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The Application of Electronic Video Techniques to Infrared and Ultraviolet Examinations

Ultraviolet (UV) and infrared (IR) radiation are used by most document examiners in the detection of alterations, erasures, substitutions, and secret writings; in the deciphering of charred or ancient documents; and in the viewing of obliterated text. The basic instrument used in conducting examinations of this sort is either the camera and photographic process or the electronic conversion tube. Most commercial equipment using these techniques has not been designed primarily for document examination but in most cases has been engineered for another purpose and then accommodated to document work. The purpose of the research reported in this paper was to use present-day technology to develop a system whereby the document examiner can conveniently take one, or, if desired, a hundred and one, questioned specimens and within a relatively short period of time observe the effects thereon of UV and IR radiation. To clarify the techniques used in this study, a few basic definitions and descriptions are being set forth.

Specimen Reaction

One of four basic phenomena can be observed occurring to a specimen when excited by energy in any given portion of the spectrum between 200 nm and 1200 nm and viewed or recorded in the same or a different portion of the spectrum as that of the exciting energy (Fig. 1). The specimen may be observed reflecting the energy (lighten), absorbing the energy (darken), transmitting the energy (disappear), or converting the energy to a longer wavelength (luminesce), depending on the properties of the specimen itself and the combination of excitation wavelength and viewing or recording wavelength.

Luminescence

Luminescence is the reaction of certain substances such as some writing inks, when excited by a specific wavelength of energy, to convert that energy to a longer wavelength and as a consequence to emit the longer wavelength of energy. Luminescence is usually classified by the wavelength of the original source of energy [*1*]. A specimen exposed to blue-green visible radiation (400 nm to 600 nm) and emitting radiation in the red, near red, and infrared (600 nm to 1200 nm) is therefore visible luminescence.

Visible luminescence is commonly referred to by most document examiners as "infrared luminescence." Although the term "infrared luminescence" is erroneous based on the aforementioned definition, it will be used in the remainder of this discussion because of its widespread acceptance in the field of questioned documents.

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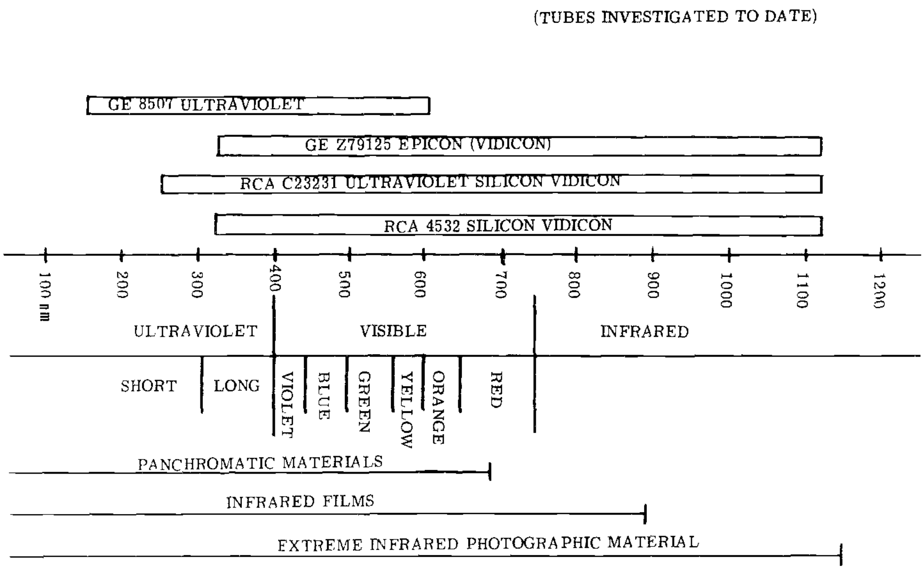

FIG. 1—*Video tube sensitivity (information from personal communications with R. H. Phillips and James Fischer and from Ref* 3).

Fluorescence-Phosphorescence

Luminescence is further subclassified into fluorescence and phosphorescence. The only difference between these two subclassifications is the element of time. If the specimen continues to luminesce longer than 10^{-8} s (an arbitrary number) after the exciting radiation is removed, the specimen is said to be phosphorescing; if the luminescence ceases in less than 10^{-8} s, the specimen is said to be fluorescing [*1*].

Present Methods of Examination

At present there are two common methods of visually examining questioned specimens in the invisible ultraviolet and infrared portions of the spectrum: image converters and photographic materials. Many image converters have a number of disadvantages for use in document examinations: limited field of view, limited spectral range, the necessity of having to change tubes for examinations in UV and IR, and relative expense. The image conversion tube's greatest advantage, however, is that the reaction of the exciting energy on the specimen can be observed instantaneously, or in real time.

Today most cursory document examinations are conducted with a conversion tube of some sort, and an in-depth examination is conducted with photographic materials (Fig. 1). A few of the advantages of photographic materials are high resolution, high quality permanent copies, and most of all, relatively high sensitivity because of the film's ability to record a weak image through time exposure. Therefore, photography makes a means by which to record weak luminescence.

Some of the disadvantages of photographic materials are the setup time, the time required for photographing and processing the image (especially if long exposures are necessary or hundreds of documents are involved), the need to photograph and process each portion of the spectrum separately, and the requirement of a new exposure and processing cycle when making subtle changes in contrast, exposure, or filtration.

Video Spectroscanner

The Video Spectroscanner system is an attempt to combine as many of the positive qualities of both the image conversion tube and photographic materials as possible, while reducing to a minimum their inherent disadvantages.

The initial research was undertaken to develop an extremely sensitive closed-circuit television system that could operate efficiently enough to allow infrared luminescence to be observed as it was occurring or at least after a relatively short recording period.[2] Since this sytem could also be used to observe reflected infrared radiation from a specimen, a relatively inexpensive scanner was developed, suitable for the study of documents, that could provide instantaneous results in conducting both infrared reflectance and infrared luminescence examinations. After experimentation with various cameras, camera video tubes, monitors, light sources, and filters, a workable system evolved.

The basic system at the present stage of development consists of the following elemental components: (1) a standard 525-line commercially available closed-circuit television camera, equipped with a Schneider-Kreuznod xenon 1:0.95/25 lens and a RCA 4532 silicon photoconductor vidicon camera tube; (2) a standard 525-line 9-in. (23-cm) closed-circuit monitor; (3) a mercury vapor microscope light source; and (4) a full array of filters (Fig. 2). This system can be used in a reasonably dark room, or if an excess of extraneous light is present, in a darkened enclosure of some type.

The heart of this specific system is the silicon photoconductor vidicon camera tube in combination with the extremely fast lens (Fig. 1). The tube is not only responsive to IR out to approximately 1150 nm, but it also is much more sensitive than most other types of camera tube. During the initial experiments with the silicon tube it was further deter-

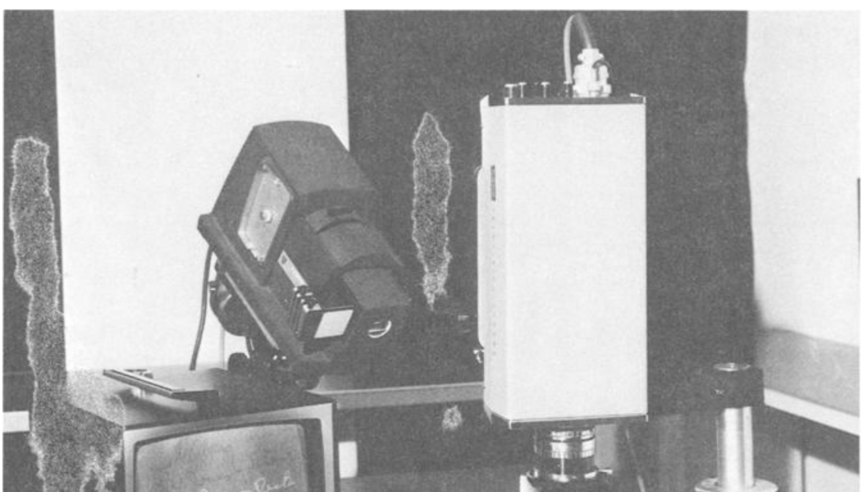

FIG. 2—*Camera, monitor and mercury vapor light source.*

[2] Thomas O. Ziebold, President, Braddock Services, Inc., personal comunication, 1975.

mined that this tube was also responsive down to 365 nm, and that with the factory addition of a fused silicon faceplate the tube's spectral response could possibly be lowered to 250 nm.[3] This determination lead to the conclusion that with the addition of a quartz lens, the single tube system under study could effectively scan a questioned document from approximately 250 nm to 1150 nm. Using the proper filter and lighting combinations an examiner could observe in a relatively short time the effects of shortwave UV reflectance and luminescence, longwave UV reflectance and luminescence, infrared luminescence, and infrared reflectance with this one instrument.

Illumination

Numerous incandescent and fluorescent light sources were tried to determine the most efficient and workable source that would enable the various examinations to be conducted with relative ease. A mercury vapor microscope light has proven to be an acceptable single source of light covering the entire spectral range under study with sufficient intensity; however, a comparatively cooler light source is being considered specifically for this scanner. The lighting arrangement will consist of two light housings placed one on either side and at a 45-deg angle to the specimen. Each housing will be divided into three sections, the top section consisting of low wattage incandescent sources, the second section consisting of high blue-green output fluorescent tubes with a Dow-Corning #9782 filter covering the tubes, and the third section containing shortwave UV fluorescent tubes. The advantages to this light source over the mercury vapor source are the reasonably low heat output and the ability to control easily and independently the three major areas of light used by the scanning system: UV, visible, and IR. Plans are also being made to use a xenon light source to determine its compatability with the scanner since this source also has a number of inherent advantages.

Filtration

For purposes of this discussion, an excitation filter is defined as a filter used over a light source to allow only certain desired wavelengths of energy to pass on to the specimen, whereas a barrier filter is a filter used over the camera lens to allow only certain desired wavelengths of energy to reach the camera lens.

To date, numerous types of filters have been used with the scanner system. All six commonly used Kodak IR transmission filters (89B, 88A, 87, 87C, 87B, and 87A) have been used, with the 88A proving most effective as a barrier filter for IR luminescence (Fig. 3) [*2*]. All of these filters are useful in observing various effects of IR reflection.

Experiments in the UV area of the spectrum have been limited to date. However, both an 18A and 2C Kodak filter (Fig. 3) [*2*] have been used, and a number of examinations are planned after receipt of a UV shortwave filter which cuts off radiation above 320 nm. This UV filter will be used as an excitation filter for UV shortwave luminescence, with the 18A being used as a barrier filter.

For IR luminescence examinations the excitation filter used is either a Dow-Corning #9782 blue-green filter or a 10% copper sulfate ($CuSo_4$) solution, with the aforementioned 88A over the camera lens as a barrier filter (Fig. 3). Figure 4 contains a listing of filters for conducting examinations with the silicon vidicon camera tube equipped with a fused silicon faceplate.

An example of a document as it appears on the monitor using visible energy, IR reflected energy, and IR luminescence is illustrated in Fig. 5.

[3] R. H. Phillips, engineer, Radio Corporation of America, personal communication, 1975.

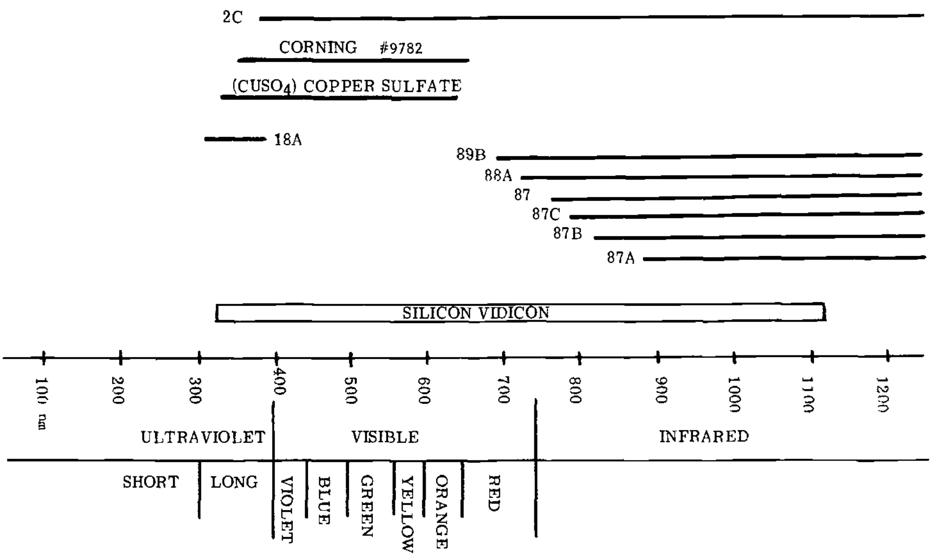

FIG. 3—*Filter wavelength transmission* [1,2].

Cost

Everything needed for a scanner used basically for IR reflectance and luminescence examinations can be purchased "off the shelf" for less than $2500, and with a small amount of improvisation and a minimum of technical knowledge, can be operational in a day or less. A convenient, custom-designed and constructed package can be ordered for notably less than the present cost of many commercial IR image conversion units.

However, cost is relative to how sophisticated a system becomes. The experimental system being researched by the writer could cost a considerable sum depending on how much electronic manipulation, beyond the basic system, proves to be of value. If experiments with the scanner in the UV end of the spectrum prove promising, a two camera/two tube system will constitute a considerable cost increase. One camera would be equipped with a standard silicon vidicon for IR work, the second camera with a GE 8507 quartz UV tube, or its equivalent, which has 40% sensitivity at 200 nm and 78% sensitivity at 300 nm, according to the manufacturer.[4]

System Improvements

A silicon vidicon camera tube modified with a fused silicon faceplate has been ordered to be placed in a high-resolution, 945-line camera and monitor system, the camera being equipped with both a standard and quartz lens. The addition of a second monitor equipped with a special photographic camera mount will allow the image to be photographed so a permanent record can be obtained. The merits of using a recording device to electronically take a "time exposure" of a weak image, such as with infrared luminescence, are presently being researched.

It is anticipated that numerous other image processing techniques, such as edge enhancement, contrast control, selective gamma control, positive to negative reversal, density slicing, soft X-ray, and computer enhancement can be incorporated into the system to examine a

[4] James Fisher, engineer, General Electric Co., personal communication, 1975.

EXAMINATION	EXCITATION FILTER*	BARRIER FILTER
UV Short Wave		
(A) Reflection	None	Special Filter (320 nm & Lower)
(B) Luminescence in UV Long Wave	Special Filter (320 nm & Lower)	18A (320 nm to 380 nm)
(C) Luminescence in Visible Light	Special Filter (320 nm & Lower)	2C (380 nm and Higher)
UV Long Wave		
(A) Reflection	None	18A (320 nm to 380 nm)
(B) Luminescence in Visible Light	18A (320 nm to 380 nm)	None
Visible		
(A) Reflection **	None	None
(B) Luminescence in IR	10% Copper Sulfate or Corning #9782	89B (690 nm & Higher) or 88A (725 nm & Higher)
Infrared		
(A) Reflection	None	87 (740 nm & Higher) 87C (785 nm & Higher) 87B (820 nm & Higher) 87A (880 nm & Higher)

* The light source can be a general source, such as mercury vapor, with sufficient intensity and spectral range.

** To observe the appearance of strictly "visible light" on the monitor, a 2C (380 nm & Higher) filter and special (750 nm & Lower) filter is necessary, since the Silicon tubes sensitivity to UV and IR, may effect to some degree the image producted on the monitor.

FIG. 4—*Examination of specimens with video spectroscanner.*

wide range of document problems, including indented writing, erasures, and obliterations. The electronic equipment for these various processes will be added to the basic system as further research dictates.

Summary

The advance of technology in the past 15 years has significantly reached into almost every area of crime detection. However, in the area of questioned document examination, applied technology seems to have been slower than in many other forensic science disciplines.

The Video Spectroscanner system is but one attempt by the writer to apply some of the already known modern-day technology to provide simpler, more comprehensive investigative tools designed specifically for questioned document problems.

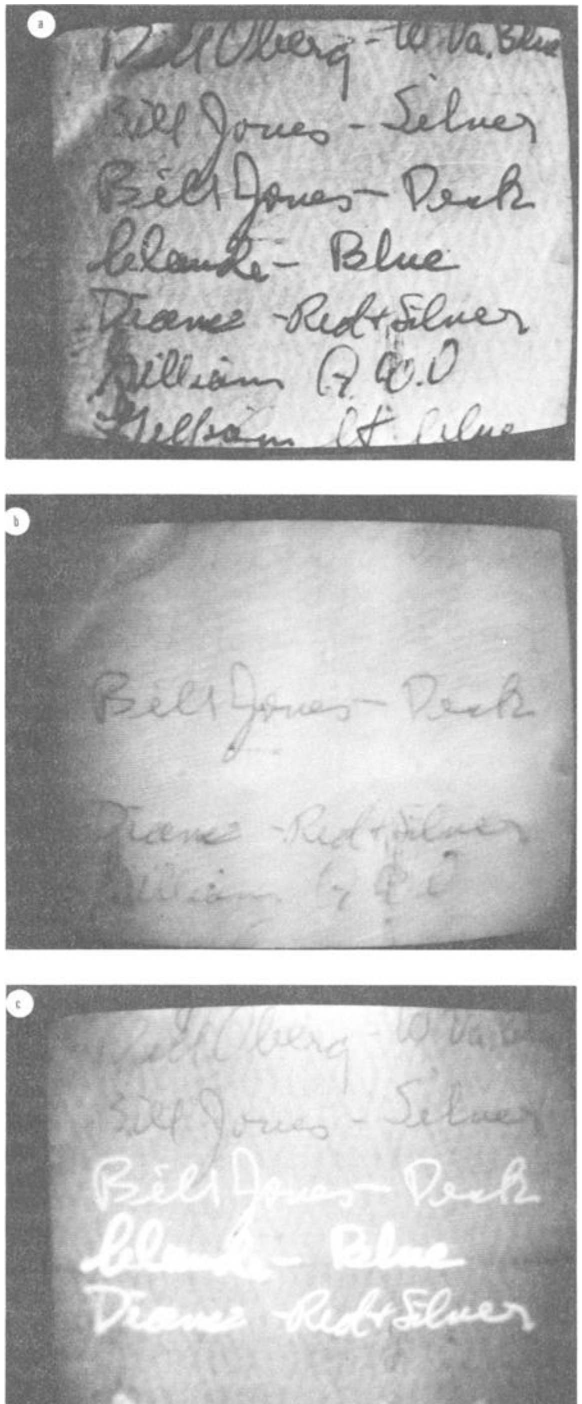

FIG. 5—*Sample of a document as it appears on a monitor using* (a) *visible energy,* (b) *IR reflected energy, and* (c) *IR luminescence.*

References

[*1*] Costain, J. E. and Lewis, G. W., "A Practical Guide to Infrared Luminescence Applied to Questioned Document Problems," *Journal of Police Science and Administration,* Vol. 1, No. 2, 1973, pp. 209-218.
[*2*] "Kodak Filters for Scientific and Technical Uses," Publication B-3, Eastman Kodak Co., Rochester, N.Y., 1973.
[*3*] "Applied Infrared Photography," Publication M-28, Eastman Kodak Co., Rochester, N.Y., 1972.

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