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Oct. 31, 1967

J. E. YOUNG

3,349,677

ALPHA NUMERIC CHARACTER PRINTER

Filed Dec. 14, 1964

4 Sheets-Sheet 1

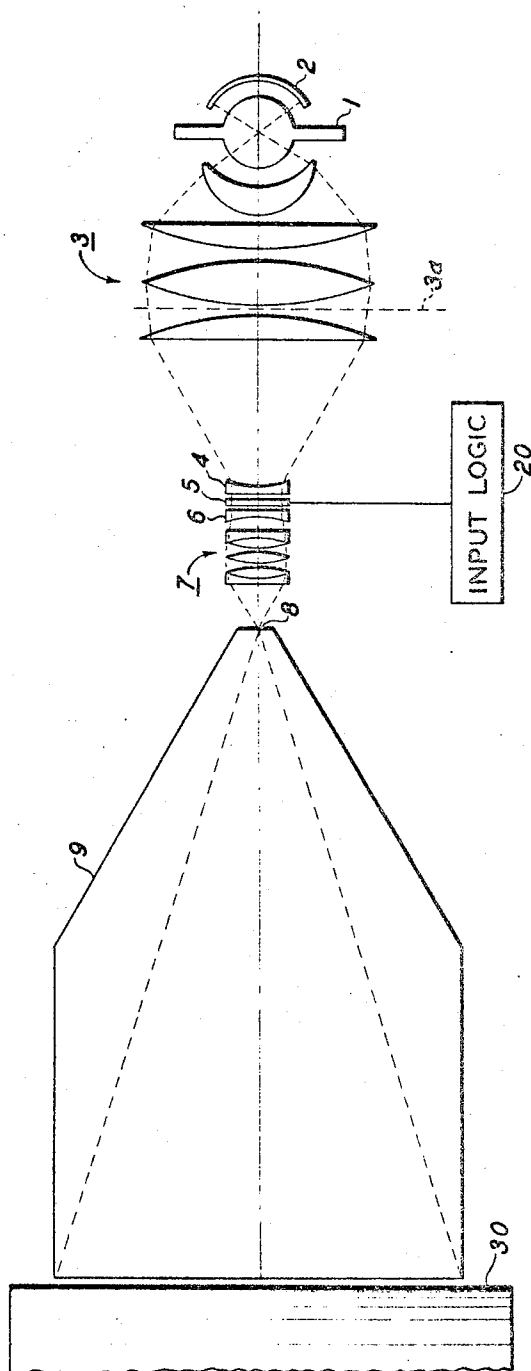


FIG. 1

INVENTOR
JAMES E. YOUNGBY *Anthony Romano*
Stanley Zee
ATTORNEYS

Oct. 31, 1967

J. E. YOUNG

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4 Sheets-Sheet 2

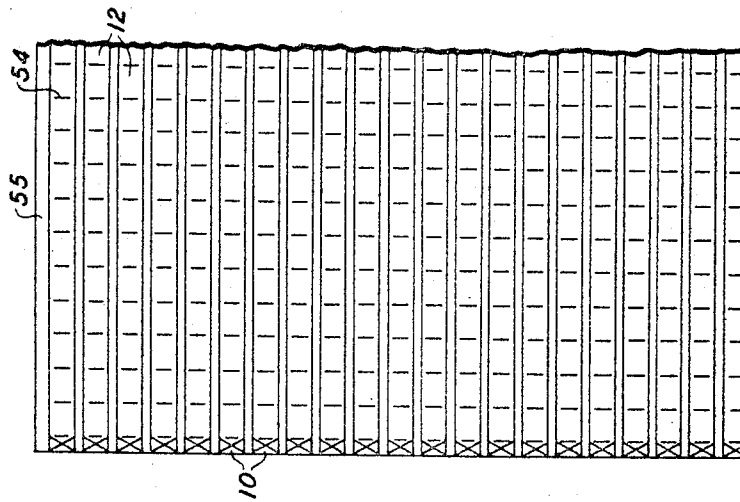


FIG. 4

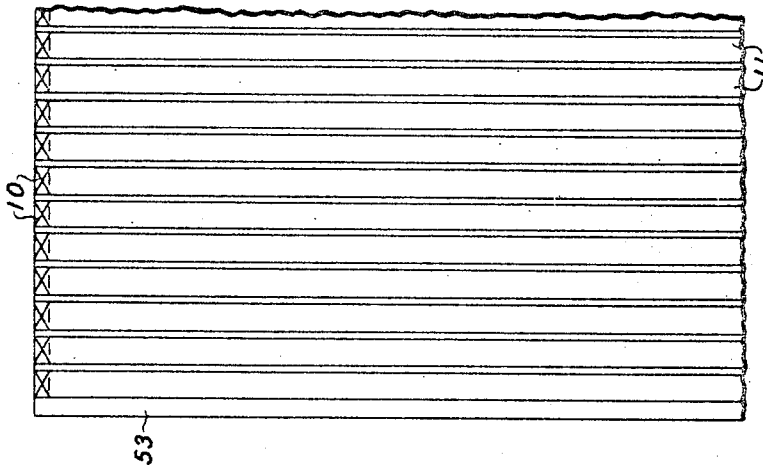


FIG. 3

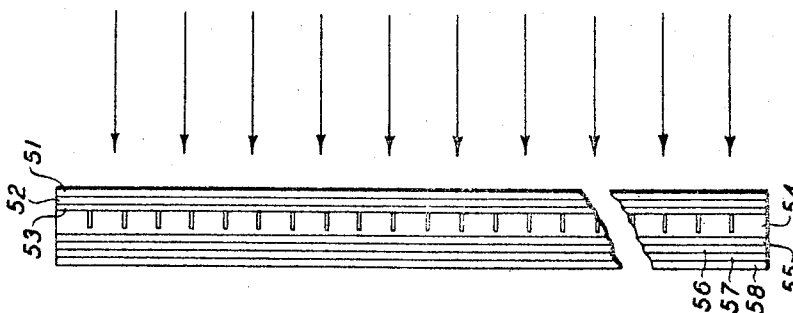


FIG. 2

INVENTOR
JAMES E. YOUNG

BY *Anthony J. Cannano*
Stanley Z. Cole
ATTORNEYS

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J. E. YOUNG

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4 Sheets-Sheet 3

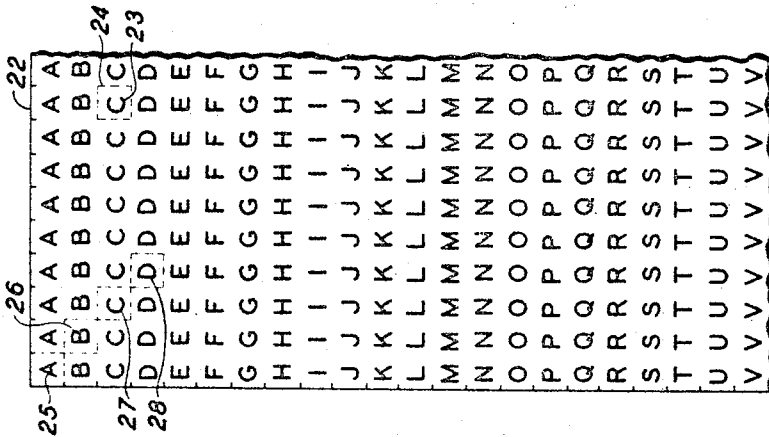
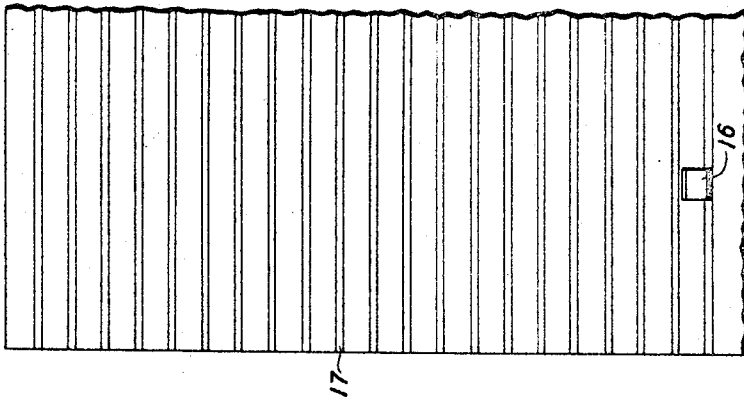


FIG. 5

FIG. 6

FIG. 7

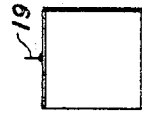
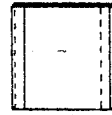


FIG. 8

FIG. 9

INVENTOR
JAMES E. YOUNG
BY *Anthony J. Cunningham*
Stanley J. Cole
ATTORNEYS

Oct. 31, 1967

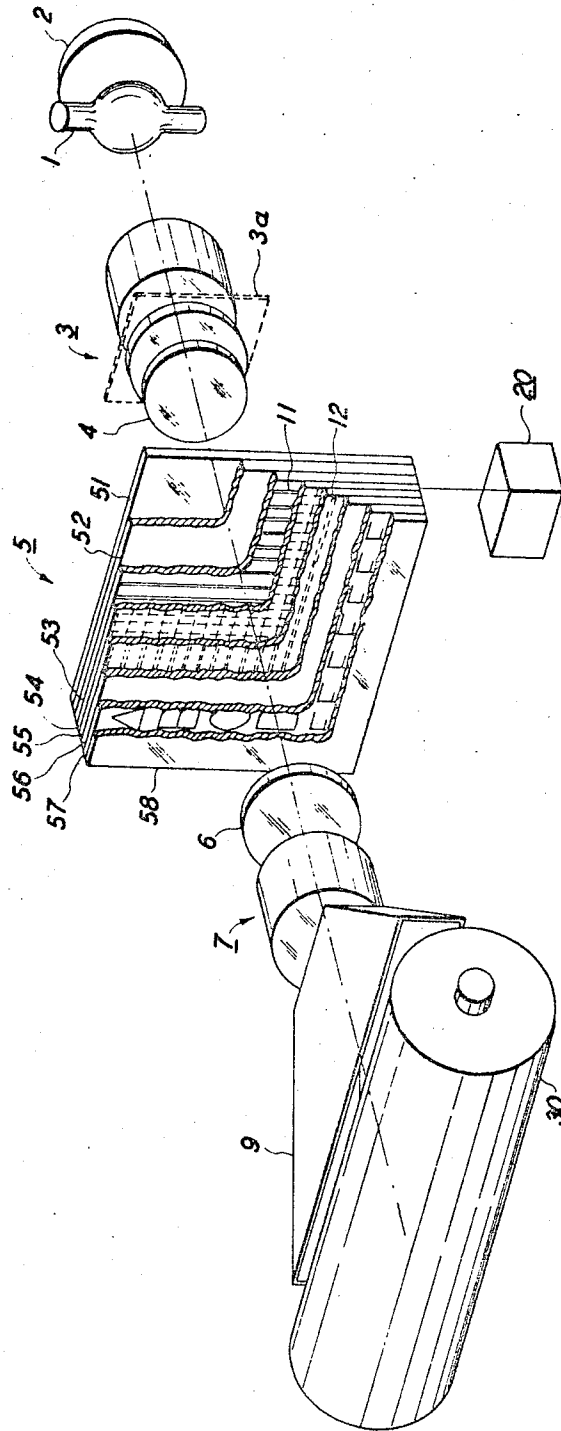
J. E. YOUNG

3,349,677

ALPHA NUMERIC CHARACTER PRINTER

Filed Dec. 14, 1964

4 Sheets-Sheet 4



INVENTOR.
JAMES E. YOUNG

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3,349,677

ALPHA NUMERIC CHARACTER PRINTER
James E. Young, Pittsford, N.Y., assignor to Xerox Corporation, Rochester, N.Y., a corporation of New York
Filed Dec. 14, 1964, Ser. No. 418,024
3 Claims. (Cl. 95-4.5)

ABSTRACT OF THE DISCLOSURE

Apparatus for generating a plurality of alpha numeric characters simultaneously and for exposing a light sensitive medium to the characters in a linear array utilizing an electro-optic crystal matrix in a light valve to selectively illuminate elements in a character matrix.

Background of the invention

This invention relates generally to high speed character generators, and more particularly, to such generators wherein purely electro-optical means are utilized to achieve selective switching among characters.

The information explosion of recent decades has brought forth a corresponding and ever-increasing demand for printing and recording devices capable of creating or recreating graphic materials at rates far in excess of those that were previously deemed to be acceptable. Purely mechanical printing devices such as printing presses and the like have proved to be completely inadequate to meet the challenge, in that all such devices have speeds inherently limited by the relatively slow mechanical movement of their elements.

Accordingly, and in an attempt to overcome the limitations of mechanical apparatus, relatively high speed recording devices have been proposed which utilize largely electro-optical techniques to switch between successive characters. One type of such device is shown, for example, in U.S. Patent No. 3,116,963 to Zen-Iti Kiyasu et al. wherein a high speed recording device is disclosed utilizing an alpha-numeric character matrix in combination with light conductive optics, discharge tubes, and external optics adapted to image the characters upon a recording media.

Another type of electro-optical character generator is shown in U.S. Patent No. 2,909,973 to A. C. Koelsch, Jr. et al. wherein a display apparatus is disclosed utilizing a large number of electro-optic crystals positioned in a plane between crossed polaroids. By selectively activating individual crystals, patterns of light can be passed through the polarization analyzer element in the rough form of a letter, numeral, or the like. A second set of electro-optic crystals is combined with suitable external optics to position on a recording media the character thus generated.

While electro-optical character generators and recording devices of the types alluded to have represented considerable improvement over the relatively slow mechanical printers, yet for one reason or another they have not been able to achieve the optimum speed and simplicity that would hopefully be present in such devices. The use of discharge tubes as light sources, for example, as in the Zen-Iti Kiyasu apparatus, introduces tremendous complexity and bulk into the system in that a discharge tube must be present for each particular character, not to mention the attendant paraphernalia such as conductive optics and the complex circuitry necessary to fire this particular discharge tube upon signal. The creation of an actual line of print in a Zen-Iti Kiyasu type device is also achieved with great complexity. This is true because characters are printed at varying vertical positions on a moving recording media, with ultimate horizontal align-

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ment of lines or print being achieved by involved timing and memory storage means.

On the other hand, character generators of the type illustrated by Koelsch, while utilizing much simpler switching means, nevertheless produce characters having relatively low resolution, in that such characters are composed as a series of dots—a form generally unacceptable for most printing purposes. In addition, devices of this latter type retain complex means for positioning of individual characters upon the recording media—such as for example, the involved double shutter arrangement of Koelsch. Moreover, such devices are not capable of printing more than one character at a time.

It is, accordingly, the primary object of the present invention to provide an alpha-numeric character generator wherein extremely high display rates are achieved through an electro-optical mode of operation and yet not at the price of the excessive complexity so prevalent in the prior art.

It is another object of the present invention to provide electro-optical display apparatus whereby individual characters may be formed upon a recording media at extremely rapid rates, and yet without loss of resolution.

It is yet a further object of the present invention to provide a high speed electro-optical character generator capable of printing full lines of characters at a time.

Summary of the invention

Briefly, the invention accomplishes these and other objects by the utilization of electro-optic light valves in combination with a complete alpha-numeric character matrix and an optical alignment system which achieves on-line orientation of vertically disarrayed matrix elements. The light valving is brought about through the use of one or more electro-optic crystals placed between crossed polaroids and positioned with respect to the character matrix to selectively transmit incident light to given matrix elements.

Brief description of the drawings

The invention is diagrammatically illustrated by way of example in the accompanying drawings in which:

FIGURE 1 is an overall planar view diagrammatically illustrating a preferred embodiment of the invention;

FIGURE 2 is a cross sectional view through the target plate of the character generator;

FIGURES 3 and 4 diagrammatically illustrate preferred modes of electrode connection to the glass plates enclosing the electro-optic crystals, where such crystals are operating in the longitudinal mode;

FIGURE 5 diagrammatically represents an electro-optic crystal matrix suitable for use in a preferred embodiment of the present invention;

FIGURE 6 is a diagrammatic representation of an alpha-numeric matrix suitable for use in the target plate of the invention.

FIGURES 7 and 8 diagrammatically illustrate a mode of electrode connection to the glass plates enclosing the electro-optic crystals where such crystals are operating in the transverse mode.

FIGURE 9 diagrammatically illustrates an alternate manner of connection for transverse mode electro-optic crystals.

FIGURE 10 is an isometric view of the present invention showing the light value means in a broken isometric view.

Description of the preferred embodiment

In FIGURE 1 and FIGURE 10, light source 1 comprises a compact mercury arc. Spherical reflector 2 is arranged to reflect the source image back upon itself. Light emergent from source 1 is condensed and collimated by

optics 3 and 4. As electro-optic crystals perform most efficiently within a narrow frequency range of incident light, an interference filter may be provided as at 3a. The filtered and essentially parallel light now passes through target plate 5 containing the alpha-numeric matrix and light valving means. Activation of the light valving means contained in target plate 5 is controlled by voltage pulses from input logic 20. Light emergent from the target plate 5 next passes through field flattener element 6; thence through projection lens 7 and aperture 8 and enters the adjacent end of flat glass plate 9.

The last named element although forming an integral part of the present apparatus is not claimed here per se. A full disclosure on this plate may be found in the United States Patent 3,279,342 issued Oct. 18, 1966 to Robert W. Thompson entitled "Communication Printer," filed on or about Sept. 1, 1964 and assigned to the same Assignee as the present invention. Briefly, it may be stated that plate 9 acts to optically align at its far end vertically disarrayed images of individual matrix elements presented to the plate at its input end. This action, as is fully explained in the copending application alluded to, is brought about by multiple internal reflection from the broad parallel faces of the glass plate. As a result, one might for example simultaneously illuminate all the character elements on a diagonal of the alpha-numeric matrix contained in target plate 5, and although the image of the character elements entering the plate 9 would be a diagonal in form, nevertheless, the output image at the far end of the plate would be a flat horizontal line of individual characters. It should be pointed out here that as the word "element" or the phrase "character element" is used here, it refers to a small rectangular area of the alpha-numeric matrix and includes not only the character itself, but the surrounding rectangular space allocated to a character on the basis of equal division of the total matrix area.

Light emergent from glass plate 9 impinges upon a recording media which in FIGURE 1 is shown as a charge-bearing xerographic drum 30. While other recording media will perform satisfactorily, the xerographic drum is particularly useful in the present invention by virtue of the fact that the light valving means employed in the invention are such that a small amount of residual light will pass even during the closed cycle of the valves; and although this small amount of residual light might prove bothersome to very sensitive recording media, yet such small amounts of light are perfectly tolerable to the usual selenium or selenium-tellurium surfaced base of xerographic drums. The information now recorded on the xerographic drum can subsequently be utilized by any of the well-known techniques of conventional xerography.

Target plate 5 is shown in detail in the cross sectional view of FIGURE 2 and also in FIGURE 10. In the sense of this diagram, parallel light from the condensing and collimating optics is assumed to enter the target plate from the right and exit on the left. The light first passes through front cover glass 51. It is then plane-polarized by vertical polarizer element 52. The light then passes through thin glass element 53, which in the preferred embodiment carries a transparent conductive pattern. At this point, the plane-polarized light reaches the matrix 54 of electro-optic crystals. The plane-polarized light will pass through this matrix but the polarization state of portions of the light so passing may be altered by selective application of electric stress to particular crystal-matrix elements. The light then passes through a second thin glass element 55 bearing a second conductive pattern and reaches horizontal polarizer element 56. It will be appreciated that polarization axis of element 56 is approximately 90 degrees out of phase with vertical polarizer element 52. Accordingly, these two elements are approximately at an extinction position and normally light incident through the system would only pass at a very low residual level. However, by selectively activating portions of the electro-optic crystal matrix 54, the plane of polarization of light passing

through the activated element may be sufficiently varied to permit light to pass through the sections of the crossed polaroids in line with the activated portion of the crystal matrix. Such light as selectively emerges from the horizontal polarizer element 56 is then incident upon corresponding portions of the alpha-numeric matrix 57, finally leaving the target plate through the rear cover glass 58.

The structures of thin glass plates 53 and 55 with their attendant conductive pattern is shown in detail in FIGURES 3 and 4. Essentially, these plates consist of relatively thin, highly transparent glass, upon which parallel strips of conductive transparent material 11 and 12 have been deposited. This transparent conductive material may suitably comprise a conductive glass, such as NESA glass, which is manufactured by the Corning Glass Works, Corning, N.Y. Provisions are made at the end of individual conductive strips to connect electrodes such as at 10. It will be noted that the conductive strips 11 on FIGURE 3 are oriented in a vertical direction whereas in the case of the corresponding strips 12 shown in FIGURE 4, orientation is in a horizontal direction. When assembled in the target plate 5, the crystal matrix 54 is sandwiched between the thin glass plates 53 and 55 and the crystal matrix 54 can be seen in shadow in FIGURE 4. The sides of the glass plates 53 and 55 bearing the conductive patterns, 11 and 12 are effectively in contact with alternate sides of the crystal matrix. It will now be seen that one may selectively establish an electric field across selected portions of the crystal matrix by establishing an electrical potential between two particular conductive strips 11 and 12. Such a field will be transverse to the plane of the crystal matrix and as the conductive strips are made to be the same width as an element of the alpha-numeric matrix, an electric field can be established within but one element of the crystal matrix at a time. Since these field-activated crystal matrix elements effectively act as light valves for corresponding elements of the alpha-numeric matrix 57, illumination and thus display and/or printing of individual or collections of characters may now be controlled by the mere application of voltage pulses from input logic 20 to the conductive strips corresponding to the character or characters desired to be recorded.

The electro-optic crystal matrix 54 is shown in further detail in FIGURE 5. In the embodiment shown, the matrix comprises a single large KD*P crystal. Individual crystal matrix elements 14 are here explicitly formed by virtue of parallel equidistant spaced saw cuts 15 which extend to approximately 90 percent of the crystal depth. The number, size, position and arrangement of crystal matrix elements corresponds to the elements of alpha-numeric matrix 57. Saw cuts 15 are not absolutely essential to the performance of the crystal matrix. Since conductive strips 11 and 12 as previously indicated are arranged to establish discrete electric fields across areas of the crystal matrix equivalent in size and location to elements 14, such elements 14 would be implicitly defined by the voltage pulses established by the conductive strips even in the absence of saw cuts. However, the saw cuts have been found useful in eliminating cross talk between closely adjacent crystal matrix elements. It, of course, will be apparent that the crystal matrix 54 might also suitably be formed of large numbers of individual crystals, each the size of a matrix element.

In the embodiment shown, the crystal matrix is formed of one or more KD*P crystals. Such a crystal is but one of a class of electro-optic crystals suitable for operation in a longitudinal mode. By this is meant the class of crystals that exhibit electro-optic polarization plane-rotating properties upon subjection to an electric field parallel to the optic axis. Other crystals exhibiting an effective electro-optic activity when operated in the longitudinal mode include KDP, ADP, KDA, and ADA crystals. Any of these would be suitable in the embodiment of the invention thus far illustrated.

There is a second group of electro-optic crystals that

exhibit electro-optic activity upon subjection to an electric field transverse to the optic axis. This is the group of so-called transverse mode crystals, represented by way of example by the cubic crystals comprising class $\bar{4}3m$ in the Hermann-Mauguin point group notation. These transverse mode crystals can also be utilized in the present invention and in some respect have advantages over the longitudinal mode crystals. For example, they are commonly—as in the class $\bar{4}3m$ cited—cubic crystals and hence can be chosen to possess no natural birefringence, such as limits to some extent the useful angular aperture of the longitudinal mode type crystal. Furthermore, since they respond to fields transverse to the light path, opaque low resistance electrodes may be employed as contrasted to the higher resistance transparent conductive strips that have been indicated for use with the longitudinal mode crystals. In addition, the transverse type crystals display a dual transverse electro-optic effect which means that simultaneous modulation of the light passing through a given matrix element is possible by employing two independent signals that cause two mutually perpendicular transverse electric fields across a given crystal matrix element.

Where transverse electro-optic crystals form the control light valves in target 5, conductive patterns would not, of course be formed upon glass plates 53 and 55 in the same manner as previously indicated. A suitable method for mounting and electrically connecting such transverse crystals is shown in FIGURE 7. There it is assumed that the elements of the crystal matrix are composed of separate individual transverse mode crystals 16. In this case, the front and rear glass plates corresponding to the elements 53 and 55 in the longitudinal mode embodiment of the target plate, now carry horizontal and vertical patterns respectively of evaporated gold or other highly conductive metal as at 17. An individual crystal shown at FIGURE 8 now carries evaporated gold edge contacts at 18. Individual crystals are activated by applying a potential across the two gold edge contacts on electrodes which make electrical contact with particular horizontal and vertical lines on the glass plates.

It is also possible to activate the transverse mode crystals completely independently of each other much as is the case in the longitudinal mode embodiments previously shown. However, this necessitates dispensing with the conductive patterns formed upon the thin glass plates that enclose the crystal matrix and instead making connections upon an individual basis to individual crystals. This is shown, for example, in FIGURE 9 where individual connections 19 are made to evaporated gold edge contacts 21 formed upon individual crystal elements 16. The individual crystal elements 16 in this case are cemented to one of the two glass plates enclosing them.

FIGURE 6 shows a portion of the alpha-numeric matrix 57 utilized in the present invention. Essentially, the matrix comprises a flat transparent plate 22 containing lines and columns of opaque characters 23. Each particular character, together with its allocated surrounding space can be considered as the matrix element, and this element 24 exactly corresponds to an element in the electro-optic crystal matrix. Thus, individual characters upon the alpha-numeric matrix may be subjected to selective illumination by activating the corresponding element of the electro-optic crystal matrix. It will, of course, be appreciated that the alpha-numeric matrix could as readily contain transparent characters upon an otherwise opaque base so that the character image ultimately projected upon the recording media can either be black upon white, or white upon black, the choice of which would depend on the recording media used and the ultimate use to which the information is being put.

The information emerging from the alpha-numeric matrix 57 is projected into and through the flat glass plate 9. As previously discussed, the action of this plate 9 is such as to optically align vertically disarrayed matrix elements. Referring to FIGURE 6, for example, one might

so activate portions of the electro-optic crystal matrix as to illuminate simultaneously elements 25, 26, 27, 28, etc. of the alpha-numeric matrix. These successive elements are seen to be along a principal diagonal of the alpha-numeric matrix. Nevertheless although the image at the input end of flat glass plate 9 will be such a diagonal, yet at its output end where it impinges upon the recording media, a straight horizontal line of characters "A B C D" . . . will result. Thus, the input logic controlling the light valving action of the electro-optic crystal matrix can be relatively simple, and it is clear that lines of information as wide as the alpha-numeric matrix itself may be printed at one time.

Since the alpha-numeric matrix 57 utilized in the invention is not an integral part of the electro-optic crystal matrix 54, it will be appreciated that alpha-numeric matrix function somewhat in the nature of a stencil. Accordingly, it can readily be interchanged with other such stencil-like alpha-numeric matrices to achieve a high degree of versatility in the overall character generator. Thus, for example, a matrix carrying script symbols, mathematical symbols, electronic schematic designations, or alphabets other than the Roman alphabet might be readily substituted in the character generator.

Having thus described the present invention, it will be clear that many modifications thereof and deviations therefrom may now be readily devised by those skilled in the art, and yet such modifications and deviations will yet come within the scope of this invention. Consequently, the invention herein disclosed is to be constructed broadly and limited only by the spirit and scope of the appended claims.

What is claimed is:

1. An alpha-numeric character generator for simultaneously exposing a plurality of characters to a light sensitive medium comprising:
 - a source of plane polarized light
 - a light sensitive recording medium
 - an array of alpha-numeric characters on a sheet of material positioned between the light source and the light sensitive medium
 - the sheet of material containing alpha-numeric characters having light transmitting characteristics whereby light transmitted from the light source to the light sensitive medium is formed into the alpha-numeric configurations
 - said array of alpha-numeric characters comprising rows of characters of identical shape and columns of characters of a plurality of shapes
 - a light valve positioned adjacent to the array of alpha-numeric characters and including
 - an electro-optic crystal capable of operation in a longitudinal mode
 - a transparent member on each side of the crystal and having parallel conductive transparent bands on the surface thereof and in contact with the crystal
 - the transparent members being oriented with respect to each other so that the parallel bands on one member are substantially normal to the bands on the other member
 - a polarization analyzer element positioned adjacent to the transparent member on the side of the crystal opposite to the light source
 - the plane of transmission of the analyzing element being different from the plane of polarization of the light source
 - and means to apply electrical signals to the conductive bands
 - input logic means connected to said means to apply electrical signals to said conductive bands to thereby simultaneously activate areas of the crystal corresponding to the location of specific characters in the array
 - and optical means to image the characters of the alpha-numeric array on the light sensitive medium in line.

2. Apparatus according to claim 1 wherein the electro-optic crystal is formed into elements corresponding to the elements of the array of characters by means of cuts made in the face of the crystal contacting one of the transparent members

the cuts extending to approximately 90 percent of the depth of the crystal.

3. An alpha-numeric character generator for simultaneously exposing and projecting a plurality of characters to a light sensitive medium comprising:

(a) a source of an intense collimated non-plane polarized light beam;

(b) a light sensitive recording medium;

(c) a matrix array of alpha-numeric characters on a sheet of material positioned in the path of said light beam between the light source and the light sensitive medium, the sheet of material containing alpha-numeric characters having light transmitting characteristics whereby light transmitted from the light source to the light sensitive medium is formed into alpha-numeric configurations, said matrix array of alpha-numeric characters comprising rows of characters of identical shape and columns of characters of a plurality of shapes;

(d) a light valve positioned adjacent to the matrix array of alpha-numeric characters in the path of said light between said source of said collimated light beam and said sheet of material containing said matrix array of alpha-numeric characters, and including,

(1) an electro-optic polarization-rotating layer comprising a single flat crystal capable of operation in a longitudinal mode, said crystal being sandwiched between

(2) two transparent parallel plates one on each side of the crystal and having parallel equidistant spaced conductive bands having a width substantially equal to the width of an individual element in said alpha-numeric matrix on the surface thereof and in electrical contact with the sandwiched crystal, said transparent plates being oriented with respect to each other so that the parallel bands on one plate are substantially normal to the bands on the other plate;

(e) a polarizing element positioned in the path of said light beam between said source and said light valve;

(f) a polarization analyzing element comprising a flat sheet of polarizing material positioned in the path of said light beam with its plane perpendicular to the propagation direction of said light beam and adjacent to the transparent member on the side of the

electro-optic crystal non-adjacent to said polarizing element and opposite to said source of said light beam, the plane of transmission of the analyzing element being approximately 90° different from the plane of transmission of said polarizing element;

(g) means to apply electrical input signals to the conductive bands;

(h) input logic means connected to said means to apply electrical input signals to said conductive bands to thereby selectively activate different portions of said electro-optic polarization rotating crystal simultaneously, said portions of said crystal corresponding to the location of specific characters in the matrix array selected in accordance with electrical input signals which apply electrical fields transverse to said crystal to rotate the planes of polarization in portions of the light beam to other than right angles to the transmission plane of said polarization analyzing element, thereby enabling the altered portions of said light beam to be transmitted through said polarization analyzing element and selectively illuminate said alpha-numeric character matrix;

(i) a projection lens positioned to receive light transmitted through the selectively illuminated portions of said alpha-numeric character matrix and to project light toward said light sensitive recording media; and

(j) a flat symmetrical plate member positioned in the path of said light beam between said projection lens and a position immediately adjacent said light sensitive surface, with its long axis coinciding with the propagation direction of said light beam, said plate member comprising a pair of converging reflective surfaces and being oriented to produce multiple internal reflections of the image of said alpha-numeric character matrix projected by said projection lens, so that said characters will image simultaneously upon said light sensitive media in a straight line configuration regardless of their actual position in the alpha-numeric matrix.

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JOHN M. HORAN, *Primary Examiner*.