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Inherent Fingerprint Luminescence—Detection by Laser

The currently used methods of fingerprint detection may be classified into two categories: those which are dependent on the adherence of inert materials to fingerprint residues (powder methods), and those which rely on chemical interaction of a detection reagent with specific components of the latent print (for example, ninhydrin method) [*1*]. Both classes, in fact all conventional fingerprint detection methods, require a chemical or physical treatment of the exhibit under examination.

Exploitation of an intrinsic property of components present in latent fingerprints, such that development can be accomplished without "staining" the exhibit under scrutiny, would be useful. Such a procedure would circumvent possible deleterious effects of the fingerprint development step on other exhibit examination procedures, whether for fingerprint detection, analysis for blood, or some other procedure.

Palmar sweat contains a variety of compounds, among them amino acids, lipids, and vitamins [*2*]. Some of these compounds show native fluorescence. For example, riboflavin and pyridoxin, present in palmar sweat, show fluorescence at 565 and 400 nm, respectively [*3*]. Since such compounds are present in fingerprint deposits in rather small quantities, fingerprints do not show discernible luminescence under normal illumination conditions. However, spectroscopists have known for some time that fingerprints can luminesce under laser illumination. In spectroscopic investigations this luminescence is generally of nuisance value, since its possible interference with the emission from the substance under study demands care in sample handling. For purposes of fingerprint detection, however, this luminescence, when coupled with photography, may supplement present-day fingerprint detection methods. The present disquisition deals with our initial exploration of the utilization of lasers in fingerprint detection.

Laser Detection

The fingerprint detection procedure consisted essentially of laser illumination of the exhibit under scrutiny and photography (or direct viewing) of the laser-induced fingerprint luminescence. Figure 1 illustrates the experimental configuration. Exhibits under investigation were illuminated with the 514.5-nm line of a Spectra Physics Model 165-03 continuous wave (CW, as opposed to pulsed) argon-ion laser. The laser power was 1.5 W, and the laser beam was expanded to illuminate an area of about 10 in.^{2} (65 cm^2).

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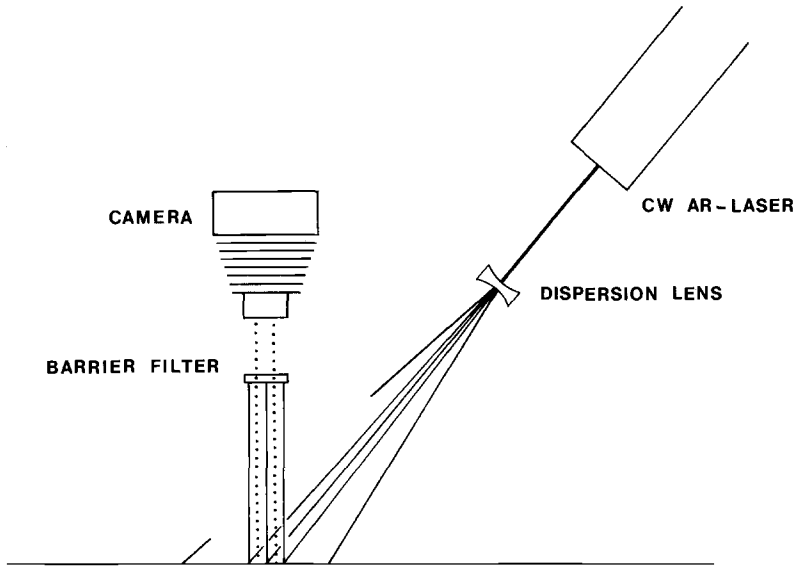

FIG. 1—*Schematic diagram of laser detection setup. Dotted lines denote fingerprint luminescence.*

The very bright laser light scattered from surfaces under examination can cause eye damage. Laser safety goggles (Fisher, 11-409-50A) with filters of optical density 7 at 514.5 nm were therefore used for viewing the laser-illuminated exhibits. The laser goggles transmit light of wavelength greater than about 540 nm and serve as convenient filters isolating luminescence occurring at these wavelengths from the laser line. For photography the barrier filter (see Fig. 1) was a Fisher 11-409-50A safety goggle filter. It serves the purpose of blocking the laser light scattered from the exhibit while transmitting the luminescent light from the fingerprint.

Since unconventional light sources and filters were employed, standard light meters and filter factors were unsuitable for determination of photographic exposure times. Exposure is best determined initially by trial and error. Most photographs were obtained with use of a 4 × 5 Crown Graphic bellows camera and Kodak Contrast Process Pan film, but any pan film with good contrast and grain characteristics should be suitable. Since long exposure times may be necessary a film of at least moderate speed is required. Laser-excitation-induced fingerprint luminescence was found to be amenable to color photography. Interfering background luminescence, which can be problematic in black and white photography, does not present difficulties in color photography if it is substantially different in color from that of the fingerprint luminescence.

Results

Fingerprints were deposited on white paper by 15 people. Prints from some individuals luminesced quite strongly so that the fingerprints could be seen easily when the observer was approximately 10 ft (3 m) from the illuminated paper sheet. Closer scrutiny revealed excellent ridge detail. However, fingerprints from about a fifth of the individuals sampled at a given time luminesced only faintly. Further sampling revealed a marked day-to-day variation in strength of this luminescence. However, when fingers were rubbed on the forehead or side of the nose prior to fingerprint deposition, visibly luminescing prints were obtained from all individuals tested to date. The color of the fingerprint lumines-

cence was a yellowish green in every case. A number of control experiments were performed to ensure that this luminescence was indeed a bona fide fingerprint luminescence and not caused by finger contamination.

A fingerprint was placed on plain white paper. The paper was then baked in an oven at 75 °C for two weeks. No significant deterioration of the fingerprint luminescence or loss of the excellent ridge detail was observed. The baked paper was then thoroughly soaked by holding it under running water for 5 min. The paper was then left to dry at room temperature. The fingerprint luminescence was only slightly fainter after this wetting, and excellent ridge detail remained observable on inspection of the laser-illuminated fingerprint via the laser goggles. This fingerprint was next subjected to treatment with ninhydrin followed by silver nitrate. Both methods failed to develop any trace of ridge detail; however, ridge detail was still quite readily visible under laser excitation. Figure 2 shows a photograph of this fingerprint developed by the laser procedure after the ninhydrin treatment.

FIG. 2—*Photograph of fingerprint on white paper after two weeks baking at 75 °C followed by soaking for 5 min under running water.*

Fingerprints were next deposited on a variety of surfaces: plastics, glass, walls, checks, cloth, wood, metals, and so forth. While some surfaces were poorly suited for fingerprint luminescence observation, either because the surface did not accept the fingerprint sufficiently well or because the surface itself luminesced strongly enough to obscure the fingerprint luminescence, we had good success in observing fingerprint luminescence with fine ridge detail on most surfaces tested. Figure 3 shows photographs of fingerprints on some of the surfaces examined.

Test fingerprints were deposited on the forearm skin of several individuals. Fingerprint luminescence with good visible ridge detail was found under laser illumination. However, with time, probably because of diffusion of the luminescing component of the fingerprint, the ridge detail became fainter and less distinct. Figure 4 shows a photograph of a fingerprint deposited on forearm skin.

To determine the applicability of laser detection to old fingerprints a few pages of a book, which had not been opened for nine years, were laser scanned with 514.5-nm light. Several prints with discernible ridge detail were found. The fingerprint luminescence was orange in color rather than the yellowish green in fresh prints. Similarly, orange luminescing fingerprints were observed on two 14-month-old letters. We note that the observed color of the fingerprint luminescence is somewhat distorted by the laser goggles, which have orange-colored filters. Figure 5 shows a photograph of a fingerprint on one of the above two letters.

Instead of laser illumination, the light from a 500-W xenon lamp, filtered with blue-green transmitting band-pass interference filters of half-band-width of 25 nm, was used.

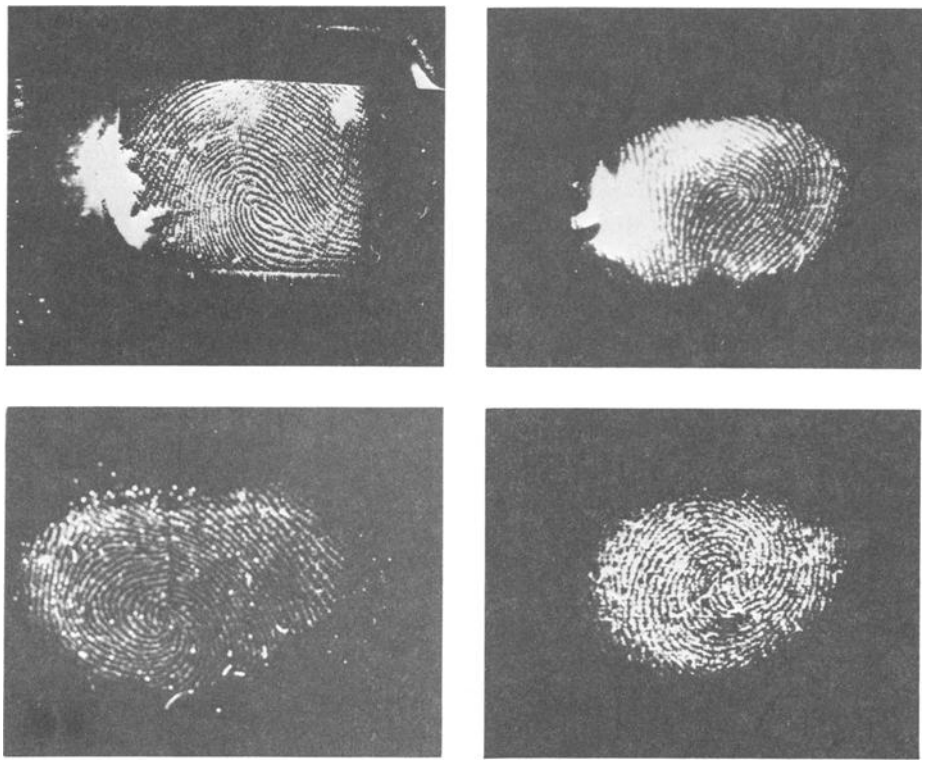

FIG. 3—*Photographs of fingerprints on various surfaces, obtained by the laser method;* (upper left) *stainless steel knife blade;* (upper right) *Styrofoam® cup;* (lower left) *brown glass bottle; and* (lower right) *white paper towel.*

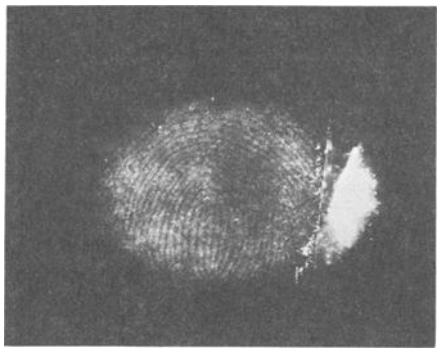

FIG. 4—*Photograph of fingerprint on living skin detected by laser excitation.*

The filtered light output was measured to be 0.5 W. Fingerprint luminescence could be observed, but not nearly as well as with laser illumination.

The natural luminescence of fingerprints is very weak, requiring laser excitation or illumination with a very strong and very well filtered lamp to bring out luminescence with ridge detail sufficiently strong for photography. While our success with laser excita-

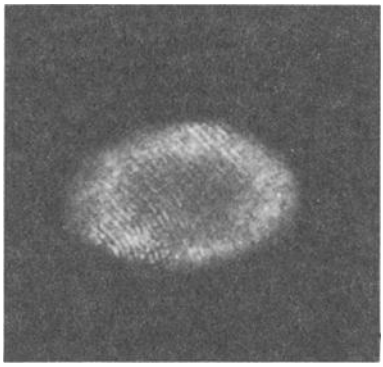

FIG. 5—*Fourteen-month-old fingerprint on a letter, detected by laser excitation.*

tion has generally been very gratifying so far, laser excitation will also find application in combination with a variety of other procedures, such as dye and vapor techniques, involving compounds which react with fingerprint components or which preferentially stain either the fingerprint or the substrate. We envision amplifying the fingerprint luminescence via treatment with such luminescent chemicals followed by laser illumination. Exploration of such staining methods is currently under way. These procedures fall outside the scope of the present account and will be reported in a later paper. Nonetheless, to demonstrate their potential, results obtained with one such method are presented. A fingerprint deposited on a glossy black cardboard surface did not show observable luminescence or ridge detail under laser illumination. The fingerprint was dusted with finely ground coumarin-6 powder (a laser dye suitable for argon-ion laser excitation). At this stage no ridge detail was discernible. Subsequent spraying of the dusted surface with methanol revealed a preferential adhesion of the coumarin-6 to the fingerprint. The photograph in Fig. 6 (*left*) shows the resultant fingerprint luminescence under laser illumination. A photograph of a similarly treated fingerprint on a wooden knife handle, which also did not show ridge detail under direct laser illumination, is shown in Fig. 6 (*right*).

Case Applications

1. A kitchen knife, the suspected murder weapon in a homicide investigation, was

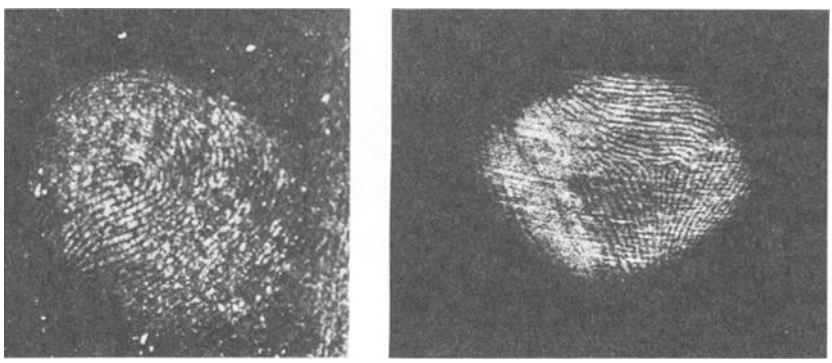

FIG. 6—(left) *Fingerprint on black carboard stained with coumarin-6 and rendered visible via the laser method and* (right) *photograph of fingerprint on wooden knife handle using laser illumination after coumarin-6 staining.*

scanned for fingerprints approximately six months after the offense. Two fingerprint fragments, with unmistakable ridge detail luminescence, were found. Although insufficient for identification, their observation demonstrates the utility of the laser detection procedure.

2. Exhibits in connection with another homicide investigation were also laser-scanned. These included checks, bank books, purses, shoes, and assorted paper articles. The scanning took place after all conventional methods had failed. Laser excitation was successful in revealing ridge detail on most surfaces. Although prints developed to date were, again unfortunately, unsuitable for identification, the laser scanning of exhibits in this case has not yet been completed.

Luminescence Spectroscopy of Fingerprint Residue

While the procedure described above has been demonstrated to be a promising new method for fingerprint detection, the approach was, nevertheless, an empirical one. We felt it important to study the luminescence characteristics of fingerprint residue in more detail. Figure 7 shows the absorption spectrum of a methanol solution of fingerprint

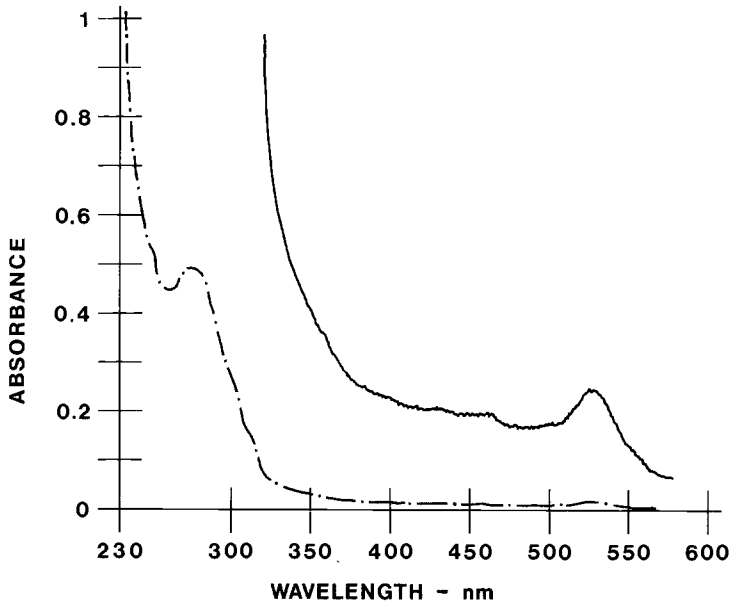

FIG. 7—*Absorption spectrum of fingerprint material in methanol solution (room temperature):* (—·—·—) *full scale = 0 to 1 absorbance and* (———) *full scale = 0 to 0.1 absorbance.*

residue obtained with a Cary 17 spectrophotometer. Of primary interest is the absorption band in the visible region at about 530 nm. Luminescence analysis, using a Perkin Elmer Model MPF-4 fluorescence spectrophotometer, revealed three main emission bands in the 400 to 700-nm region, with maxima at 470, 500, and 550 nm. These bands, with 295-nm excitation, are shown in Fig. 8.

Excitation spectra, which probe the absorption spectra of the luminescing substance corresponding to each emission band, are shown in Fig. 9. The close similarity in the excitation spectra corresponding to the 470 and 500-nm emission bands suggests that these probably arise from the same compound. The excitation spectrum corresponding to the third emission band, at 550 nm, is quite distinct from those of the other two and

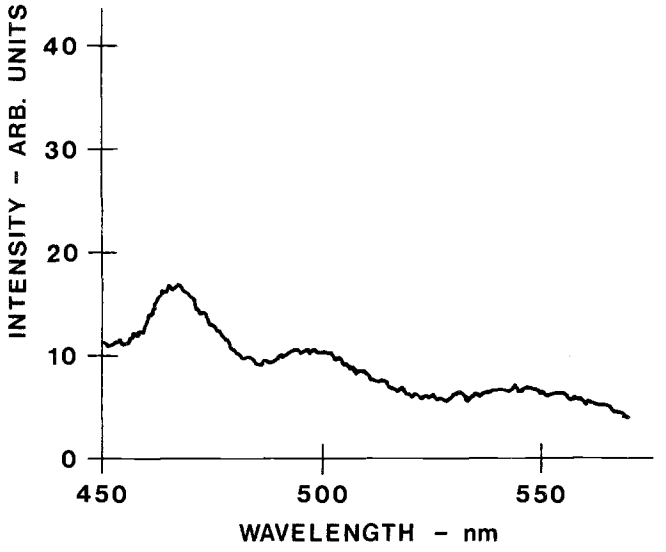

FIG. 8—*Emission spectrum of fingerprint material in methanol solution (room temperature) obtained with 295-nm excitation.*

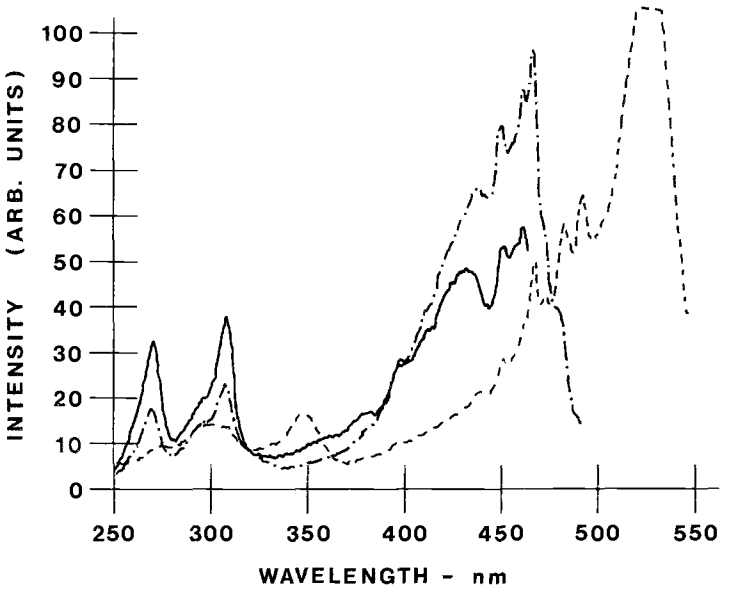

FIG. 9—*Excitation spectra (room temperature methanol solution) corresponding to the 470* (———), *500* (—·—·—), *and 550-nm* (— — —) *emission bands. See text and Fig. 8.*

is ascribed to a different species. This species is clearly the compound giving rise to the laser-induced fingerprint luminescence described above.

A study was carried out on undissolved fingerprint material deposited on Mylar®. Emission and excitation spectra, corresponding to the 550-nm emission band in solution, are shown in Fig. 10. The emission peak of the fingerprint deposit on Mylar® is shifted

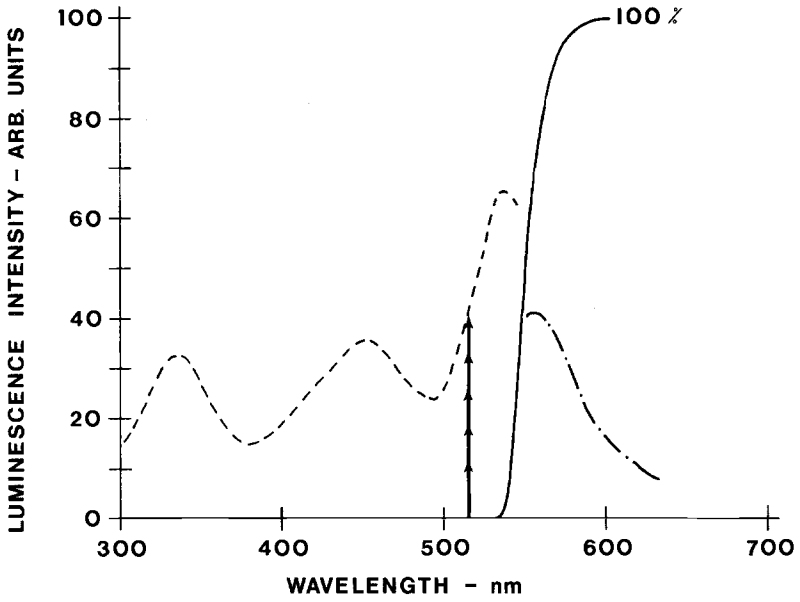

FIG. 10—*Emission spectrum using 520-nm excitation* (—·—·—) *and the corresponding excitation spectrum* (— — —) *of fingerprint material deposited on Mylar® plastic transparent film. Also shown are the transmission curve of the laser goggle filter* (———) *and the 514.5-nm laser line* (→→→).

to 560 nm. The same figure also shows the laser line (514.5 nm) as well as the transmission characteristics of the laser safety goggle filter. It is indeed fortunate that the absorption band responsible for the observed yellow-green fingerprint luminescence and the 514.5-nm argon-laser line, the strongest line of the laser, are almost ideally matched. Identification of the luminescent species must await further spectroscopy coupled with its isolation from fingerprint material.

Discussion

Choice of Illumination

To date we have mainly confined our studies to utilization of CW argon-ion lasers. Pulsed lasers are not likely useful since pulse widths are small and repetition rates are generally low. A CW dye laser may be useful when coupled with staining procedures involving fluorescent compounds, since it extends the range of available laser wavelengths to about 700 nm. High-power argon-lasers, with power greater than 10 W, are commercially available, and with use of suitable cavity mirrors make available laser wavelengths in the 350-nm region.

Our success in utilizing lamps and filters for fingerprint luminescence detection has not been comparable to laser excitation. To a large extent this is due to filtering problems. Band-pass filters, needed to isolate a relatively narrow spectral region of the lamp output, tend to pass a small amount of light (typically 0.01 to 0.1%) at wavelengths outside the desired transmission band. This amount of "stray" light is often sufficient to obscure the fingerprint luminescence. These filtering problems can be overcome, albeit at the expense of the light power incident on the exhibit. While lamps (either continuous or flash) will likely not provide the sensitivity lasers can offer, lamps have the advantage

that they can be used in field work for fingerprint detection. This is not practical with lasers because of their delicacy, 208-V three-phase power, and water cooling requirements. We have found that a 1 kW lamp, as a minimum, is needed. Still, with this lamp power, the detection sensitivity is generally an order of magnitude lower than that achieved with argon-laser excitation.

Desirable Features of Laser Detection

1. The laser detection procedure represents a nondestructive detection method; that is, if it fails to reveal a fingerprint the various other development techniques can still be employed.
2. Fingerprints exposed to extremes in temperature and moisture, at least on certain surfaces, remain amenable to laser detection (see Fig. 2).
3. Fingerprint age does not appear to preclude the applicability of the laser detection procedure (see Fig. 5).
4. Laser-excitation-induced luminescence from latent prints, whether obtained directly or with aid of staining with a luminescent substance, can be obtained from many surfaces. For examples, see Figs. 2–6.
5. Although it is advisable to use the laser detection method first, it has been found that the method remains effective even after the exhibit has been treated with the traditional detection methods (namely, ninhydrin, silver nitrate, and powders) investigated to date. We found, however, that silver nitrate and dusting procedures reduce the fingerprint luminescence detectability.

Future Potential

Examination of Figs. 7–10, which show the salient features of the fingerprint luminescence, indicates several possible improvements in the laser detection procedure discussed above. These and other potential extensions of the scope of the method are listed below.

1. A wider range of excitation bands in the 300 to 530-nm spectral region would be desirable. An argon-laser, set up for all-lines-lasing, at least partially achieves this purpose.
2. Use could be made of other luminescing fingerprint components (see Fig. 8) with suitable excitation and filter combinations.
3. The discovery of at least two different luminescing components in fingerprint deposits brings up the possibility of dating prints. If it were found that one (or more) of the components responsible for the emission were unstable, then one might make use of the relative intensities of emission bands to date fingerprints. Indeed, as noted earlier, old fingerprints take on an orange color, whereas fresh fingerprints exhibit a green color. The demonstration of this aging determination requires extensive research, but, given its potential forensic value, such an effort should be well warranted.
4. Given our success in developing fingerprints on living skin (see Fig. 4), we anticipate application of laser illumination to fingerprint searches on cadavers.
5. A problem occasionally encountered with the laser detection procedure involved luminescence from some substrates containing fingerprints. If fingerprint material were to contain a phosphorescing component, then phosphorescence detection might allow elimination of this background interference.
6. The success encountered with the earlier-described coumarin-6 staining procedure (see Fig. 6) indicates that laser excitation combined with staining by luminescent chemicals can vastly expand the scope of the laser detection method.

The above extensions of the laser detection procedure are currently under study, and,

while the full exploitation of the method has yet to be achieved, we believe that the results obtained to date in laboratory experiments and actual cases demonstrate the value of the method to criminal investigations.

References

[1] Olsen, R. D., Sr., "The Oils of Latent Fingerprints," *Fingerprint and Identification Magazine,* Vol. 56, No. 7, Jan. 1975, pp. 3–12.
[2] Olsen, R. D., Sr., "The Chemical Composition of Palmar Sweat," *Fingerprint and Identification Magazine,* Vol. 53, No. 10, April 1972, pp. 3–23.
[3] Guilbault, G. G., *Practical Fluorescence, Theory, Methods, and Techniques,* Dekker, New York, 1973, p. 334.

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