TECHNICAL NOTE

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Fluorescence Spectroscopy as an Aid to Imaging Latent Fingermarks in the Ultraviolet

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ABSTRACT: Two- and three-dimensional fluorescence spectroscopic data have been recorded from sebum-rich latent fingermarks on quartz and white card. The fingermark residue was found to fluoresce between 310 to 380 nm and have an excitation range between 260 to 300 nm. The data are used to describe the results observed when imaging the inherent ultraviolet photoluminescence of latent fingermarks.

KEYWORDS: forensic science, fingerprints, lasers, fluorescence

Fluorescence detection is a common enhancement method used to enhance latent fingermarks. In practice, there are three main techniques: (a) the use of a chemical that reacts with a residue component to produce a fluorescent/colored product, (b) staining with a nonreactive fluorescent/colored compound, and (c) inherent fluorescence.

It was the introduction of laser technology that made the detection of latent fingermarks by inherent fluorescence practical, with the operational reliance based on the detection of visible fluorescence (1,2). However, more recently, it has been shown that fingermark residue also fluoresces in the ultraviolet region (3).

A knowledge of fluorescence data allows the photographer to setup the illuminating and detection systems to provide the maximum contrast (4,5). Three-dimensional fluorescence spectra can provide the spectroscopic information in a more effective format than is available from two-dimensional fluorescence spectra. Such spectra contain the fluorescence information in a single data file: the range of excitation and emission wavelengths and the intensity values. This proves particularly useful when there is a mixture of components that fluoresce, which could be important when trying to distinguish between background and latent fingermark fluorescence.

This report presents the results of three-dimensional ultraviolet fluorescence spectra recorded from latent fingermark residue. The spectroscopic data are used to describe results obtained photographically. Furthermore, the fluorescence spectra provide the information required for the development of latent fingermark imaging systems in the ultraviolet.

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Method and Instrumentation

A three-dimensional fluorescence spectrum is a collection of emission spectra recorded over the same wavelength range where each spectrum is recorded at a different excitation wavelength. Such spectra are normally represented as a contour map where each contour connects data points of the same intensity values in the same way as height is represented on a geographical map. A fluorescence peak corresponds to a hilltop in the contour map.

The spectra were recorded on a commercial fluorescence spectrophotometer (Hitachi, F-4500) using a solid-state sample holder. Calibration of the instrument on the Raman peak of distilled water at 450.1 nm gave an excitation and emission wavelength accuracy of ± 2 nm.

Fluorescence spectra were recorded in the wavelength range 250 to 310 nm for excitation and 290 to 380 nm for emission, with 5-nm excitation/emission slits, and 2-nm steps in both excitation and emission. Fingermarks were examined for fluorescence between one hour and one week after deposition. Samples were stored under ambient laboratory atmospheric and lighting conditions (23–26°C, 10–50% Relative Humidity, and fluorescent strip lighting).

Fluorescent spectra of fingermark residue were recorded from ten individuals (five female and five male). Residue samples were collected in two ways: by direct placement of a fingermark onto a quartz slide and by gently wiping the fingertip onto the side of a slide before transferring to a second slide. The latter method provided a more concentrated skin-surface residue sample to be analyzed. The fingertips were washed before deposition and then wiped against the forehead to produce sebum-rich samples. Quartz was chosen as a substrate because it has no fluorescence in the spectral region of interest.

Quartz provided the ideal nonporous substrate, and white card was chosen as a representative porous substrate. Latent fingermarks were laid down on the white card in the same manner as those on quartz slides. Because the contrast observed is dependent upon the relative fluorescent intensities of the residue and the substrate, spectra were recorded for both the white card and fingermarks on the white card.

Imaging Setup

Fingermarks on white card were imaged using a method described previously (3). Briefly, the 4th harmonic of a ND:YAG laser (Spectron laser Systems SL400) provided the 266 nm illuminating light source. Photographs were taken with a Nikon F3 35-mm single lens reflex camera using a 105-mm UV Nikkor quartz lens with extension tube. Several different bandpass filters were used, see Table 1 for details. Using Ilford FP4 125ASA, panchromatic film typical exposures of 20 to 120s at F5.6 were sufficient for good contrast to be obtained through the B&W bandpass filter.

Results

Shown in Fig. 1 is a three-dimensional spectrum acquired from a latent sebum-rich fingermark on a quartz slide. Spectra obtained from latent fingermarks were identical to those obtained from the concentrated skin-surface residue samples but had a factor of ten lower signal-to-noise ratio. The high intensity continuous diagonal peak seen in the top left of the spectrum is due to the detection of first order Rayleigh scatter. The emission and excitation spectra were fairly broad band and featureless, with excitation between 260 and 300 nm, and emission between 310 and 380 nm, see Fig. 2.

TABLE 1—*The transmission data of the ultraviolet bandpass filters used for imaging latent fingermarks.*

Filter	Maximum transmission wavelength (nm)	Full width at half maximum (nm)	Transmission maximum (%)
320	320	10	25
340	340	10	35
360	360	10	28
B&W	360	60	70

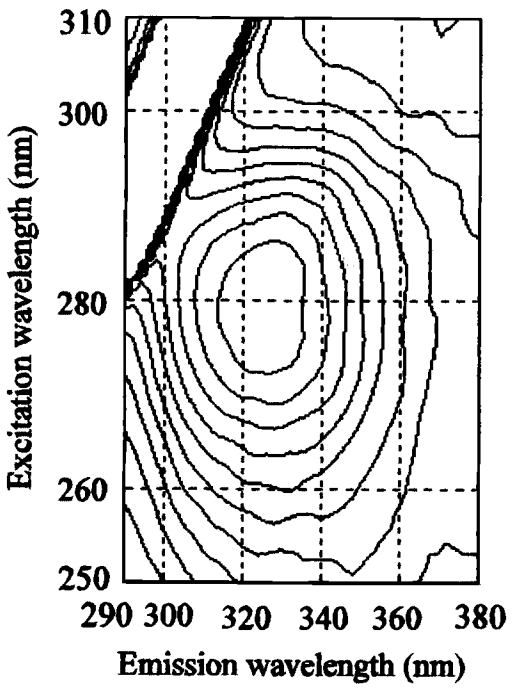

FIG. 1—*Three-dimensional fluorescence spectrum of a sebum-rich latent fingermark on quartz.*

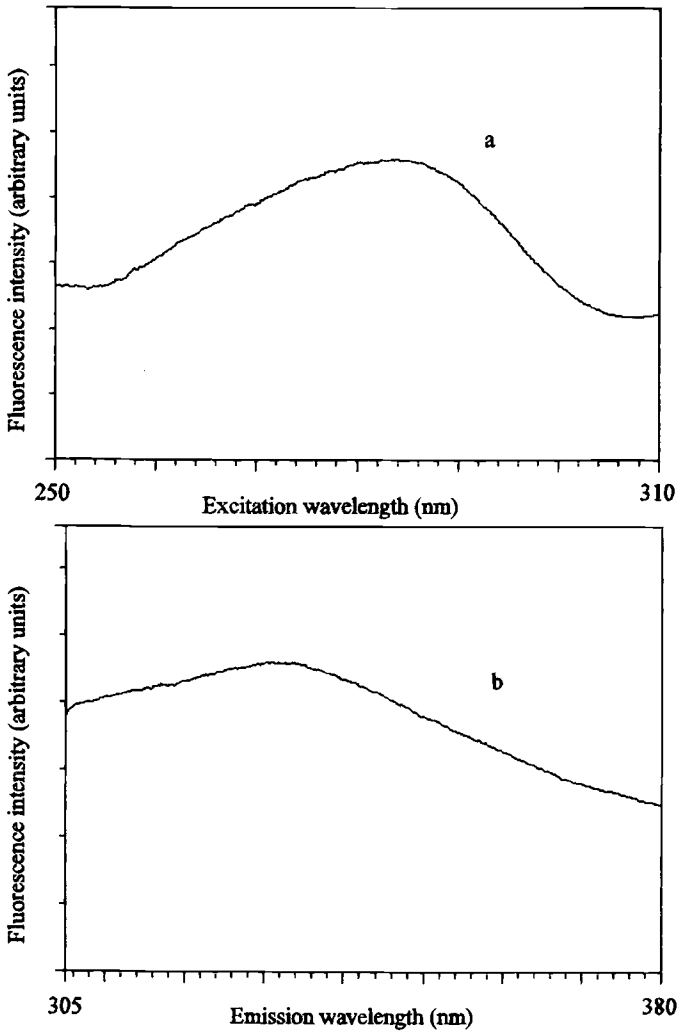

FIG. 2—*Two-dimensional spectra of a sebum-rich latent fingermark on quartz: (a) excitation spectrum with detection at 334 nm, and (b) emission spectrum with excitation at 280 nm.*

No significant difference was found between the spectra of individuals, although there were some trend differences between males and females. First, the maximum wavelength for excitation appeared to shift slightly to shorter wavelengths for females, see Table 2. However, the resolution of the spectra does not allow for

TABLE 2—*Maximum excitation and emission wavelengths together with intensities (relative to sample 6) for the fluorescence from latent fingermarks on quartz.*

Sample	Gender	λ_{max} Excitation (nm)	λ_{max} Emission (nm)	Relative intensity
1	Female	278	324	0.14
2	Female	276	340	0.09
3	Female	276	326	0.34
4	Female	276	338	0.12
5	Female	272	336	0.30
6	Male	298	334	1
7	Male	282	322	0.21
8	Male	280	330	0.19
9	Male	280	326	0.56
10	Male	274	334	0.59

this observation to be conclusive. Second, the relative intensity of female fingermark fluorescence was approximately half that of the male samples (the intensifies in Table 2 are scaled relative to the highest recorded).

Aging of the samples under ambient laboratory atmospheric and lighting conditions only reduced the intensity of the fluorescence. Because there were no changes in wavelength, characteristics aging was not considered any further in this study.

Photographs of ultraviolet fluorescing fingermarks imaged through the different bandpass filters given in Table 1 are shown in Fig. 3. The images with highest contrast were recorded using the 320 and 340 nm bandpass filters, Fig(s). 3a and 3b. The B&W gave poorer contrast images but a much shorter exposure time (approximately 5 times).

A three-dimensional spectrum of a sebum-rich latent fingermark on white card is shown in Fig. 4. The main fluorescence of the two components can clearly be distinguished: the peak in the bottom left is due to the fingermark, and the peak around 440 nm with broadband excitation between 250 and 410 nm is white card fluorescence. The fluorescence data for sebum-rich fingermarks on the white card were the same as those obtained on quartz substrates.

Two-dimensional fluorescence spectra, with 266 nm excitation, for the white card, fingermark on white card, and the difference between the two, are shown in Fig. 5. Highest contrast between the fingermark and the white card was found to be between 320 and 350 nm.

Discussion

Measurement of fluorescent spectra direct from a latent fingermark under ambient conditions provides the data required for the optimum imaging setup. The relative difference between the fluorescence from the white card and the latent fingermark residue is highest around 320 to 350 nm. This confirms the results obtained photographically where the highest contrast was obtained by imaging through the 320 and 340 bandpass filters. Use of the B& W filter causes detection of the background fluorescence because it does not cut off before 400 nm, thus reducing the contrast. The small decrease in excitation wavelength between male and female samples is insignificant in imaging terms.

Searching for ultraviolet fingermarks is clearly a problem, but the data given here have defined the needs for any excitation and detection apparatus. Although the optimum excitation wavelength is approximately 280 nm, the broad excitation band allows for some leeway on the choice of excitation wavelength. In this study, good quality images were obtained through excitation at 266 nm.

Although the use of natural fluorescence for enhancing fingermarks is an effective technique, the amount of literature on the fluorescence properties of fingermark residue is relatively sparse, with only a few two-dimensional studies in the visible and ultraviolet regions (1,6,7,8).

Previous fluorescent measurements in the ultraviolet have been on extracted material from sweat/sebum residue. Ohki used ether and ethanol/water (1:1) solvent systems to extract residue from gauze that had been in contact with hands and feet for 1 to 7 h (7). Different spectra were obtained for each of the solvent systems: the maximum excitation emission wavelengths for the ether extract were 300 and 350 nm, respectively, and 315 and 400 nm for the ethanol/water extract, respectively. Johnson et al. obtained ultraviolet fluorescence spectra from methanol/water (1:1) washings of fingers and found a broad band emission between 300 and 400 nm with the maximum emission around 325 nm (8).

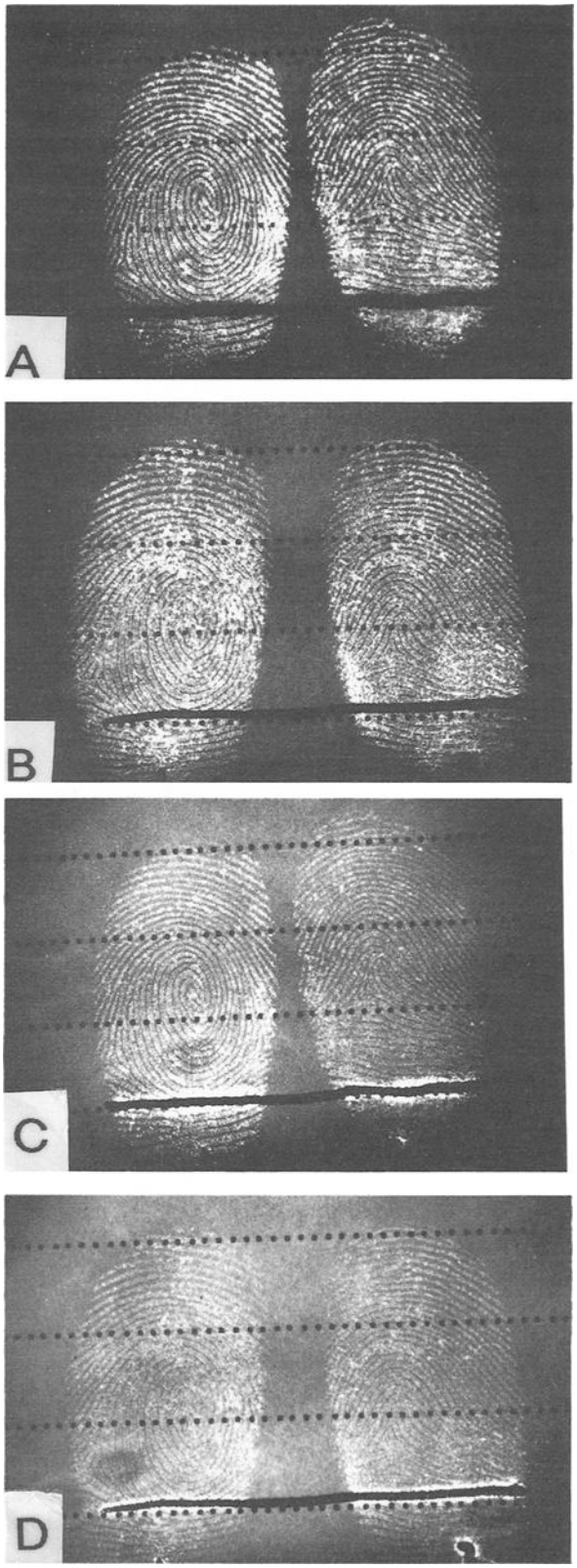

FIG. 3—*Photographs of two sebum-rich latent fingermarks on white card imaged through: (a) 320 nm, (b) 340 nm, (c) 360 nm, and (d) B& W bandpass filters.*

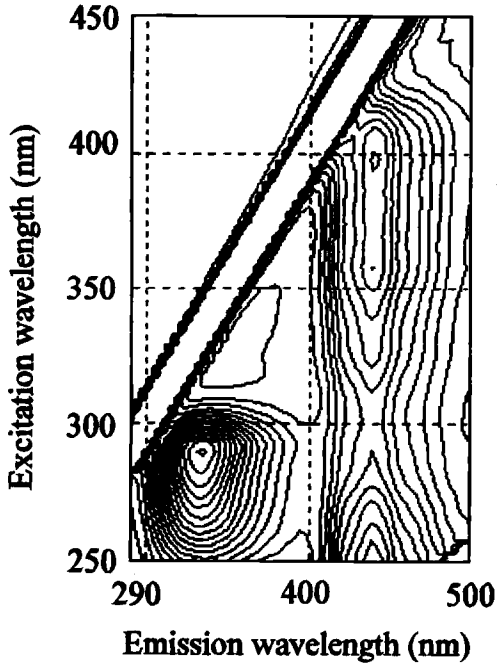

FIG. 4—*A three-dimensional spectrum of a sebum-rich latent fingermark on white-card.*

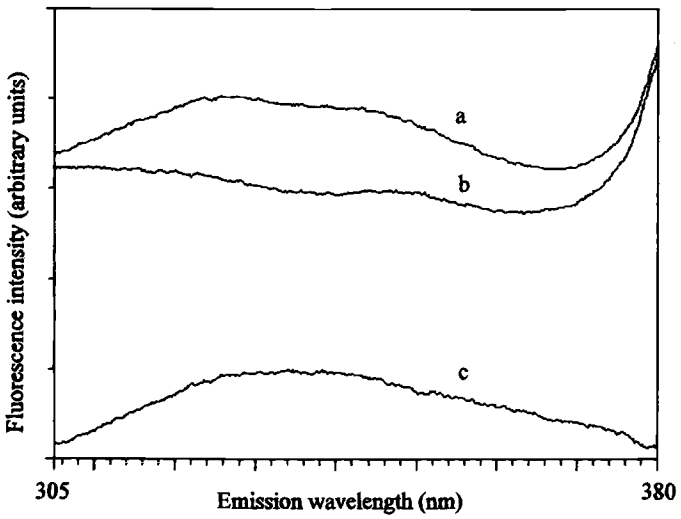

FIG. 5—*Two-dimensional emission spectra of: (a) a sebum-rich fingermark on white card, (b) white card, and (c) the difference between the two. The excitation wavelength is 266 nm.*

Comparison with control samples led them to conclude that the aromatic amino acids tyrosine and tryptophan accounted for 83% of the observed fluorescence. Direct comparison with the results reported here is difficult due to the different phases and components analyzed. Clearly, observation of the fluorescence from a latent fingermark provides the specific information required by a photographer but limits the understanding of the photophysics. The two previous studies indicate that both lipid and amino acid components may be responsible for the fluorescence. The relative contribution of each component to the total ultraviolet fluorescence is unknown, although recent thin-layer chromatography experiments have shown that the lipid fraction appears to provide the largest contribution (9).

Conclusion

Determination of the three-dimensional fluorescence spectra of sebum-rich fingermark residue under ambient conditions has provided the relevant data for the optimum excitation and detection wavelengths for effective image capture in the ultraviolet. It should be stressed that when imaging fluorescing fingermarks, there is always the need to determine the relative difference in intensities between the fingermark fluorescence and any substrate fluorescence at a particular wavelength or wavelength range. Three-dimensional fluorescent spectroscopy allows the observation of several fluorescent components at once giving the operator all the data for imaging in a single spectrum.

The use of ultraviolet fluorescence imaging of latent fingermarks has its niche in the enhancing marks on valuable documents or during covert operations. It has been shown to be less sensitive than treatment with DFO (1,8-diazafluoren-9-one) (3) and thus, is not in routine operational use in the Metropolitan Police Forensic Science Laboratory.

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