction of surface movement, or more especially where the projection angle onto surface **36** is other than

90°. The square dots may also be intentionally oriented with respect to the dimensional directions of surface **36** so as to look like diamonds or lozenges rather than squares. Such alterations and substitutions, and changes as to other details, are intended to be covered by the invention as defined in the appended claims.

What is claimed is:

1. A luminous output transducer for the preparation of photographic reproductions consisting of discrete half-tone dot patterns corresponding to electrical signals, comprising means forming two beams of light defining geometrically identical images of a predetermined shape each of said images having substantial dimensional extension in two orthogonal directions in a plane perpendicular to its respective beam direction, means for projecting said images in focussed and contiguous condition upon a moving light-sensitive medium to provide a combined luminous image pattern corresponding to the desired dot profile and which is the geometric double of said shape, beam controlling means for simultaneously altering the sizes of said images without disturbing their shapes or their contiguous relationship in the focal plane, electrical signal-responsive means for controlling said altering means to vary the size of said pattern, and means for wholly interrupting the transmission of said beams periodically during movement of said medium to cause the discrete sequential exposure of spaced points thereof to the varying size pattern of light to produce the desired half-tone dot representation of said signals.

2. The invention in accordance with claim 1, in which said means for projecting comprises means defining separate optical paths for said beams, and a reflector in at least one of said paths, and in which the number of reflectors in said respective paths differs by an odd integer.

3. The invention in accordance with claim 1, in which the means forming said two beams of light comprises at least one element having a triangular beam-defining aperture.

4. The invention in accordance with claim 1, in which the means forming said two beams of light comprises at least one mask having a chevron-shaped aperture.

5. The invention in accordance with claim 1, in which said signal-responsive means comprises a mirror galvanometer.

6. The invention in accordance with claim 1, in which said means for projecting comprises an occluding element common to said two beams of light, and in which said means for altering the sizes of said images comprises means for moving the direction of the rays forming said images with respect to said occluding element.

7. A luminous output transducer for the preparation of photographic reproductions consisting of discrete half-tone dot patterns corresponding to continuous electrical signals, comprising: a light source, means defining an aperture of chevron shape, said light source being disposed to illuminate said aperture, a ray deflector positioned to receive rays passing through said aperture from said light source, means for rotating said deflector to vary the direction of the rays reflected thereby in accordance with said electrical signals, a light occluding element having one straight edge positioned with respect to said deflector so as to intercept more or less of the beam of rays leaving said deflector, on a line connecting the legs of said chevron, optical means for dividing said beam into two components each having rays imaging the shape of said aperture as modified by said occluding element, means for focussing said components upon a moving light-sensitive medium in contiguous relation at the image of said line to form a succession of illuminating spots shaped substantially as hollow rectangles of external sizes determined by the instantaneous position of said deflector, and means for periodically interrupting said beam components during motion of said medium to image upon the latter a discrete series of spaced dots of varying sizes, and of which the dots corresponding to larger external size receive at their central region a reduced total intensity of applied illumination.

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