Technical Note

Extending Detection Reach with a New Narrow Bandpass Filter

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Abstract: Fingerprints have been detected and photographed by fluorescence for four decades. The technique has required the use of a barrier filter, in most cases orange, to block the light source reflection and isolate fluorescence. In some cases, however, the substrate also exhibits fluorescence, which can partially or totally obscure the fingerprint. A new narrow bandpass filter, used in combination with the standard barrier filter, can add significantly to both the extent and clarity of inherently and chemically treated fluorescing fingerprints. Moreover, in certain borderline cases, the chemical solution alone may be insufficient, but tailored optics can save the situation by converting an otherwise useless stain to an identifiable impression.

History of Luminescence Detection

Luminescence detection of untreated fingerprints began in 1977 [1] and relied on intrinsic fluorescence. This procedure has continued to be part of latent print detection protocol to the present time. Early chemical extensions [2, 3] did not achieve full effectiveness until the introduction of dye-staining combined with cyanoacrylate fuming [4]. As with any detection method, the impressions of greatest significance in an investigation are not necessarily the easiest to visualize and photograph. In the authors' experience, many of the latent prints that ultimately were most pivotal to investigations were observed and photographed at the threshold of visual perception.

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The fluorescence of untreated latent prints is typically (although not exclusively) weak and is often obstructed by substrate fluorescence. The orange barrier filter, used as both viewing goggles and photographic filter, often allows the analyst to see at least the presence or indication of a friction ridge impression. In many cases, however, the signal-to-noise ratio is very small, and even when contrast adjustments are made in image processing software, sufficient clear and continuous ridge detail may remain just out of reach. This applies to both untreated impressions and those revealed by chemical techniques. It is well known to identification photographers that the quality and extent of ridge detail cannot always be accurately assessed by the human eye. It is frequently necessary to photograph an impression and apply digital image processing to determine the full value of the impression.

The orange barrier filter is effective at blocking the reflected emission of the source (when appropriately matched) and transmitting fluorescence that has been generated. It is not, however, specific to the desired fluorescence, and it readily transmits substrate fluorescence in the orange and red range of the spectrum (Figure 1).

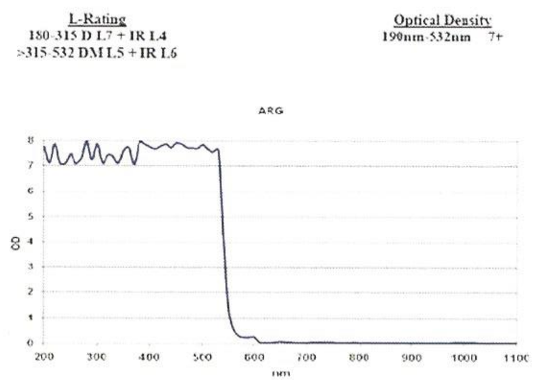


Figure 1

Absorption spectrum of Coherent filter 1153747, indicating virtually total blockage of blue and green wavelengths, and high transmission of yellow, orange, and red wavelengths.

Light Sources and Filters

A schematic illustration of exciting, isolating, and detecting fluorescence can appear quite simple when it appears in a PowerPoint slide. The reality is anything but, because of the following variables:

- Monochromatic and broadband light sources in use
- The specific wavelength(s) emitted from each source
- Variety of long pass barrier filters in use
- Variety of fluorogenic targets
  - Untreated fingerprints (infinite variation)
  - Chemical extensions (including but not limited to)
    - Rhodamine 6G
    - Brilliant Yellow 40
    - Indanedione
    - DFO
    - Acid Yellow
- Fluorogenic substrates (infinite variation)

The drive to produce a less-expensive, portable, and durable alternate light source (ALS) has resulted not in a viable replacement for lasers, but in a series of complementary processes. All laser alternatives to date feature wavelength bands (as much as 100 nm in width), compared to the monochromatic output of the laser. Filtered lamps and light-emitting diode sources (LED) offer versatility in excitation across the spectrum, but are more likely to excite background fluorescence. The two types of light source simply do not furnish the same results. Each is capable of revealing evidence missed by the other.

The first application of fluorescence detection was serendipitous [1]. The fingerprint was excited by an argon-ion laser (514.5 nm). The long pass absorption filter (Fisher 11-409-50A, Fisher Scientific, Hampton, NH) was contained in the safety goggles–required eye protection for safe use of the argon laser, featuring a virtually absolute blockage of the laser wavelengths (optical density 7). Fortuitously, it also transmitted the relatively weak intrinsic fluorescence of the fingerprints under scrutiny. It should be emphasized that prior to these experiments, the filter goggles were nothing more than health and safety equipment, analogous to nitrile gloves and particle masks. They henceforth assumed a considerably greater role–the wearer could see fluorescing fingerprints under the

illumination of an argon laser. Photography was accomplished by simply removing one lens from the goggles and taping it to the camera lens.

This became the operational procedure for examining crime scene exhibits by laser for several years, without variation or refinement, during which time, the orange barrier filter revealed one significant limitation–it transmits all yellow, orange, and red wavelengths well. Substrates under scrutiny routinely exhibit fluorescence, at wavelengths and intensities similar to those of the fingerprint, and could partially or completely obscure the fingerprint.

Narrow Bandpass Filters

Optical coating technology allowed for the creation of high-performance interference filters that use ultra-thin optical coatings designed to either pass or reject a few nanometers of incident light. By stacking hundreds of slightly shifted coating layers, filter manufacturers have created very narrow bandpass filters with fast turn-on and turn-off slopes of less than 1 nm each. The turn-on and turn-off slope refers to the efficiency and transition rate of the filter from absorption to transmission of light, and vice versa. The turn-on and turn-off slope is wavelength dependent and is subject to the filter design. These terms relate to the transition from rejection (i.e., reflection) of light to transmission of light, and vice versa. A slower turn-on and turn-off means that light transmission as measured over the wavelength spectrum of the bandpass filter will appear as a bell curve with a lower transmission on the outer limits and higher transmission in the center. Faster turn-on and turn-off reduces the wavelength range where light is rejected (i.e., reflected), thus making the bell curve appear more square [5].

Narrow bandpass filters have had a wide range of applications including clinical chemistry, spectroscopy, astronomy, and aerospace [6]. They have been used in the Hubble telescope to capture spectacular images of the galaxy [7].

The first research and application of narrow bandpass filters to photography of laser-excited latent prints occurred in 1982 [8]. It was found that the visibility and clarity of some could be increased by suppressing substrate fluorescence. One such filter was found to be the most effective: Melles Griot 03-FIV-079. It featured a peak transmission of 550 nm and a bandwidth of only 10 nm. For reasons as yet unknown, this filter could not (and cannot) be used in isolation, when exciting with laser. It displayed an image-destroying leakage on the green side necessitating its use in combination with the long pass orange absorption filter. When used in this way, it was extremely effective in revealing fingerprint detail much more clearly than with the orange filter alone, frequently making the difference between a suggestion of a fingerprint and an identifiable impression.

To the knowledge of the authors, no subsequent research on narrow bandpass filter application in fingerprint photography (excepting reference 12) was conducted. Several factors have contributed to the lack of mainstream application in the intervening time. From 1977 to 1985 (prior to the introduction of filtered lamp sources), lasers were the sole means of exciting untreated fingerprints to fluoresce, and they were located only in a handful of large police agencies. Because of the combined optical density of the narrow bandpass and the barrier filters, they could not be used for direct viewing and evaluation by an analyst. They were cumbersome and lacked a threaded ring for easy attachment to a camera lens, requiring that they be affixed to the camera lens with tape or some other means. The largest diameter available was 50 mm, necessitating a hand-constructed device for attachment to the barrier filter. Lastly, they revealed a propensity for transmitting laser reflection, requiring that they be used in combination with the orange barrier filter, resulting in high filter factors and long exposures.

In 2012 [8], a procedure was outlined for the mounting of a narrow bandpass filter onto an assembly of threaded stepping rings, which would allow for the rapid addition of the narrow bandpass filter to the barrier filter when needed.

Since 2012, it has been brought to the authors' attention that Melles Griot no longer manufactures these filters. Attempts to procure larger diameter filters (62 mm) with similar properties had not been successful until the release of the FF-1.0 (Arrowhead Forensics, Lenexa, KS). Both prototypes, the FF-1.0 and the similar filter peaking at 550 nm, were manufactured for this research initiative.

Laser Comparison Study

The authors are currently engaged in a wider, ongoing comparative study of the sensitivity of different lasers in the detection of untreated fingerprints. The exhibits included used railway tickets and university examination papers. These exhibits

were selected to closely approximate actual circumstances of crime scene exhibits under scrutiny, on the basis of two criteria:

- Unprepared touching by a wide range of different donors (railway tickets).
- Touching by donors in a state of emotional acceleration (examination papers).

No prepared or groomed impressions were included in the study. The decision was made to restrict the findings to two groups: indications of ridge detail and identifiable impressions. The results of the entire project will be reported in a future paper. It became readily apparent that simply viewing the exhibits while wearing goggles would not result in accurate data. Most of the impressions exhibited weak fluorescence, and many were occluded by substrate fluorescence or pattern. Narrow bandpass filtration and fast Fourier transform (FFT) were used to minimize these obstructions and permit a more accurate evaluation of the data. FFT is a post-photography procedure that is effective in reducing or removing repetitive patterns that occasionally obscure ridge detail in fingerprint images.

Equipment

Examination was conducted with a TracER 532 nm 4W laser (Coherent Inc., Santa Clara, CA), and Flare Plus 2 (505) nm LED source (Rofin Forensic, Melbourne, Australia). The emission spectra for these sources, although similar in color, are quite different (Figure 2).

Pattern removal was completed with FFT in Image Pro Premier, a stand-alone image-processing software program (Media Cybernetics Inc., Rockville, MD).

The orange barrier filter that was used was a Coherent 1153747 (Coherent Inc., Santa Clara, CA). The standard for the forensic industry has been to use long pass absorption barrier filters. The materials in these filters are designed to absorb the shorter wavelength light source light and pass the longer wavelength latent print fluorescence. The curved barrier filter has a turn-on slope with 0% transmission at 532 nm, 4.39% transmission at 550 nm, and levels off at 90% transmission from 590 nm on into the infrared (Figure 1) [9].

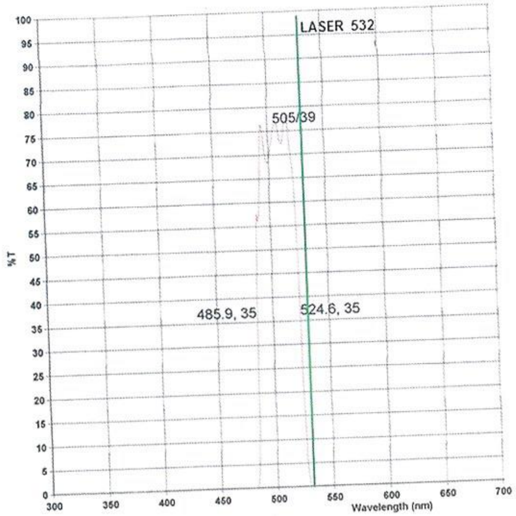


Figure 2

Emission spectra of Flare Plus 2 (505 nm) and TracER laser 532.

Photography

Sharp focus is critical for optimum results in any photographic situation, but it can be particularly challenging in fluorescence recording, when faint subjects and high filter factors can frustrate the autofocus feature of DSLR cameras. Either of two strategies to ensure sharp focus can be implemented.

1. Use autofocus with oblique white light before affixing the filter(s) to establish pinpoint accuracy of focus, and then disable autofocus feature.
2. Use autofocus with bright white light, with the filter(s) in place to establish sharp focus. Disable autofocus feature before proceeding with photography.

FF-1.0 Narrow Bandpass Filter

The previous narrow bandpass filter that has been used successfully since 1982 [2, 3] exhibited peak transmission at 550 nm, with a 10 nm bandwidth. During this examination phase, two new prototype narrow bandpass filters were tested [7], both of which feature 62 mm threaded mounts for easy attachment to the barrier filter and camera lens.

Initial tests used a prototype 16 nm bandpass filter centered at 550 nm with a total in-band transmission of 93% [10]. When stacking this fast turn-on bandpass filter with the slow turn-on curved orange long pass barrier filter, the combined transmission at 550 nm was approximately 4% (93% of 4.39%). Although the combined optical density was sufficient to produce high-quality images, the exposure time of the camera was increased, because the long pass barrier filter was blocking most of the latent print fluorescence.

The final filter (FF-1.0) selection for all subsequent activities was a 10 nm bandpass filter centered at 560 nm (Figure 3). This filter has 98% in-band transmission and transmits approximately 39% of the fingerprint fluorescence when stacked with a curved orange long pass barrier filter.

Images with the FF-1.0 revealed no significant difference in blocking the substrate fluorescence effectively, while affording a significant increase in the transmission of desirable fluorescence, resulting in shorter camera exposures.

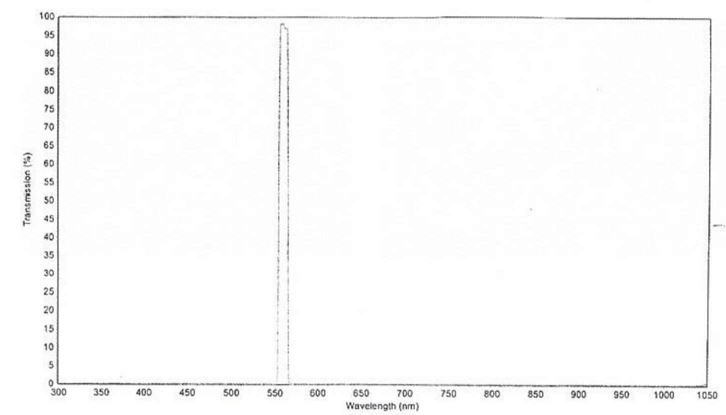


Figure 3

Transmission spectrum of FF-1.0.

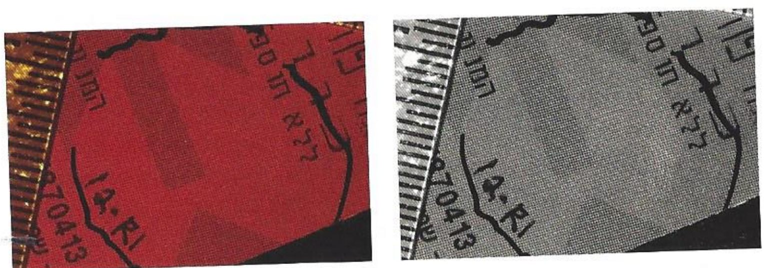
Example 1

A used train ticket from Israel was examined using the TracER laser (532 nm). One area of faint ridge detail was observed, marked, and photographed, using the same orange barrier filter for both examination and photography. The resulting image revealed no indication of ridge detail, indicating that there are differences in the spectral sensitivity between the CMOS camera chip and the human eye (Figure 4).

The image was opened in Photoshop, and the green channel was isolated (Figure 4). Ridge detail could be seen that approximated the strength and clarity of the initial viewing with the goggles. The impression was then photographed using the barrier filter and the narrow bandpass FF-1.0 in combination (Figure 5).

Conversion to gray scale and inversion revealed considerably stronger ridge detail, but significant obstruction from a printed pattern on the ticket remained (Figure 5).

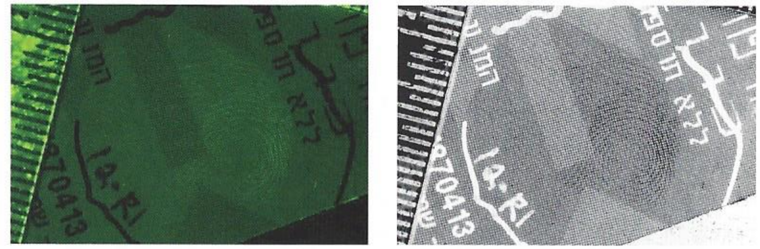
The image was opened in Image Pro Premier, and the pattern was edited with FFT, revealing clear ridge detail (Figure 6).



(a) *(b)*

Figure 4

Fingerprint recorded (a) with orange barrier filter; (b) green channel of image.



(a) *(b)*

Figure 5

Photographed with (a) barrier and narrow bandpass filter; (b) inverted and converted to grayscale.

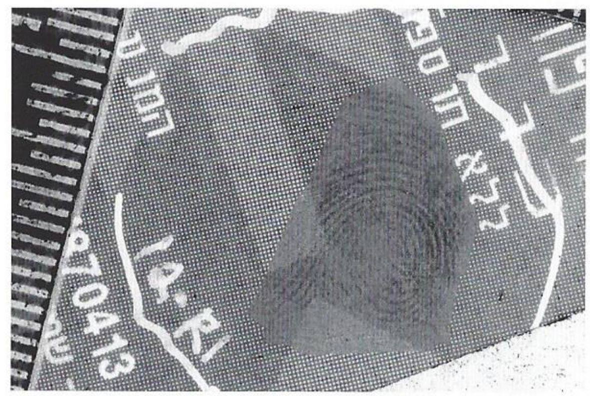


Figure 6

Pattern removed with FFT.

Banded Light

Although the initial research was restricted to different lasers, the potential of the FF-1.0 filter for optimizing borderline latent prints prompted testing its performance when used with banded light. The same impression appearing in Figure 1 was photographed and digitally processed (in a similar manner to the laser version) using the Rofin Flare Plus 2 (505 nm) LED as the light source. The final result (Figure 7) did not display clear and continuous ridge detail on a level revealed when the laser was used as the source.

It should be noted that this is one specific example, and results can vary in other situations. In the authors' experience, monochromatic laser excitation has proven to be generally more sensitive than banded sources in the detection of untreated latent prints, but there have been notable exceptions.

An extremely faint untreated impression was located on an examination paper from Australia and was recorded using the TracER 532 laser, first by orange barrier filter alone, and again in combination with the FF-1.0 narrow bandpass (Figure 8).

The same impression was then recorded by Flare Plus 2 (505 nm), first with an orange barrier filter, and then with the FF-1.0 alone (Figures 9a, 9b). The banded light source revealed a subtle but definite increase in the clarity of detail over what is seen in the laser image, both with the barrier filter alone and with the FF-1.0 narrow bandpass filter alone.

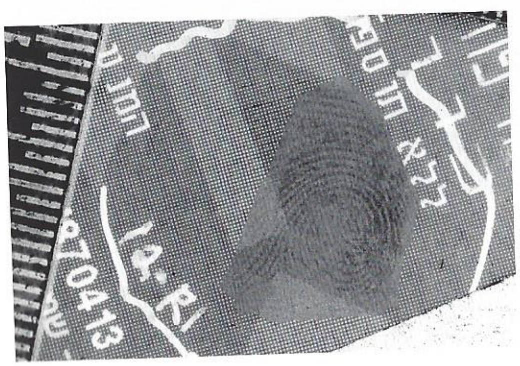


Figure 7

Flare Plus 2 (505 nm) LED used as source, converted to grayscale, inverted, and edited in FFT.

(a) *(b)*

Figure 8

Untreated fingerprint recorded by TracER 532 laser with (a) barrier filter and (b) combined barrier and FF-1.0 narrow bandpass filters.

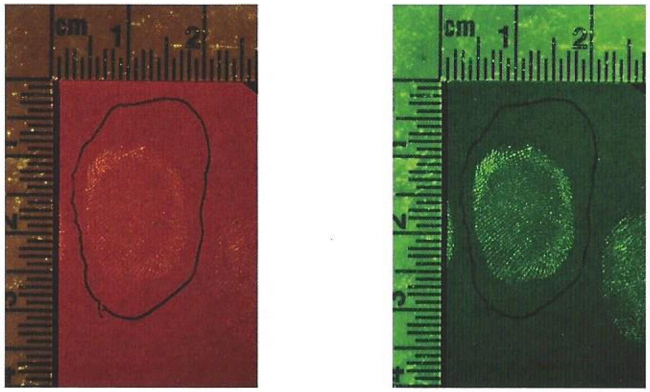
(a) *(b)*

Figure 9

Same impression recorded by Flare Plus 2 (505 nm); (a) with barrier filter alone; (b) with FF-1.0 narrow bandpass filter alone.

Indanedione

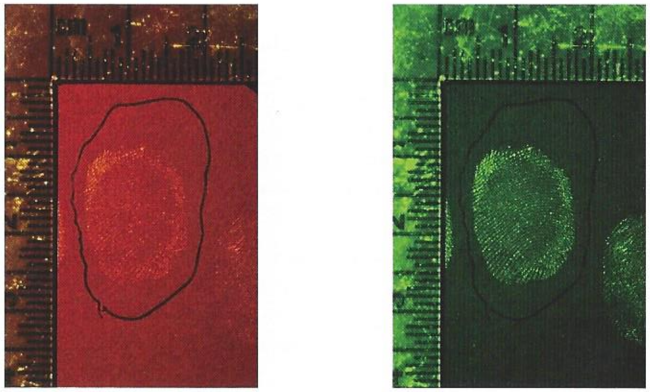
The use of the narrow bandpass filter is not restricted to the detection of untreated latent prints. It has been useful in isolating faint indanedione impressions on fluorescing paper substrates, including brown manila envelopes. The Australian formula was used in these studies [10]. The use of the Rofin Flare Plus 2 (505 nm) as a light source offers one significant advantage. Images of the indanedione impression on manila paper were recorded using the FF-1.0 both in combination with the orange barrier filter, and alone. No difference in image quality or clarity was noted. This means that the FF-1.0 can be used as a stand-alone filter when using the Rofin Flare 2 light source. Additionally, no discernable difference in quality was observed in the laser or Flare Plus 2 version of the fingerprint (Figures 10a–11b), but in both cases, use of the FF-1.0 resulted in ridge detail of significantly higher clarity and contrast.



(a) *(b)*

Figure 10

Indanedione impression on manila envelope, photographed with Flare Plus 2 (505 nm) LED; (a) orange barrier filter; (b) FF-1.0 alone.



(a) *(b)*

Figure 11

Same impression photographed with TracER 532 laser; (a) orange barrier filter; (b) orange in combination with FF-1.0.

Rhodamine 6G

Prior to the introduction of the FF-1.0 filter, a series of tests were conducted with cyanoacrylate → rhodamine 6G-developed impressions (methanol formula) [11] on plastic bags with obstructive overprinting. One chance impression, when recorded with the orange barrier filter alone, exhibited clear ridge detail on the unprinted surface of the bag, ending where the red overprinting began (Figure 12a). The narrow bandpass filter (Melles Griot 03-FIV-079, now unavailable) previously adapted for easy camera mounting [12] was used in combination with the orange barrier filter, resulting in a continuous display of ridge detail in the previously occluded area (Figure 12b). This sample is no longer available for testing with the FF-1.0 filter.

Using the FF-1.0 filter to record similarly obstructed impressions developed by cyanoacrylate → Rhodamine 6G is currently underway and will be reported in a future article.

Case Report

Prior to the introduction of the FF-1.0 filter, an anonymous letter in a manila envelope was received for latent print examination. The envelope bore a self-adhesive postage stamp, which was removed from the envelope and treated on the adhesive side for fingerprints with Lightning/Liquinox, a powder suspension technique that combines Liquinox, a commercial detergent, Lightning Black Powder, and distilled water. A small area of indistinct ridge detail was developed on a corner of the stamp and determined to be unsuitable for comparison (Figure 13).

The manila envelope was treated with indanedione. Extremely faint ridge detail in the area previously covered by the stamp was observed and photographed with the TracER laser (532 nm) and an orange barrier filter (Figure 14).

The impression was then photographed with the orange barrier filter in combination with the 550 nm narrow bandpass filter in use at that time (Figure 15). A clear and detailed impression was noted. The position and direction of the ridge detail on the envelope was consistent with the ridge detail observed on the adhesive side of the postage stamp. Moreover, the ridge detail appearing on the envelope ended abruptly along the edge of the area previously covered by the stamp. This is strongly consistent with the developed impression being transferred from the adhesive side of the stamp as a mirror image of the original contact.

(a) (b)

Figure 12

Cyanoacrylate → rhodamine 6G impression recorded by TracER 532 laser; (a) orange barrier filter alone; (b) orange barrier and FF-1.0 narrow bandpass filters in combination.

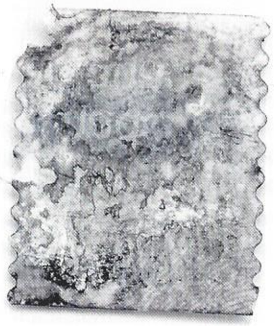


Figure 13

Adhesive side of postage stamp bearing ridge detail (reversed).

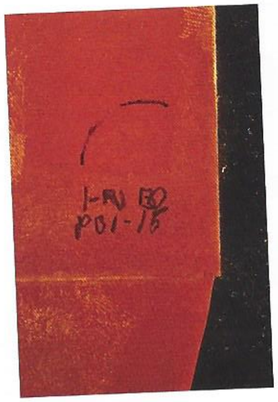


Figure 14

Indanedione development in area previously covered by stamp, photographed by 532 laser with orange barrier filter.

Figure 15

Indanedione-developed impression recorded by TracER 532 laser with orange barrier filter in combination with FF-1.0 narrow bandpass filter.

Although the exhibit in this investigation is no longer available for further examination, on the basis of results attained with indanedione on similar substrates, it is reasonable to assume that the FF-1.0 filter would produce similar results.

Discussion

Untreated latent prints occasionally exhibit fluorescence, usually of low intensity, and often obstructed to some degree by substrate fluorescence. It is not always possible to assess the value of such impressions by eye alone.

Most intrinsically fluorescing latent prints, in the authors' experience, tend to fluoresce generally in the yellow range, although exceptions have been observed. Unlike known chemical extensions like DFO, indanedione, and Rhodamine 6G, untreated latent prints have no exact or predictable absorption and emission properties, and the range of possible substrates on which they appear is equally varied. For these reasons, the possibility that other narrow bandpass filters with different transmission peaks may offer optimal results in specific cases should be considered. Results reported herein apply to the group of samples under current scrutiny.

Monochromatic excitation (laser) has in many cases resulted in significant friction ridge detail that was not observed as clearly (or at all) with banded excitation, but the potential for a reverse scenario clearly exists.

A narrow bandpass filter, at or close to the emission peak of the latent print, may reduce substrate fluorescence and increase the signal-to-noise ratio, resulting in additional or clearer detail.

The TracER laser, with emission at 532 nm, is 23 nm below the stated transmission threshold of the FF-1.0 narrow bandpass filter. When used stand-alone with the laser, the FF-1.0 fails to block the reflected emission, which obstructs the desired latent print fluorescence. When used in combination with the orange barrier filter, it is highly effective at isolating both treated and untreated latent prints on fluorescing surfaces.

The Rofin Flare Plus 2 (505 nm) LED has a stated band width of 40 nm, indicating that its longest emission is at 525 nm. Results would indicate that this is just far enough away from the transmission band of the FF-1.0 to be effectively blocked without the need to use the orange barrier filter in combination.

Monochromatic excitation (as evidenced here by the TracER 532 nm laser) and banded excitation [as seen with the Rofin Flare Plus 2 (505 nm)] each have the potential to be the best or the only light source for visualizing fluorescing latent prints. Consequently, if both sources are not used, fingerprint evidence may be underevaluated or missed.

The FF-1.0 narrow bandpass filter, when used with either monochromatic (laser) or broad band excitation, can be highly effective at isolating desirable latent print fluorescence while suppressing background obstruction, frequently making the difference between an unusable indication of ridge detail and an identifiable latent print.

Conclusion

Latent prints must be routinely photographed, and occasionally subjected to post-photography digital processing, before they can be accurately evaluated.

Narrow bandpass filters certainly reduce the amount of light that reaches the examiner's eye or the camera, but they can considerably improve the signal-to-noise ratio in images, and this is the investigator's goal.

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