350-3.74

XR 3,566,137 SR TX 3045Y
Y 3046C

(2)

United States Patent

[11] 3,566,137

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[54] **HOLOGRAPHIC CHARACTER READER**
9 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **250/219,**
340/141.3, 350/3.5, 346/74
[51] **Int. Cl.** **G06k 9/00**
[50] **Field of Search** 250/219
(CR), 237; 356/71, 74; 350/160, 161, 162 (SF), 3.5(Hobg), 3.5(SF); 340/146.3; 346/74; 96/1.1

[56] **References Cited**
UNITED STATES PATENTS

3,195,396	7/1965	Horwitz et al.	356/71
3,274,565	9/1966	Wright	250/219X
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ABSTRACT: Apparatus for recognizing serially viewed characters of a known font of type is achieved by imaging the characters onto a substrate bearing an electrically charged liquid photoconductor medium deformable in accordance with the optical image. When the deformed portion of the medium is rotated into the beam of a pulsed laser, spots are imaged upon a matrix of photodetectors by passing the laser beam emergent from the medium through a multiple spatial filter made by positioning the type for each of the expected characters in a vertical line.

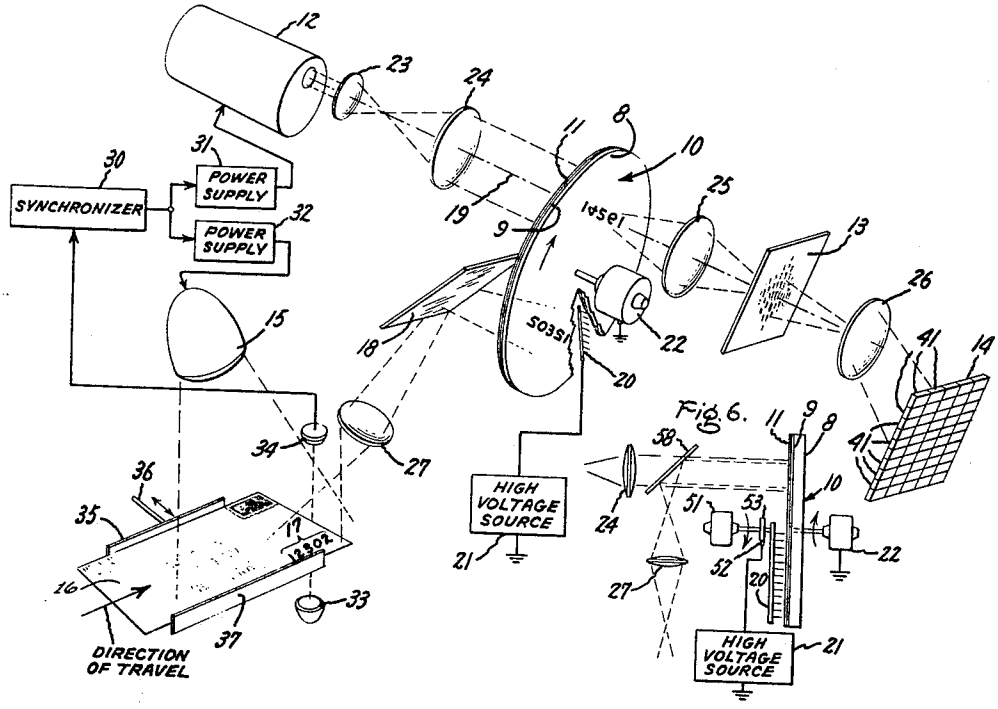


Fig. 6.

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OR IN 250/550

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SHEET 1 OF 2

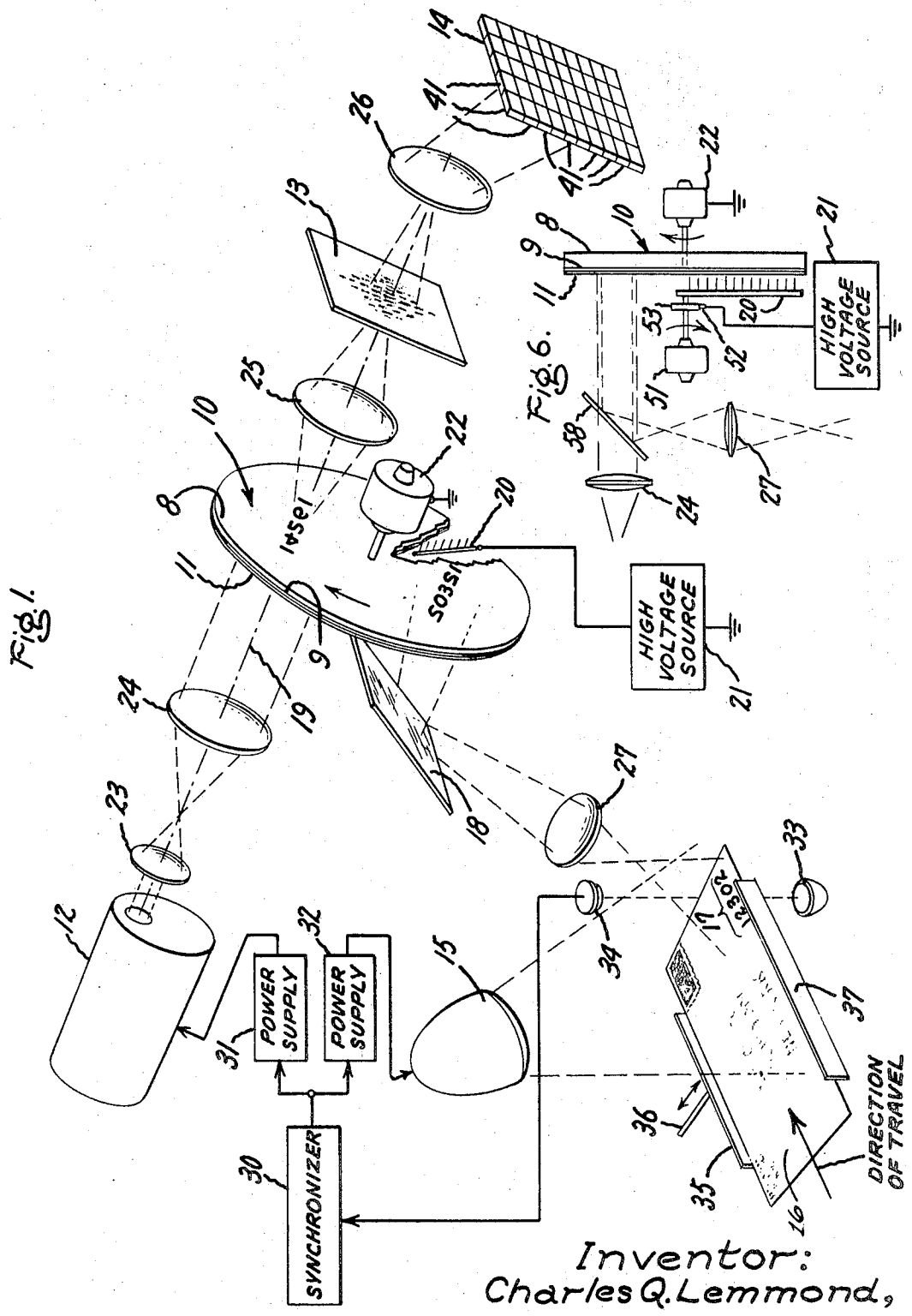


Fig. 1.

Fig. 6.

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Fig. 2.

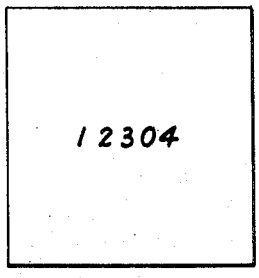


Fig. 3.

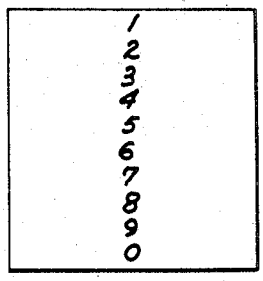


Fig. 4.

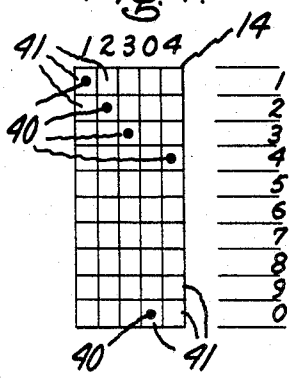
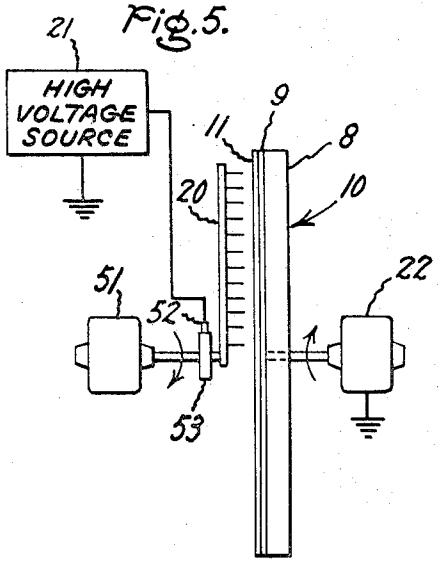


Fig. 5.



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HOLOGRAPHIC CHARACTER READER

BACKGROUND OF THE INVENTION

This invention relates to holography, and more particularly to a holographic character reader using a liquid photoconductor for recording input images.

The problem of automatic character identification in operations wherein different sets of graphic characters are displayed at high frequency rates has, in the past, presented formidable technological obstacles. One area in which this problem is of particular importance, for example, is in sorting mail. If it were possible to automatically identify only the address ZIP codes so as to facilitate sorting by mechanical means according to postal zones, the need in Post Offices for manual sorting of mail with U.S. addresses could be restricted solely to sorting by box number or street address. This would result in a great decrease in cost of mail handling, along with elimination of human error involved in misreading the ZIP codes. Other examples of where rapid character identification would be advantageous include railroad car identification, operations in which articles on a moving conveyor belt are labeled with printed characters, and in fact any type of system in which items may be identified by alphanumeric characters incorporated thereon.

The advent of holography has resulted in a powerful new tool for pattern recognition. For example, in the Autonomous Space Navigation System of J. M. Holeman and J.D. Welch, application Ser. No. 622,965, filed Mar. 14, 1967 and assigned to the instant assignee, holography is employed to obtain optically a "fix" or positional information in space. Moreover, holography is also employed to identify graphic characters, as in the Graphic Character Recognition System of J. E. Bigelow and C. Q. Lemmond, application Ser. No. 560,419, filed Jun. 27, 1966 now U.S. Pat. No. 3,374,717 and assigned to the instant assignee. However, in the aforementioned Bigelow and Lemmond application, the graphic characters comprising input data to be identified are detected initially by a vidicon camera tube. The present invention permits omission of television apparatus in reading graphic characters at a high rate of speed, thereby effectuating a significant reduction in complexity of apparatus and attendant costs.

BRIEF SUMMARY OF THE INVENTION

Accordingly, one object of the invention is to provide a simplified character recognition system capable of identifying in essentially real-time, images of alphanumeric characters presented in rapid succession.

Another object is to provide a graphic character recognition system wherein each image of characters to be identified is inserted in the path of coherent light rays without first undergoing transformation from visible to electromagnetic signal form.

Another object is to provide a character recognition system wherein the medium for recording the visible image displayed to the system is continually usable without heat development and with essentially no thermal gradients introduced therein.

Briefly, in accordance with a preferred embodiment of the invention, an improvement in a graphic character recognition system of the type which includes a source of coherent radiation pulses, radiation detecting means responsive to the radiation, spatial filter means interposed between the source of coherent radiation and the radiation detecting means, and media bearing sets of characters to be recognized, is provided. This improvement comprises a substrate coated with a deformable liquid photoconductor and situated intermediate the source and the filter means. Means are provided for illuminating sequentially each of the media in order to image the set of characters on each medium onto a region of the liquid photoconductor coating and deform the region accordingly. Means are also provided for situating the deformed region of the coating in the path of the coherent radiation.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the invention believed to be novel are set forth with particularity in the appended claims. The invention itself, however, both as to organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic diagram of the character recognition system of the instant invention;

FIG. 2 is an illustration of the image on the input plane in the system of FIG. 1;

FIG. 3 illustrates a typical order in which the characters to be recognized are arranged prior to being recorded in the multiple spatial filter in the system of FIG. 1.

FIG. 4 illustrates images of optical recognition spots as produced at the input to the detecting means in the system of FIG. 1;

FIG. 5 illustrates a second embodiment of the character recognition system of the instant invention; and

FIG. 6 illustrates a third embodiment of the character recognition system of the instant invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The character reader of the instant invention is schematically illustrated in FIG. 1. A thin, transparent disc 10 comprised on a conducting material 9, such as stannic oxide, overlaid on a transparent dielectric base 8, such as glass, and coated with a liquid material bearing a suitable photoconductor 11 on one surface thereof, is situated in the pulsed beam of coherent light emitted by a laser 12 operated from a power supply 31. The laser light beam is passed from disc 10 through a multiple spatial filter 13 to impinge upon light detecting means, such as a photodetecting diode matrix 14. Matrix 14 is offset form the optic axis 19 so as to respond to first order images, or diffraction images immediately adjacent the optic axis. Multiple spatial filters and a method of making are described in detail in J. M. Holeman and C. Q. Lemmond application Ser. No. 492,187 filed Oct. 1, 1965 and assigned to the instant assignee.

A second, momentary beam of light is produced by a source of light which may be incoherent, such as a flashlamp 15 operated from a power supply 32, and illuminates a medium 16, shown as an envelope bearing, together with its address, alphanumeric characters to be identified, such as the ZIP code 17. These characters are of a known font of type and located in a predetermined position as, for example, the lower right-hand corner of the envelope. Operation of laser 12 and flashlamp 15 is coordinated with the detected appearance of each of media 16 bearing characters 17 to be identified, through a synchronizer 30 which is actuated by detecting means such as a lamp 33 providing a beam of light to a photodetector or photocell 34. Thus, if media 16 are transported on a conveyor (not shown) in the direction of travel indicated, power supplies 31 and 32 are actuated in synchronism with the appearance of each one of media 16 on the conveyor. To properly position each envelope to be sensed by the system, a vertical member 35, which is moved by a shaft 36 in the direction indicated by the double arrow, slides each envelope on the conveyor against a stationary member 37. Both member 35, which is moveable with respect to envelope 16, and member 37, which is stationary with respect to the envelope, are carried along on the conveyor.

The light produced by flashlamp 15, which is selected to be of a wavelength falling within the sensitivity range of liquid photoconductor 11 on disc 10, impinges upon the photoconductor in a region which may be substantially diametrically opposite the region on which the beam of coherent light from laser 12 impinges, since light from flashlamp 15 reflected from medium 16 is directed by a reflector 18 onto disc 10. A high voltage corona discharge is produced by electrodes 20 which are connected to a DC source of high voltage 21. The corona discharge produces a continuous electric field which is

directed across the thickness of the liquid photoconductor so as to establish an electrical charge on the surface of the photoconductor. This charge is applied to the photoconductor in a region which is adjacent and immediately ahead of the location at which light from flashlamp **15** impinges on the photoconductor. Disc **10**, which is shown partially cut away to illustrate the position of electrodes **20**, is driven by a synchronous motor **22** in the direction indicated by the arrow, so that the newly charged region of the photoconductor is immediately thereafter positioned in the path taken by light reflected from medium **16**. Conductive layer **9** on disc **10** is grounded through the shaft and housing of motor **22**.

The laser beam is widened and collimated by a pair of lenses **23** and **24** respectively, while light emerging from transparent disc **10** is imaged by a lens **25** onto multiple spatial filter **13**. Similarly, light emerging from spatial filter **13** is imaged by a lens **26** onto photodiode matrix **14**. Characters **17** to be identified are likewise imaged by a lens **27** onto liquid photoconductor coating **11** on disc **10**.

A suitable liquid photoconductor film **11** may be cast from a suspension of 1.2 grams of copper phthalocyanine such as Ciba Microlith Blue 4 GT toner (available from Ciba Pharmaceutical Products, Inc., Summit, New Jersey) in 19 grams of a highly viscous liquid polymer of poly-α-methylstyrene such as Dow Resin 276 V9, (available from Dow Chemical Company, Midland, Michigan) dissolved in about 20 grams of toluene. A one-half hour bake at 85° C. suffices to remove enough of the solvent from the film for suitable operation. For a photoconductor film of this type, the corona electrodes typically comprise sharp tips on short lengths of wire, for example about 1 inch of 10 mil diameter nickel wire, with the tips mounted about 1 to 2 inches above the film surface, and from −2.5 kilovolts to −10 kilovolts of DC voltage on the tips. Alternatively, other types of liquid photoconductors may be used, such as those described in J. Gaynor application Ser. No. 526,757, filed Feb. 11, 1966, now U.S. Pat. No. 3,450,837, and assigned to the instant assignee.

In operation, disc **10** is continuously rotated at a constant speed by motor **22**. Medium **16**, bearing the alphanumeric characters to be identified, is precisely positioned beneath flashlamp **15**, as by a conveyor (not shown) and members **35** and **37** carried along on the conveyor, and is illuminated momentarily by the flashlamp for a fraction of a millisecond. The image of the alphanumeric characters is focused by lens **27** and reflector **18** onto liquid photoconductor film **11** on disc **10** in the region of the film bearing a charge newly supplied by electrodes **20**. As the disc is rotated in the indicated direction, the charged region on which the alphanumeric characters are imaged undergoes a change in resistivity according to a pattern corresponding to the image of the characters, as described in J. Gaynor Pat. No. 3,291,601, issued Dec. 13, 1966 and assigned to the instant assignee, so that the electrical charge on the surface of the film in those portions of the film illuminated by the light of the flashlamp will become electrically neutral. Since the coating is in liquid form, the remaining charges cause the liquid to deform so as to produce a three dimensional recording of the alphanumeric characters to be recognized. Because the coating is in liquid form at room temperatures, no heat development is required.

As the disc continues to rotate, the electrical charge image on photoconductor film **11** is next positioned in the path to be taken by the coherent light produced by laser **12**. Laser **12** is preferably a pulsed laser, synchronized through synchronizer **30** and photodetector **34** with the rate at which media **16** appear, and coordinated with the angular velocity of disc **10**, which is driven by a synchronous motor operated, for example, from a commercial 60-cycle AC source. Thus, laser **12** emits a momentary pulse of light each time the portion of liquid photoconductor film **11** deformed in accordance with the image produced by a flash of light from flashlamp **15** has been positioned by disc **10** in the path of coherent light emitted by the laser. The laser light produces a Fourier transform of the imaged alphanumeric characters as it emerges from disc **10**, and this transform is imaged by lens **25** onto multiple spatial filter **13** which contains a plurality of diffraction patterns corresponding to those produced by all of the characters expected to be recognized by the system. In this instance, the multiple spatial filter is fabricated as described in the aforementioned Bigelow et al. application Ser. No. 560,419 and Holeman et al. application Ser. No. 492,187, with the characters to be recognized, here the ten decimal digits, positioned in a vertical line in the manner illustrated in FIG. **3**. Since the input transparency borne by disc **10** contains a horizontal format of alphanumeric characters to be recognized, as shown in FIG. **2**, it is possible to identify each character in the image and determine its ordinal position in the image according to its vertical and horizontal location respectively in the recognition plane. Thus, FIG. **4** illustrates how the recognition spots of light **40**, each of which comprises the first order image emergent from spatial filter **13**, are related in position to the arrangement of characters from which the filter was made and the arrangement of the input characters to be recognized, for an assumed input image made up of the characters 12304. Each spot of light **40**, shown in FIG. **4**, represents its individual location on photodiode matrix **14**, while each quadrilateral **41** within matrix **14** represents an individual photodetector of the matrix.

Coherent light from laser **12** in the configuration of FIG. **1** passes through disc **10** and photoconductive film **11** thereon to spatial filter **13** and thence to photodiode matrix **14**. Since the positions in the matrix of the photodetectors which sense the light spots are determined by the numbers in the ZIP code and the order in which they appear in the ZIP code, it is clear that the ZIP code number is coded by the position of the photodetectors which respond to spots of light. Also since the photodetectors are subjected to one of two light levels dependent upon the presence or absence of light spots, it is clear that the output is of one or two levels and therefore may be considered digital. Output of photodiode matrix **14** comprises a digitally coded signal which may control operation of utilization means, such as a letter sorter for use in a Post Office if automatic identification of ZIP codes is being performed. Photodiode matrix **14** could, in the alternative, be replaced with a scanning image tube, such as a vidicon or an image orthicon, thereby removing constraints on the ZIP code location except for rotational position constraint; in this instance however, a logic circuit, such as that described in the aforementioned Bigelow et al. application Ser. No. 560,419, would be required to determine the order in which the recognition spots were scanned by the scanning beam. Regardless of whether radiation detecting means **14** comprises a photodiode matrix or a scanning image tube however, the short time interval which elapses between the instant an input image is detected by the system and the instant at which the characters have been recognized as determined by the electrical output signals produced by radiation detecting means **14** provides the system with essentially real-time recognition capability.

FIG. **5** illustrates another embodiment of the holographic character reader. In this embodiment, electrodes **20** are rotated at a constant angular velocity by a motor **51** in a direction opposite to the rotation of disc **10**. High voltage source **21** is connected to electrodes **20** through a brush **52** in contact with a slip ring **53** mounted on the shaft of motor **51**. By rotationally passing electrodes **20** over the surface of liquid photoconductor **11**, the photoconductor can be evenly charged so that light imaged thereon can deform the photoconductor. Reapplication of an even charge on the photoconductor prior to focusing another light image thereon, achieved by another pass of electrodes **20** over the surface of the photoconductor, restores the surface of the photoconductor to a flat configuration, enabling application of a new image thereon.

FIG. **6** illustrates yet another embodiment of the holographic character reader of the invention. In this embodiment, both electrodes **20** and disc **10** are made to rotate in opposite directions, as in the apparatus illustrated in FIG. **5**. However,

by use of a beam splitter **58** instead of a mirror to image the characters to be recognized onto liquid photoconductor **11**, with the beam splitter situated in the path of coherent light emitted by laser **12** so as to pass coherent to the liquid photoconductor, the characters to be recognized are imaged onto the disc within the path of the coherent light. In this embodiment, it is not necessary that disc **10** be rotated at all; however, some slight rotation of the disc may be desirable in order to keep the liquid photoconductor evenly dispersed over the entire surface of grounded conductive layer **9**, provided the rotational speed is low enough to allow a brief interval between occurrence of the flashlamp pulse and the laser pulse during which the liquid photoconductor can deform. By use of a xenon flashlamp in all embodiments of the invention, deformation of the liquid photoconductor occurs due to its sensitivity to the wavelength of light (blue-green) produced thereby. By use of a helium-neon laser, for example, to produce the coherent read-out beam, the wavelength of the readout beam is only at the red end of the optical spectrum, and thus produces no deformation of the liquid photoconductor.

The foregoing describes a simplified graphic character recognition system capable of identifying, in essentially real-time, images of alphanumeric characters presented in rapid succession. Each image of characters to be identified is inserted in the path of coherent light rays without first having undergone transformation from visible to electromagnetic signal form. The medium for recording the visible image displayed to the system is continually usable without heat development and with essentially no thermal gradients introduced therein.

While only certain preferred features of the invention have been shown by way of illustration, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit and scope of the invention.

I claim:

1. In a graphic character recognition system having essentially real-time recognition capability and including a source of coherent radiation pulses, radiation detecting means positioned in the path of said radiation, spatial filter means interposed between said source of coherent radiation and said radiation detecting means, and media bearing sets of characters to be recognized, the improvement comprising: a substrate coated with a deformable liquid photoconductor and situated intermediate said source and said filter means; means for momentarily illuminating each of said media in sequence; optical means for imaging the set of characters on each medium when illuminated onto a region of the liquid photoconductor coating so as to deform said region accordingly; and means for situating the deformed region of said coating in the path of said radiation.

2. The character recognition system of claim **1** wherein said means for illuminating sequentially each of said media comprises a flashlamp and means for moving said media in relation to said flashlamp.

3. The character recognition system of claim **1** including means synchronizing said source of coherent radiation pulses with said means for illuminating sequentially each of said media.

4. The character recognition system of claim **2** including means synchronizing said source of coherent radiation pulses and said means for illuminating sequentially each of said media with the rate at which each one of said media is detected.

5. The character recognition system of claim **1** wherein said means for situating the deformed region of said coating in the path of said radiation comprises means mechanically coupled to said substrate for impelling said substrate to transport the deformed region of said coating into the path of said radiation.

6. The character recognition system of claim **5** wherein said substrate comprises a disc and said means for impelling said substrate comprises a synchronous motor.

7. The character recognition system of claim **5** including means for establishing an electrical charge on the surface of said coating in the region of said coating immediately ahead of the location at which said characters are imaged onto said coating.

8. The character recognition system of claim **5** wherein said source of coherent radiation pulses comprises a laser and said radiation detecting means comprises an array of photodetectors.

9. The character recognition system of claim **6** including means for establishing an electrical charge on the surface of said coating immediately ahead of the location at which said characters are imaged onto said coating.