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Spatially Resolved Fluorescence Spectroscopy: Application to Latent Fingerprint Development

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ABSTRACT: A spatially resolved fluorescence spectrometer that uses laser excitation is described. The instrument is designed for electronic development of latent fingerprints.

KEYWORDS: criminalistics, fingerprints, lasers, fluorescence, spectroscopy

Until recently, it was generally not possible to identify a developed latent fingerprint without a suspect on hand because searching of the file print collections (in the form of fingerprint cards) of major law enforcement agencies was utterly prohibitive. Now, however, computers are available for storing file prints and it is possible to enter an unknown print and search the complete file. Major law enforcement agencies and metropolitan police departments are beginning to acquire such systems. In time, one can envision a nationwide network.

Latent fingerprints developed by the procedures currently employed routinely in law enforcement, namely dusting, iodine fuming, silver nitrate, and ninhydrin [*1*] are generally photographed. To enter thus developed prints into the computer, the photograph is projected onto a screen interfaced to the computer and the coordinates of points of identification together with additional information, such as the general direction of ridge flow and the nature of the point of identification (for example, ridge ending, bifurcation, and so forth) are entered into the computer by a light marker or similar device. This is a somewhat cumbersome procedure. Since 1976, a new technique for latent fingerprint development, involving laser-induced fluorescence, has been explored by Menzel and co-workers in a series of investigations [*2-10*]. Others have contributed to this technique as well [*11-12*]. Laser detection of latent prints has been reviewed in two articles [*13,14*] and one law book chapter [*15*]. It has been demonstrated in several case studies [*5,16-18*] that latent prints can frequently be developed by laser when the above cited conventional procedures fail, that is, the technique has a wide range of use. By now, a number of law enforcement agencies use lasers for fingerprint work. It was suggested some time ago that laser detection of latent finger-

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prints should lend itself to automation, that is, electronic development of ridge detail instead of photography [5]. This would not only permit a more direct approach to entering latent prints into computers, but would also facilitate image processing to enhance ridge detail. In this paper, we describe an instrument that demonstrates the feasibility of this concept.

Instrumentation

The sample to be analyzed is placed on a scanning *x-y* stage. The beam from an argon-ion laser (air cooled, Spectra-Physics Model 162-03, 15 mW all lines) is focused onto the sample via a lens to a spot size smaller than a fingerprint ridge width. The luminescence from the sample passes through the same lens, a filter which blocks scattered laser light, and either impinges directly onto a photomultiplier tube of extended S-20 response or passes first through a scanning monochromator (¼ m, Jarrell-Ash Model 82-410 with the manual grating drive mechanism coupled to a variable speed motor) if the fluorescence spectrum is to be measured. Because of limitations in the instrumentation available to us, computer and display were replaced by an *x-y* recorder to plot the fingerprint or the fluorescence spectrum or both. For spectral measurements, the photomultiplier signal controls the vertical recorder pen position while the horizontal pen scan speed is adjusted to be commensurate with the monochromator scan speed. For fingerprint plotting, the recorder pen is positioned via potentiometers connected to the motorized *x-y* stage and the recorder pen lift is controlled by the photomultiplier signal. Figure 1 shows a block diagram of the apparatus. Even though laser beam scanning would be faster than mechanical scanning of the *x-y* stage, we have chosen the latter because the optical path to the scanning monochromator does not vary, that is, spectral distortions, which would arise with laser beam movement, are eliminated.

Scan Control

Control circuitry for *x-y* scanning is widely employed, and we will only outline the circuit function in our instrument. The position of the motor-driven *x-y* stage is monitored by two position-sensing potentiometers connected to the motors. The voltage output levels of the potentiometers provide an input to the *x-y* recorder's pen-positioning servo mechanism. They also provide reference levels via which electronically controlled, automated, scanning is

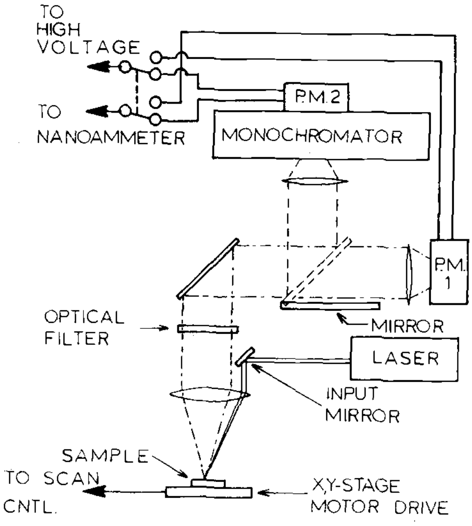

FIG. 1—*Block diagram of spatially resolved spectrometer.*

achieved. The fingerprint area to be scanned and the corresponding area on the chart paper, that is, the magnification, are adjustable. Starting at the upper vertical limit on the chart paper, controlled by a voltage comparator which senses the output of the y-potentiometer, the recorder pen scans an adjustable distance in the horizontal (x) direction first from left to right and then from right to left. The x-scan limits are controlled by a voltage comparator which senses the output of the x-potentiometer. Once the left-hand x limit is reached in the right to left scan, the y-position is changed downward by a distance just larger than the width of the recorder's ink trace by means of an electronically controlled step of the y-motor. The bidirectional x-scan is then reactivated. A block diagram of the scan control circuit is shown in Fig. 2.

Signal Processing

Although the incident laser light is focused onto the fingerprint sample to a spot size less than a fingerprint ridge width, laser light scattering, dependent on the nature of the surface holding the print and the thickness of the fingerprint deposit, causes a fluorescence "halo" which is unwanted. In addition, the surface holding the print often fluoresces itself. This fluorescence needs to be suppressed as well. Elimination of these spatially slow-varying "background" signals is accomplished as follows. The output of the instrument's photomultiplier tube is amplified by a nanoammeter (Keithley Model 150A) and further amplified by an isolation amplifier that splits the signal into two equal parts. One of these two signals passes through an integrator and is then fed into a difference amplifier together with the other signal. The output of the difference amplifier is processed by a level detector. A block diagram of the signal control circuit is shown in Fig. 3.

For a x-scan across the sample, the output of the isolation amplifier consists of a set of spikes (fingerprint ridge profiles) superposed on a slow-varying background (halo and substrate fluorescence). The integrator acts *partly* as a low frequency pass filter to suppress noise. The difference amplifier subtracts the integrator signal from the other portion of the isolation amplifier signal. The level detector subtracts a constant (adjustable) voltage from the difference amplifier signal. Voltage spikes larger than this constant voltage activate the x-y recorder pen-lift mechanism, dropping the pen onto the chart paper. The overall circuit schematic is shown in Fig. 4. A detailed description of the components and function of this circuit is given elsewhere [*19*].

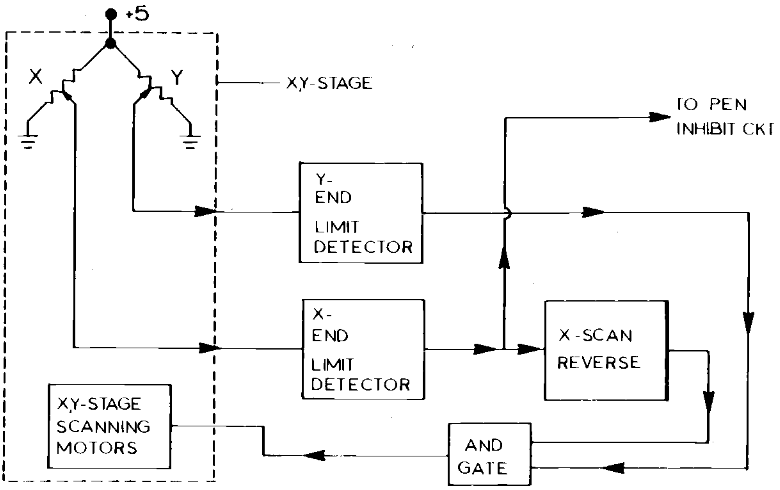

FIG. 2—*Block diagram of scan control circuit.*

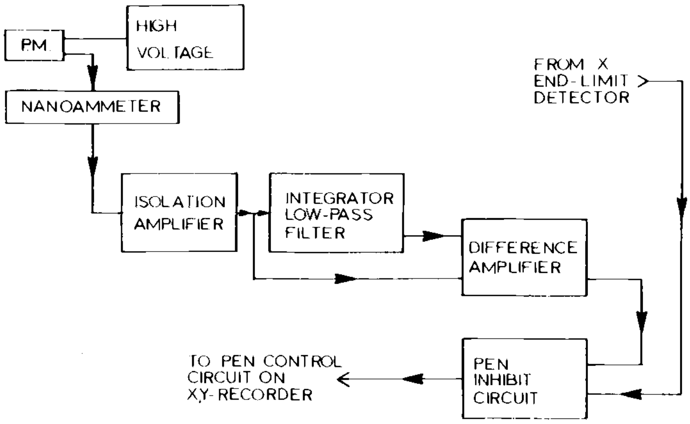

FIG. 3—*Block diagram of signal control circuit.*

Image quality is controlled by the interplay of the variable capacitor of the integrator and the voltage setting of the level detector. This interplay is depicted in Fig. 5. The idealized signal profile for a scan across a single ridge of uniform fluorescence is shown in Fig. 5*a* (solid line). The corresponding output of the integrator (additional to any slow-varying background signal) is shown as the dashed line in Fig. 5*a*. The output of the difference amplifier is shown in Fig. 5*b* (solid curve) with the portion of the signal exceeding the level detector reference voltage shown shaded. The corresponding pen trace length, Fig. 5*c*, is thus controlled by the capacitor charging rate and the reference level of the level detector. The integrator thus serves a triple purpose, namely to eliminate high frequency noise by acting as a low pass filter, to eliminate slow-varying background via the subsequent difference amplifier, and to control ridge tracing (intermediate frequency signals). In essence, the signal control circuit is designed to sense the leading edges of fingerprint ridges.

The trailing edges of fingerprint ridges are sensed by reversing x-scan direction to provide more accurate, high contrast, ridge plotting. In Fig. 6*a*, the signal output of the difference amplifier is shown for a left-to-right scan across two weak ridges on either side of a strong ridge. Because of the integrator capacitor recovery time, the weak ridge on the right is not plotted, being below the level detector setting (dashed line). For the corresponding right-to-left scan, the weak ridge on the left is not plotted, as shown in Fig. 6*b*. By scanning bidirectionally, all three ridges are recovered, that is, the bidirectional scanning designed into the scan control circuit provides a graphic mode of signal averaging. It should be noted that spatial intensity plots can be obtained by varying the level detector reference voltage. Such plots may provide information on how the print was deposited (pressure pattern), a potentially valuable piece of information.

Results

A latent print was placed on aluminum foil and was developed by evaporative dye staining with rhodamine 6G [*9,12*]. The print, plotted with the described instrument, is shown in Fig. 7*a*. The print was also photographed through an Oriel G-772-5400 filter under all-lines (blue-green) illumination with a Spectra-Physics Model 164-05 argon-ion laser, with the laser beam expanded to cover an area of about 10 cm^2, and is shown in Fig. 7*b*.

Although ability to develop electronically latent fingerprints constituted the central design issue, the instrument also finds use in our ongoing investigation of fiber analysis by laser-induced fluorescence. In that application, the fluorescence from the fiber passes through the monochromator (Fig. 1) and the nanoammeter controls the y-position of the recorder pen. A

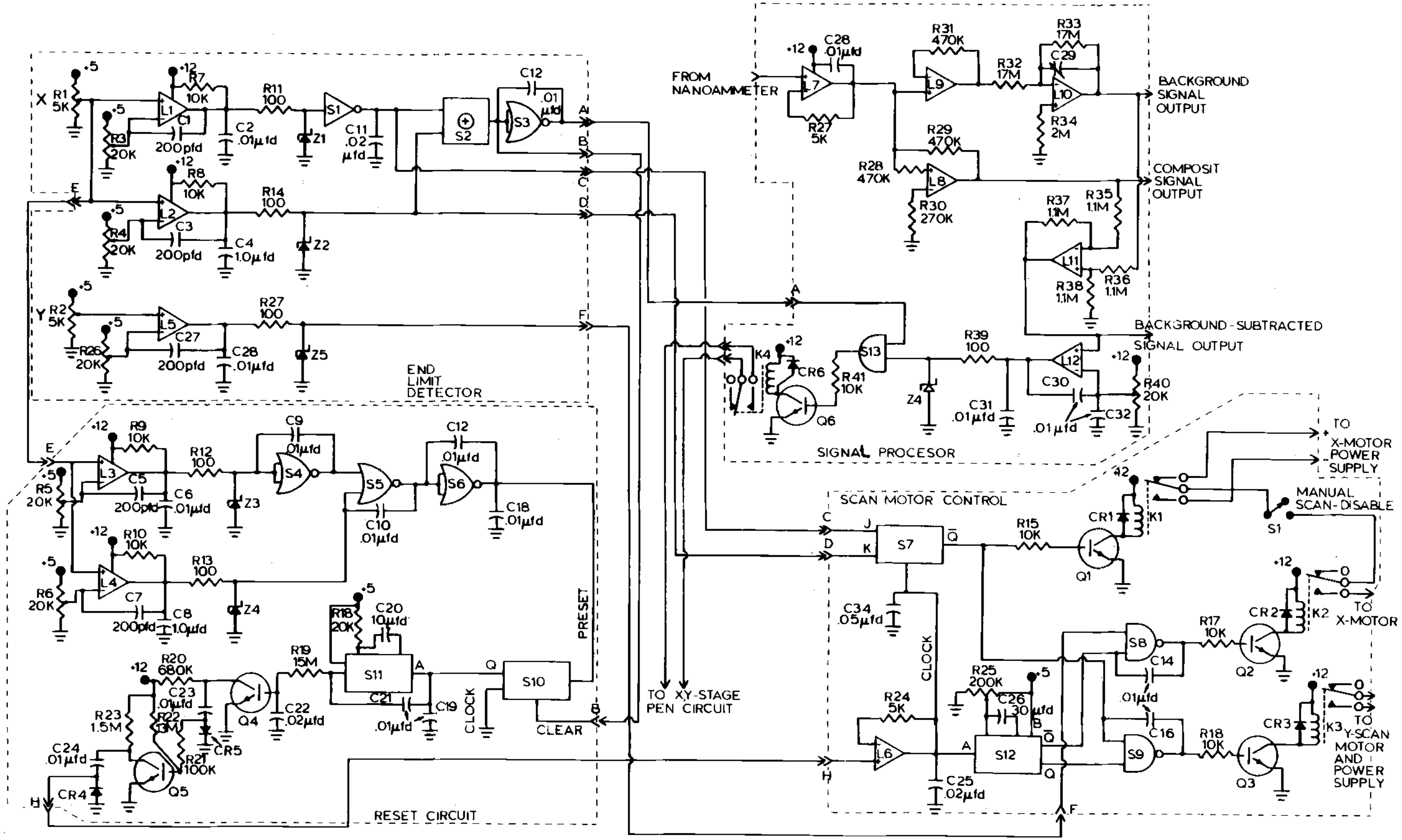

FIG. 4—*Overall circuit schematic.*

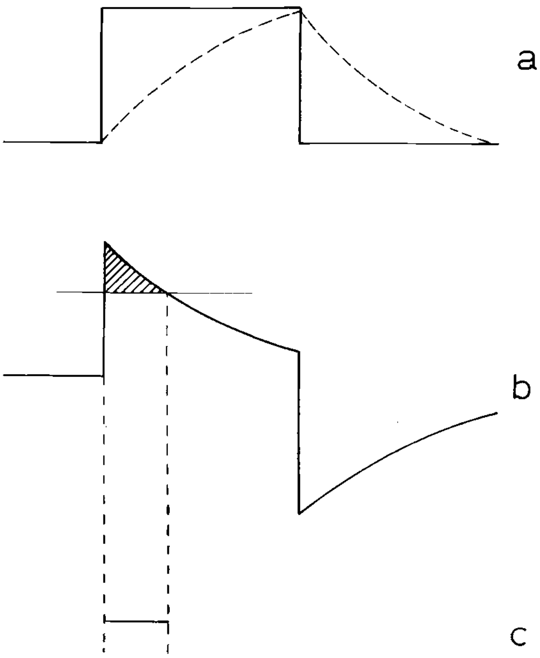

FIG. 5—*Idealized fluorescence signal for a scan across a fingerprint ridge* (solid line) *and integrator output* (dashed line): (a) *difference amplifier output;* (b) *with shaded area corresponding to signal exceeding level detector setting; and* (c) *recorder pen trace length.*

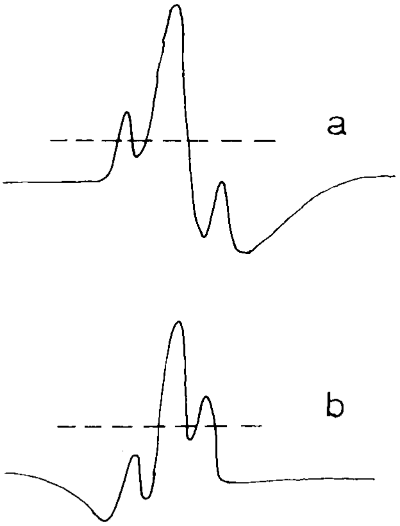

FIG. 6—*Difference amplifier signal* (solid line) *and level detector setting* (dashed line) *for left-to-right scan across two weak ridges on either side of a strong ridge* (a) *and corresponding right-to-left scan* (b).

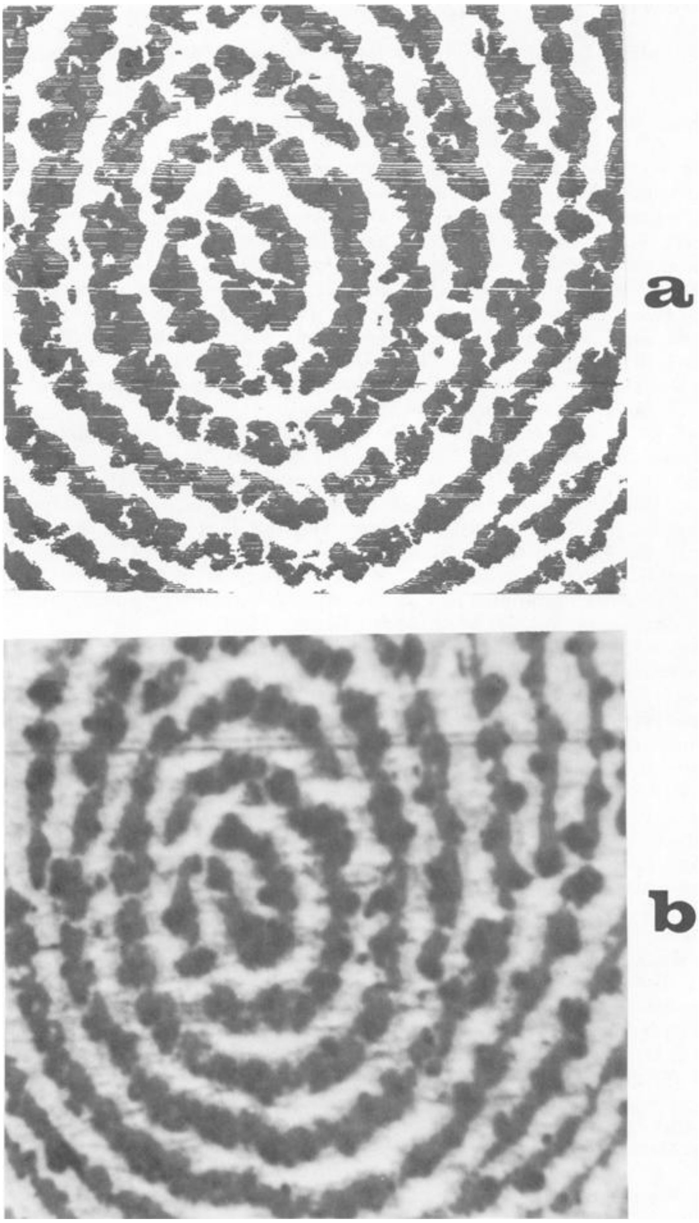

FIG. 7—*Plotted latent fingerprint* (a) *and corresponding photograph* (b).

Spectra-Physics Model 164-05 argon-ion laser and a Spectra-Physics Model 375 dye laser are coupled to the instrument to provide excitation wavelengths ranging from the near-ultraviolet to the red for greater flexibility in spectral analysis. When the nanoammeter provides insufficient sensitivity, it is replaced by a photon counting system comprised of Princeton Applied Research Model 1112 photon counter/processor and Model 1120 amplifier/discriminator.

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