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# Short UV Luminescence for Forensic Applications: Design of a Real-Time Observation System for Detection of Latent Fingerprints and Body Fluids

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**ABSTRACT:** An assembly that allows a pseudo real-time (one second delay) observation of latent fingerprints by their short ultraviolet luminescence was designed. It is composed of a mercury-xenon lamp and a CCD camera, both water-cooled and computer-controlled. The system is used to study the behaviour of latent fingerprints and stains of body fluids such as blood, semen and saliva under short-UV illumination.

**KEYWORDS:** forensic science, short UV excitation luminescence, real-time observation, fingerprints, body fluids

Following recent reports on the UV luminescence of latent fingerprints and other body fluid stains, it was decided to investigate the possibility of the use of electronic imaging with a portable, field operable system.

Short UV luminescence (short UV excitation luminescence) was reported in recent years as a sensitive, non-destructive technique for detection of latent fingerprints (1–3) and other body fluids (4). The experimental systems, however, were rather cumbersome and could hardly fit police operational work. Certainly not for crime-scene examinations. They were composed of a good size Nd-YAG laser as the short UV light source and a film camera with UV optics as the recording device. No real time observations were reported.

The present work describes an attempt to design a more flexible, field operable system for the detection of latent fingerprints and other invisible marks of forensic interest by the short UV luminescence phenomena.

In order to design such a system, some quantification of the luminescence properties was needed. To achieve this aim, a set of measurements, similar to Bramble's (1–3) was performed. Specifically, the fourth harmonic of a Nd-YAG laser (266 nm) was used as the excitation source and photographic recording was utilized for the luminescent measurement. These measurements served to obtain an estimate of the luminescence efficiency of body fluid stains. Using these estimates it was possible to design an illumination-imaging system based on portable lamp illuminator and a cooled CCD imaging camera. Such a system was realized, its performance matched the designed goals.

A series of measurements was performed on various body fluid stains and latent fingerprints, most of them eccrinic. The results of the latent fingerprints luminescence differ from those reported by Bramble, his being mostly sebum rich. Our results show that only a small number of fingerprints do show significant fluorescence. In most cases no such activity was detected. In the cases that such an activity was detected, the electronic images were of good and of useful quality. The active fingerprints did not show significant deterioration over a period of 6 months and extended periods of UV illumination.

## Calibration

An initial estimate of the luminescence efficiency was obtained by using the fourth harmonic of a Nd-YAG laser (266 nm) and photographic imaging. The particulars of this experiment are summarized as follows.

*Source*—A Nd-YAG laser, fourth harmonic, 60 mJ per pulse, spot size of about 50 $cm^2$, 10 pps.

*Camera*—F/# = 5, Filter 18A (300 nm–400 nm). Exposure time, 4 seconds. Film, AgfaPan, 100ASA.

*Samples*—The samples used were stains of body fluids (whole blood, semen and saliva) deposited on various substrates. The substrate used for the quantitative measurement was a floor tile (porous).

*Configuration*—The samples were 20–25 cm. from the filter of the light source and 70 cm from the camera.

*Luminescence Efficiency Calculations*—The basic results show that under these conditions, the recorded density is in the range of 0.15–1.

From these results, using the film's sensitivity data, one can calculate the emittance of the luminescence. Knowing the laser characteristics and the geometry one can calculate the exciting photon flux. One obtains the following: The exciting UV flux is about $10^{21}$ photons $meter^{-2}$. The emitted flux is in the range

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$10^{17}$–$10^{18}$ photons meter$^{-2}$. Thus the fluorescence efficiency is in the range 0.001–0.0001.

The wide range of the results is due to the inherent inaccuracy of using the film as an absolute radiometric device. The lower number is obtained using the definitions of the 100ASA film, while higher efficiency is obtained using the sensitivity curve of the particular film used. Even so, due to variations in film age and developing procedure the inaccuracy remains. For the design of the required system, the lower efficiency was used.

## The Designed System

Based on the previous results it was possible to converge on a system based on a "small" illuminator and a CCD, TE cooled.

*Illuminator*—The chosen illuminator was the Photon Technology International (PTI) A1010 system, consisting of an ellipsoid reflector and a 200W MercuryXenon arc lamp. This assembly is water cooled and ozone safe. The efficiency of this illuminating system using the #5 filter (see later) and the 18A filter is demonstrated in Fig. 1, where the photographic recordings of the same fingerprint (on glass substrate) under the laser excitation and the lamp illuminator excitation are compared.

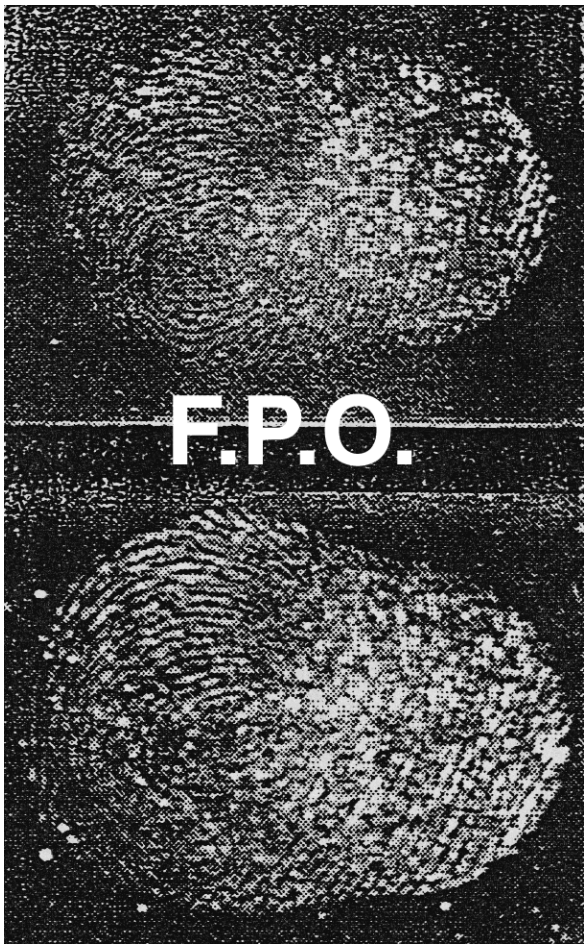


FIG. 1—*The comparison of a photographic recording of the same fingerprint sample fluorescence under laser and lamp excitation. Upper image; UV lamp (105 watts) 10 seconds exposure. Bottom image; laser excitation, 22 mJ per pulse, 10 pps, 10 seconds exposure. The lamp illumination is filtered by the #5 filter. In both cases the camera filter was the 18A filter.*

The spectral emittance of this lamp is shown in Fig. 2. A very rough estimate can be performed. From the curve shown in Fig. 2, one can conclude that a lower estimate of the spectral intensity is about 2500 μW/str/nm in the 250–300 nm range. The filters used, transmit in a bandwidth of about 30 nm, the illuminator utilizes about 1 str, thus the illuminating power is about 75 mW. The optics of the illuminator forms a circular patch of 10 cm in diameter, thus the illuminating flux is about 1 mW cm$^{-2}$. Which is about $210^{15}$ photons cm$^{-2}$ sec$^{-1}$.

*Camera*—From the above estimate of the available excitation flux, it can be seen that the numbers of photons per CCD pixel will be very low. In order to be able to detect these, the camera noise has to be very low. Furthermore, even with low dark currents, a CCD camera operating at standard video rate will introduce readout noise. The solution for both difficulties is the use of a cooled CCD, thus reducing the dark noise, and a variable (long) exposure CCD, in order to reduce the number of readouts. The solution was found in the Princeton Instruments TE cooled CCD camera. The CCD is a SITE 512 × 512 pixels chip, the size of each detector being 24 × 24 μmeter, back-illuminated with UV antireflection coating, the spectral response is shown in Fig. 3.

The controller being the ST130. The UV lens purchased with this camera being Nikon lens with a 105 mm focal lens and UV coating. The camera and the associated image processing and image handling are controlled by a company supplied software called WinView.

*Filters*—The camera filter, which should transmit in the 320–360 nm range was chosen to be Schott's SFK-2 filter.

A custom made filter, called #5 filter, its spectral characteristics shown in Fig. 4. A second custom filter, called KF1 was tried as well. Schott's UV-KMZ 20-3 was tried as well, (found to be not useful).

*Estimated Performance*—Estimating (from the manufacturers data) that the filter optics efficiency is about 0.1, using F/# = 2 and assuming fluorescence efficiency of 0.0001 one gets that the flux at the focal plane (CCD) is about $10^9$ photons sec$^{-1}$ cm$^{-2}$. The area of each pixel being 24 × 24 $10^{-8}$ cm$^2$ thus each pixel receives about 5000 photons/second, the quantum efficiency being about 0.6 (Fig. 3) so that about 3000 photoelectrons per second are collected. This number shows that exposures of about 0.1–1 seconds will produce useful signals.

This rough estimation demonstrates the various tradeoffs considered during the design stage, where a large number of illuminator-camera pairs were compared. As will be shown shortly, this estimation is validated by the experiment.

*Measured Performance*—On the delivery of the system components and their assembly into a working measuring setup, a set of preliminary experiments was carried out in order to validate (or refute) the estimations. That is, the experiments were carried out in order to check the suitability of the system.

The number of the impinging photons was directly measured by using the illuminator, illuminator filter (filter #5) illuminating white paper and the camera without a filter. Recording the reflection image allows to count the photoelectrons in each pixel. For an exposure of 0.1 sec about 43,000 photoelectrons per pixel were recorded. At this spectral range, 250–280 nm, the quantum efficiency is about 0.4, thus about 110,000 photons were reflected from each pixel object. Normalizing to unit time, one concludes that the reflected flux is 1.1 $10^6$ photons/sec per pixel object. In

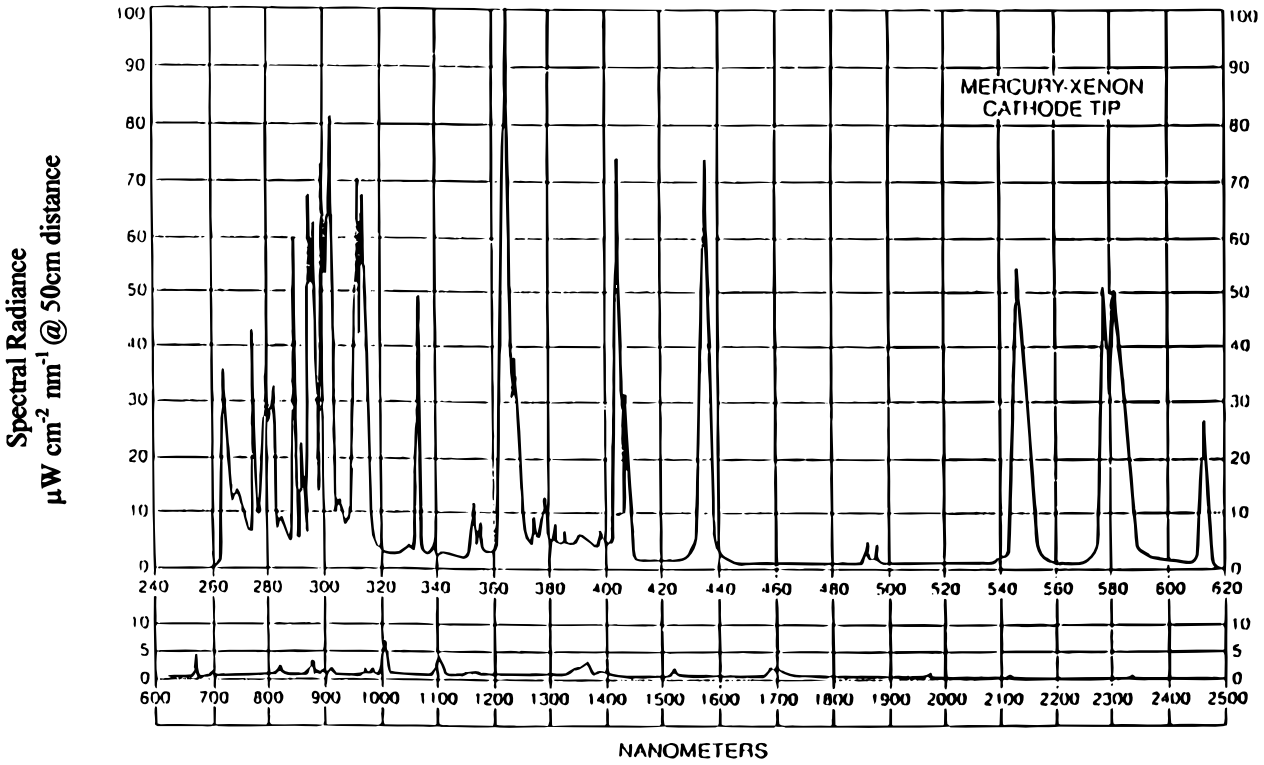


FIG. 2—*The spectral emittance of the Xe-Hg lamp in the PTI illuminator.*

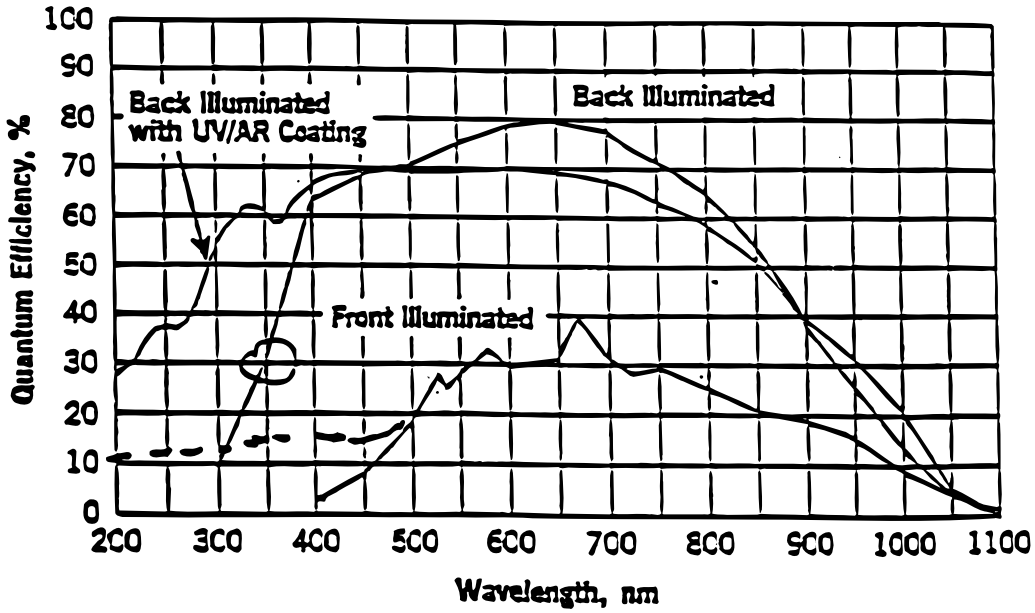


FIG. 3—*The spectral sensitivity of the SITE CCD. The one used in the present setup is the back illuminated with UV/AR coating.*

Fig. 5, the fluorescence image obtained from a blood stained tile is observed. The image was recorded with the camera filter on and exposure time of 1 second. The number of photoelectrons in the pixels consisting the stain (cross shaped) is about 330. The photoelectron count was performed in exactly the same pixels used for the reflection measurement. In the spectral range of the camera filter, the quantum efficiency being about 0.6 (see Fig. 3), thus one concludes that the number of received photons was 550. As the transmittance of the camera filter is 0.3 one concludes that the object corresponding to each pixel emits 1830 photons/second. Consequently, the fluorescence efficiency of this particular sample, whole blood, is about 0.0016. This number agrees very well with the upper limit of the calibrating experiment and validates the estimated system performance.

## Results

50 latent fingerprints originating from different persons, half on glass and half on white paper, were checked for fluorescence, not

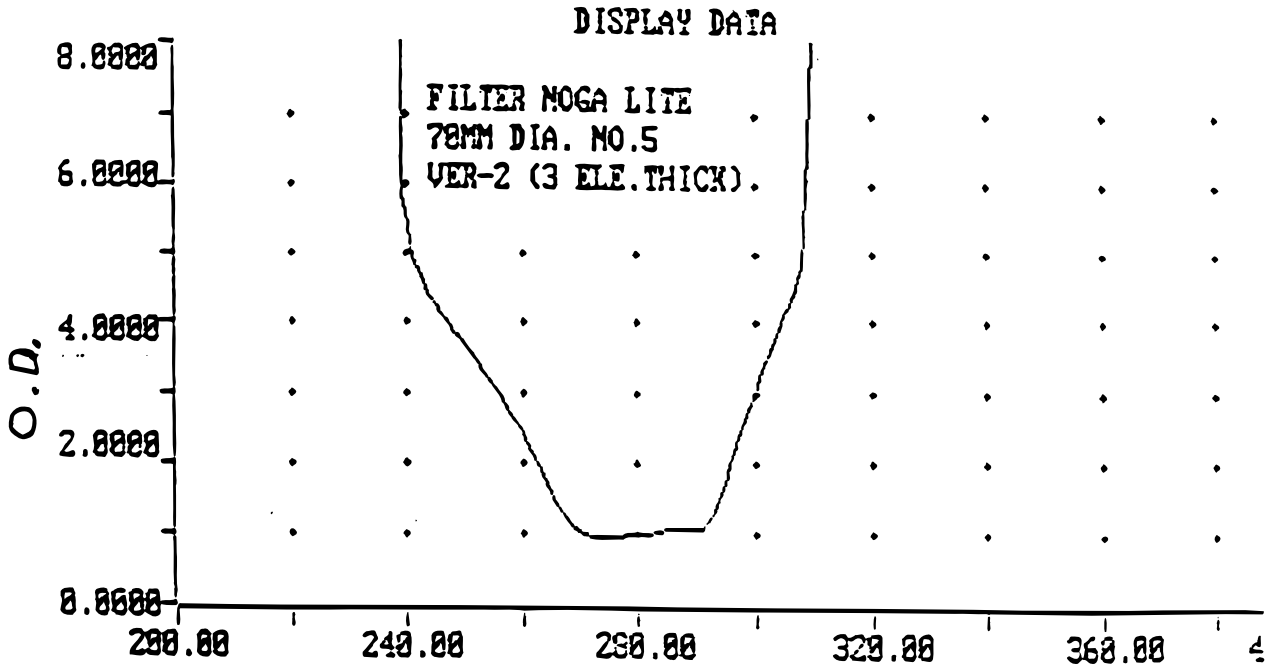


FIG. 4—*The spectral transmittance of the #5 filter used in the illuminating system. Notice that this is an optical density curve.*

more than 5 being sebaceous. The setup was the optimal one, i.e., illuminating filter #5 and the SFK-2 filter as camera filter. Filter #5 transmits in the 250–290 nm band, filter SFK-2 transmits in the 315–365 nm band.

Most of the fingerprints did not show any significant fluorescence. Only 5 did show detectable fluorescence with an efficiency of about 0.0002. The others had an efficiency of less than 0.00001 which in some cases were detectable but did not produce any useful image.

This 10% success is much below the results reported by the British group (1). The discrepancy may be that due to the fact that our prints were mostly eccrinic, while Brambles's were mostly sebum-rich. Bramble, in fact, showed that a sebum component like squalene is responsible for the fluorescence he observes.

Those fingerprints that did show useful fluorescence originally did so 6 months later after being exposed (cumulatively) for more than 1000 seconds to UV illumination. Figure 6 shows one such fluorescence image of a six month old fingerprint. Bramble reports a much faster decay (about 3 weeks).

Those fingerprints that did show fluorescent activity were used in order to derive the 3D fluorescence spectra. Our measurements were less detailed than those reported by Bramble. We used a set of 10 nm bandwidth filters and not a spectrometer. Our results are similar to those reported by Bramble, the "best" combination for fluorescent imaging of latent fingerprints is excitation in the 250–290 nm band, and detection in the 310–360 nm band. Care should be taken not to have a spectral overlap of the excitation and emission bands.

A 280 nm filter, used as camera filter together with the #5 excitation filter were used to check UV reflection from fingerprints. Figure 7 shows such an image of two fingerprints overlapping. The horizontal fingerprint (bottom) is 4 months old, the vertical


FIG. 5—*The fluorescence of a blood stained tile. The illumination filter being the #5 filter. The camera filter being the SFK-2 filter. Exposure time is 1 second.*


FIG. 6—*The electronic image of the fluorescence of a six month old fingerprint.*

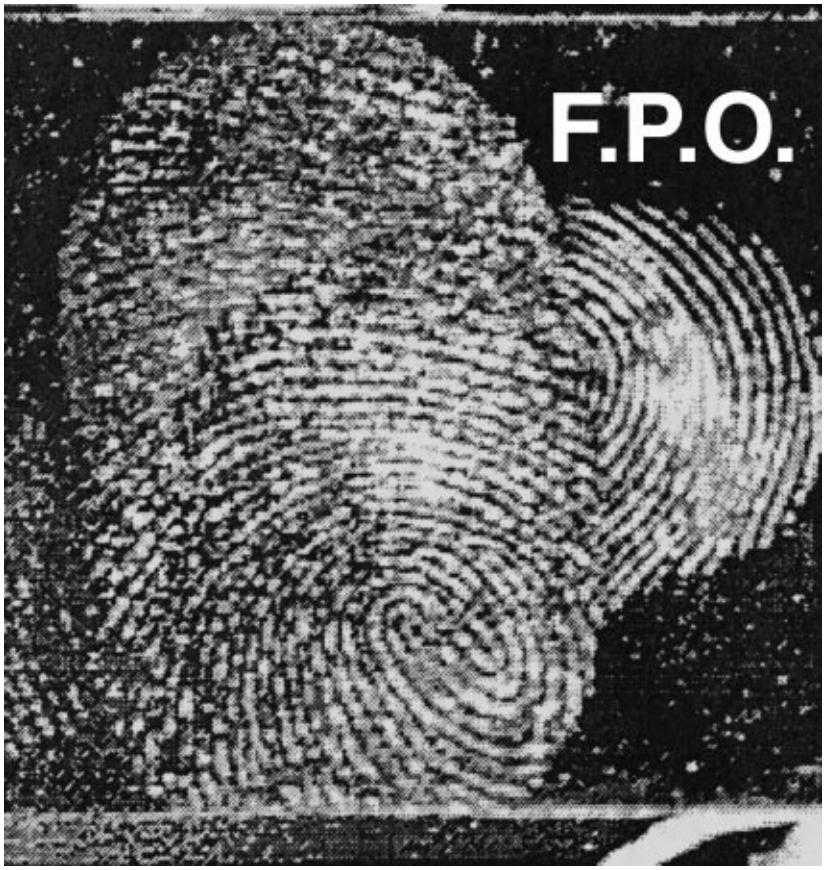


FIG. 7—*The electronic image of the UV reflection (280 nm) from fingerprints. The horizontal fingerprint is four months old, the vertical one was deposited minutes before exposure.*

one (top) was deposited minutes before exposure. One observes that good resolution and good contrast exists, as previously reported (5).

## Discussion

It was shown that the combination of a lamp illuminator and a TE cooled CCD camera can be used for fluorescent imaging of latent fingerprints and other body fluid stains. Such a system is semi-portable and can be adapted for field use. The exposure times needed for recording are about one second, which is practically "real time." The main deficiency for crime scene use is the small field of view (about 10 $\times$ 10 centimeters) which eliminates its use for scene scanning.

The fluorescence efficiency was found to be in the range 0.001–0.0001.

The UV spectral range is important to use at the scene of crime. We have studied the feasibility of detecting body fluids and fingerprints by UV fluorescence. Ideally, the system should be small, portable and ready for field applications with a real time response.

It is worth noting, finally, that the illumination of body fluids or body fluid residues with shortwave UV radiation can have consequences in terms of subsequent DNA typing results (6).

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