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15 January 1965

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Attention: John R.

Gentlemen:

We are sending you the enclosed rough draft at your request in a partially edited form. Some discontinuities are still evident but I thought you would like to have it as soon as possible. We will continue here to make a smoother version of this for final presentation and will look forward to receiving your recommendations as soon as possible. Perhaps the quickest way of transmitting information is to mark up the extra copy and send it back with your comments.

Please call on [redacted] if you need help getting things back and forth. STAT

Sincerely,

[redacted]

STAT

[redacted]

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Program Manager

WDS:jsf

[redacted]

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[redacted] Register No. 23-2554A STAT

IMPROVED REAR PROJECTION VIEWING SYSTEMS

This proposal is presented by [redacted] with the coopera- STAT tion of the [redacted] to extend the capability of the prese STAT day rear projection viewing system. The proposal recommends the extension of the fluorescent screen development and provides for additional research in the areas of electro-chemical and chemical screen development, band width limited physical optics, light sources and computer interface displays.

Considerable attention has been paid during the prior feasibility study to the possible outcome of a program of this type. As a result of this thinking, there will be found in the body of this proposal several research reports which are applicable. [redacted] has long been searching for an information system regardless of STAT the media to reproduce the data contained within the confines of a simple 2¼" x 2¼" film negative. It is not difficult to see that the criteria which any information system needs to meet to equal a visual photographic capability needs extremely wide band width and, as a result, very high frequency. Storage of a single 2¼" x 2¼" film negative with high resolution in a computer memory system may require as much as 50 billion bits of information. The proposal discusses means to decrease the storage capacity through discrete scanning techniques in selection of what we term "foveal memory areas". A report will also be found discussing the known means for transmission of film negatives through television channels.

It is in this area that we find the band width restrictions limiting the amount of resolution which is capable of being handled by typical cathode ray tube systems. Carriers of the order of 100 kilo-megacycles have been estimated to be necessary to provide the reproduction of high resolution film. In directing comparison is the physical optical reproduction which utilizes the infinitely broad band width of the light beam to transmit the required detail. In other words, photographs may be reproduced by electro-sensitive phosphors to the degree necessary for recreating high resolution if transparent phosphors are used but the state-of-the-art limits the band width capabilities necessary to convey the information from the film to the phosphor. It is felt that these technologies are not to be overlooked for certain specific purposes such as the recognition of details once it has been ascertained that there is some detail by scanning for preliminary examination of the film through an optical device. Thus, the proposal contains a technical discussion on the use of cathode ray tube systems proposed to enhance detail through the use of "unsharp masks" and to provide an eletronic system for tone reversal.

The results shown by the newly developed fluorescent screens promise in themselves to provide the information content necessary to fulfill the band width requirements. Limitations here are represented only by the efficiency of the light sources available and the possibility for discrete enhancement of details within the scanned area. There have been recent innovations which promise to point the way towards the relaxation of these limitations. The body of the proposal contains a research report describing a system which may be used scanning a laser beam at kilo-megacycle rates. Again, the band width problem arises. Any system involving the use of feedback control faces this limitation. The systems may still have a function, however, by providing masks or image enhancement when they are combined with physical optical systems.

The most promising aspect seems to lie in the structure of photosensitive phosphors and semiconductors used as screen materials and excited by projection systems utilizing ultraviolet and visible light. The use of non-linear or superlinear phosphors may provide a ready source intensity or electrostatic modulation of the phosphor.

As mentioned before, the proposal divides itself into four categories of technology. A brief description of the contents of each of these categories follows:

SCREEN DEVELOPMENT

The fluorescent screen has proven itself by producing resolution capabilities above 200 lines per millimeter at brightness levels which average from 5 to 10 foot lamberts highlight brightness. It is proposed that these screens ~~by~~ be tested for their lifetime capability and that a large screen (30" x 30") be constructed using minimum tooling from the best material from consideration of brightness and lifetime. It is proposed that the field of non-linear phosphors and superlinear phosphors be examined for image enhancement purposes.

A new development in the field of non-organic phosphors has appeared throughout — the addition of sodium to the fluorescent material to greatly increase the light output in the lifetime of the phosphor. It is proposed that these systems be examined. Electrostatic enhancement of the ultraviolet image is discussed along with the enhancement by electro-luminescence for the combination of a photoconductor phosphor two layer screen. In this case, a photoconductor acts directly upon the phosphor to enhance the image without the use of frequency limiting electron feedback systems. An attractive advantage of this lies in the possibility for electro-sensitive modulation of the phosphor. In addition to the direct excitation of a screen by a light source, two methods for producing image enhancement are described utilizing the assistance of a cathode ray tube which combines an electric mask, the projected image of the film negative.

BAND WIDTH LIMITED AND SPECIAL PURPOSE OPTICS

Since the ultraviolet seems to offer the best solution to high resolution projection systems this proposal includes a discussion on zoom lenses to be utilized over a 9½" format at minimum magnification and to be extended over an approximate four to one magnification range for scanning purposes. Since the ultraviolet system at present utilizes light sources which produce both visible and ultraviolet light be divided after passing through the film for use in two separate lens systems, one which produces the high resolution at maximum magnification for energizing the ultraviolet screen and the other a zoom lens for scanning purposes producing an image on a separate screen with visible light. New capabilities in the use of Fresnel lenses for condensing the dichroic mirrors are proposed. The design of mirrors for discrete reflections of the wanted wavelengths is proposed to provide retension of at least 90% of the ultraviolet available from the source. The proposal includes a discussion of the application of methods for the use of aspheric design, the production of lenses having extremely high resolution capabilities, and proposes that these lenses be tested utilizing the optical transfer function techniques and ultraviolet sensors consisting of photomultiplier tubes in the fiber optic path of a microdensitometer having an aperture of less than .06" diameter.

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LIGHT SOURCES

The system now in existence utilizes a 2500 watt mercury vapor compact arc lamp. This lamp produces 8% of its total radiated power in the 2654 Å region, but a great deail of power is lost by radiation due to the heating of the electrodes. It is proposed that a substitute be examined which has 10 times the ultraviolet production efficiency and falls into the extended arc type. These extended arcs have as much as 80% of their light output available in the ultraviolet region, and if folded properly and focused as a semi-extended source can provide in those ultraviolet energy. In addition, it is suggested that the internal coating of the tube containing the extended arc be examined by the application of phosphors which themselves produce an efficient cold source for ultraviolet energy.

Lasers are discussed as a means for providing a scanning system capable of providing feedback controlled image enhancement. Two means for deflection of the laser are discussed, one of which is the typical Kerr Cell, the other of which is a recent patent application by [redacted] pertaining STAT to the use of a laser in place of the typical electromagnetic galvanometer. The plasma source is discussed for information purposes only and is regarded as least promising due to the high energy consumption required by this source.

COMPUTER INTERFACE DISPLAYS

In this section a discussion of the limitations of the types of displays capable for computer presentations are discussed with regard to the quantity of memory required to provide high resolution reproduction of such things as maps and photographs. [redacted] has at the present a computer developed which operates on what STAT is termed as "foveal area memory". A brief discussion follows. For a totally scanned image of the typical film negative only discrete bits of information are retained by the computer upon command. The computer is capable of being zoomed to select any area of interest within the photograph and can utilize its photomemory capabilities over that particular foveal area. The computer will retain image contrast levels particular to that area. These contrast levels can then be compared to prestored memory images which are auto-correlated to an image in storage. The system is presently used to identify satellites against a star background. The interface in this case is not a film negative but a field of 13" aperture 400" telescope by a scan by an image orthicon. It is operating at [redacted] STAT at this time.

DETAILED TECHNICAL DESCRIPTION

The presentations which follow have been generated by different individuals and are presented as such. The distinct fields present areas in which research is believed to be most rewarding in the improvement of rear projection viewing systems. Some of the areas cover extensions of the work now being done while others propose new approaches, knowledge of which has been gained through prior experimentation.

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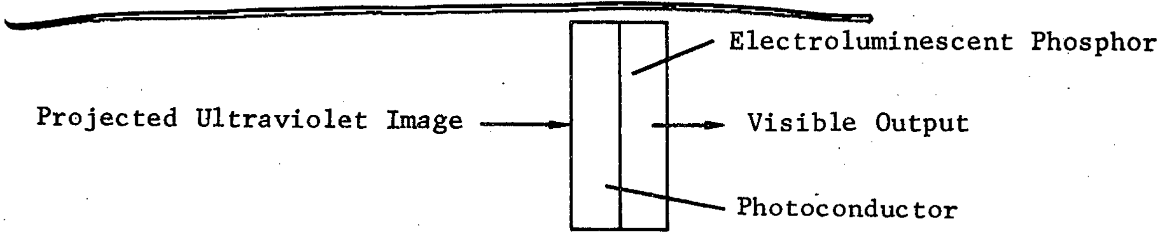
Chemical and Electrochemical Screen Development

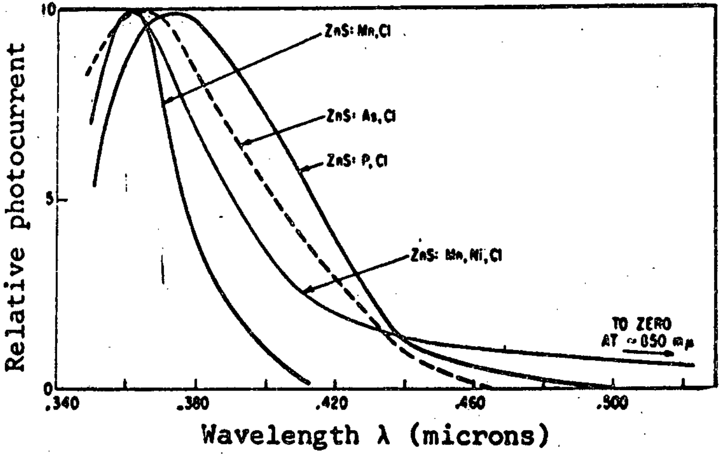
Image Intensification

A multiple layer system of photoconductor and electroluminescent phosphor may be used to provide image intensification. The photoconductor should be sensitive to u-v only or else there should be a barrier to visible light between the two layers to eliminate positive feedback and a "runaway" condition.



The external surfaces would be coated with transparent conductors. The photoconductor would conduct when illuminated, applying a larger voltage gradient to the phosphor than existed in the dark condition. The phosphor would then electroluminesce with an intensity determined by the excitation intensity.

Typically ZnS may be useful since it is not photoconductive in visible light but is sensitive to ultraviolet. Therefore "runaway" would not occur due to roomlight photoconduction or phosphor output feedback. By suitable doping, e.g., (ZnS: Mn_2Cl for 3650Å)(4) ZnS can be made to absorb with a peak at 3650Å. See Figure.



Emission as a function of wavelength for zinc sulfide crystalline films, 5 - 15 microns thick.

The use of the non-organic phosphors is not to be discounted. These components are considered to be more stable than organic phosphors and thus much less susceptible to aging. In addition, the non-organic phosphors present more potential light output. It has been found that the transparent phosphors previously fabricated in the research center lacked one essential ingredient, that ingredient is sodium. The addition of this element transduces energy levels necessary to highlight output. Experiments with phosphors containing sodium would prove most rewarding. Theoretically it can be shown that these phosphors will provide three times the light output of the presently developed organic screen.

Oversimplified

A two layer phosphor - photoconductor could be used to fabricate a fluorescent screen, enhancement by electroluminescence. This would require a transparent photoconductor sensitive to the emission spectrum of the phosphor. The photoconductor would be in contact with the phosphor and each of the two exposed phases would have transparent electrodes. When the ultraviolet sensitive phosphor is struck by light the resulting fluorescence would cause the photoconductor to conduct, increasing the field across the phosphor and adding electroluminescence to the existing fluorescence. It can be shown that assuming a 10% loss in transmission due to each of the two electrodes and an additional 10% loss due to the photoconductor and a developing of the light output of the phosphor due to electroluminescence that the light available to the observer will be 140% of that due to ultraviolet stimulation fluorescence alone. However, since the photoconductor is sensitive to visible light, the screen may have to be operated in a room with controlled ambient light.

So what

max brightness? response time?

Contrast Enhancement

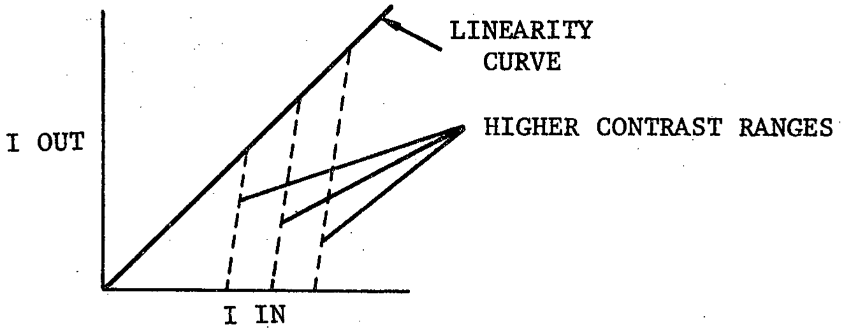
Contract may be increased or reduced, depending on the materials used, as a function of the excitation intensity reaching the screen by utilizing superlinear phosphors. These effects have been known for about 25 years. Riehl,(1) Urbach,(2) and others(3) have published on this subject.

The intensity is determined by the absorption due to detail in the film being projected. The use of the superlinear effect may be understood as follows:

what range

Suppose the film to be projected contains a density step wedge having steps of transmission increasing by 2 times from one to the next. A superlinear phosphor, onto which radiation through the step wedge has fallen, would radiate with steps having brightness ratios greater than 4 times from one to the next (since an index of at least 2 has been reported(3)). In this way contrast from one step to the next would be increased. Urbach showed that the effect discovered by Riehl can be enhanced enormously, using a quanching agent, such as nickel, in a ZnS phosphor. The deviation from linearity at highlight levels may be so large that the luminescence yield is several hundred times larger than that at low intensity. Factors which would have to be investigated would include absolute intensity range and spectral region in which these effects may be produced.

By varying the intensity of the excitation source, the level of the range of contrast enhancement may be selectable. See Figure.



References

(1) Riehl, N. "Uber einen neuen Effekt an lumineszierendem ZnS," Z.f. techn. Phys. 20,152 (1939).

(2) Urbach, F., Urbach, A., and Schwartz, M. "The Brightness of Apparent Fluorescence as a Function of the Exciting Intensity," J. Opt. Soc. Am. 37, 122 (1947).

(3) Nail, M.R., Pearlman, D., and Urbach F. "Photoluminescence of Some Sulphide Phosphors as a Function of Intensity," in The Preparation and Characteristics of Solid Luminescent Materials, (Cornell Symposium of the American Physical Society, October 24 through 26, 1946, John Wiley & Sons, New York, 1948.)

(4) Cusano, D.A., "Cathodo-, Photo-, and D.C. -Electroluminescence in Zinc Sulphide Layers," in Luminescence of Organic and Inorganic Materials. Edited by H.P. Kallmann and G.M. Spruch. (John Wiley & Sons, New York, c1962), P. 494-522.

Modulation of Phosphor Intensity

Electroluminescence may be excited by application of AC potentials. The photoconductor - electroluminescent phosphor sandwich model discussed in the section dealing with image intensification, may be operated with AC upon which a variable amplitude DC is superimposed. In this manner regions near threshold excitation will be pushed in and out of the light emission region. If a suitable nonlinearity of electroluminescent intensity with voltage can be obtained near threshold the contrast of low intensity detail may be increased. By analogy with vacuum tube characteristic curves, a change in bias voltage will shift the output to that from another one of a family of curves. A shift of AC voltage will vary the average intensity and hance the region of intensity over which the contrast is varied. A lot of hurdles have to be crossed before above is feasible to investigate.

Life Tests on Luminescent Materials

Previous work showed that most organic materials, and in some conditions inorganic materials also suffered a reduction in luminescent output with exposure to the excitation radiation. The mechanisms involved may in some cases be photochemical change of molecules. In other cases, the charge may be due merely to oxidation which occurs with or without ultraviolet but is quicker with ultraviolet.

Life tests will be made on screens developed. In the case of luminescent ultraviolet excited screens, a constant excitation intensity will be used and output of the screen monitored. It will be necessary to use accelerated tests which will show the relative merits of materials. In the case of electroluminescent screens accelerated tests probably are not applicable since output can only be increased by applying greater voltage gradients than the phosphor layer will support and breakdown will occur. In this case, there is no substitute for time.

PATENT DISCLOSURE
ELECTRONIC SYSTEM FOR TONE REVERSAL

This invention relates to the production of tone inversion for the display of a positive picture from a negative (or vice versa) with use of an electron beam scanning technique.

Using a conventional television system a tone reversal may be produced by connecting together a flying-spot scanner, a video amplifier with polarity reversal and gamma correction and a picture monitor. The expenditure involved is unnecessarily high as the potentiality for transmission over distance inherent in the method is not required for a self contained unit.

The method herewith described and its variations involve only a single cathode ray tube and simplifies the design substantially. The set-up in its basic form involves a flying-spot scanning system in which the CRT, unlike the usual procedure, is modulated by the signal derived from the scanned image in such a way that light absorption creates an increase in screen luminance for each individual picture element. A feedback amplifier with adequate high frequency response, low phase distortion and short time delay is connected between the photomultiplier and the brightness control of the CRT. This amplifier works in such a way as to maintain a nearly constant current output at the multiplier. The reversed image can be observed at the CRT which thus serves a dual purpose.

A problem arises from the fact that phosphors with a suitably short decay time have their emission located in the blue and ultra-violet part of the spectrum, which makes it inconvenient for visual display.

A phosphor with a color more suitable for visual display will require an electronic high-pass filter network to prevent excessive picture streaking. It is probable that such a filter may produce a finite time lag which is of no importance in television but would be detrimental for this particular use.

A second method suggested here is to utilize a screen made up of a mixture of two distinct phosphors, one of blue and ultra-violet color and very rapid decay for the scanning process and the other one of yellow-green color without any blue or ultraviolet emission and of slower decay, for visual display. The separation of the two light qualities is easily obtained with suitable filters.

A third approach is to make use of a somewhat more elaborate CRT represented in a sectional view of a practical embodiment in the diagram.

Inside the glass envelope (1) of the CRT is a fluorescent screen composed of two different phosphors with similar qualities as above mentioned, but in two distinct layers, an outer layer (2) for visual display and an inner layer (3) for scanning. The outer layer may become luminescent either by the impact of electrons having passed through the inner layer, or by activation by the light emission of short wave length of layer (2), or by the combined action of both.

The screen is imaged through the flat section of the glass envelope (4) on the transparency (7) by the lens (6) after reflection at the surface mirror (5). The condenser (8) collects the transmitted light on the photomultiplier (9). The amplifier (10) works in the manner described above. A visible pattern, reversed in tone with regard to the picture (7), is made visible on the screen and may be viewed at (12).

For all described examples there is no problem in accuracy of scanning or in electron optical imaging, as scanning and display are effected at substantially the same location.

The feature of the feedback system adds the advantage of equalizing unevenness of light distribution due to the irregularities of the screen as well as amplitude distortions of the separate elements (multiplier unit, amplifier and CRT).

Electronic reversal of motion pictures on film seems feasible using either optical compensation and continuous film motion or a blanking time compatible with conventional projectors (>12mm) and synchronous with film motion.

Equipment is about to be set up to study and demonstrate the method.

No reference applicable to image reversal by the described method has been found yet. An article by R. Thesle and H. McGhee, "The Application of Negative Feedback to Flying Spot Scanners", Journal British JRE, June 1952, 325-339 analyzes feedback systems for the purpose of gamma correction and screen afterglow compensation.

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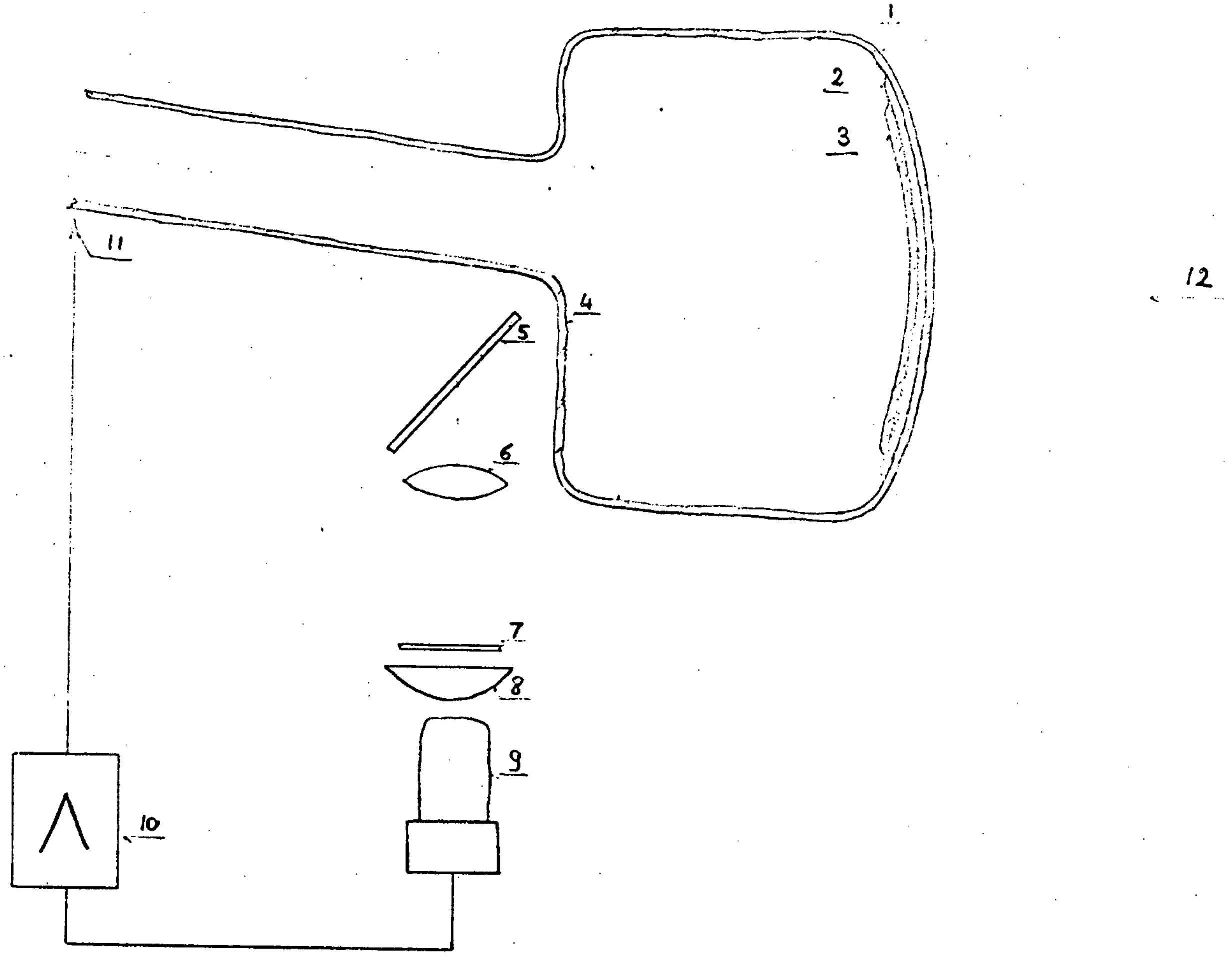
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Limitations of Electroluminiscent Displays

Ordinary television practice requires a signal to noise ratio of at least 35 DB. 40 DB is considered excellent but S/N ratios less than 30 DB are totally unacceptable. Systems which reproduce photographs by electronic means are subject to noise influence particularly because of the decay rates of phosphors when applied to scanning systems. The information content of a photograph requires band widths as high as 1500 megacycles for reproduction equivalent to that of a single optical system. The following calculation shows what can be expected of systems of this type.

THE PICK-UP OF FILM FOR DISPLAY OVER THE TELEVISION SYSTEM, A SURVEY OF TECHNIQUES

INTRODUCTION

To view negative films as positive, using mere physical means rather than to proceed through a photographic process, seems to be advantageous in cases where rapidity of access is important. To use television techniques for this objective seems obvious. It is relatively simple to produce any reasonable transfer function with electronic means, inverting tone values and shaping gradation curves at will. The main problem is that of television film pick-up. The feasibility of an inexpensive system will greatly depend upon the choice of the system.

OUTLINE OF THE PROBLEM

The major difficulty of displaying conventional films over the television system arises from the fact that both techniques have standardized to a different frame repetition rate. Commercial films are run at a speed of 24 frames/sec.; amateurs usually use 16 frames/sec., whereas television technique has adopted in this country a repetition rate of 30 frames/sec., interlaced 2 to 1, or 60 half-frames/sec.

Many difficulties would be eliminated if special films comprising 60 frames/sec. were used for example. The cost of operation need not be higher than with 24 images/sec. as an anamorphosis producing a corresponding compression of the picture height could still result in an acceptable resolution. Unfortunately this is not a current practice, so television engineers had to use their inventive strength for finding their way out of the difficulty.

CLASSIFICATION OF THE FILM PICK-UP SYSTEMS

Depending on whether one considers it practical to depart from conventional techniques either for film or for television for special applications, four combinations are possible:

1. Standard motion-picture film in conjunction with the conventional television system as for broadcast use;
2. Film of unconventional standard specially produced for television display;
3. A modified television system, suitable for closed circuit television using simplified design;
4. The fourth combination with both unconventional film and television system does not seem to add a practical advantage.

A classification of the three first-named combinations with subdivision of a variety of pick-up systems are listed in Figure 1. Only the first combination is used commercially.

TECHNIQUES USED IN BROADCAST TELEVISION

A. Flying Spot Scanners for Still Pictures

The principle of the set-up used for a still picture is shown in Figure 2. The television raster is written on the screen of a flying spot tube (1) which uses a phosphor having a very rapid light decay. A lens (2)

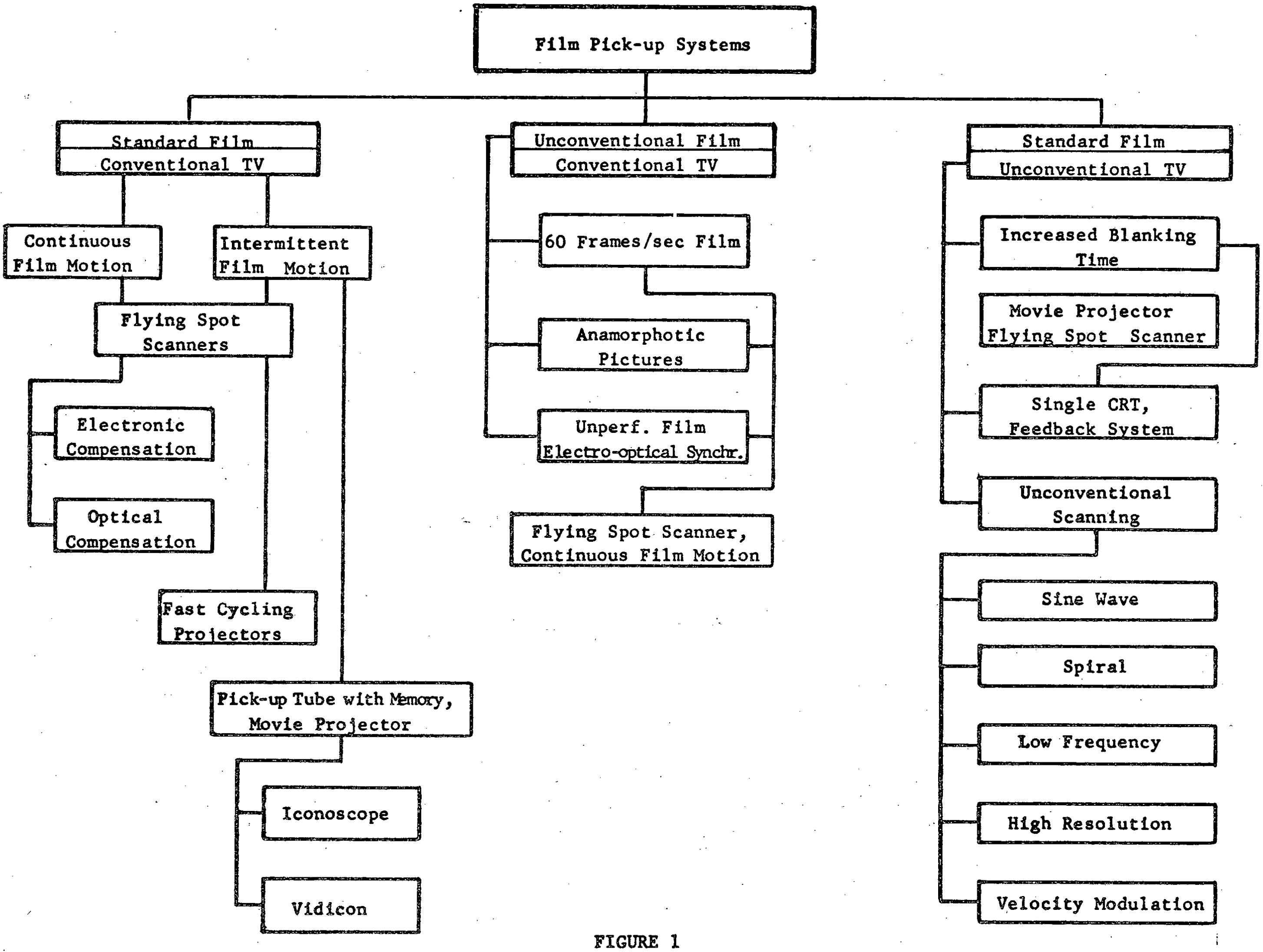
Film Pick-up Systems
Standard Film
Conventional TV
Continuous Film Motion
Intermittent Film Motion
Flying Spot Scanners
Electronic Compensation
Optical Compensation
Fast Cycling Projectors
Pick-up Tube with Memory, Movie Projector
Iconoscope
Vidicon
Unconventional Film
Conventional TV
60 Frames/sec Film
Anamorphotic Pictures
Unperf. Film Electro-optical Synchr.
Flying Spot Scanner, Continuous Film Motion
Standard Film
Unconventional TV
Increased Blanking Time
Movie Projector Flying Spot Scanner
Single CRT, Feedback System
Unconventional Scanning
Sine Wave
Spiral
Low Frequency
High Resolution
Velocity Modulation

FIGURE 1

projects the raster on the transparency (3) and a condenser (4) collects the transmitted light which falls on a photocell of the multiplier type (5).

The picture quality obtainable is high. The limit of resolution using conventional components can exceed the limit of the television system. There is a fair relationship between signal amplitude and the transparency of the slide and the light transfer characteristics need little to be corrected. Signal-to-noise ratio of the video signal is high for transparency of not too high density ($D < 2$).

B. Flying Spot Scanners with Electronic Compensation

The pick-up of film adds a kinematic problem because of the different repetition rates and the very short blanking time of the television system. One approach to the problem involves a flying-spot scanning system and continuous film motion. The raster on the flying spot tube is displaced vertically in a sequence of 5 distinct levels by adding a composite step signal to the conventional vertical saw-tooth scan. One film frame is scanned three times, the next frame twice, the following three times again, thus producing the average ratio of 5:2.

Although this system seems very simple it is almost impossible to achieve the required accuracy of a fraction of a line for all 5 scans over the entire picture, as well as an even distribution of light. For a frame rate of 16 images/sec., with the required ratio of 4:1, the difficulties would be even greater.

C. Flying Spot Scanners Using Optical Compensation

Here the geometrical correlation between the continuously moving film

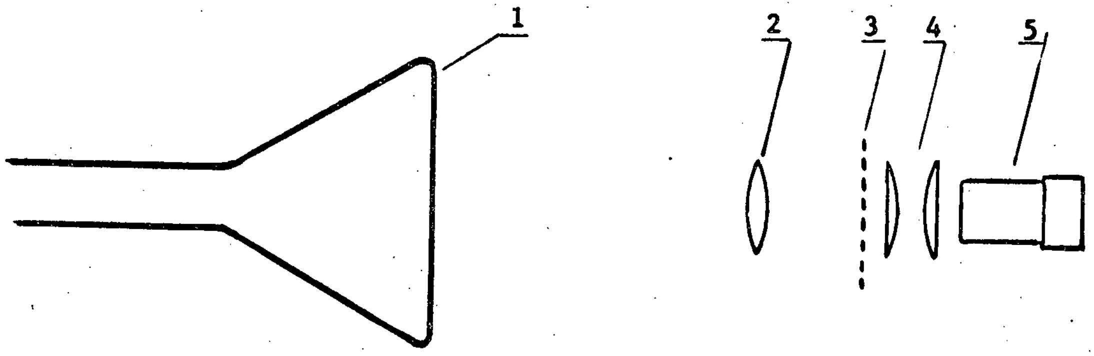

FIGURE 2

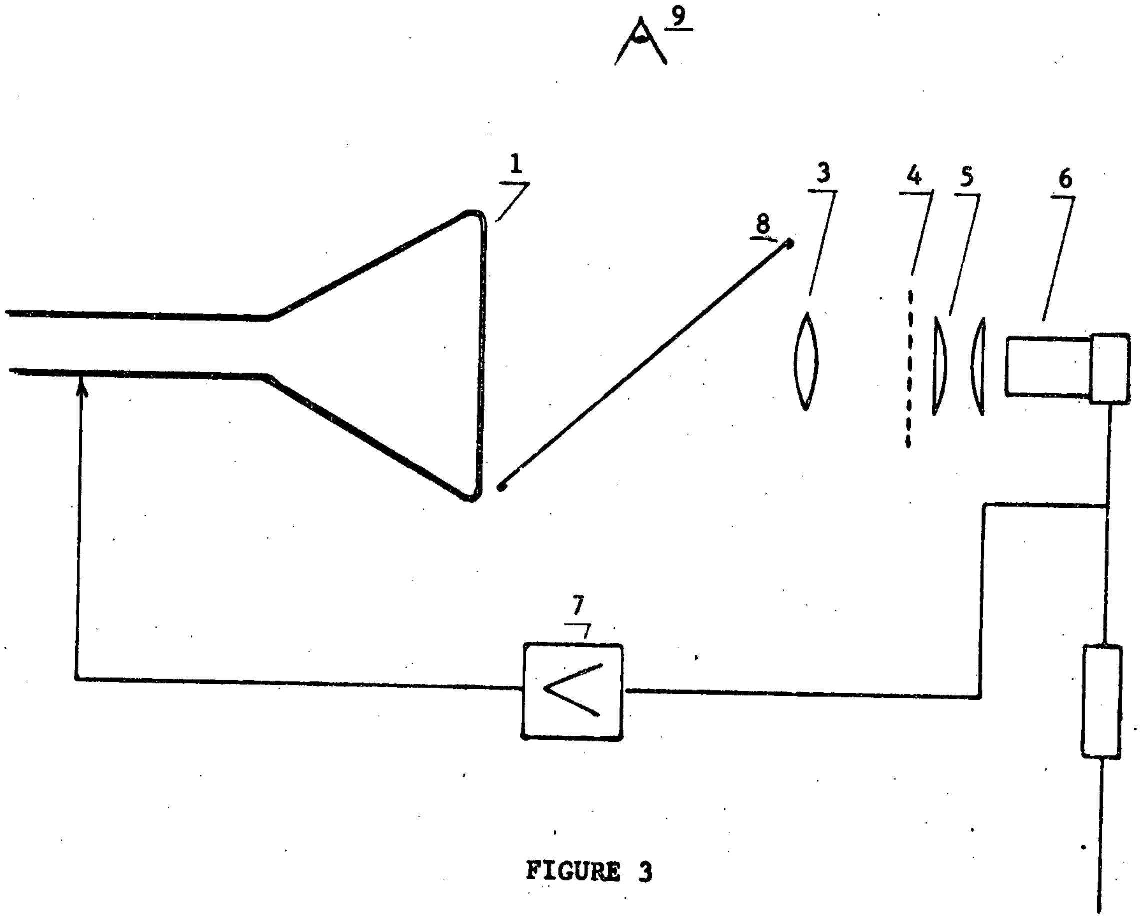

FIGURE 3

and the scan is performed by optical means. The optical elements most used for performing this compensation are either rotating and tilting mirrors or rotating glass polygonal prisms. These optical elements follow the film movement in such a way as to produce a virtually immobilized image of the film frame in its conjugate plane. Many different systems have been proposed and built but only very few have reached the market. This is perhaps illustrative of the difficulties encountered.

In order to produce a high picture quality without noticeable jumps between image change-over and without flicker, it is necessary to apply unusually high mechanical precision and a rather expensive set-up. As with electronic compensation, a film shrinkage correction is required.

D. Fast Cycling Systems

As mentioned above the blanking period of the television standard is much shorter than the cycling or pull-down times of conventional film projectors. The blanking period comprises 13 television lines or 0.83 msec. compared with some 15 msec. for current projectors.

Some projectors have been designed for moving the film in a time comparable with the blanking period, taking care not to exceed the tensile strength of the film base. The severe problems encountered here are those of excessive wear of the mechanism as well as the film itself and high noise level.

E. Systems Using Pick-up Tubes with Storage Characteristics

The progress made on vidicon pick-up tubes has enabled one to build very simple and efficient television film scanners. These are, in fact, the most used type for film pick-up today, and most manufacturers have ceased to produce flying-spot film scanners as well as pick-up projectors using iconoscopes.

In principle, the set-up involves a movie projector and a vidicon camera. The image projected on the photoconductive layer of the vidicon produces a pattern of conductivity which decays slowly with time. The image can thus be scanned several times without significant loss in signal amplitude.

The image quality compares quite favorably with that delivered by the before-mentioned systems, especially with respect to lack of flicker and jitter. The resolution produced by the vidicon is comparable with that of regular 16 mm film and is slightly less than that obtainable with still picture flying-spot scanners. The possibility of aperture response correction (restoration of full level for high picture frequencies) is particularly inviting because of the high signal-to-noise ratio. Of course, only an increase of the horizontal resolution is practical, although methods for vertical aperture correction have been proposed.

NON-CONVENTIONAL SYSTEMS

For some purposes different from pick-up of motion picture films for broadcast transmission, there is no compulsion to stick to established standards. Some variations seem able to simplify the problem tremendously. As mentioned in the introduction, film specially designed for television transmission with 60 frames/sec. would greatly simplify the design of flying-spot scanners while replacing film perforation by optical synchronization marks may result in a better utilization of the sensitive surface.

A substantial increase of television frame blanking time enables one to use regular film cycling mechanisms together with flying-spot techniques to make a relatively simple setup. To compensate for the decreased time left for transmitting picture information, a higher line scanning and frame rate and thus a higher frequency limit is dictated.

One system which seems particularly suited for negative-positive conversion is the

SINGLE CRT FEEDBACK SYSTEM

Fig. 3 shows the principle of operation.(1) is a flying-spot tube whose raster is projected through lens (3) on to the negative (4). The condenser (5) collects the transmitted light on the photomultiplier (6) as for a regular flying spot scanner. A feedback amplifier (7) works in the direction of increasing the luminosity of the cathode-ray tube in proportion to the amount of light absorbed by the negative for every picture element. The result is a positive displayed at the flying-spot tube itself which can be viewed, e.g., through a semitransparent mirror by an observer (9).

The necessary amplification is roughly estimated in the following calculation. Assume that a change of 5V at the grid of the flying-spot tube is necessary to produce a change in luminous flux emitted from the screen of 0.5 lumen. If the lens f number is 4, the highest useful negative density of 2.3 (transmittance) = 0.005, the magnification of the imaging system 0.08, the light efficiency of the system 0.1, the luminous sensitivity of a typical photomultiplier tube (1P21) 50 A/lm and the load resistor 500 Ω, the output voltage at this resistor is

$$\frac{0.5 \times 0.005 \times 0.08 \times 0.1 \times 50 \times 500}{4 \times 4 \times 4} = 0.78 \cdot 10^{-2} V$$

and the required amplification is thus approximately 650.

With a scanning system of increased blanking time the tone inversion of film seems easily achieved with the film cycling mechanism of a regular movie projectors.

One limitation over a two-tube system is that there is no way to increase the gamma above 1. One more severe drawback is produced by the blue color of the viewed picture (all short decay phosphors are blue) which makes it difficult to judge the tone value.

One way of overcoming this limitation is by making use of a more complex CRT. Fig. 4 shows a setup with a special scanning-spot tube (1) comprising a double layer phosphor (2). The inner coating is a short decay, blue phosphorescence-type phosphor of the P16 type. The outer coating is of a color close to white with a decay time of a few tenths of a second. Through the optically flat glass plate (3) and the mirror (4), the raster is imaged in the usual way on the negative. The blue sensitive photocell (8) reacts to the transmitted light and, together with the amplifier (9) controls the luminosity of the CRT. The negative pattern produced can be viewed at (10). The white phosphor is excited either by electron bombardment or by fluorescence from the blue light of the P16-type phosphor or by both radiations. The electron gun and the optical

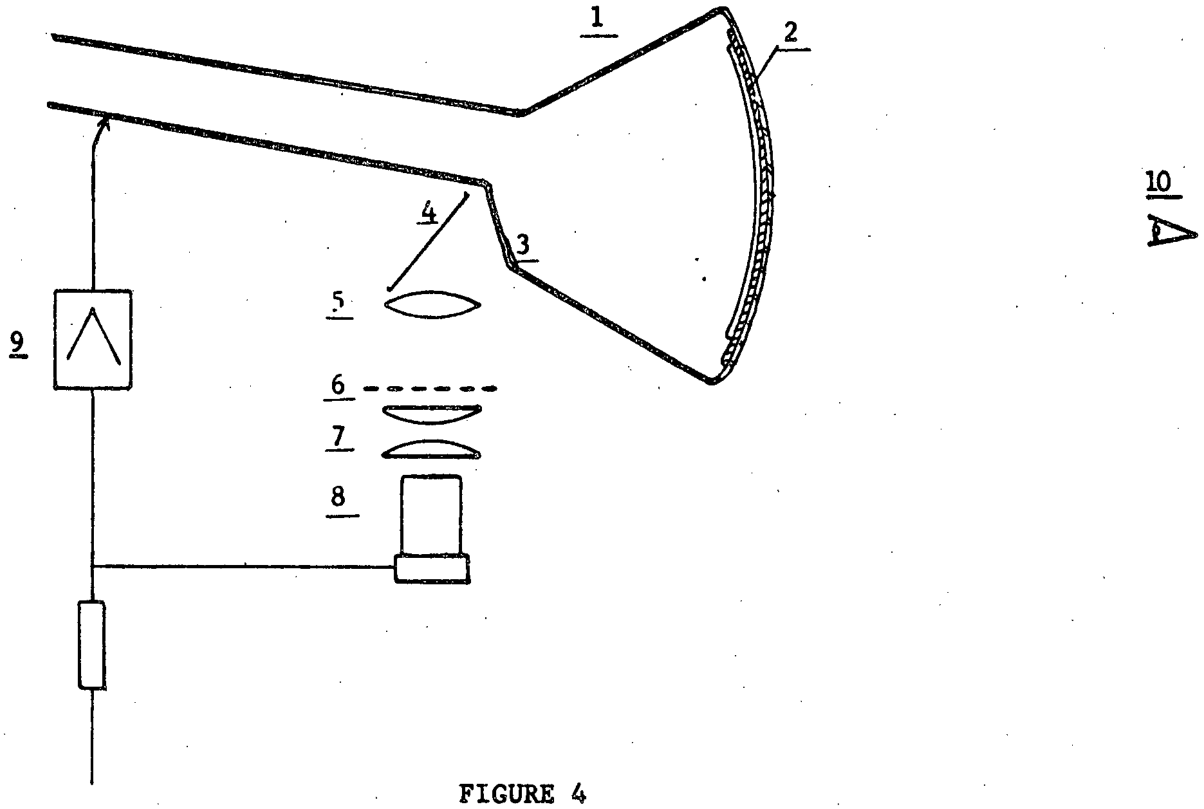

FIGURE 4

axis going through the phosphor layers depart slightly from 90° as both are on the same side of the screen. The advantage of such a system over the before mentioned inverse feedback system is to produce a white picture with a smaller flicker effect, as the white phosphor for visual display need not be of extremely short decay. A suitable CRT is presently not available commercially.

OTHER METHODS OF TONE INVERSION, NOT USING SCANNING TECHNIQUES

One method not correlated with TV techniques makes use of the effect known as phosphor quenching. A phosphor layer is equally irradiated with ultraviolet light and emits visible light. A negative is projected on this layer with red or infrared light of high intensity. As radiations of long wavelength will inhibit the fluorescence of some phosphors, a positive image is made visible.

An apparatus using this effect is produced by Meteor, Siezen, Westfalen, Germany and sold under the name of "Vertoscope" by C. P. Goerz, American Optical Company. It is suitable for still pictures only.

As a different approach to the problem, it may be possible to use the subtraction of light energy by utilizing coherent light, with a kind of interferometer setup. One severe problem may arise from the fact that photographic transparencies are not of truly equal thickness.

A further method to produce negative tone rendition for still pictures may be to use reversible chemical color reactions initiated by light of specific wavelength and destroyed by different wavelength. Several dyes formed by ultraviolet light and bleached by red light are known.

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Signal to noise ratio of output of flying-spot scanner, considering only shot noise of photo current and effect of luminescence decay of phosphor for practical example.

Energy impinging on screen of typical flying-spot CRT: 27 kv x 150 uA : 4.05 W

Conversion efficiency of P-16 phosphor : 8%

Light (UV) flux emitted : 0.32 W

Light gathering efficiency of optical system for a lens aperture of F/2 : 0.062

Light flux reaching photocathode through film of density 0.3 (transmission 0.48)

0.32 x 0.062 x 0.48 : 0.95×10^{-2} W

Sensitivity of photo-cathode of 1P21 photomultiplier for spectral emission of P-16 phosphor : 30 mA/W

Photo current $I : 0.95 \times 10^{-2} \times 30 \times 10^{-3} = 28.5 \times 10^{-5}$ A

Shot noise $I_r = \sqrt{2 \cdot e \cdot I \cdot \Delta f}$

Signal to noise ratio $\frac{S}{N} = \sqrt{\frac{I}{2e}} \cdot \frac{1}{\sqrt{\Delta f}}$

$$= \sqrt{\frac{28.5 \times 10^{-5} \text{ A}}{2 \times 1.6 \times 10^{-19} \text{Cb}}} \cdot \frac{1}{\sqrt{\Delta f}} = \frac{\sqrt{8.9 \times 10^{14}}}{\sqrt{\Delta f}} = 3 \times 10^{7} \cdot \frac{1}{\sqrt{\Delta f}}$$

Signal loss due to value of luminescence decay for P-16 phosphor:

for 3 Mc bandwidth, signal decreased to 0.93 (luminescence decay to 7% after 0.15 us)
10 Mc 0.75
30 Mc 0.40
100 Mc 0.08 (extrapolated value)

$$S/N \text{ for } 3 \text{ Mc} = \frac{3 \times 10^7 \times 0.93}{1.73 \times 10^3} = 16000 \text{ or } 42 \text{ db}$$

$$10 \text{ Mc} = \frac{3 \times 10^7 \times 0.75}{3.3 \times 10^3} = 6800 \text{ or } 38 \text{ db}$$

$$30 \text{ Mc} = \frac{3 \times 10^7 \times 0.4}{5.5 \times 10^3} = 2200 \text{ or } 33 \text{ db}$$

$$100 \text{ Mc} = \frac{3 \times 10^7 \times 0.08}{10^4} = 240 \text{ or } 24 \text{ db}$$

Quality limitation of flying-spot display

Resolution

Scanning raster, bandwidth, spot size of scanning and display CRT due to beam diameter and light scatter in phosphor persistence; optical aberrations.

Noise

Phosphor granularity, photo multiplier noise (mainly photoelectric shot noise, also noise from thermionic emission of photo cathode and electron multiplier); amplifier noise.

January 14, 1965

[redacted] STAT

finer pho[redacted] through imagination [redacted]

[redacted] STAT

INTEROFFICE CORRESPONDENCE

To: [redacted] STAT

Subject: Optical-electronic Display System *Date:* 13 January 1965

cc: [redacted] STAT
File

The diagram shows a proposed projection system which incorporates a variable edge-gradient enhancement feature. It is a two-stage system, with a cathode-ray tube screen at the intermediate image position.

The picture to be viewed is contact-printed (e.g. continuous tone diazo, for preservation of fine detail) to a high contrast--too high for direct projection. The ~~print~~ film is placed in the projector gate, on left of the TV tube. A field lens is also used here*, so that the light enters a second projection lens beyond the TV tube and is projected on the screen.

The TV tube adds an electronic image at the intermediate image position. (It is possible that the combination could be viewed directly, but the second stage of the projection system is shown for completeness.) The electronic image is obtained by scanning the original negative, or a print from it. It is of low contrast, negative and unsharp. When it is added to the high contrast positive image, it has the effect of reducing the gross contrast to a contrast which is more suitable for viewing. However, because this negative image is unsharp, the contrast of the fine detail in the composite image is not reduced, and so fine detail appears enhanced in contrast by comparison. Control of the contrast of the negative image gives a degree of control of the apparent fine detail contrast in the composite image.

* i.e. at the TV tube

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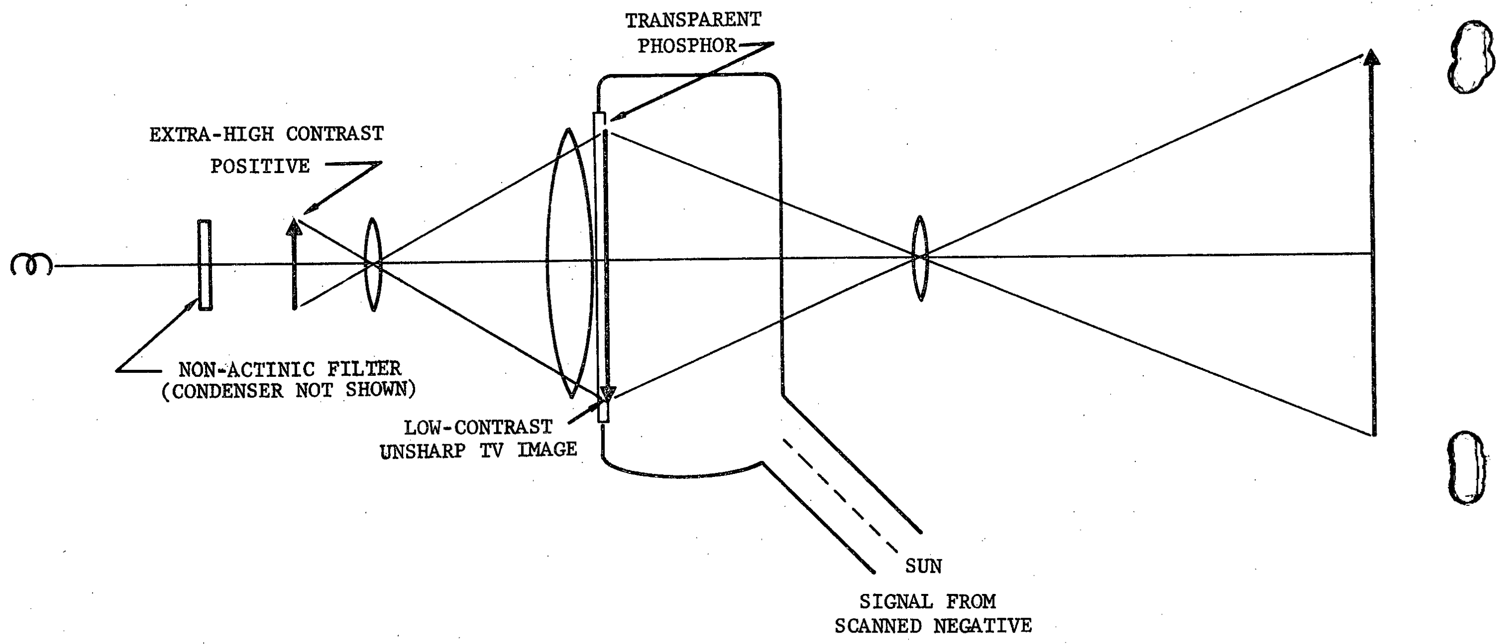
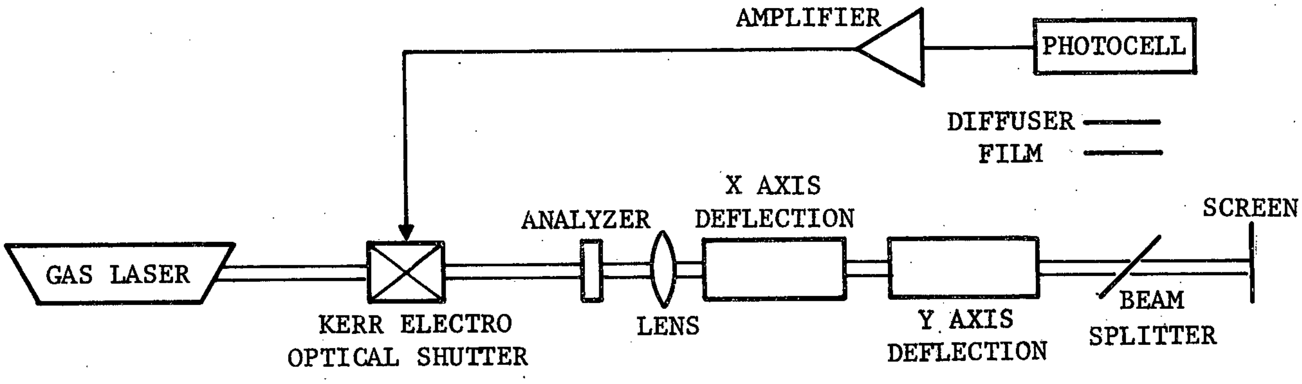


OPTICAL PROJECTOR WITH ELECTRONIC EDGE ENHANCEMENT

Swept Laser With Feedback for Contrast and Brightness Control



Contrast and intensity range of a projected image may be controlled using a scheme such as that shown in Figure . As shown, a gas laser produces a beam of plane polarized light. The beam passes through a Kerr Electro-optical shutter to an analyzer which is set to transmit the unrotated plane polarized light. The beam then passes through a lens which is brought to a focus at the screen. On the way it passes through X and Y axis deflection birefringent crystals for X and Y scanning of the beam across the screen. It also passes through a beam splitter which extracts a portion of the light which is focused on the film to be projected.

Light passes through the film, as the beam is deflected, is partially absorbed by image detail and reaches the photocell after being diffused at the diffuser. The photocell output is thereby amplitude modulated and after amplification applies feedback control to the laser beam intensity by means of the Kerr shutter. By appropriately varying the gain of the amplifier both absolute brightness and contrast may be controlled.

BANDWIDTH LIMITED OPTICAL SYSTEMS

Zoom lens technology and aspheric lens design is discussed here. The testing of the lenses by means of Optical Transfer Function testing is recommended.

These films are to be examined for their best application after determination of the best projection method is established since enough is known about their capabilities.

Scanned Systems are devised with the means for scanning.

PRESENT PROBLEMS AND DESIRED PARAMETERS FOR VIEWING

We should remember that the basic requirement is for maximum information transfer in a minimum possible time to an observer from a filmed object. In particular we must concern ourselves at present with the mechanical restrictions as now known. These restrictions must confine us to considerations of information transfer from 9-1/2, 5, or 2-1/4 inch film onto a screen, as an intermediate step, for observation by one or several viewers. In a flow chart, the information transfer thus follows the following path:

Object being observed ------ Film record ------ Screen ------ Observer

It has apparently been determined that a screen of the approximate size of 30" x 30" best fulfills present purposes, that viewing in normal room illumination is highly desirable, and that a capability of reaching 50 to 70 foot lamberts is necessary. Resolutions of 400 lines per millimeter at the film plane is a requirement. It must be pointed out as discussed in "Methods of Engineering Photographic Systems" by Geirge C. Higgins, Applied Optics, January 1964, Volume 3, Number 1, that high resolution and high contrast are not necessarily related. In viewing systems it is at least as important to keep both resolution and contrast at a maximum in order to impart information to an observer being focused by the lens not contributing to the image core be removed from the image to enhance contrast, even to the degradation of light levels.

It is desired to be able to rapidly scan photographs to find areas of interest, to then observe these areas more closely at high resolution and magnification under optimized conditions. Optimization techniques may include changing room illumination, varying image intensity, increasing contrast, or digitally analyzing the image. These techniques may or may not be independent of each other and will to some degree determine final optical requirements.

A REVIEW OF THE PRESENT APPROACH TO THE PROBLEM

It was previously decided to limit present considerations to a fixed magnification lens for enlargement of 2-1/4 x 2-1/4 film to 30 x 30 inch screen. Because of the characteristics of the screen materials, color correction of the lens was limited to 3650-4050 angstroms. Later attempts to modify this lens to accommodate other formats by interchanging elements were unsuccessful, partially due to the double-Gaussian form used. It had been concluded that design at that time that the design of a fixed focus lens should precede the design of a ultraviolet zoom lens.

The present projection system utilizes a 2500 watt mercury short arc lamp. By means of a primary and secondary mirror in combination with a heat reflecting filter, dichroics, and coated elements about 3% of the energy is transferred to the screen. The percent lens design is an 8 inch f/2.8 lens with a diffraction limited aerial image on axis and approximately 200 lines per millimeter 5 degrees off axis. The double-Gauss form was used because of its inherent symmetry and consequent ease of correction due to cancellation of aberrations between halves. It unfortunately also has inherent problems of tangential and radical oblique spherical aberrations that degrade off-axis resolution unless vignetted or corrected by aspherics. It is our present desire to first check the lens when finally assembled by vignetting these aberrations. This will quickly tell us what the aberrations are doing to resolution, contrast, and illumination. We will then conclude on asphERization. It is often the case that aspherizing improves contrast of images while actually degrading resolution. It is thus extremely important that the matter be carefully studied.

POSSIBLE APPROACHES BASED ON ABOVE CONSIDERATIONS

The above requirements indicate some method of changing format and magnification. Suggested are magnifications of:

a. 13 x (2 1/4 x 2 1/4 to 30 x 30)
b. 6 x (5 x 5 to 30 x 30)
c. 3 x (9 1/2 x 9 1/2 to 30 x 30)

Reviewing would be accomplished by reviewing the 9 1/2 inch film at 3 x magnifications. When areas of interest pre found, a change of magnification to 6 x or 13 x and the consequent decrease in format area could be accomplished. These magnifications would be compatable with other film sizes also.

General approaches to this could be:

a. A zoom lens corrected for magnifications of 13, 6, and 3 x and continuously variable.

b. Variable magnification at 3 discreet magnifications by the replacement of part or all of the elements by a turret or similar arrangement.

c. Multiple presentation of images on 3 separate screens by 3 separate lens systems.

ZOOM LENS

A most simple mechanical solution to the variable magnification - variable format problem would be a zoom lens. Optical design solutions to zoom lenses require simultaneous solutions to the lens equations for different magnifications. Thus instead of solving to minimize (neglecting chromatic aberrations) the 4 third order aberrations (neglecting higher order!) we must now solve for 4 x 3 or 12 conditions.

It is in practice found that, although in theory, the twelve simultaneous solutions may be solved, no practical solution always exists when constraints on glass thickness, index, ahromatic corrections, and higher order aberrations are added. The design thus in practice becomes a compromise at 3 points.

It is conceded that it is possible to use the basic zoom lens types and design for a high state of correction at one particular format, while settling for more mediocre solutions at other magnifications. It is suggested that a more detailed study should be given to the design of a high resolution, zoom lens of our requirements. On the surface, this approack appears of sufficient difficulty to study carefully all alternate approaches.

TURRET APPROACH TO OPTICAL DESIGN

The design of a variable magnification lens by use of interchangeable components is well-known. Generally, this amounts to a stationary positive group with wide-angle, normal, and telephoto attachments. Variations may include more general replacement of elements.

Going one step further, it would be possible to use three distinct lenses (one for each format). This suggests, however, perhaps an unique approach.

MULTIPLE PRESENTATION

Using three lenses it would be possible to present, simultaneously on three separate screens, three images. A simple design would include dichroic beam-splitters to separate spectral components. These components would then be focused by different lenses and directed to screens. A possible layout is illustrated on the following page.

The advantage of this approach is immediately obvious. Presently, dichroic beam-splitters are being used to separate out the ultraviolet energy for projection onto the phosphorescent screen. This method would not cut the ultraviolet radiation levels but would make efficient use of the other light already available and not being used. It would furthermore allow simultaneous examination of areas without changing the scanning format, allowing a comparison at two magnifications.

Each lens could have a narrow spectral correction and could possibly be purchased off the shelf, eliminating the necessity of lens design or at least allowing test of the system without awaiting a lens.

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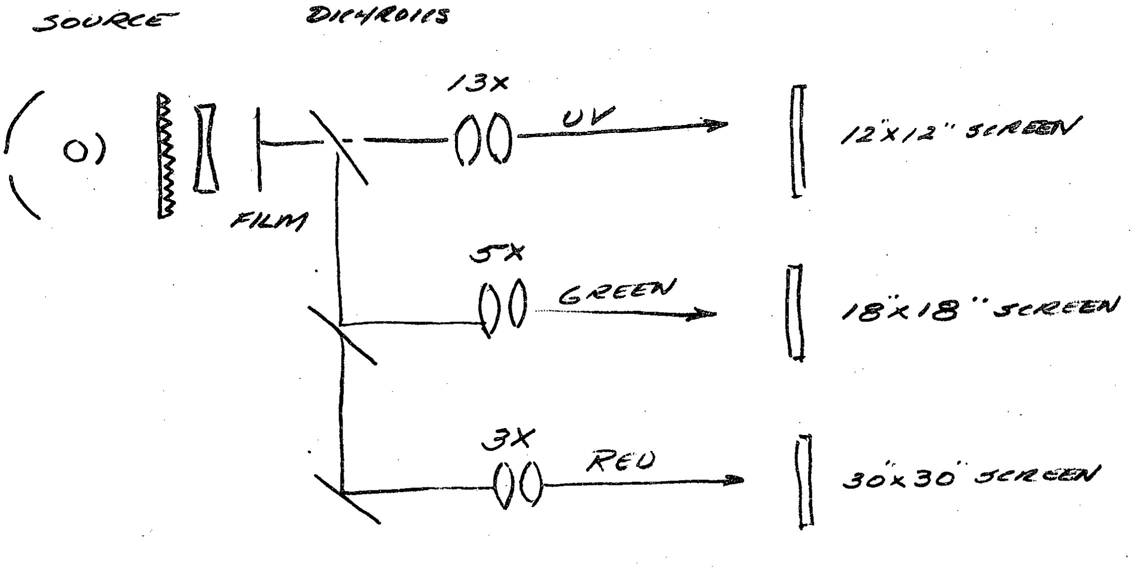
JOB NO. 2554 A

HIGH RESOLUTION
VIEWING SYSTEM.



SIMULTANEOUS PROJECTION OF DIFFERENT MAGNIFICATIONS TO PERMIT EXAMINATION OF DETAILS WHILE SCANNING.

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WDS.

LENS COATING

New high efficiency loatings (HEA Multilayer) are providing up to 95% transmission capability in the ultravoilet and visible regions. It is proposed that these coatings be used not only in the lens elements but also on the screen face to eliminate room reflections. One of [redacted] primary interests STAT lies in the production of multilayer coatings. The following discussion originates from the person who was primarily concerned with the computer programming and development of techniques for making both HEA coatings and dichroic filters.

THE OPTICAL TRANSFER FUNCTION

The bearing of the Modulation Transfer Function upon low contrast photography is related to the ability to obtain as high a resolution as possible. In evaluation of improving the visual recognition of images is yet to be determined in terms of the MTF. This MTF enables the lens designer to judge what changes are necessary to improve the lens. If for example, the film is the limiting factor in the overall MTF, then it is futile to continue attempting to improve the lens design. In this particular situation it becomes necessary to find a more suitable film.

The optical transfer function (OTF) has been introduced as an optical analyses technique over the last ten years. The concept of an optical transfer function is an extension from the electrical engineering communication theory and many of the same concepts are applicable.

Basically, the OTF is the result of employing a Fourier Intergral to obtain the properties of the optical image. The integral can be employed for the target, the lens system, and for the film upon which the image is recorded. Once the OTF has been obtained for one component of the total optical system, the overall recorded image quality can be obtained.

The Fourier Integral is given below. The term e^{-jwx} is known as the Kernal Function. By performing this integration, the components of f(x) can be obtained. Essentially, we then obtain the frequency components of the integrand f(x). The complete integration will result in components which have some magnitude as well as phase. For this discussion it is only necessary to consider the amplitude at each spectra or frequency.

$$F(w) = \int_{\infty}^{\infty} f(x)\, e^{-jwx} dx \qquad \text{Fourier Integral}$$

In general, this integration is a complex integration process and rather difficult to compute by manual methods. However, high speed digital computers have reduced the amount of effort necessary to evaluate such integrals.

In order to analyze the system, it is only necessary to determine the amplitude of the OFT. This amplitude is called the Modulation Transfer Function (MTF). The MTF is a normalized amplitude, which is obtained by dividing the amplitude at any particular frequency by the value of the amplitude at zero frequency. An MTF can be established for several parts of the system independently or together. By multiplying the several MTF's together, the total amplitude of the MTF through the complete system can be calculated to evaluate the overall system.

The MTF of the film and lens system might be linear, but the screen MTF may not be linear. The problem in this case is to determine several film MTF's of various lighting conditions for the film type and the method of developing the film.

The optical transfer function permits both the designer and the user to judge what portion of the projection process that improvements should and can be made.

DETERMINATION OF THE MODULATION TRANSFER FUNCTION

Various methods are presently available to determine the MTF. Some of these methods are the active type employing rotating lenses, prisms, etc. These active devices possess vibration problems which limit their use. The more generally employed method at the present is the use of a sinusoidally modulated target. This target is made up of a series of repeating sine waves whose density varies as the sine function. The more frequently this pattern repeats itself, the greater its frequency. This sinusoidal target is imaged by the lens system. Before the image reaches the image plane, it passes through a slit parallel to the sine wave pattern. The slit permits scanning only along one line. A film strip is utilized to record the impression as the target is drawn past. This process is demonstrated in Figure B-1.

By observing the flourescent screen formed by this target and analyzing the amplitude of the light, an MTF can be determined. The screen light intensity can be read by means of a microdensitometer and by plotting the results from the lowest to the highest frequency distinguished by the system. The output of a lens system may also be read on a photomultiplier tube to analyze the output light. A similar configuration of target lens system and scanning slit would be used for the phototube method. [redacted] employs the most recently developed photometric microscope and linear logarithmic photometer manufactured by Gamma Scientific, MOD 700-10 and MOD 700. This instrument is capable of measuring areas as small as 0.00015 inch in diameter with the proper eyepiece and fiber optic photometric optical objective. STAT

After performing the process of taking the picture of the target as shown in Figure B-1 a set of curves will be obtained by reading the microdensitometer. Its output will be a series of nearly sinusoidal waves expressed as a function of the frequency of the target. As the frequency increases, the system becomes less able to distinguish one sine wave from another as demonstrated by the reduction of the amplitude change of the density in Figure B-2 (a). The amplitude at the lowest frequency is then selected as a normalizing value and the normalized values of the amplitude ration can be plotted as shown in Figure B-2 (b).

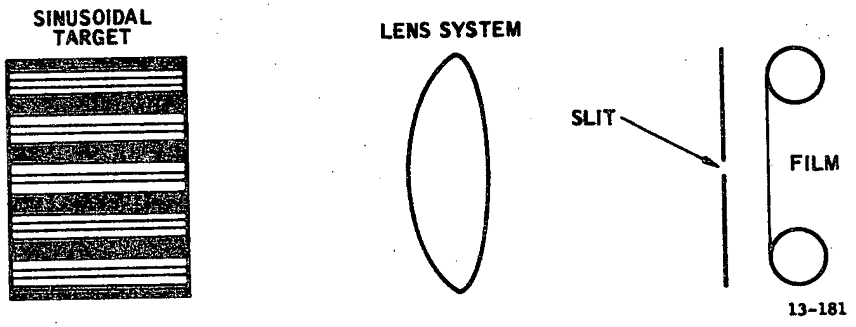


FIGURE B-1
Measurement of the Modulation
Transfer Function
of a Lens

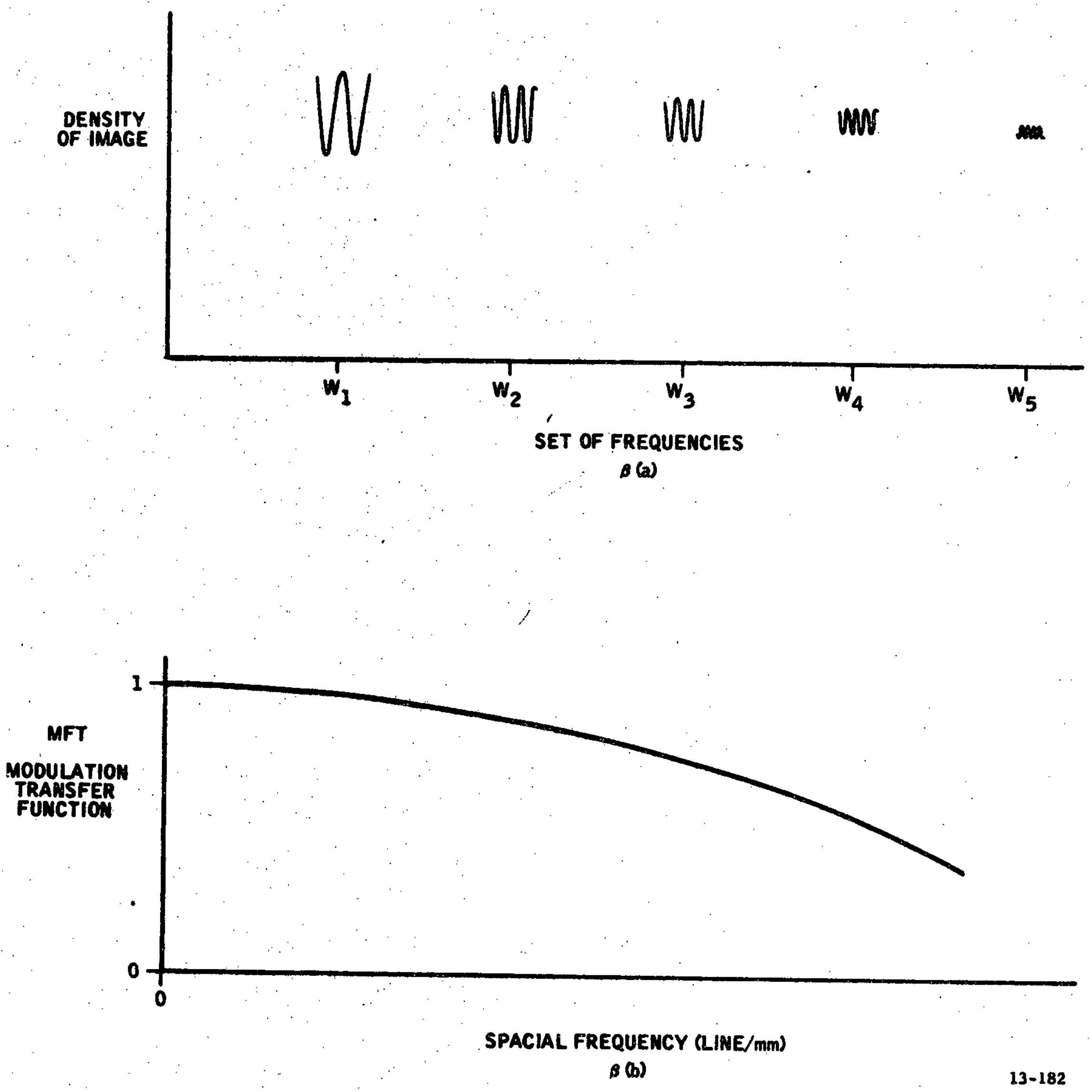


FIGURE B-2
Reducing Data to Obtain the MTF

THIN FILM TECHNOLOGY

Multiple layer optical coatings have been investigated by [redacted] STAT
[redacted] since the World War II period. In recent years, efforts have been devoted to developing mathematical solutions and computer programs for designing multilayer coatings. Programs were developed for solving the reflectivity and transmission of multilayer films with variations of the following parameters: (1) number of layers (any number); (2) refractive index; (3) thickness; and (4) wavelength. STAT

Methods for calculating absorbing films, nonhomogeneous films and variations with angle of incidence, have also been developed. Simplified methods for vector analysis have been developed and suffice as guides to exact computational research for new coating configurations.

Utilizing the theoretical approach, special coatings are investigated by computer before experimentation. This investigation includes the calculating of the progressive changes in reflectivity or transmission as each layer is being deposited. The prediction of these changes in reflectivity has also led to the development of monitoring devices for the precise control of coating thicknesses. For some of the coatings developed, the monitoring equipment has been automated for production purposes.

Extensive research has been conducted in developing evaporation techniques and in studying the properties of numerous stable oxides such as TiO_2, Al_2O_3, SiO, CeO_2, and La_2O_3, many fluorides such as CeF_3 and LaF_3, beside the commonly used materials such as MgF_2, and ZnS. Investigations of refractory metals and many rare earth compounds have also been performed. In addition, work has been done in evaporating metals such as chrome-nickel alloys, chromium, gold, silver, aluminum, and copper as transparent conducting films.

The development of evaporation techniques and investigation of materials has resulted in a selection of materials which has a variety of indices, absorption coefficients, and environmental stabilities, and are available for solving optical thin film problems.

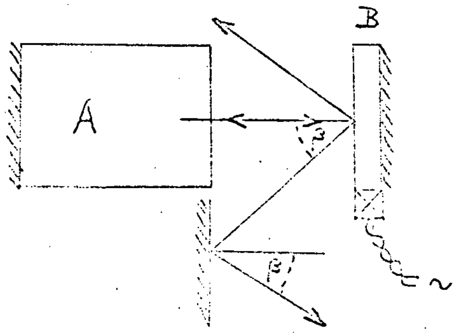
Utilizing computer programs, materials technology, and monitoring devices, we have developed coatings for antireflection systems, color corrected (by use of thin films) lens systems, transparent conducting films, and numerous neutral and dichroic beam splitters. Some of these coatings were of the classical struction of 1/4, 1/2, etc., layer thicknesses of the central wavelength. Other coatings, however, consisted of layers which were not 1/4 wavelength or a multiple thereof in thickness.

GALVANOMETER WITH VERY HIGH FREQUENCY CAPABILITY

The possibility of using a CW (injection) solid state laser as a light source in a recording oscillograph has brought within sight a potential writing speed some 300 times that available with present-day silver halide materials.

Such a writing speed, of perhaps 1.5 x 10^7 inches per second, will be quite useless unless a galvanometer is available capable of a frequency response of the order of 5 megacycles. This is quite impossible with mechanical systems, which now go up to 13 kc and which cannot be pushed much further, even if radically different configurations are considered.

A virtually inertialess light deflecting device might be made as part of a laser cavity, in the manner to be described. However, the reduction to practice of such a device would be dependent on the availability of a suitable ultrasonic transducer for use in the thousands of megacycles range, and with the necessary wide bandwidth.

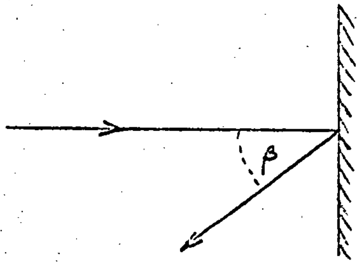


In the diagram, A is an injection (solid state) laser cavity (plan view) with a totally reflecting surface on the left. B is a cell containing an ultrasonic modulating element[1]. In this case the totally-reflecting surface on the right of the light modulator completes the laser cavity. A source of Kilomegacycle electrical energy is connected to a transducer at one end of the cell. The other end should be such that the energy is absorbed rather than reflected. The ultrasonic energy in the cell has the effect of a diffraction grating. While most of the radiation is reflected in the zero-order back into the laser cavity, thus providing the required feedback, some radiation comes out at an angle on either side, mostly in the first order. Since the energy in the zero order is returned to the system, it may be expected that the energy in one side beam will be close to 50% of the available output.

The angle of diffraction will vary with the frequency of the ultrasonic output to the cell, as described below. Hence, the beam will move through an angle in the same way as a beam from a mirror galvanometer. Deflection could be very much faster than is feasible with a system, such as that of a mirror galvanomer, having mechanical inertia.

Calculation of Grating Constant d

A 4" (double-amplitude) deflection with 11" optical arm is usual for a galvanometer in oscillograph recording. This is about 10°20' each side of normal. We shall calculate the grating constant for a diffracted angle of 45°±10°20', i.e. 34°40',45° and 55°20' ($=\beta$) for the first order. $n\lambda_o = d \sin\beta$ where n (order) = 1



Assuming a wavelength of 6500 A = 6.5×10^{-5} cm,

$$\frac{1}{d} = \frac{\sin\beta}{6.5\times10^{-5}} \quad \text{cm}^{-1}$$

$$\text{For } \beta = 34°40', \quad \frac{1}{d} = \frac{0.5688}{6.5\times10^{-5}} = 0.875\times10^{4} \quad \text{cm}^{-1}$$

$$\text{For } \beta = 45°, \quad \frac{1}{d} = \frac{0.7071}{6.5\times10^{-5}} = 1.088\times10^{4} \quad \text{cm}^{-1}$$

$$\text{For } \beta = 55°20', \quad \frac{1}{d} = \frac{0.8224}{6.5\times10^{-5}} = 1.265\times10^{4} \quad \text{cm}^{-1}$$

In a similar calculation for the second order beam, we find that for 60° deflection a reciprocal grating constant of 6.66×10^{3} cm^{-1} would be required. At the grating constants calculated above, the second order would be diffracted more than 60°, so the second order beam would not overlap the range of the first order beam, and may be cut out by a suitable mask.

Frequency of Ultrasonic Radiation

The velocity of sound in liquids and solids varies from 500 m/sec for rather soft solids up to about 6000 m/sec. The lower the velocity, the lower the frequency required for a given grating constant. The frequencies will be calculated for water using a velocity of 1460 m/sec.

$$v = n\lambda, \text{ or } n = \frac{v}{\lambda}$$

Where v = velocity of sound = 1.46×10^{5} cm/sec in water

n = frequency

λ = wavelength

At 34°40', $\frac{1}{\lambda} = 0.875\times10^{4}$ $\quad n = 1.46\times10^{5} \times 0.875\times10^{4} = 1.278\times10^{9}$ sec^{-1}

At 45° , $\frac{1}{\lambda} = 1.088\times10^{4}$ $\quad n = 1.46\times10^{5} \times 1.088\times10^{4} = 1.588\times10^{9}$ sec^{-1}

At 55°20', $\frac{1}{\lambda} = 1.265\times10^{4}$ $\quad n = 1.46\times10^{5} \times 1.265\times10^{4} = 1.847\times10^{9}$ sec^{-1}

The figures given are very approximate because no account has been taken of dispersion; i.e., variation of velocity with frequency. A substantial variation may have accrued by the time these KMC frequencies are reached.

As regards the problem of generating ultrasonic radiation in the kilomegacycle range, the newly developed depletion layer transducers appear to be promising. 2 These devices function in the desired frequency range. Furthermore, their resonant frequency may be varied by a d.c. bias. They may be made from such materials as gallium arsenide or cadmium sulfide.

Response Time

If the frequency with which the transducer is excited is abruptly changed, this change will be propagated along the cell, across the laser beam. While the change is in transit, part of the beam will be diffracted at the old angle and part at the new. Hence the transit time across the beam is of interest.

Typically, a beam from the kind of laser under consideration would be .004" = .010 cm wide. At a velocity of 1.46×10^5 cm/sec, transit time $= \dfrac{10^{-2}}{1.46\times10^5} = 68.5\times10^{-9}$ sec.

Since we spoke earlier of a frequency response of 5 megacycles, it is of interest to see what this response time amounts to in terms of a phase angle at 5 megacycles. Duration of 1 cycle at 5 mc = 200×10^{-9} sec.

$$\text{Phase angle} = \frac{68.5}{200} \times 360 = 124^\circ$$

At 1 mc, phase angle = 25°

While this does not look too encouraging on paper, it should be remembered that high frequency response is normally required for recording rapid changes in the quantity being measured; and when the recording beam is in rapid motion across the paper, the fact that it has a "tail" may not be of great importance. The effect may be minimized by using a material in the light modulating cell in which the ultrasonic velocity is much higher. In practice it could be about four times higher than in the example given. But to produce the same grating constant a higher ultrasonic frequency has to be used in the same ratio as the velocity of its propagation. For example, if a medium were chosen in which the velocity were 6000 m/sec., the frequencies required would be $\frac{6000}{1460}$ or 4.1 times those calculated for a water cell; that is, about 5 to 7×10^9 sec^{-1}. The phase lag at 1 mc would then amount to 6°.

[redacted]

JHJ:fm

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1. G. W. Willard, J. Acoust. Soc. Amer. 21, 101 (1949)
2. "Depletion Layer Transducer - a New High Frequency Ultrasonic Transducer," by Donald L. White of Bell Telephone Labs, 1961 I.R.E. International Convention Record, Part 6, p. 304.

COMPUTER INTERFACE DISPLAYS

Associated with the problem of storage and processing information is the display of the information for human observation. The historical method has been to sweep the display horizontally one line at a time similar to television. This method could also be applied in presentation of digital information on a cathode ray tube. The ordinary T.V. (21") with 535 lines represents approximately 25 lines per inch or 1 line/mm. This is a relatively coarse picture as far as resolution is concerned.

Now it would appear that the CRT offers a more versatile method of presentation than is normally done. That is, with the proper controls on the CRT including Z-modulation (brilliance) it is possible to draw lines of any length and at any angle starting at any particular point. Perhaps several lines could be drawn parallel to widen lines without "blasting the phospher" with high electron beam intensity. Care should also be taken to assure that a sufficiently small spot be utilized.

Another possibility is to employ printers to actually print maps. In the case of printers, it would be more beneficial for the machine to print one line of output at a time.

If an X-Y plotter were used, the various lines, axes, or dots could be made although the settling time for an electro-mechanical system would require an inordinately large time to print a bit of information contained in one dot compared with the time to draw a straight line.

The various aspects of CRT's versus printers versus plotters would have to be analyzed in the light of specific requirements.

SUMMARY

Cathode Ray Tubes would be the most practical system to be employed for rapid visual presentation. A one-line-at-a-time printer could be employed to stamp out digits. In the case of an X-Y plotter, it may prove more beneficial in essentially drawing one line at a time to result in a faster production of a display with a minimum requirement for storage of information. Various other display devices will be examined to evaluate their usefulness for this purpose.

MAP Display

Presentation of a map will require just two states of amplitude information. That is whether there is a light or a dark area. This as a picture (map) is scanned in a series of digits picked up which can represent the picture. Let our format be divided up into a dimension X by Y millimeters. If these dimensions are to have a resolution of α spotes per millimeter then across one dimension say X we should have a total of $\alpha \cdot X$ spots. Allowing two states of amplitude we should get $2 \cdot \alpha \cdot X$ spots in one trip across X. Now in order to cover the Y dimension, we have to give the same resolution factor to Y as we did to X with the result that the total number of sweeps is αY.

A total information count can be calculated by $2 \cdot \alpha^2 \cdot X \cdot Y$. The process of information storage becomes quite large if we consider X & Y to be 50 mm each, and α to be say 100 lines per mm. Hence, the total can be calculated to be

$$2 \times 100^2 \times 50 \times 50 = 5 \times 10^7 \text{ bits.}$$

The IBM 1620 computer has a capacity of 4000 words which are in decimal form. Since a decimal equivalent storage expressed in binary is 120,000 bits, it would require $5 \times 10^7/1.2 \times 10^5$ or 41-1/2 IBM 1620 computers to store all the information (on a black and white basis) in the map. Were we to permit shades of gray (say 10 different shades) the overall requirement then becomes $5 \cdot 10^7 \cdot 10^2$ or 5×10^9 bits. Needless to say this represents a very large amount of information.

Two alternatives are available to us: either increase the storage capacity of the computer or decrease the stored information on the map at least on the basis that we have assumed for representing this map. It may prove more advantageous to store different types of information which may be various types of short line segments or other types of geometric figures, like crosses or circles. What is required is a review of information theory in regards to character representation. Perhaps this review of information theory should be tempered by what physical elements are available to both identify and print our (or display) the character before going into too thorough a study. It would be well to make such a review to better adapt the available machines to the problem at hand.

SUMMARY

Perform a review of information theory to reduce the storage requirements for representing the map. This review should take into account the devices which would perform the extraction of information from some original map to the devices which would perform the display of the map. It might well prove that the best way to draw a map is not a simple dot drawing but a series of short lines (or even continuous lines) might prove more beneficial than the dot system.

IMAGE ENHANCEMENT

Thoughts on Image Enhancement with FB Techniques

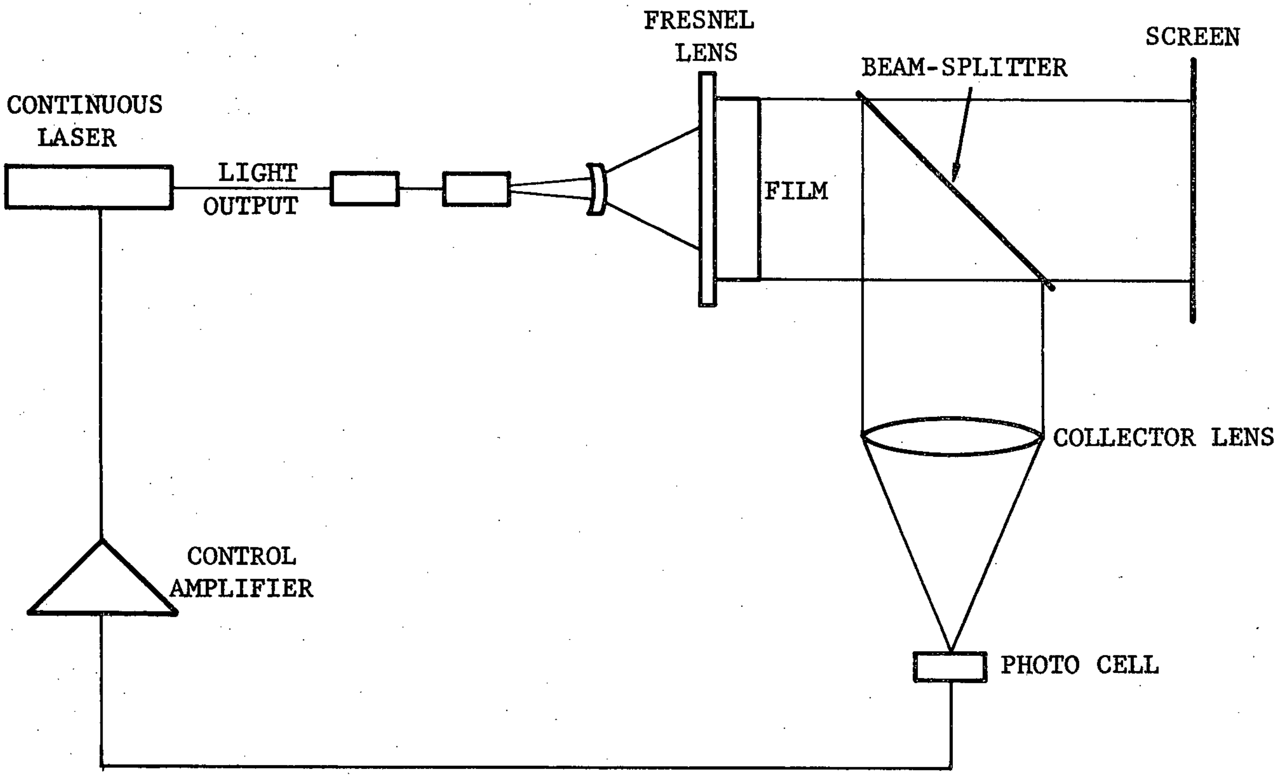
Feedback Theory

In general, a normal feedback system tends to employ proportional signals to cause output to follow input. This is the general negative feedback employed in many systems. However, there is a useful purpose in the use of positive feedback. If a photocell output were fed back to modulate a light source, a control of intensity could result. For instance, during scanning it would be possible to increase at a relatively low density portion of the image and decrease intensity at a relatively high density portion of the screen. This scheme would work like a "volume-expander" in an audio amplifier. The result should improve contrast in a low contrast photograph. However, since the process really represents positive feedback, some care must be observed in building such a feedback network. This technique is only possible on a scanner system (an active system) where the illuminated spot is small.

The technique is not necessarily limited to U.V. but could also be utilized with any light. It would work better with U.V. than visible light because of ultra violet's shorter wave length.

A beam splitter could be employed to "pull off" some of the light after it had passed through the transparency. A modulation of light source intensity could then be made. It may be necessary to slow down the sweep to give the feedback mechanism some time to stabilize at the correct amplitude. The fall-off at end of the margins of the format (Cos 4 Law) could also be corrected by attempting to bring the average intensity back to a normalized value.

It might also be possible to increase the intensity of the image in high resolution points by use of lead networks. The problem here might be the phase shift of the high resolution points. That is, an apparent shift in intensity location might occur, but as long as the film is swept in the same direction the image properties should be preserved.



Physical Setup

SYSTEMS FOR SWEEPING/SCANNING

A pattern for scanning is important to establish the overall objects of drawing maps versus detailed pictures versus character presentation. If it is known that what is being scanned is binary then at some point in space (or time) then a simple binary bit can be reproduced.

One can consider various mechanical systems such as rotating lenses, perhaps even moving a laser at various angles would permit a scan to be made. The lightest system would inherently possess the lowest inertia and would have the highest response. This lightest system is a mirror or galvanometer used in oscillographs. However, even the best response of galvanometers is in the order of 15 kilocycles.

Now to briefly examine the requirements of sweeping. If an assumption of 100 lines/mm resolution is made and a format of 25 mm high is taken, then the number of sweeps to be made is 2500 lines. Furthermore, if a sweep is to be made in 1/30 second then a capability of 75 kilocycles is necessary assuming a fast "fly back." If an assumption is made where a sine wave is to be employed, then since a sine wave sweeps up across and back in one cycle, then only half the rate or 37 kilocycle response is required.

Now the requirement for 100 lines/mm over a 9 inch format is much greater. The basic requirement in cycles per second is

100 x 9 x 25 x 30 or 675 kilocycles

for a saw-tooth wave form and only 338 kilocycles for a sine wave trace. The actual capability requirement for response should be an order of magnitude greater so a response of 7 megacycles would be a definite requirement in this application.

This high requirement eliminates any common mechanical system consideration. It becomes obvious that an electronic system of modulating light then is quite necessary for a direct or real time scanning system. [redacted] STAT [redacted] has considered a system of modulating continuous lasers. STAT This concept should be capable of modulation up to 5 megacycles. The conceived system operates by use of building an ultrasonic transducer as a part of the continuous laser.

In addition to the requirements for speed it is also necessary to consider the problem of spot size. That is, it does not do any good to make 100 sweeps per mm unless the spot has a size 1/2 of (1/100) millimeters (.0002 inches). This size of spot would be of question and would take considerable development but should be possible.

LIGHT SOURCES

All known UV light sources will be investigated to determine the most practical source for projection systems utilizing a transparent luminescent screen. The search will include, but not be limited to, the following prime UV sources:

1. Mercury Arc Lamps, High Pressure-Point Source
2. Mercury Arc Lamps, Low Pressure-Extended Source
3. Plasma
4. Laser Type in a Scanning System
5. UV Source, Optically Concentrated, in a Scanning System Compared with a Conventional Projection System.

Two extended mercury sources are to be considered. The first is a folded tube, low pressure mercury vapor filled. Internal surfaces are phosphor coated to increase the 3654Å energy emittance. These UV enriched sources are approximately 75% efficient. Transmission and transmittance of the optics and filters in the condensing and projection system reduce the usable 3654Å energy to 10%. Further UV enrichment may be possible by selective construction of the extended source.

The second type is a high pressure mercury vapor in quartz or vicor tubes. This may be enriched in the same manner, phosphor coating inside the tube. More support equipment, ballast, power supplies, starters, etc., are required with the high pressure system. However, more 3654Å energy per watt input is available.

BY .... DATE .... SUBJECT .... SHEET NO. .... OF ....

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SOURCE TYPE	INPUT WATTS	SOURCE SIZE	TOTAL RADIATED ENERGY AT 3654 A° (WATTS)
1. HG - HI PRESSURE			
a. COMPACT	100	POINT	3.4
	1000	POINT	60.
	2500	POINT	200.
b. EXTENDED	2100	21 IN LONG	180.
2 HG - LOW PRESSURE			
a. EXTENDED & UV ENRICHED	250	27 IN FOLDED TO 3 X 3 IN	180.
3. LASER CW			
a. GAS	55 ?	8 MM DIA	.008
b. SOLID STATE	2000 ?	.250 IN DIA	.015
4. HYDROGEN DISCHARGE TUBE	1000	1.5 SQ CM	.0008

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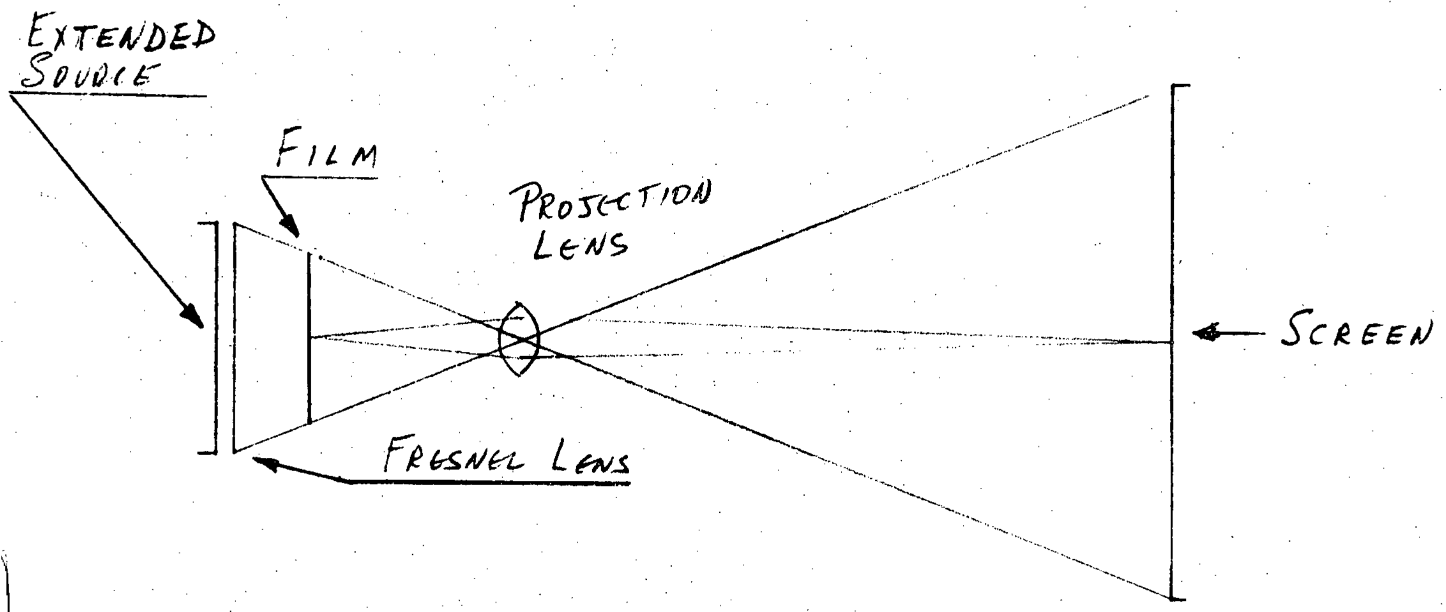

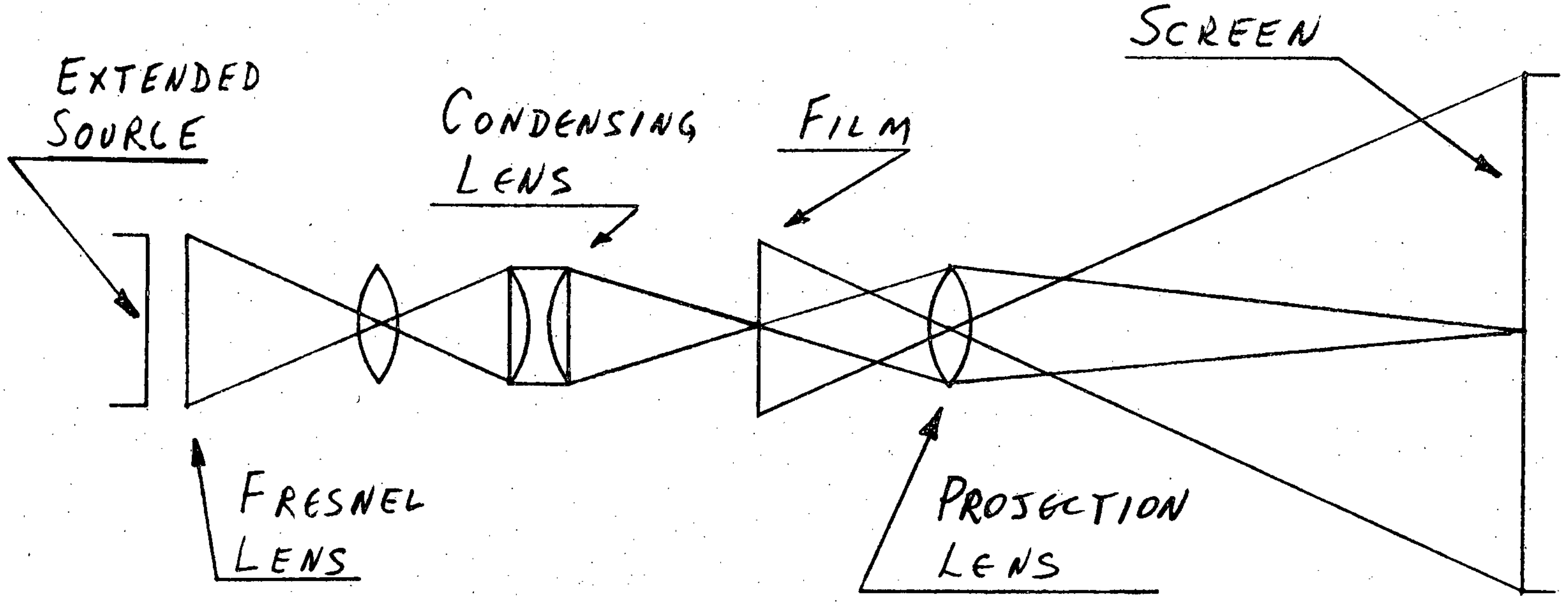

SPECTRAL ENERGY DISTRIBUTION
of Radiated Mercury Lines in
HANOVIA HIGH-PRESSURE QUARTZ MERCURY-VAPOR LAMPS

Lamp code	SOL	SH	S	L	A	SA	LL	SS	BMS	PS	MSS	PIS	HST
Lamp Cat. No.	608A	616A	654A	679A	673A	674A	189A	78A	47A	59A	77A	57A	40B
Lamp watts	100	100	200	450	550	700	1200	2100	3500	4500	4500	5000	7500
Lamp volts	100	100	125	135	145	150	285	550	925	1050	900	1260	1700
Current, amps.	1.2	1.2	1.9	3.6	4.4	5.2	4.7	4.2	4.4	5.0	5.0	4.5	4.5
Arc-length (inch)	2.9	1.7-U	4.5	4.5	4.5	7.5	12	21	48	58	42	46.5	59.0
Mercury lines (angstroms)						RADIATED ENERGY IN WATTS							
13673 (infrared)	0.65	0.95	1.0	2.6	4.6	4.1	10.15	19.0	34.9	39.0	30.1	26.2	39.3
11287	0.62	0.85	1.3	3.3	3.8	5.0	6.93	14.2	27.8	30.2	21.9	30.8	46.2
10140	0.85	1.30	1.8	10.5	12.2	14.6	31.60	55.2	88.8	51.3	78.0	110	165.0
5780 (yellow)	1.55	1.50	3.4	20.0	23.0	32.1	69.35	120	165	141	175	198	297.0
5461 (green)	1.35	1.50	3.0	24.5	28.2	34.0	40.52	92.2	156	150	163	193	290.0
4358 (blue)	1.08	0.84	2.6	20.2	23.3	29.0	53.00	101	151	142	140	144	216.0
4045 (violet)	0.75	0.51	1.6	11.0	12.7	15.9	24.20	47.3	90.5	94.7	82.8	100	150.0
3660 (U-V.)	1.40	1.82	3.1	25.6	30.1	40.5	97.10	180	268	302	310	295	443.0
3341	0.13	0.18	0.36	2.4	2.8	3.8	6.93	16.8	20.9	32.3	29.2	31.0	46.6
3130	1.02	1.30	2.3	13.2	15.0	21.0	50.6	105	153	195	200	180	270.0
3025	0.41	0.57	0.86	7.2	8.2	11.3	32.9	64.8	80.1	76.3	74.7	78.4	117.6
2967	0.32	0.30	0.48	4.3	5.0	6.5	15.2	28.2	43.5	44.7	44.3	44.6	66.9
2894	0.10	0.19	0.20	1.6	1.8	2.3	4.41	8.22	13.8	13.3	15.1	14.0	21.0
2804	0.12	0.19	0.30	2.4	2.8	3.8	13.9	24.9	31.5	41.7	40.0	42.6	63.9
2753	0.06	0.08	0.14	0.7	0.8	1.0	4.2	7.5	8.2	13.0	12.3	14.4	21.6
2700	0.07	0.09	0.14	1.0	1.2	1.3	4.85	8.6	9.8	14.7	13.0	15.2	22.9
2652	0.30	0.47	0.64	4.0	4.6	6.6	27.80	50.2	71.5	83.3	92.2	105	158.0
2571	0.11	0.19	0.20	1.5	1.8	2.3	6.30	9.30	14.0	18.8	16.4	20.7	31.0
2537 (reversed)*	0.34	0.37	1.10	5.8	5.0	7.3	24.1	53.2	62.8	97.1	87.4	84.7	137.0
2482	0.10	0.19	0.20	2.3	2.6	3.2	10.15	17.0	26.1	31.9	24.8	27.9	41.8
2400	0.05	0.12	0.20	1.9	2.2	2.9	7.30	13.6	13.2	22.1	18.7	21.2	31.9
2380	0.03	0.09	0.12	2.3	2.6	3.2	8.40	15.3	12.6	25.7	22.4	25.5	38.4
2360	0.02	0.06	0.08	2.3	1.8	2.3	6.20	11.5	10.0	19.9	14.2	19.1	28.7
2320	0.02	0.02	0.03	1.5	2.4	3.1	7.65	15.5	8.9	24.1	10.3	20.8	31.2
2224	0.04	0.02	0.03	3.7	4.2	4.7	9.20	21.0	26.5	30.8	21.9	26.3	39.4
Total watts	11.49	13.70	25.18	175.8	202.7	261.8	572.9	1093.5	1588.0	1740.9	1737.7	1868.4	2814.4

* 2537 line is reversed in high-pressure lamps.

In order to find the intensity in microwatts per square centimeter of any line [illegible]:

- 0.5 meter (i.e. 50 cm or about 20 inches). On line bisecting center of lamp multiply the above watt value for the line by 38.4 for lamps SOL, SH, S, L, A, and SA: by 57 for LL lamp; by 71 for Lamps SS, BMS, PS, MSS, PIS, HST.
- 1.0 meter (i.e. 100 cm or about 40 inches) multiply watt value for the line by: 10.87 for Lamps SOL, SH, S, L, A, SA, LL: by 12.3 for SS lamp; by 31 for Lamps BMS, PS, MSS, PIS, HST.

When [illegible] does not have reflector, inversed square law of intensity versus distance applies for all distances greater than 32 inches for LL lamp, greater than 50 inches for "SS" lamp, and greater than 100 inches for the others.