Information Display

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New High-Density Large-Screen 4-Color LCD System is demonstrated by SID Members Theodore B. Aitken and Dr. Robert C. Tsai of The Singer Company, Librascope Division, Glendale, CA. This is said to be the largest liquid crystal display with such high resolution — 8 million pixels available for presentation on a 48" x 48" screen.

Two smectic liquid crystal light valves (SLCLVs) present data in three colors on a fourth background color. The SLCLVs are optically addressed by a Nd: YAG laser controlled by a modulator and deflection system under the direction of a microprocessor. A flashing pointer in the system enables the display operator to enter, modify, or delete alphnumeric and graphic data. Each of the two light valves can be operated both in a bright field mode (black image on color background) or in a dark field mode (color image on black background). With red, green, yellow, and black available as either background or image colors, a wide variety of color combinations can be generated. Because each light valve can generate 2048 x 2048 addressable pixels within a 1" x 1" data format, the system has extremely high resolution — 2500 TV lines per inch. With the raster scan mode, 2500 alphanumeric characters can be generated within a second.

A detailed description of this new LCD system by Bob Tsai, manager of this project at Singer/Librascope, begins on page 3.

FRONT COVER MATERIAL WELCOMED: Every month **Information Display** usually features one or more active members of SID and the products with which they are most closely associated. Please send a glossy print and appropriate captions so that you, too, can be on our front cover. Send your material to Ted Lucas, Editor, P.O. Box 852, Cedar Glen, CA 92321, or to our National Office Manager, June Friend, for Information Display, 654 North Sepulveda Blvd., Los Angeles, CA 90049. Next deadline for material from you is August 10. If you miss that, try for the November issue NOTE: We also welcome feature articles on interesting projects.

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High Data Density 4-Color LCD System

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Abstract

A large-screen LCD system, including a high resolution and high contrast laser-addressed liquid crystal color display, has been developed for acquisition and exploitation of high density alphanumeric and graphic data. The display system consists of two smectic liquid crystal light valves (SLCLV) which are thermally addressed by a single laser selectively. Each light valve can generate 2048x2048 addressable pixels within a 1'' x 1'' data format. There are 8×10^6 pixels available for data presentation.

The laser writing system consists of the laser, a modulator for formation of discrete data elements on the SLCLV, a 2 axis galvanometer deflection unit, and beam splitting optics to multiplex the writing laser on each SLCLV. A closed-loop galvo deflection system can position the focused laser beam to an accuracy of 0.1% across the screen. Laser focus lens is an f/8.0 telecentric design to produce a 1'' x 1'' data format on the SLCLV with spot size less than 0.0004''. Color images from each light valve are superimposed onto the screen by a wide angle f/8.0 projection lens This lens, with 48X magnification, relays the combined color image to a 48'' x 48'' screen with less than 0.1% distortion. The possible contrast of the display is up to 60 to 1. The overall dimensions of the rear-projected color display are 60'' x 52'' x 31''.

Current CRT or CRT-driven large screen displays do not provide enough resolution elements to display massive amounts of information. This new large screen color LCD with smectic liquid crystal light valves has been developed by Singer to handle high data density graphic and alphanumeric presentations for status summary, simulation, tactical and strategic combat situations.

This paper describes an ultra-high resolution 4-color liquid crystal projection system which utilizes two smectic liquid crystal light valves (SLCLV) to present data in three colors on a fourth background color. The SLCLVs are optically addressed by a Nd:YAG laser through the control of a modulator and deflection system which is powered by a microprocessor. A flashing pointer is included in the system to provide the interactive features which enable the operator to enter, modify, or delete alphanumeric and graphic data on request.

Principle of Operation

Smectic Liquid Crystal Light Valve (SLCLV)

Both Schiff-based and biphenyl families of the smectic liquid crystals have been investigated in this study. These mixtures exist in a smectic state at room temperature. They may be highly scattered or highly transparent depending on whether molecules are in an ordered structure or not. The structure of the SLCLV is shown in Figure 1. Liquid crystals are sandwiched between two substrates coated with vacuum sputtered indium tin oxide transparent electrode and the organic surfactant. Dow Corning's alkoxysilane, [1,2]e.g., N, N-dimethyl-N-octadecyl-3-aminopropyltrimethoxysilyl chloride and carboxylate chromium complexes were tested to induce a homeotropic alignment of the liquid crystal molecules.

Indium tin oxide coating (ITO). Transparent conductive coatings of SnO_2 doped In_2O_3 were vacuum sputtered on the substrate surface. High optical transmission in the visible spectrum and high absorption at the Nd:YAG laser wavelength are essential to ensure the performance of the light valve. In-house sputtered ITO coating has a sheet resistance of less than 2Ω/□ and yet has high optical transmission. The optical characteristics of sputtered ITO thin film are shown in Figure 2.

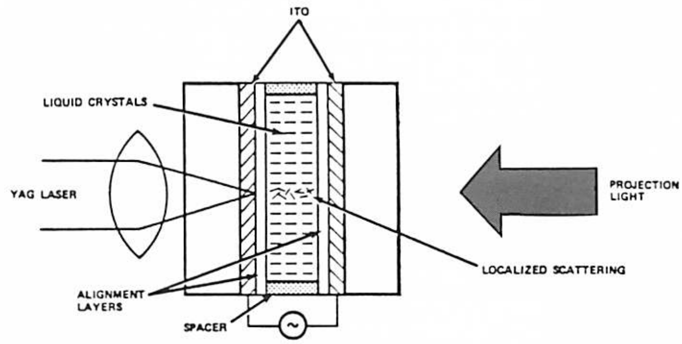

Figure 1. Storage mode liquid crystal light valve.

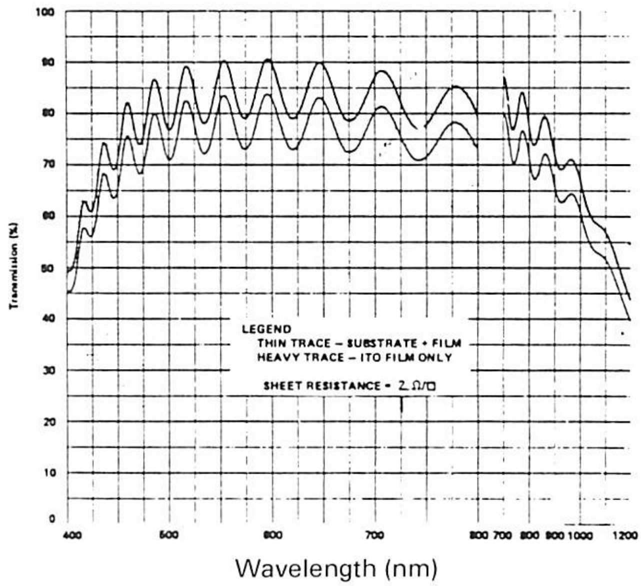

Figure 2: Optical characteristics of vacuum sputtered In_2O_3/SnO_2 thin film.

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Writing/erasing mechanism. At normal operation, the liquid crystal temperature is biased a few degrees below the smectic-nematic transition. Switching between states is done by heating a region of the assembly so that the liquid crystal changes to the nematic or isotropic states. The local heating effect on the LC molecules is achieved by focusing a laser beam onto the ITO coating. Absorbed laser energy causes the LC molecules to transform into the isotropic state and to possess a randomly oriented order. If the cooling is slow, LC molecules will align themselves and produce a clear state due to the boundary condition induced from the alignment layer on the light valve substrates. However, if the cooling is rapid, they will not be able to align themselves in time and therefore assume the random orientation to form a highly scattered state. This will show as a dark image on the screen if the light valves are projected by the projection optics to the screen.

To erase selectively, an ac bias is applied simultaneously with the laser scan. Liquid crystal molecules respond to the electric field and align into the field direction while still in the nematic state to erase the previously written image.

Bulk erase is also possible by applying an ac bias across the light valve with higher amplitude or to raise the light valve temperature to nematic state externally and then to erase by ac bias. The typical writing and erasing rate per pixel element is about 5 microseconds, and the time delay for the erase is about 1 msec for each erase.

Due to the inherent characteristic of the smectric liquid crystals, the written image on the light valves can be stored in the display for hundreds of hours without degrading the contrast.

Twelve levels of the gray scale have been generated digitally with the microprocessor control. This is achieved by laser intensity and ac bias amplitude modulation.

Optic design. A writing system consisting of a focus lens and a relay lens was designed to focus infrared energy from the Nd:YAG laser upon the SLCLVs. The entrance pupil of the scanning focus lens is located sufficiently in front of the lens to enable placement of the last deflection mirror without the mirror striking the lens or its housing. The telecentric focus lens is designed to work at f/8.0 for 1.06u wavelength. A schematic of the scanning lens is shown in Figure 3. The laser spot diameter is approximately 0.0004" at 50% power level.

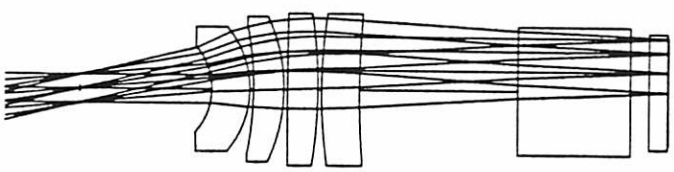

Figure 3. Computer ray trace of the laser writing focus lens.

Light valve images are projected to the screen by means of light source optics and a projection system. A f/8.0 telecentric wide angle projection lens is designed to project the 1" x 1" image on the SLCLV onto a 48" x 48" screen with distortion of less than 0.1%. The projection lens has modulation transfer function of 50% at 40 line pairs per mm. A contrast of greater than 25 to 1 is typical for the color system. However, contrast greater than 60 to 1 has been achieved with black-and-white images.

Color generation: Two SLCLVs are used in this display system to produce 4 colors. Information can be displayed in 3 colors with a fourth one as background. Figure 4 illustrates the optical arrangement of the system. The YAG laser beam is directed to address an assigned light

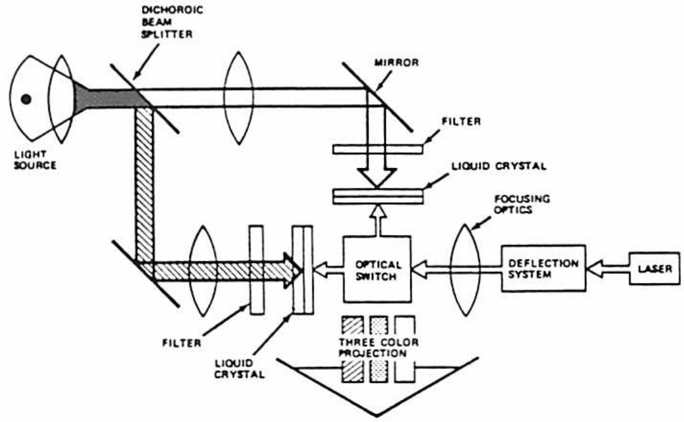

Figure 4. The functional diagram of the 4-color liquid crystal large screen projection system.

valve channel by means of a proprietary optical channel-selecting element. Either light valve can be addressed selectively or simultaneously to create a color spectrum between the two prime colors determined by the color filters inserted in each light valve projection path.

Through the illumination optics, the two SLCLVs are projected separately through a color filter to generate two colors (red and green) of different images on the screen. The third color image (yellow) is obtained by superimposing two identical images from both of the liquid crystal light valves. The fourth color (black) is produced by blocking off the projection light by the same image in both channels. Each light valve can be operated in both bright field mode (black image on color background) or in the dark field mode (color image on a black background). Therefore, an interesting variety of color combinations can be generated by this scheme.

Results

Figure 5 is a photomicrograph of a portion of the light valve with image of resolution test pattern. Lines and spaces on Figure 5 are 0.0004 inches wide. A resolution of 2500 TV lines per inch on the SLCLV has been demonstrated.

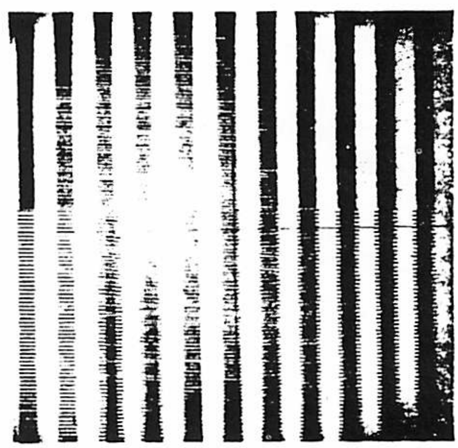

Figure 5. Photomicrograph of liquid crystal data cell with stored resolution test pattern. Lines and spaces are 0.0004 inch wide.

In general, the line width of the written information is a function of operating temperature, laser power, and the writing speed. With a contrast writing speed at constant temperature, the line width of a written image is a linear function of the laser power. Figure 6 is the data collected from a Schiff-based smectic liquid crystal mixture.

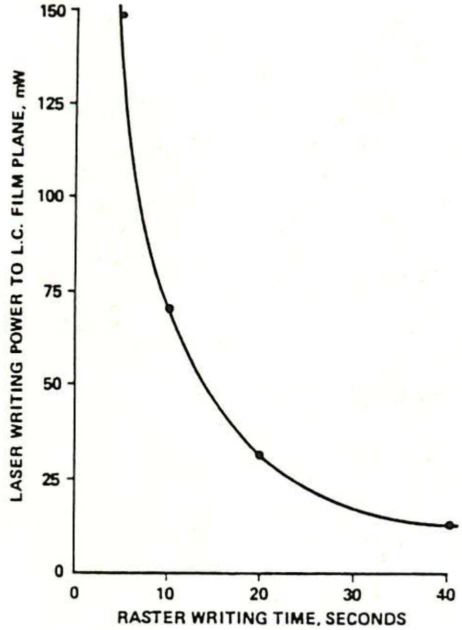

Figure 6. Lineal writing time to produce a 1.2 cm x 1.2 cm 1024 line raster versus laser writing power.

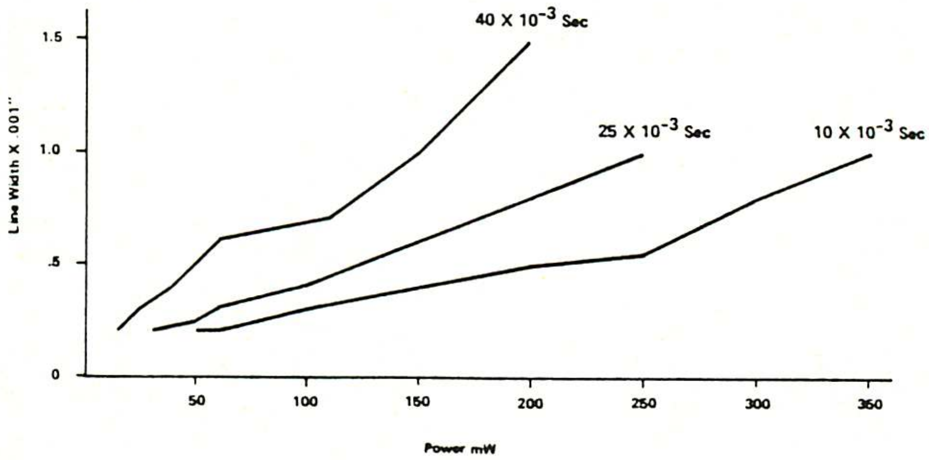

Figure 7. Liquid crystal line width versus laser writing power at constant raster write rate. Numbers shown on the curves indicate the time for a single scan.

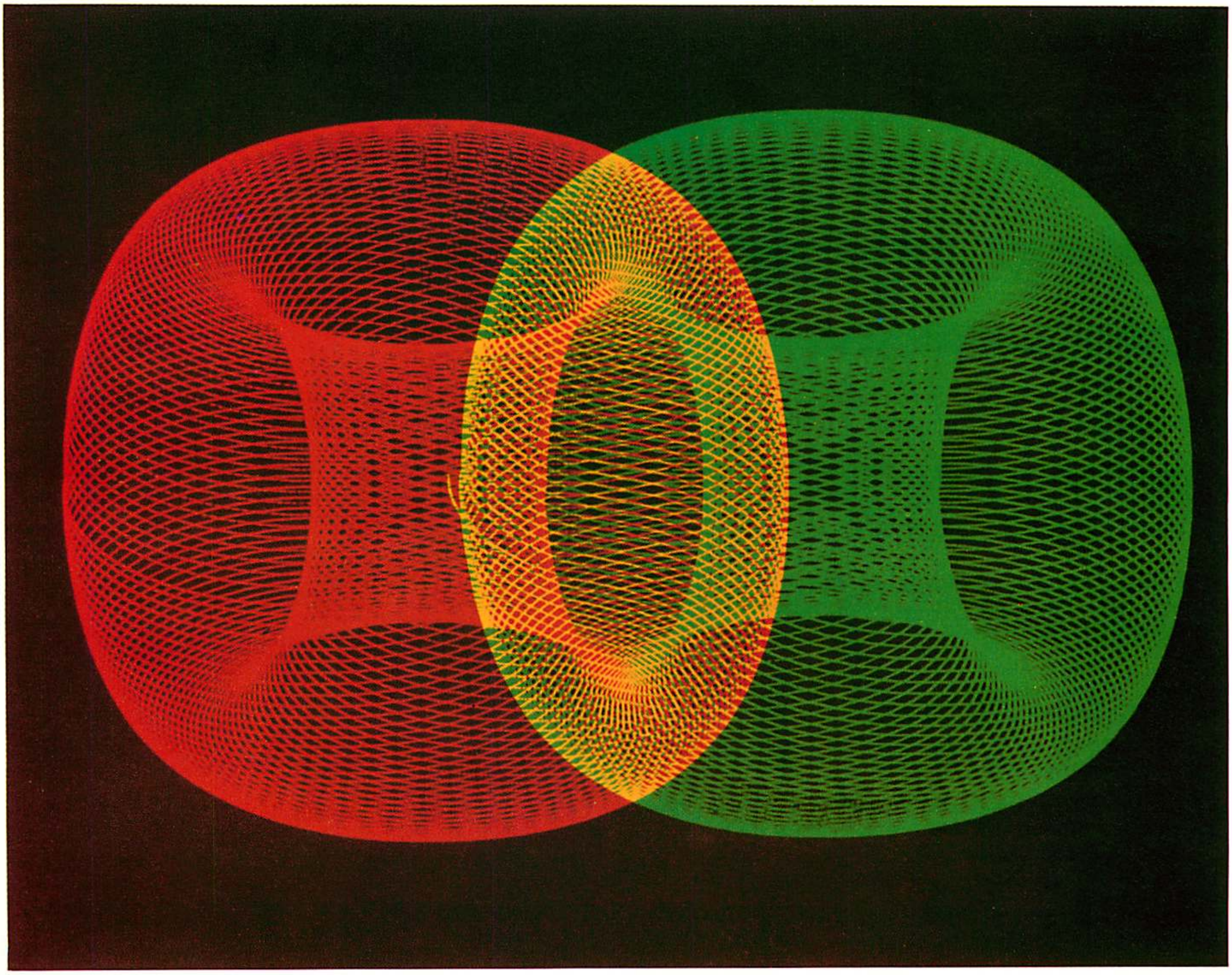

Figure 8. Three-color computerized graphics.

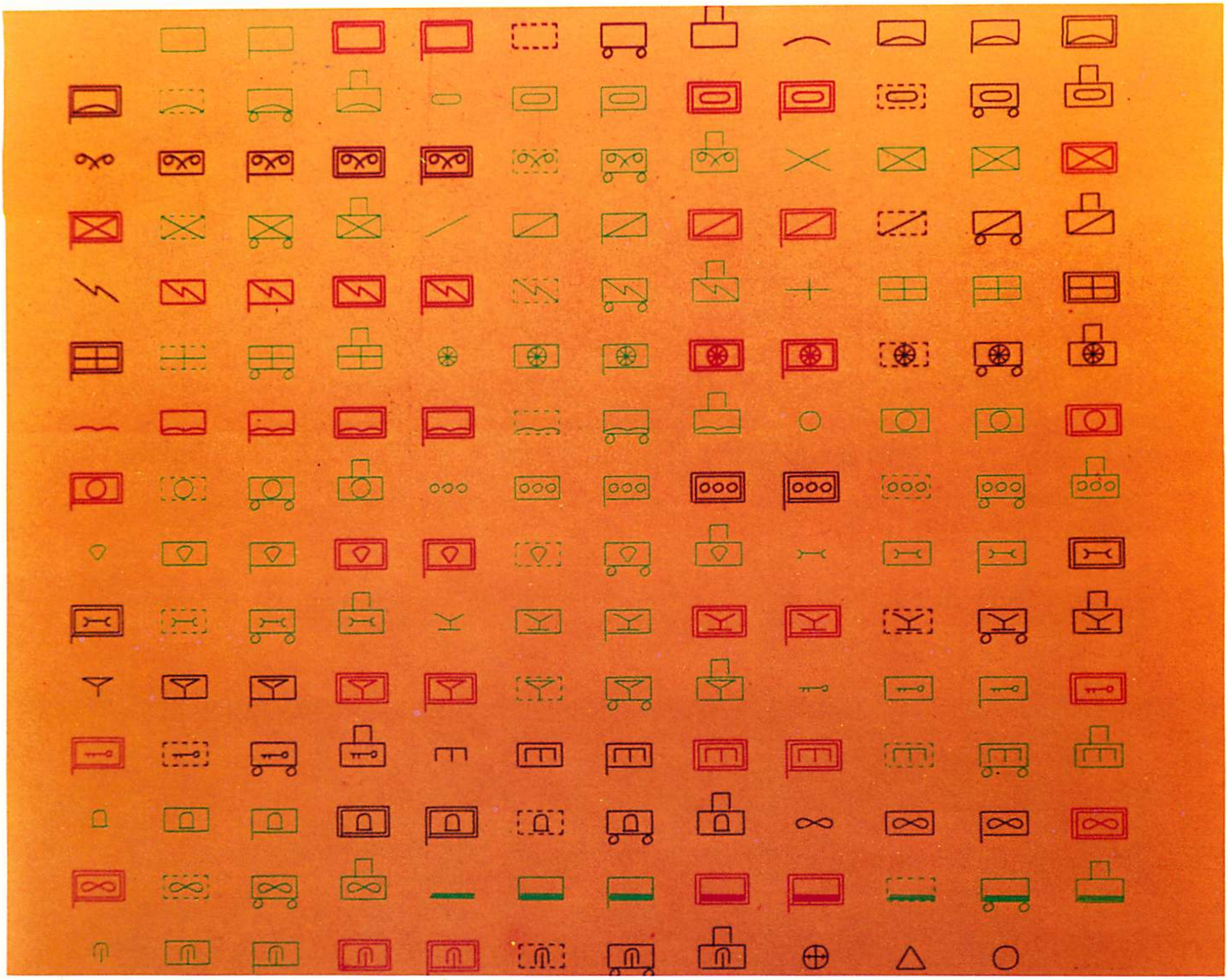

Figure 9. Random access writing of the 3-color Army symbols.

The laser power required to form 60 to 1 contrast at different writing speeds is shown in Figure 7. The horizontal axis indicates the time required to perform raster scan of 1024 TV lines on 1/2" x 1/2" format on the SLCLV.

The laser writing of the liquid crystal light valve can be in raster or random access modes. The writing speed per pixel for a 2048 x 2048 line display is typically 5u sec. With the raster scan mode, 2500 alphanumeric characters can be generated within a second.

A black and white photo of a 3-color graphic pattern is shown in Figure 8. These images were generated from a microprocessor which then controls the deflection system and laser intensity to write on the SLCLV in random access mode.

A 3-color Army symbol presentation is shown in Figure 9. The images shown on both figures were generated within 1/2" x 1/2" format (1024 x 1024 pixels) on the light valves with registration accuracy of less than 1/2 of the pixel element.

Acknowledgements

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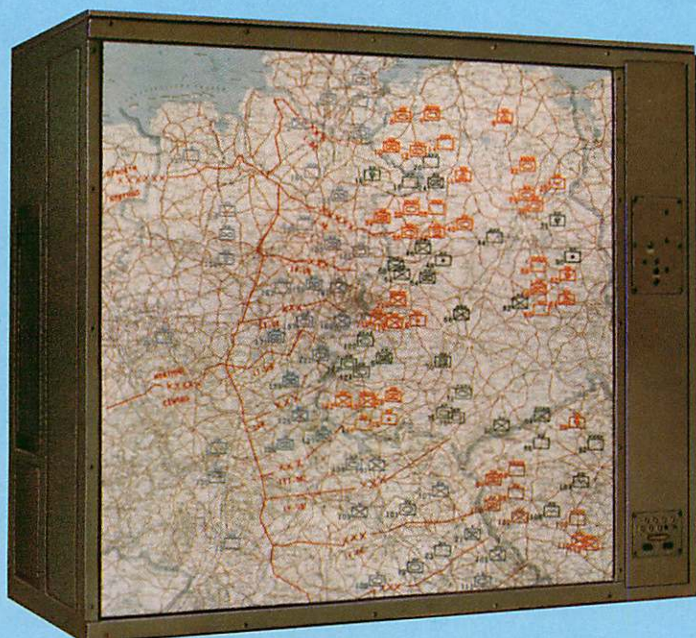

System is shown here in vertical self-contained configuration, with a 48x48-inch image area.

FEATURES:

- Contrast Ratio: Up to 60:1
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- 2048 x 2048 Pixels/Channel
- Selective Erase

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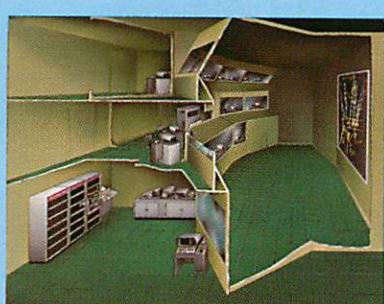

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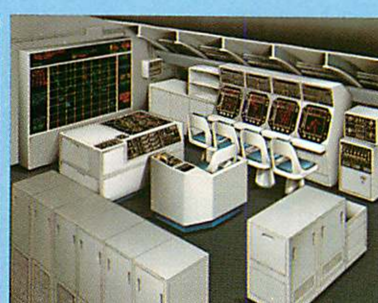

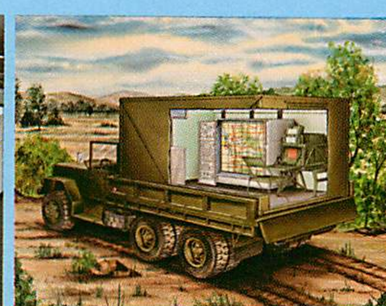

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