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Comparison of Fingermark Detection Using Semiconductor Laser and LED Light Sources with Three Chemical Reagents

Project Information

Title: Comparison of Fingermark Detection Using Semiconductor Laser and LED Light Sources with Three Chemical Reagents

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Stakeholder: Forensic Science Community

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Manufacturer Information

Product: TracER™ 460nm, 532nm and 577nm lasers

Manufacturer: Coherent® Inc.

Phone Number: (408) 764-4983

Internet address: http://www.coherent.com/

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Manufacturer Information

Product: Polilight® Flare Plus LED

Manufacturer: Rofin Forensic

Phone Number: 61 3 9558 0344

Internet address: http://www.rofinforensic.com.au/

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Evaluation Summary

A variety of light sources and reagents are available for the detection and identification of latent fingermarks. This study was undertaken to explore the optimum light and filter combinations of laser and light-emitting diode (LED) light for use with indanedione and two new chemical reagents, genipin and lawsone. The light sources utilized were Coherent® TracER™ lasers operating at 460nm, 532nm and 577nm and the Rofin Polilight Flare Plus LED

operating at 505nm. Deliberate and randomly created fingermarks were first examined utilizing the light sources alone and then again following treatment with one of the reagents.

Background

Lasers and forensic light sources have been instrumental additions to the crime scene and exhibit examination disciplines for decades. Filtered lamps and, more recently, LED sources were introduced to replace the more costly, fragile and non-portable lasers in the detection of physical evidence. A growing body of anecdotal evidence suggests, however, that such sources, which emit a specific band of wavelengths, complement rather than replace monochromatic lasers. Before discussing this particular study, it is useful to revisit the progression of light source development, and the contributions of each to the practice of forensic science.

Argon Ion Laser

Collaborative work in 1977 between the Ontario Provincial Police and Xerox Research Centre culminated in the first operational laser in a police laboratory for the purpose of fingermark detection. Before any dyes or fluorescing agents, this laser was used initially and exclusively to find evidence through inherent fluorescence [1].

Argon lasers were ideal in emission properties, producing only blue-green wavelengths, but not so ideal in other ways. They were expensive, temperamental, and definitely not portable. Nevertheless, valuable evidence of all kinds (fingermarks, hair/fiber, body fluids and transferred foreign material) not responsive to conventional detection was revealed by laser.

The value of the laser was extended with the introduction of CA/rhodamine 6G dye-staining and 1,8-diazafluoren-9-one (DFO) a few years later, but the cost and lack of portability placed the technology beyond the resources of all but a few large police agencies. The search began almost immediately for a cheaper, portable and more robust alternative to the laser.

Filtered Lamps

The Luma-Lite™ was introduced circa 1980 as the first "Alternative Light Source" which attempted to emulate the argon laser's ability to excite evidence. It was based on a strong white light in combination with dichroic exciter filters, each of which allowed emission in a different part of the spectrum. It was followed by others, including the Quaser®, Omnichrome®, Polilight, Crime Scope™ and a few more [2]. Of greatest value was the ability of these lamps to excite trace evidence, body fluids, cyanoacrylate dyes and DFO.

The authors are aware of very few reports, either published or anecdotal, prior to 2000, of any criminal investigation in which a filtered lamp revealed an intrinsically fluorescent fingermark.

Other Lasers

Copper vapor lasers made a brief appearance in the mid-1980s. Emitting green and yellow lines, they were initially promising, but were confined to the laboratory [3]. No recent reports of operational use have been made.

The Nd: YAG frequency-doubled pulse laser made an initial entry circa 1980. With a monochromatic emission at 532nm, and definite portability, the YAG laser appeared promising, but the first version had a low and annoying repetition rate (16Hz). This was improved in the early 1990s and the YAG became a mainstream forensic tool [4].

Anecdotal reports of inherently fluorescent fingermarks revealed by this laser first came to the authors' attention during the 1990s.

LED

During the 1990s, LED sources represented a new and exciting approach to offering excitation bands throughout the spectrum. Versions of this technology include Polilight Flare Plus and Crimelite. Less expensive, highly portable and robust, they have allowed for routine light scrutiny at crime scenes, as well as conventional examinations in the laboratory. Lower cost has made acquisition possible for many more police agencies.

Optically-Pumped Semiconductor Laser

In 2006 the Coherent optically-pumped semiconductor laser was introduced [5]. In addition to being a robust, portable and powerful source of monochromatic light at 532nm, this new technology offers the possibility of monochromatic emission at virtually any point in the spectrum, which in turn will allow the user to tailor the light source to detection reagents, instead of the reverse.

Two new semiconductor lasers, with blue emission at 460nm and yellow at 577nm, have also been introduced.

Light Sources in This Study

- TracER 460nm laser
- TracER 532nm laser
- TracER 577nm laser
- Polilight Flare Plus 505nm LED

The barrier filter used with the TracER 460nm, the TracER 532nm and the Polilight Flare Plus 505nm was the OD550nm (orange). The NoIR TRC filter was used with the TracER 577nm laser.

Chemistry

Fingermark reagents are chemical compounds that are used for the enhancement of latent fingermarks through the formation of color or fluorescence with one or more of palmar sweat ingredients. Until the early 1980s, most of the fingermark reagents were "borrowed" from other fields of chemistry. For example, ninhydrin has been used for several decades as an amino acid reagent, and iodine fumes have been used to stain spots of chemical compounds on chromatography plates. Since the early 1980s, a range of ninhydrin analogues have been synthesized and tested for their suitability as reagents for the detection of latent fingermarks. Two of the new compounds have found widespread operational use: 1,8-diazafluoren-9-one (DFO) and, more recently, 1,2-indanedione; the latter, in combination with catalytic amounts of zinc chloride [6-12]. These reagents develop highly fluorescent fingermarks at room temperature and hence do not require further treatment. In 2005, Almog and co-workers discovered that genipin, a natural product which is extracted from several plants, has a high potential as a latent fingermark detection reagent [13, 14]. In the wake of this discovery, other potentially active natural products have been studied. Lawsone, an ingredient of henna, was found to develop latent fingermarks as colored impressions that also fluoresce without a secondary treatment with metal salts [15].

1,2-indanedione was introduced more than ten years ago, and is now accepted by a number of police agencies and researchers as the most sensitive amino acid reagent for paper surfaces. Its performance is significantly enhanced when applied together with catalytic amounts of zinc chloride. It produces colored impressions, ranging from moderate to strong, which fluoresce intensely under green excitation. The impressions are routinely viewed and photographed with an orange barrier filter (Schott KV550, or equivalent).

Genipin, which also reacts with amino acids, is an extract of the gardenia fruit. It was developed more than five years ago as a potential fingermarks reagent, and has been cited by Israeli researchers as effective on brown wrapping paper. Genipin produces a sporadic blue color and exhibits red fluorescence which is excited by Polilight PL500 at 590nm. Viewing and photography are accomplished with a Kodak® Wratten #92 filter.

Lawsone is an extract of henna and also reacts with amino acids, visualizing latent fingermarks as brown-colored impressions. The product exhibits red fluorescence when excited by yellow light (Polilight PL500), and viewed through the Kodak Wratten #92 filter.

Product Specifications

<u>Photos</u>

Coherent TracER Laser

Rofin Polilight Flare Plus LED

1,2-indanedione

Genipin

Lawsone

Product Details

Coherent TracER:	Type: Semiconductor laser Dimensions: 16" x 14" x 12" Weight: 45 lb Power Req.: 110V AC Cost: Approx. $45,000 Storage Conditions: Room Temperature Operational Conditions: Room Temperature http://www.coherent.com/downloads/TracER_brochureRevA.pdf http://www.coherent.com/downloads/TracER_DS.pdf
Rofin Polilight Flare Plus	Type: LED Dimensions: 11" x 2.6" dia. (battery + head) Weight: 2 lb (battery + one head) Power Req.: 12 V battery (charger: 110V AC) Cost: Approx. $15,000 (incl. all heads and accessories) Storage Conditions: Room Temperature Operational Conditions: Room Temperature http://www.rofinforensic.com.au/pdf/PolilightFlare_Plus_Brochure.pdf

Instrument Setup Comments

- TracER – 532nm viewing filter, standard orange cutoff
- TracER – 460nm, orange filter
- TracER – 577nm, NoIR filter, peak transmission: 590nm
- Polilight Flare Plus – 505nm viewing filter, standard orange cutoff

Level of Operator Knowledge (Set per Manufacturer)

☐ Non-Scientist ☒ Technician ☐ Scientist

Procedure

Reagent Preparation

Working solutions of the three reagents were prepared according to the optimal formulations in the recent forensic literature. Indanedione (ID) solution (0.1%) was prepared according to Wallace-Kunkel [10]; zinc chloride solution was prepared according to Ramotowski [16]; genipin (0.17%) according to Almog [14]; and lawsone according to Lewis [15].

Sample Collection

Deliberately Made Latent Marks: Latent marks were collected from twenty subjects, both male and female. Each subject placed one hand on a sheet of bond paper and the other on a sheet of brown wrapping paper for approximately ten seconds. This procedure was repeated three times for each donor, under the following conditions:

A. Without any preparation
B. After hands were enclosed in plastic bags for 5 minutes
C. After hands were rubbed on nose and ears, in attempts to obtain sebaceous transfer

Random Marks: University examination books consisting of lined white paper were used as samples of sustained random handling.

Examination of Untreated Samples

Both sets of exhibits, deliberate and random, were examined using the light sources for inherently fluorescing ridge detail. All exhibits were examined first by the TracER 532nm laser. This laser was chose as a screening tool because of its history of being useful in producing significant numbers of inherently fluorescent prints. Only the exhibits producing positive results (rated as bearing significant ridge detail) were subsequently examined by the other light sources. (Note: Establishing whether an impression was identifiable was deemed to be too time consuming, and in many cases, would require photography and further digital processing to confirm, so any significant presence of ridge detail was marked as a positive.)

As shown in the table below, only the samples revealing significant detail by the 532nm (green) laser were further examined using the other light sources. For example, nine sheets of white paper bearing spontaneous fingermarks were examined using the 532nm (green) laser, with four positives. Only the four positives were then examined using the other light sources (each producing two positives).

Deliberate Exhibits

	Spontaneous	Accelerated	Sebaceous
Green Laser – 532nm			
White Paper	4/9	7/19	5/21
Brown Paper	11/16	16/18	5/21
Yellow Laser – 577nm			
White Paper	2/4	2/7	5/5
Brown Paper	9/11	14/16	2/5
Blue Laser – 460nm			
White Paper	2/4	6/7	N/A
Brown Paper	9/11	13/16	N/A
LED – 505nm			
White Paper	2/4	5/7	2/5
Brown Paper	4/10	8/16	1/5

All untreated impressions revealed by light sources exhibited weak fluorescence, requiring very careful scrutiny during the examination stage. It was in this region that very slight differences in intensity and clarity were crucial. Careful photography and subsequent digital image adjustment were required to display the ridge detail at maximum clarity.

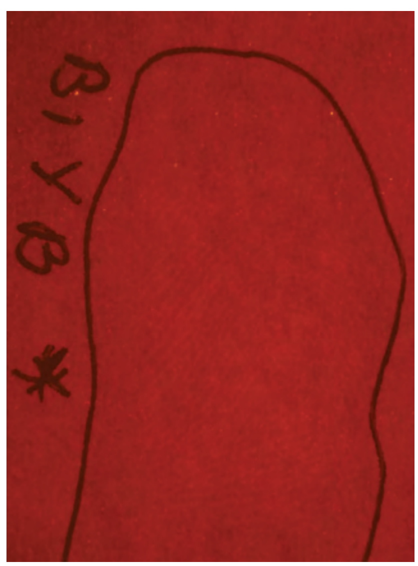
In the authors' experience, strong intrinsic fingermark fluorescence is extremely rare. Since many of the untreated fingermarks revealed by light alone in the past failed to appear with subsequent chemical treatment, it is critical in an investigation context to note and record all significant presence of ridge detail at this noninvasive stage of examination. The subtle differences in signal-to-noise ratio with different light sources are shown below. It is apparent that fingermarks photographed under the TracER 532nm laser and the Polilight Flare Plus 505nm LED are difficult to assess for quantity and clarity of ridge detail.


(a) TracER 532nm

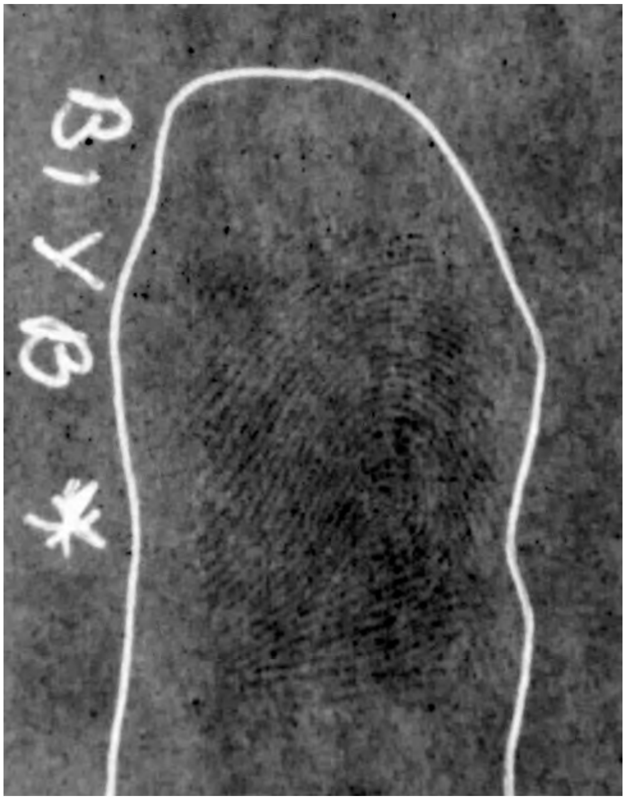

(b) Polilight Flare Plus 505nm


(c) TracER 577nm

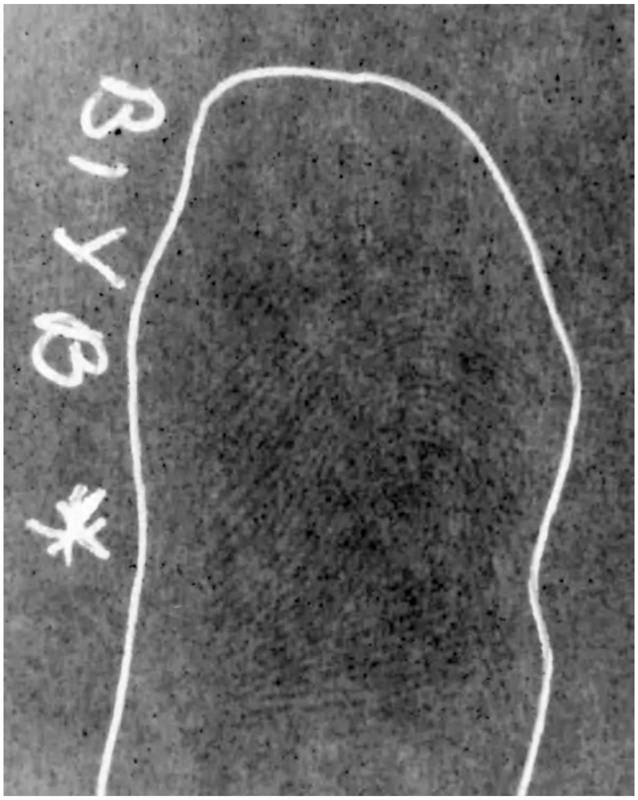

(d) TracER 532nm


(e) Polilight Flare Plus 505nm

However, when the images are adjusted in Photoshop to maximize contrast, there is greater clarity in the version photographed under the TracER 532nm laser, as shown in the following images.



(a) TracER 532nm



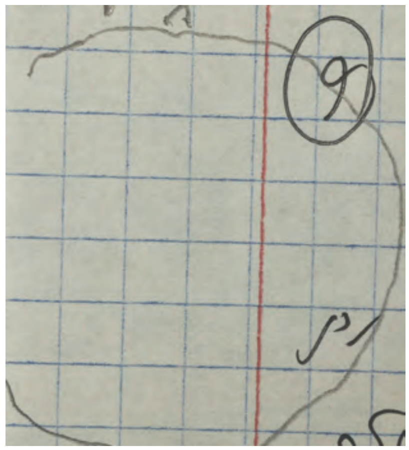
(b) Polilight Flare Plus 505nm

The clarity and sharpness (and the ability to compare the impression) are increased still further by the use of a Melles Griot narrow band filter (peak wavelength 550nm, 10nm bandwidth), as shown in the following image. This underscores the fact that identifiable untreated impressions may not initially appear so, and may require atypical photography (narrow band filter) and/or post-photographic processing.

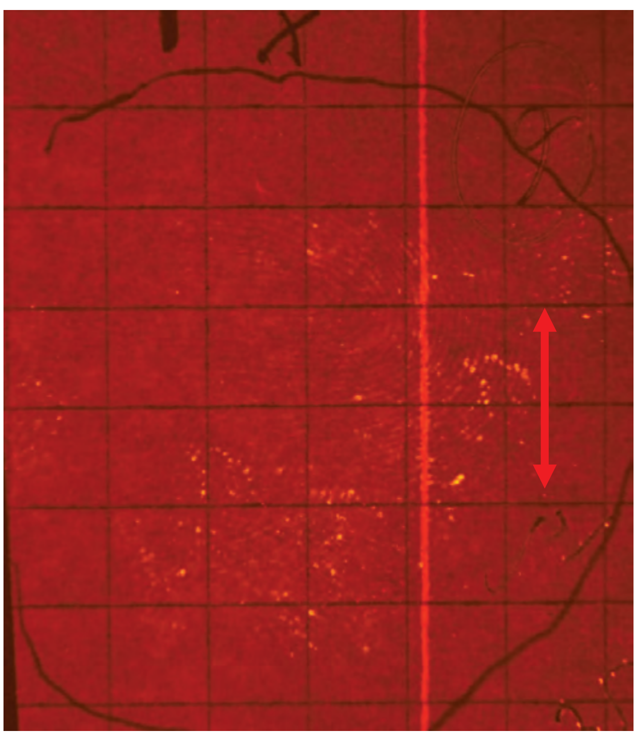
TracER 532nm + Narrow Band Filter

Examination of Random Exhibits

Similar to the experience with the deliberately prepared samples, numerous areas of ridge detail were located by the TracER 532nm laser. In each case, the impressions were either less distinct when illuminated by the Polilight Flare Plus or not seen. There were subtle differences in ridge detail and pen strokes between the images acquired with the different light sources, as shown in the following images.



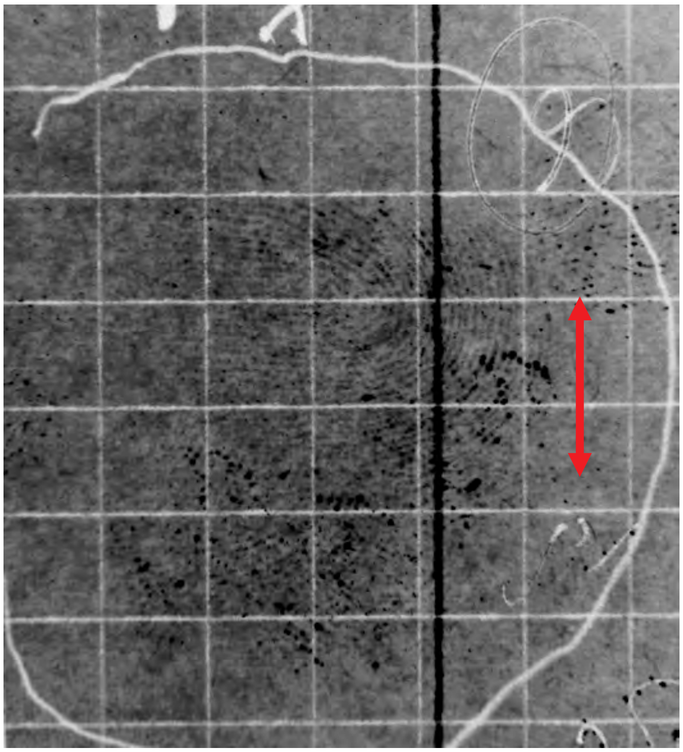
(a) White Light



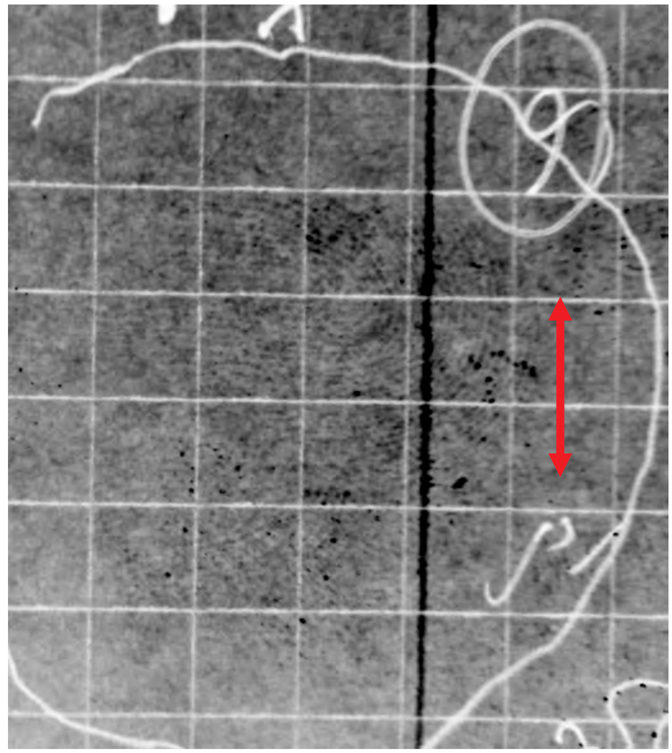
(b) TracER 532nm

(c) Polilight Flare Plus 505nm

The above untreated impression reveals subtle differences between the versions captured by TracER 532nm and Polilight Flare Plus 505nm, respectively. The ridge detail is slightly more distinct in the laser version, as are the areas of spot fluorescence. Also, two areas of writing are significantly less distinct (see arrows). This is more distinct when viewed in grayscale, as shown below.



(a) TracER 532nm (grayscale)



(b) Polilight Flare Plus 505nm (grayscale)

Treated Fingermarks

Samples from five donors were processed in indanedione, genipin and lawsone. The images below and on the following pages show the samples in white light and under the TracER 532nm, Polilight Flare Plus 505nm and TracER 577nm light sources.

Indanedione + Zinc Chloride | Genipin | Lawsone

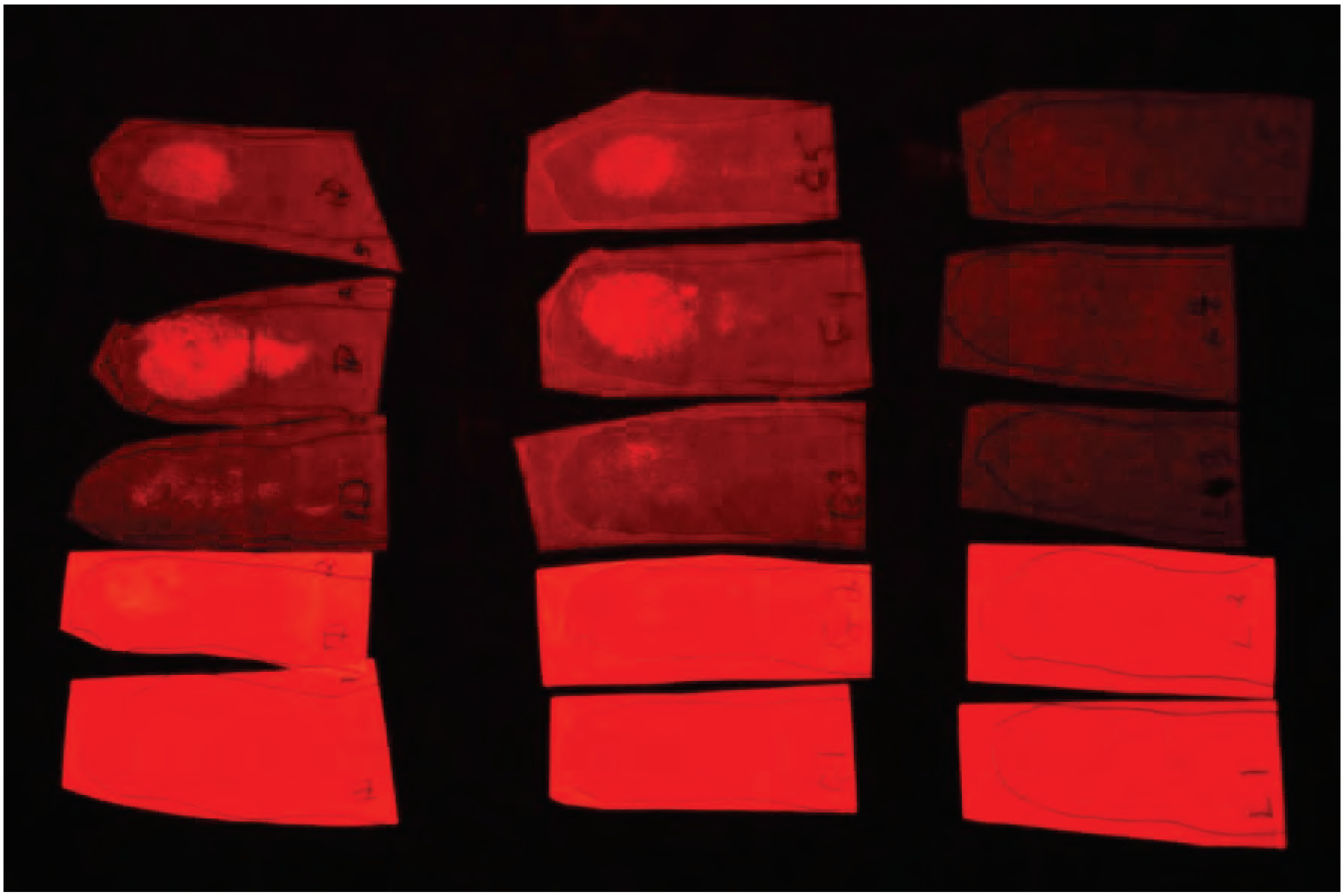
Five Donor Samples in White Light

Indanedione + Zinc Chloride | Genipin | Lawsone

TracER 532nm

Indanedione + Zinc Chloride | Genipin | Lawsone

Polilight Flare Plus 505nm



Indanedione
+ Zinc Chloride

Genipin

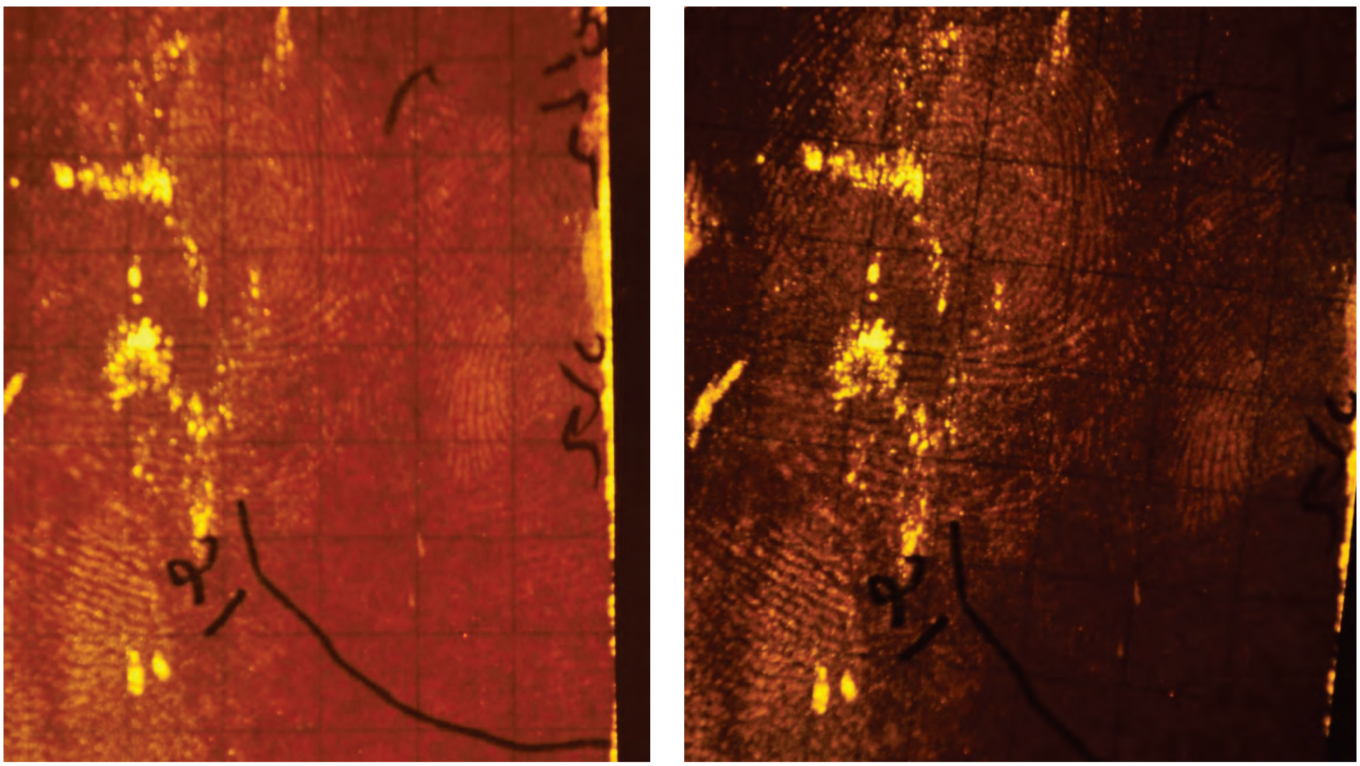
Lawsone

TracER 577nm

Chemistry Results

Indanedione/Zinc Chloride: Latent fingermarks treated with indanedione/zinc chloride exhibited strong fluorescence when excited by the TracER 532nm and Polilight Flare Plus 505nm (see images below), although results with the TracER were sometimes slightly better. Occasionally, the laser emission excited the background less than the broadband choices, resulting in a slightly higher signal-to-noise ratio. This made little or no difference on strong latent prints, but may be critical on threshold impressions.

Many of the treated marks also showed visible color that varied between light pink to red. Fluorescence was noted with the TracER 460nm and 577nm. Although both TracER 532nm and Polilight Flare Plus 505nm excited strong fluorescence, in several cases there was slightly clearer separation between ridge detail and substrate with the TracER 532nm.

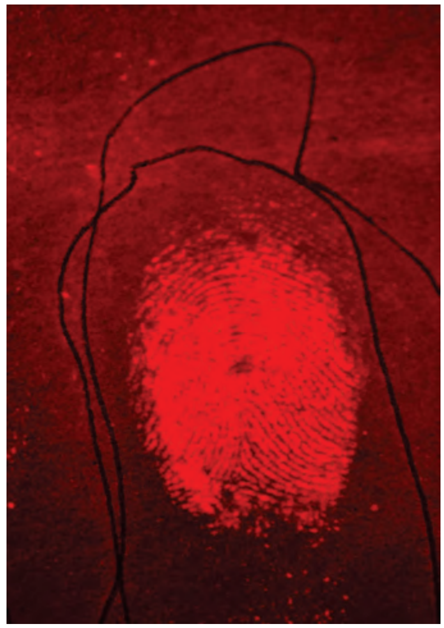


(a) Polilight Flare Plus 505nm

(b) TracER 532nm

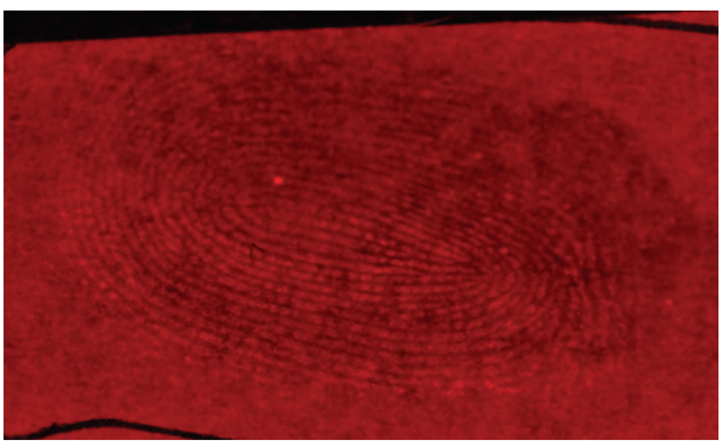
Genipin: Results with genipin were somewhat disappointing. Few samples exhibited either color or fluorescence. Weak fluorescence was noted on several samples with the TracER 532nm laser. The fluorescence was stronger with the TracER 577nm laser (see image below) and the NoIR TRC filter or the Kodak #92 filter. Several fingermarks appeared in color mode after two weeks without heat or humidity treatment.

(a) White Light



(b) TracER 577nm

Lawsone: Only two samples treated with lawsone displayed discernible fluorescence, and none of the samples treated had any trace of color development.



TracER 577nm

Findings

The table below presents a summary of the chemistry findings.

Chemistry Findings Summary

	Indanedione	**Genipin**	**Lawsone**
TracER 532nm	Strong	Weak	N/A
TracER 460nm	Moderate	N/A	N/A
TracER 577nm	Moderate	Strong	Weak
Polilight Flare Plus 505nm	Strong	Weak	N/A
Results	**Numerous**	**Few**	**Negligible**

Discussion

Results indicated that treatment with indanedione/zinc chloride was most effective at excitation of fingermarks. With the exception of the 577nm laser and genipin, the two new reagents, genipin and lawsone, did not provide useful results under test conditions. Although the LED light source revealed a significant number of untreated impressions, the laser light source proved to be more sensitive at detecting untreated impressions and the ridge clarity was frequently higher on the samples examined. Monochromatic sources (lasers) and broad band sources such as LEDs each exhibited the potential to detect evidence missed by the other.

Conclusions

- Monochromatic sources (lasers) and broad band sources (filtered lamps, LEDs) each have the potential to detect evidence missed by the other.
- The TracER 532nm laser is more sensitive at detecting untreated impressions than the other sources tested, and the ridge clarity was frequently higher on the samples examined.
- The Polilight Flare Plus 505nm revealed a significant number of untreated impressions, although fewer in number and frequently less clear in detail than those revealed by the TracER 532nm laser.
- It was noted that untreated fingermarks do not typically exhibit strong fluorescence, and the discovery of them occurs at the limits of the visible threshold. It is in this region that very slight differences in intensity and clarity are crucial. Careful photography and subsequent digital image adjustment are routinely required to display the ridge detail at maximum clarity.
- The TracER 577nm laser did reveal a number of untreated impressions. The goggles and filter supplied with the laser were used. Other filters may offer different results.
- Broad band sources present greater versatility than lasers, in offering different emission ranges across the spectrum. This allows for the matching of emission to the specific target, be it body fluids or detection by chemistry.

- All sources tested were successful in excitation of indanedione-developed prints, with significantly better results realized with the TracER 532nm and the Polilight Flare Plus 505nm. Occasionally, however, the laser emission excited the background less than the broad band choices, resulting in a slightly higher signal-to-noise ratio. This makes little or no difference on strong fingermarks, but may be critical on threshold impressions.
- Genipin produced very few positives on the treated samples, either in fluorescent or color mode, but occasional strong fluorescence was excited by the TracER 577nm laser.
- One type each of brown wrapping paper and bond paper were tested in these experiments. The many other commercial versions of these two papers may produce different results.
- It is evident that the formulations and working conditions for the two new reagents, genipin and lawsone, are still far from optimal. A comprehensive set of experiments, involving variations of solvents, concentrations, processing temperatures and humidity conditions, are required for exploiting the full potential of these reagents.
- The TracER 577nm is an effective light source for excitation of genipin.

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