unique properties as applied to visual simulation in training devices. This program has been active for the past three years and many new ideas and concepts such as multi-imaging techniques and contour generation have been explored and developed.

What is in the future concerning holograms and training devices? NTDC feels sure that there is great promise in applying holography to visual simulation. The work here will continue to expand, covering the many aspects of holography. Some of the future possibilities which are foreseen in training devices include the utilization of three-dimensional holographic, large screen, motion pictures and television, 360° holograms to be viewable from all directions, and complete landing and docking simulators using holograms as the visual display. As holography grows out of its infancy, many new and better ideas will develop. These ideas will become the basis for future work making "Better Training Devices through Holography."

LASER DISPLAY

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I. INTRODUCTION

The development of the laser has made possible a new approach to a large-screen, high-brightness, high-resolution, real-time display for training device applications. This paper will describe efforts by the Naval Training Device Center and others who are striving to improve methods of display by utilizing the laser.

A large screen laser display would be useful in rapidly communicating information from a computer to a trainee and allowing him to interact with this information. A large screen real-time laser display would also be of value in presenting larger, faster, brighter, real-time tactical data to a large audience at a control center in an undarkened room.

The laser display is essentially an "open air" cathode ray tube. In a laser display system the beam is not maintained in a vacuum as in a CRT, therefore, the previous physical limits on screen size and brightness have been removed and the resolution capabilities are determined by physical optics instead of electron optics. Therefore, it is expected that the laser will provide the key to larger, brighter and higher resolution displays. The crucial areas of research are the development of efficient higher power lasers and better methods of both light deflection and modulation. Present lasers are not compact, require maintenance and lack the desired reliability for field use. A single multi-color emitting laser would also reduce the required equipment for color displays. At the present time light cannot be deflected as easily as the electron stream in a CRT, therefore, high speed, large angle deflectors must be developed.

We feel these problems will be solved and the laser will eventually be utilized in large screen displays.

II. LASER DISPLAY CONFIGURATION

An experimental model has been constructed for the Naval Training Device Center to demonstrate the efficacy of laser display techniques. This display was constructed and delivered by the Lockheed Electronics Company under Contract Number N61339-66-C-0096, August 1967.[1]

In order to illustrate the basic display configuration, I will review the basic components of this display. (Figure 30)

This system is a multiple symbol/target, multiple color laser projector. A simple, four-stroke character generator is used to display 10 different symbols and target spots, each in a different color anywhere on a 10-foot square screen.

This system is analoguous to an open-air color television display where the electro-optical light modulator, EOLM, corresponds to the Z-axis modulation, the deflection galvanometers correspond to the horizontal and vertical deflectors, the lasers correspond to the electron guns, and the display screen corresponds to the picture tube face. The major difference in the analogy is that the laser display screen is passive because the color information is contained in the laser beams.

Multicolor capability is obtained by generating three primary laser colors and using additive mixing to obtain a desired color making use of colorimetric techniques. The three primary colors are red (6328Å) generated by a helium-neon laser, blue (4880Å) and green (5145Å) generated by an argon laser.

A Spectra-Physics Model 125 helium-neon laser source provides a minimum of 50 mw of 6328Å. The output beam diameter is 2 mm with a beam divergence of 0.7 milliradian.

A Raytheon Model LG-12 argon laser provides one watt over its entire spectrum. One watt is necessary in order to balance the primary colors for proper mixing. This laser emits two major lines at 4880Å and 5145Å. The output beam diameter is 2 mr with a beam divergence of less than 1 milliradian. The maximum output power is 400 mw at 4880Å and 250 mw at 5145Å. A dichroic mirror is used to separate the green and blue lines from the argon laser beam. This mirror, when at 45^{o} incidence, reflects 99% of 5145Å and transmits 93% of 4880Å.

The three primary colors are next each passed thru an electro-optical light modulator, EOLM, to obtain the correct intensity for color mixing. The modulators are Pockel's effect devices. This device operates with two deuterated potassium dihydrogen phosphate (KD*P) crystals excited in the transverse mode followed by a polarizing prism. The two crystals are oriented orthogonally so that 45^{o} phase retardation in each is sufficient to rotate the polarization vector of the input light a full 90^{o}. Because of the transverse excitation and dual crystal construction, a half-wave retardation voltage of only 450 volts is required. This is desirable because solid-state drivers can be used and operation from DC to the 120 MHz region can be obtained.

The EOLM rotates the light wave's polarization vector. A polarization analyzer is used after the EOLM to pass only that portion of the light vector with which it is aligned. A Glan-Thompson prism is used as an analyzer.

Light beams leaving the blue and green EOLM are mixed in a beam splitter. This beam splitter is 65% reflective and 35% blue transmissive. This is necessary since the argon laser produces at 1 watt output, 400 mw of 4880Å and 250 mw of 5145Å. The output of the first beam splitter mixer is fed to a second mixer which is also a beam splitter with 50% reflective and transmissive capability. At this beam splitter the blue and green are mixed with the red to form a multicolored light. This second mixer output, a single beam, is then fed to the galvanometers for deflection.

The single, multicolored light beam is deflected by a pair of high speed galvanometers with a frequency response from DC to 10 KHz. By orienting the galvanometer mirrors orthogonal and facing each other, the light beam is deflected in both vertical and horizontal directions. The electronically controlled elements (galvanometers and (EOLM) are driven by a solid-state character generator which develops the necessary sweep and amplitude waveforms as well as timing and positioning waveforms.

The galvanometers are Century Models 210C67 with a flat frequency response for DC to 5 KHz. The mirrors are only 0.025 inches by 0.2 inches so a beam reducing lens system is necessary. The galvanometer system is shown in Figure 31. The laser beam is incident on the X deflecting mirror first. The beam next is reflected from the Y deflecting mirror which directs it to the screen. Full deflection requires 60 ma to drive the galvanometer coils with 500 u sec. required for full deflection from the center of the screen.

In the writing cycle the EOLM's are initially gated off and the galvanometers are directed towards the center of the screen. When the first symbol/target is required, a signal from the character generator rotates the galvanometers to position the light beam to the desired location. Upon reaching this position, a small AC signal is added to the positioning voltage to stroke out a character or symbol. Simultaneously with the stroking, any combination of the laser primaries is selected by gating signals to the EOLM. Thus the symbol is generated on the screen in any one of 10 colors. Specific colors for any symbol is selectable by varying the DC bias on the EOLM by potentiometers.

To keep the display above the flicker rate the 10 target/symbols are displayed 30 times a second. The light sources provide maximum intensity so that the display can be viewed in a lighted room.

The capabilities of this system will be upgraded, but research will be necessary to provide replacements for several of the weak links in this type projection system prior to practical usage.

The galvanometers or deflection system is one area where major improvements are required.

Research must also provide higher power lasers with longer tube life and lower failure rates. A single laser with the required primary lines would be an aid to reducing the systems size.

Aligning the many beams to be coincident also provides difficulty in optical alignment and new methods to accomplish this task must be found.

The following section will discuss laser deflectors.

III. LASER DEFLECTION DEVICES

Devices to deflect a laser beam may be separated into three general classes:

(1) Mechanical Deflection Devices - motor driven rotating mirrors or oscillating galvanometer mirrors.

(2) Acoustic Deflection.

(3) Electrooptic Deflection.

These devices will be reviewed briefly.

A. *Laser Deflection By A Torsionally Resonant Horn Loaded Piezoelectric Ceramic.*

The piezoelectric device to be described is the work of R. Klaiber and G. Derderian and was developed by NTDC.[2] This device utilizes a piezoelectric transducer to drive a mechanical amplifier to obtain deflection of a mirror attached to the mechanical horn. The device is shown in Figure 32.

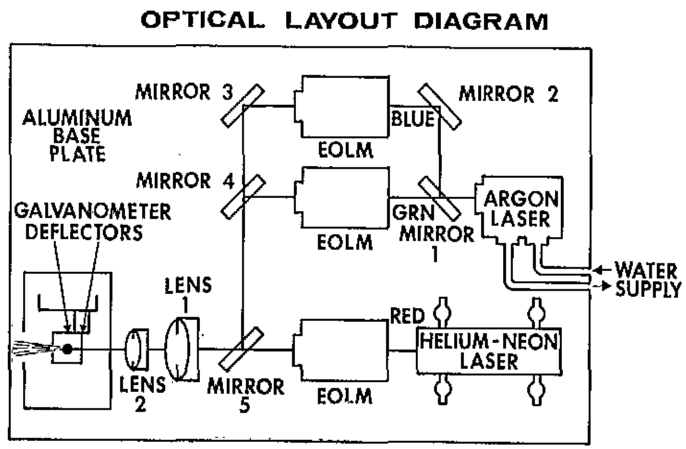

Figure 30.

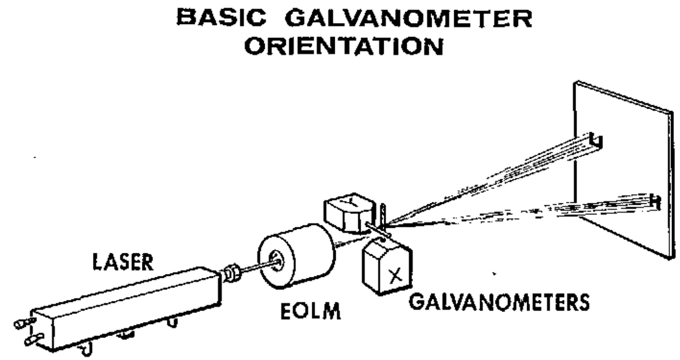

Figure 31.

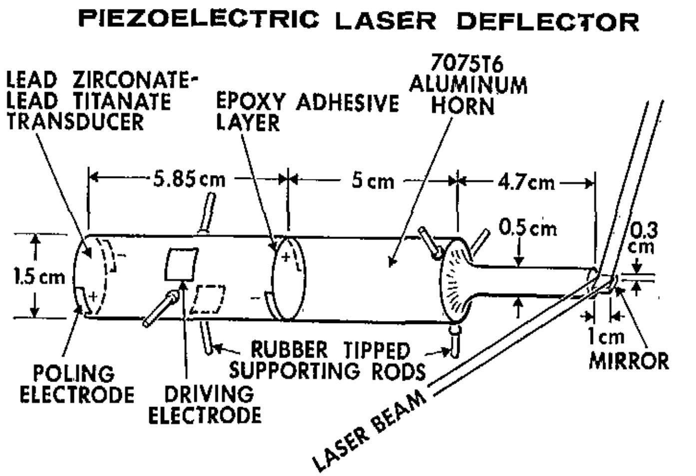

Figure 32.

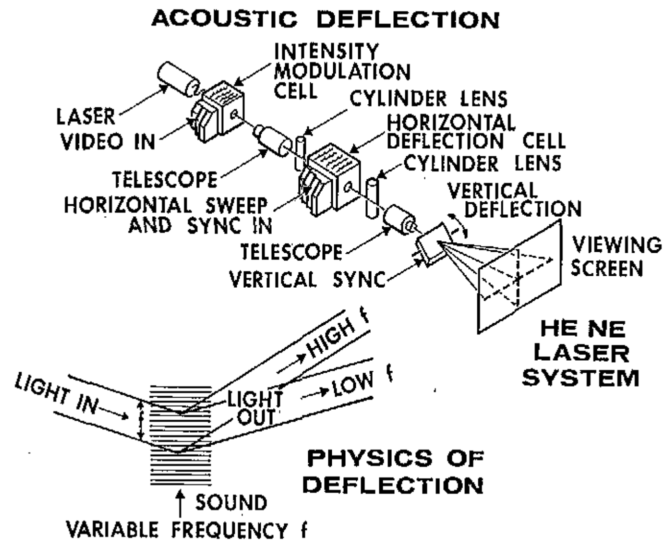

Figure 33.

The device operates by causing the lead-zirconate-titanate to twist under the application of an electric field.

The piezoelectric ceramic is poled by application of a large DC poling field (30KV). Poling orients the dipolar molecules of the ceramic in the direction of the field. After poling, the molecules of the ceramic are reoriented from the preferred poled direction by application of a driving electric field. The poling and driving geometry are arranged so that the ceramic will be constrained to twist under application of a driving field. Because the transducer is not under application of an external force, there is no net movement, only a twisting displacement with an amplitude node located centrally along the longitudinal axis. The torsional shear wave generated by the twisting ceramic transducer propagates through a thin adhesive boundary and into the metal amplitude transformer or horn. The horn twists in response to the shear wave. As the shear wave propagates into the small diameter section, a large amount of energy is expended in a relatively small volume, causing large angular displacements of the material. As the wave progresses, the horn tip becomes twisted through a much larger angle than the piezoelectric transducer and hence is amplified. The amplification is proportional to the ratio of the fourth powers of both the tip and large end horn diameters.

Deflection of $\pm 4^{\circ}$ have been obtained with this deflection. The deflection is sine wave in nature.

B. Acoustic Deflection

An acoustic modulation and deflection system is primarily being developed by Zenith. This approach dispenses with all moving parts but the galvanometer-like vertical scanner [3, 4] (Figure 33).

This device operates on the principle that when a transparent substance is subjected to mechanical stress, its optical refractive index n changes. Therefore, an acoustic wave passing through the substance is accompanied by a similar wave of varying n. The periodic pattern of layers of alternately higher and lower n is capable of acting like a grating, efficiently diffracting incident light.

One can understand light-sound interaction in several ways. A person familiar with classical optics may think of the sound wave as a moving three-dimensional phase grating that scatters incident light waves. A physicist may find the ideas of quantum mechanics useful and think of this process in terms of collisions between photons and phonons in which energy and momentum are conserved. This is similar to Bragg reflection of X-rays in a crystal lattice.

The deflection of direction of the light is changed by changing the acoustic frequency.

This method of deflection is currently only used to make monochrome pictures.

Different types of materials, liquids and solids can be used but possibly the best in water.

A TV type display is accomplished by applying ultrasonic waves to a water cell producing a diffraction-grating effect. A laser beam is used to illuminate the cell, and the deflection of the laser light produces the horizontal deflection for the television display.

What appears on the screen is not a single spot of light but a wide segment that contains many picture elements. To get this segment, the designer shapes the modulator cell so that it takes 50 microseconds for the ultrasonic wave to traverse the laser beam.

Lenses gather the optical signal corresponding to the most recent 50 microseconds of information applied to the modulator and focus it on a screen. Use of a telescope lens permits the screen to be brought 15 times closer.

The entire image of the cell is scanned both horizontally and vertically. Left-to-right and right-to-left movements are equally fast. The two scanning motions, taken together, give the illusion of a stationary picture.

The acoustic system suffers from the fact it has dispersion and also is presently monochrome.

C. Rotating Mirrors

The earliest method used to deflect light is from a rotating mirror or polygon. Light reflected from the mirror surface is scanned through twice the mirror rotation angle due to the doubling upon reflection. Mirror scanning devices are desirable for the following reasons: (1) They produce large linear scan angles without magnification; (2) the laser light loss is low; (3) they can be used to scan concentric multicolor beam to form perfectly-registered images; (4) they preserve coherence. Some of the problems that exist are mechanical jitter and synchronization of electronics and mechanical system. GT&E Laboratories and Texas Instruments are both working on mechanical scanning devices.[5]

D. Electrooptic Deflection

Electrooptic deflection is accomplished either by refraction at a dielectric interface or refraction by an index gradient.

Refraction at a dielectric interface has been most often utilized in the form of a prism of variable refractive index. A light beam traversing the prism is deviated by an amount depending upon the prism shape, orientation and refractive index.[6,7]

Refraction also takes place when a gradient of refractive index exists in the propagation media perpendicular to the wavefront normal. For a linear gradient the wavefront remains planar and the ray trajectory is bent in the direction of the gradient. See Figure 34.

This type of scan is well adapted to large-screen, high-brightness displays that call for selective or aperiodic access at microsecond slewing rates.

The disadvantage of electrooptic deflection is the high capacitance load which is typically 500 to 1000 picoforads, and therefore require low driver out-put impedance and kilowatts of driver power for wide-band operation.

E. Scan Laser

IBM has invented a scan laser, in which all of the optical components are internal to the cavity (Figure 35). A means of selecting laser modes has been developed. This means that at any one instant all modes but the desired one are kept below the threshold of oscillation.

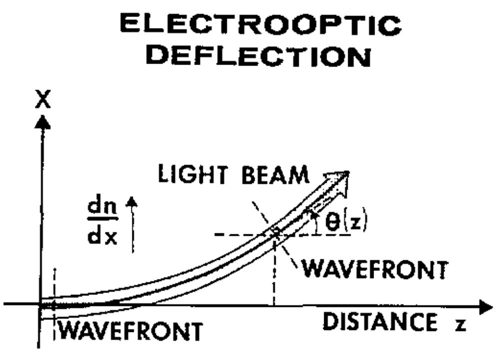

Figure 34.

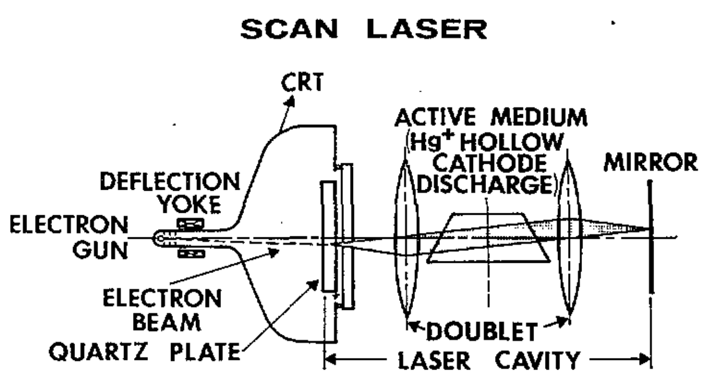

Figure 35.

Since the light from each mode comes out of the lasing medium at a different angle, a moving spot of light can be formed in this manner.

Flat reflecting surfaces are placed in the focal plane of two lenses. The lenses are spaced so that the laser modes correspond to a point on one mirrored surface being imaged onto the other.

An electron beam is used to select the modes. The electric charge is applied to an electro-optic crystal that is transparent on one side and coated with a series of dielectric layers on the other. This makes the crystal reflective at the laser wavelength, so that the surface serves not only as the target for the scanning electronic beam but also as one of the laser mirrors.

As the electron beam strikes different spots on the mirror, different modes are selected in the same manner forming a moving beam.

The light emerging from the resonator is directional, although it tends to diverge. The light output can be collected and focused by a lens system. This system is not currently considered practical for large screen displays.[8, 9, 10]

IV. LASER SAFETY

Image speckle can present a viewing problem and is commonly reduced by vibrating the projection screen. However, to many observers the speckle is not annoying unless they concentrate on it. Safety problems may be avoided by using a rear-projection screen with an enclosed projection path. It is extremely important that safety calculations be made on a proposed laser display.

Laser safety is now an active project at NTDC and answers are sought to questions arising to human viewing of laser displays.

V. CONCLUSION

The major areas to be solved prior to the development of a practical display are as follows:

(1) Higher power output lasers.
(2) Reduction in size and amounts of equipment.
(3) Development of efficient laser deflector and associated optics.

When the above are accomplished a revolution will occur in large screen displays.

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NAVAL TRAINING DEVICE CENTER TRAINING DEVICE COMPUTER SYSTEM (TRADEC)

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The purpose of this presentation is to apprise industry of the computational facility to be installed at NTDC - hereafter to be referred to as the TRADEC system. TRADEC is the abbreviation for training Device Computer.

I will indicate the organizational structure under which the TRADEC installation will operate. I will review the purpose, present status and characteristics of the installation itself.

The TRADEC facility is under the jurisdiction of the Research Directorate, Code 50. Reporting to the Associate Technical Director are five research laboratories, one of which is the Computer Laboratory, Code 54. The direct responsibility for the operation of subject facility rests with Code 54. The Computer Laboratory is headed by Mr. Milton Fischer.

On 28 June 1967 a contract was awarded to Sylvania Electronic Systems, East Division, Needham, Mass., to provide a modern simulation and computation facility to meet the needs of the Center's research programs for a number of years. This contract culminates in the delivery of the system in March 1969, and in its becoming operational the second quarter of 1969.

The TRADEC system, along with existing equipment, will be used in the conduct of research in simulation, and will provide support for the Center's various projects. It will be utilized in all phases of our simulation research program.

Figure 36 is an artist's concept of the physical plant, presently under construction, which will house the TRADEC system and existing equipment. The site consists of an existing building to which a new wing is being attached. The existing building has been modified and will accommodate the new digital and the existing analog computer systems. The new attached wing will house the motion and cockpit systems.

The TRADEC digital computer is a Scientific Data Systems Sigma 7. Figure 37 is a scene of the computer at Sylvania where system integration is in process.

The digital hardware system: A simplified block diagram of the digital computer is shown in Figure 38. Direct access to memory is available to the central processing unit, peripheral I/O processors, and a special interface I/O processor.

A description of each of these areas will clearly indicate the hardware and the capability of the digital system.