Forensic Technology Testing & Evaluation Report

Forensic Technologies Center of Excellence (FTCoE)

Cooperative Agreement Award #2008-MU-MU-K003

Final Report Date: November 16, 2009

Project Title:	**Projected Start Date:**
Comparison of Monochromatic Light Source and Banded Light Source for Detection of Evidence	
Evaluation Type: (Instrument, kit, procedure, product-to-product comparison study, etc.)	**Projected End Date:**
Coherent® Semiconductor Laser vs. Rofin Polilight® Flare Plus (LED)	
Evaluation Team Leader:	**Contact Telephone:**
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Manufacturer Information for product(s) being evaluated

Manufacturer	Address	Contact Person	Phone
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Rofin Forensic	**40087 Mission Blvd, Ste 165 Fremont CA 94539**	**Keith Breeding**	**510-217-3457**

Forensic Technologies Center of Excellence (FTCoE), Managed by National Forensic Science Technology Center
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Evaluation Overview

Evaluation Summary:
(Overview of this project, including background information, objectives and forensic applications)

Argon lasers were first used for detection of fingerprints and trace evidence solely through inherent luminescence in 1977. Factors limiting their rapid acquisition by the forensic community included:

- Initial cost ($50K +)
- Operating cost
  - 3-phase power – 50-70 amps per phase
  - Water-cooled
- Reliability
- Maintenance cost
- Lack of portability
- Uniformity of light – coherent "speckling". (This problem was more or less solved by vibrating the light guide.)

Although larger police laboratories acquired lasers, the cost was perceived to be too high for use by most police agencies.

Although the first operational use of an argon laser resulted in a criminal identification, the success rate through intrinsic fingerprint fluorescence was quite sporadic compared with chemical techniques. Many of these successes, however, were not duplicated by other techniques.

So-called "Alternate Light Sources", engineered to replace lasers, first appeared in the early 1980s. This development was more or less concurrent with the combination of cyanoacrylate/dye treatment for plastics and other nonporous surfaces. Exhibits were stained with Rhodamine 6G, rinsed and viewed under laser light.

The combined process offered several advantages:

- Extended sensitivity over inherent fluorescence alone
- Extended sensitivity over glue fuming alone
- Success on additional surfaces on which laser (and all other existing techniques) had previously failed to reveal fingerprints.

Ardrox® was introduced as a dye for post-Super Glue® staining which could be excited by an ultraviolet lamp, a far less expensive solution than an argon laser. The only comprehensive and unpublished (1991) research comparing the sensitivity of Ardrox to Rhodamine 6G and BY40 revealed that Ardrox was significantly less sensitive. Nevertheless, Ardrox has remained a popular choice in many identification labs for over two decades in spite of its limited reach. In

the writer's opinion, this is because only an inexpensive ultraviolet lamp is required to excite it.

No widespread fluorescent chemical technique existed for paper exhibits until the advent of DFO in the late 1980s.

In the opinion of the writer, detection range and sensitivity became secondary to economy and ease of use. Lasers remained an expensive and largely unchosen option for most laboratories until the mid-1990s, when the YAG (Yttrium-Aluminum-Garnet) laser was introduced.

These new solid state lasers were 110V-powered, air-cooled and eminently portable, although much more expensive than a filtered lamp such as the Polilight®. The factors limiting laser acquisition were thus reduced to:

- Initial cost: $60-90K
- Reliability
- Uniformity of light (coherent speckling)

However, increase in laser acquisition remained slow, because of price and the perception that lasers and filtered lamps did essentially the same job.

Light-Emitting Diode sources (LED) entered the forensic workplace in the 1990s, and have now been refined and improved to the point where their emission is comparable in both intensity and spectral output to filtered lamps such as Polilight and CrimeScope®.

In 2006, the optically pumped semi-conductor laser (Coherent® TracER™) was introduced at lower cost than previous lasers ($45K).

Continuing anecdotal evidence during the past three decades has indicated that monochromatic light sources and sources emitting specific bands of wavelengths do not accomplish exactly the same tasks in excitation of evidence, and that each search option has the potential to reveal targets missed by the other.

Experimental Design:

Sample Collection

Fingerprint, semen, saliva and blood samples were collected on a range of surfaces.

Untreated Fingerprints

- Paper
- Plastic
- Metal
- Glass
- Tape (adhesive side)

Cyanoacrylate/Dye

- Plastic bags
- Metal
- CDs
- Glossy paper
- Foil

Porous Surfaces – (DFO and Indanedione)

- Papers
- Cardboard
- Wood

Body Fluids

- Saliva
- Semen
- Blood

Enhanced Blood Fingerprints

- Leuco Crystal Violet
- Acid Yellow

Tapes – Adhesive Side

- Tape Glo
- Acid Yellow
- Rhodamine 6G

Viewing

Samples were viewed under:

- Rofin Polilight-Flare® Plus
  - 450 nm (approximately 100nm bandwidth)
  - 505 nm (approximately 40 nm bandwidth)
- Coherent TracER OPSC Laser

Photography

Selected samples were photographed.

Comparison – Monochromatic Laser vs. Filtered Lamp vs. LED

Results obtained on each type of sample with lasers and forensic light sources were compared on the basis of:

- Target intensity
- Substrate interference

Projected Major Milestones:
Procedural outline for this evaluation:

Samples

- Cloth
  - Red, blue, striped, multi-colored pattern
  - Vinyl, face side and cloth backing
- Paper
  - White, lilac, green, pink, blue, cardboard, paper towel, Kleenex®
- Aluminum foil
- Plastic bags
  - Red, white, black trash

Saliva samples were taken from three donors and placed on each type of sample.

Semen was placed on each type of sample.

Blood drops were placed on each type of sample.

Finger impressions in blood were placed on each type of sample.

Fingerprints were placed on each type of paper and plastic sample.

Chemistry

Indanedione Stock

1 gm – Indanedione dissolved in 40 ml dichloromethane

80 ml – ethyl acetate

10 ml – glacial acetic acid

2 ml – zinc chloride stock solution

Zinc Chloride Stock

2 gm Zinc chloride

50 ml – absolute alcohol

Indanedione Working Solution

50 ml stock solution to 450 ml HFE 7100

DFO

.05 gm – DFO dissolved in 10 ml methanol

5 ml – glacial acetic acid

235 ml HFE 7100

Brilliant Yellow 40

.5 gm – 250 ml ethanol

Rhodamine 6G

.15 gm – 250 ml methanol

Acid Yellow

Prewash

11 gm – 5-sulfosalicylic acid dissolved in 500 ml distilled water

Working

.5 gm – dissolved in 25 ml glacial acetic acid

125 ml – ethanol

350 ml – distilled water

Rinse

125 ml – ethanol

25 ml – glacial acetic acid

350 ml – distilled water

LCV (Leucocrystal Violet)

2.5 gm 5-sulfosalicylic acid dissolved in 125 ml hydrogen peroxide

9 gm – sodium acetate

.25 gm LCV

Treatment

Paper samples bearing fingerprints were treated in each of the following reagents:

- Indanedione
- DFO

Plastic bag and foil samples were fumed with cyanoacrylate and sprayed with

- Rhodamine 6G
- Brilliant Yellow 40

Samples bearing blood impressions on plastic bags and foil were treated with each of the following:

- Acid Yellow
- LCV

Examination

The following were examined by TracER laser, Flare Plus 450nm and Flare Plus 505nm:

- Plastic bags and foil bearing untreated fingerprints
- Samples bearing saliva
- Samples bearing semen
- Samples bearing blood drops
- Samples bearing blood finger impressions
- Samples treated with indanedione
- Samples treated with DFO
- Samples treated with Rhodamine 6G
- Samples treated with Brilliant Yellow 40
- Samples treated with Acid Yellow
- Samples treated with LCV

Selected samples were photographed.

Product(s) Specifications:

Brief description of Product(s)/Technology/Procedure being evaluated:

Product Name(s)	**Model Number:**	**Serial/Lot Number:**	**Dimensions:**
Coherent TracER™ (semiconductor laser)			16”x14”x12”
	Cost:	**Weight:**	**Power Req.:**
	Appr. $45,000	**45 lbs**	**110V**
Storage Conditions			
Operational Conditions:			
Associated costs: *(consumables, maintenance, etc.)*			

Product Name(s)	**Model Number:**	**Serial/Lot Number:**	**Dimensions:**
Rofin Polilight® Flare Plus			22”x14”x9”
	Cost:	**Weight:**	**Power Req.:**
	Appr. $15,000	**28 lbs**	**110V**
Storage Conditions			
Operational Conditions:			
Associated costs: *(consumables, maintenance, etc.)*			

Results of Evaluation (Tables, Graphs)

Note: See Appendix to view images of all samples.

Saliva Samples

The saliva samples fluoresced weakly at best, but the optimum excitation depended in several instances on substrate and on donor. For example, samples on the vinyl cloth were visualized most distinctly with laser, followed by Flare Plus 450, with 505nm slightly less apparent.

In contrast, the samples from donors A and C on brown cardboard were not rendered visible by any of the lighting options, and the sample from donor B was slightly more distinct when illuminated by 450nm.

Certainly, the successful viewing of any fluorescent evidence is to some degree substrate dependent, but nowhere is this more evident than in the examination of weakly fluorescent body fluids like saliva and semen. The ability to use filtered lamps and LED sources at all of the exciter filter options can mitigate this limitation, but when using the laser, either it works or it doesn't.

See Figure 1 - SALIVA ON VINYL CLOTH, THREE DONORS and Figure 2 – SALIVA ON BROWN CARDBOARD, TWO DONORS

Semen

Semen fluoresces more strongly than saliva and all three light options gave satisfactory results on most substrates, but in most cases the 450nm was the most visible. Once again, the substrate fluorescence determined how easily the semen could be seen, and the different lighting options occasionally provided differing substrate fluorescence. This illustrates the value of the 450nm option on any forensic light source for a *preliminary* crime scene examination. It must be noted, however, that other choices (including the monochromatic output of the laser) may reveal important fluorescence that fluoresce poorly or not at all under 450nm illumination.

See *Figure 3 – SEMEN ON MULTI-COLORED CLOTH* and *Figure 4 – SEMEN ON STRIPED CLOTH (Note different substrate response)*

Leucocrystal Violet (LCV)

LCV is used primarily as a stain for blood enhancement but it has become known in recent years that a fluorescent mode can also be exploited, depending on the amount of blood present and the substrate.

LCV exhibits occasional red fluorescence when excited by green light, for which the TracER laser is ideally suited. The usefulness and clarity of this fluorescence vary considerably with the color of the substrate and the amount of blood in the deposited impression. Neither the 450nm nor the 505nm of the Flare Plus gave satisfactory results. When the 530nm head was used, however, the results were equal to those obtained with the laser, but the red barrier filter must be used to eliminate reflected light from the source entering the camera lens. When using the laser, either the orange or the red barrier filter can be used.

See *Figure 5 – LCV – WHITE LIGHT, LASER W/ORANGE FILTER, LASER W/RED FILTER, FLARE PLUS 530 W/RED FILTER*

Acid Yellow

Acid Yellow is used exclusively as a fluorogenic reagent for blood impressions on dark

nonporous surfaces. It would not be an effective choice for light-colored substrates, where amido black or LCV would provide excellent results. Acid yellow displays vigorous fluorescence when excited by blue light, for which the Flare Plus 450nm is ideally suited. Although some quiet fluorescence is noted under laser excitation, the results are far below those achieved with blue light. As powerful and useful as the laser is, its emission is simply in the wrong part of the spectrum for satisfactory results with acid yellow.

See *Figure 6 – ACID YELLOW ON GREEN GARBAGE BAG, WHITE LIGHT, FLARE PLUS 450, LASER*

Indanedione

Indanedione is an excellent fluorogenic reagent for paper and cardboard, which has been formally designated as the reagent of choice for paper exhibits by an increasing number of police and forensic agencies including the US Secret Service and the Australian Federal Police. The product of the reaction with amino acids has a broad absorption band, excited admirably by most light sources emitting in the blue-green region of the spectrum. One must not consider only the target reaction. It is always the *signal-to-noise ratio* that determines how much clear detail is revealed. The differences in results spring from the substrate response to the respective light sources and their outputs. In these experiments, the laser and the Flare (at 450nm and 505nm) both performed well, but subtle differences in the amount of substrate fluorescence can be observed. Occasionally the laser excites less background fluorescence than the Flare Plus.

As mentioned, these differences may be slight, and in the case of strong exemplar fingerprints, of no significance. The differences can have considerable impact with faint, borderline impressions, for which it may be necessary to increase the contrast in the image after photography.

The difference in background fluorescence is seen clearly in the example of indanedione on paper towel and newsprint, between the images captured by laser and those captured by Flare Plus at 450nm and 505nm, respectively.

Substrate fluorescence may be reduced or eliminated in some instances by merely changing from an orange barrier filter to a red one.

See Figure 7 – INDANEDIONE ON BROWN CARDBOARD, WHITE LIGHT, LASER W/ORANGE FILTER, LASER W/RED FILTER, FLARE PLUS 505 W/ORANGE FILTER, FLARE PLUS 530 W/RED FILTER

Figure 8 – INDANEDIONE ON KLEENEX®, WHITE LIGHT, LASER, FLARE PLUS 450, FLARE PLUS 505

Figure 9 – INDANEDIONE ON PAPER TOWEL, WHITE LIGHT, LASER, FLARE PLUS 450, FLARE PLUS 505

Figure 10 – INDANEDIONE ON NEWSPRINT, WHITE LIGHT, LASER, FLARE PLUS 450, FLARE PLUS 505

Figure 11 – ENLARGEMENT OF INDANEDIONE ON NEWSPRINT – LASER, FLARE PLUS 450, FLARE PLUS 505

Figure 12 – INDANEDIONE ON PINK INDEX CARD, WHITE LIGHT, LASER, FLARE PLUS 505

Untreated Fingerprints

Fingerprints were placed on green garbage bags and on white grocery bags. They were then examined by laser and Flare Plus 505 nm. Inherently, fluorescing fingerprints are not an everyday occurrence, but many high profile cases have profited by their recovery since the inception of luminescence as a detection strategy in 1977.

Fluorescence of this kind is rarely intense, and is more often positioned on the very threshold of vision. Many analysts and scientists believe that most if not all naturally fluorescing fingerprints fluoresce because of contaminants rather than perspiration ingredients. This does not affect the demonstrative value of such evidence, but rather underlines the value of sequential processing.

Many such impressions discovered during actual investigations were not visualized by any other process. If it is indeed true that intrinsically fluorescing ridge detail is almost invariably due to contamination, such impressions are not likely to be discovered by chemical techniques which target such natural components as lipids, amino acids, urea and sebaceous oil.

See Figure 13 – UNTREATED PRINT ON PLASTIC BAG A, FLARE PLUS 505, LASER

Figure 14 – UNTREATED PRINT ON PLASTIC BAG B, FLARE PLUS 505, LASER

Figure 15 – UNTREATED PRINT ON PLASTIC BAG C, FLARE PLUS 505, LASER

Post-Evaluation Findings

Strengths/Results & Areas for Improvement:

Polilight-Flare® Plus

The Flare Plus offers the user a wide range of excitation options, at substantive power levels, and without the requirement for electrical power (unlike larger units like Crime Scope and Polilight), thus allowing light examination at remote scenes. It is less bulky than larger plug-in units and, in the writer's opinion, just as easy to use.

Photography is accomplished easily, but photography for this project was done by hand-holding the light source. The Flare Plus would be greatly improved by addition of a tripod mount for hands-free operation.

Coherent TracER Laser

The monochromatic output of the laser is unsurpassed for detection of untreated fingerprints. Also, its monochromatic output occasionally reveals evidence without as much background excitation as the Flare Plus or other broad band sources.

Although it can also be operated by battery without the need for electrical power, the case is somewhat bulky and awkward. A re-design of the case (more rectangular) with wheels would improve its crime scene presence immensely.

The laser is a powerful tool, but limited at present to physical evidence revealed by 532nm emission. Monochromatic output at different points in the spectrum would excite other types of evidence not currently reached by the 532nm version. This is currently available with a separate laser at 460nm.

Limitations of Technology:

1. It can be seen repeatedly that no lighting option – either the banded emission or the single laser line – always produces the best results. The clarity of the target is dependent not only on its fluorescent response but also that of the substrate on which it is found. A band of excitation with a peak wavelength of 450 nm will occasionally provoke a different fluorescent response in a substrate than one centered at 505 nm, or the monochromatic laser output at 532 nm.

2. The inherent energy (and consequently the potential to excite fluorescence) decreases as the wavelength increases. Examination with a band of light 100 nm wide, centered at 450 nm will cause many compounds to fluoresce, both target and substrate. It is immensely valuable to examine evidence with banded light of different wavelengths, resulting in the optimal signal-to-noise ratio.

3. It can be concluded therefore that even though one light source may clearly excite a given target more efficiently than the others, it may also excite undesirable obstructing fluorescence on some substrates, and consequently, may not provide the best overall results. Another light source, while perhaps not exciting as strong a fluorescent response in the target, may provide the best overall result *for that substrate* by exciting the substrate minimally or not at all.

4. Forensic specialists are trained in signal recognition. Long before a conclusion is drawn as to the donor of a fingerprint, it must be detected and recognized as friction ridge

detail. Fingerprints, either patent or revealed by chemistry and light, are often found (or not found) on the very threshold of visual perception. For this reason, it is critical to employ all of the complementary tools available to extend our detection reach and minimize the chances of missing crucial evidence.

Training Requirements:

As can be seen in the figures (see Appendix), positive results can be subtle, and dependent on using the optimum combination of excitation and barrier filter. A basic knowledge of the action of light will allow the user to troubleshoot and problem-solve effectively.

This knowledge should include:

- ✓ Meaning of terms, including: luminescence, fluorescence, Stokes shift, absorption, reflection

In order to record all detail detected by eye, the user should have complete familiarity with the camera being used, and a knowledge of exposure and filters.

Health and Safety Issues:

The health and safety issues associated with chemistry used aside, the one concern with high intensity light sources is eye safety.

Strict adherence to the following will protect anyone in the examination room from injury.

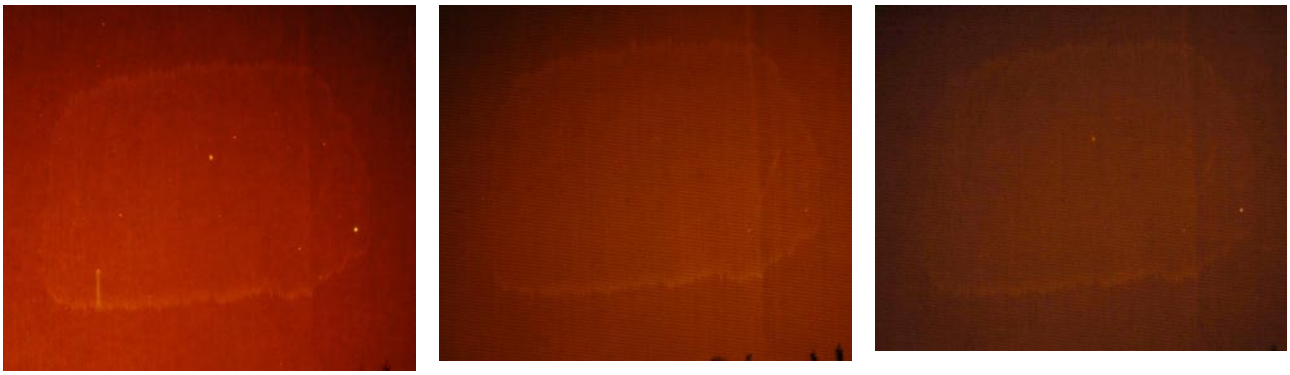
1. Always wear goggles when operating the laser.
2. Ensure that the examination room is closed, and remains closed during operation, and that a warning sign is posted, saying “laser in use – do not enter”.
3. Reduce or eliminate reflective surfaces in the examination room. The examination process is improved by covering the table with black paper.
4. When more than one person is in the room during operation, state “Goggles on!”, before turning on laser.

APPENDIX — Figures 1-15

SALIVA ON VINYL CLOTH

LASER 450NM 505NM

DONOR A



DONOR B

DONOR C

Figure 1 Saliva On Vinyl Cloth, Three Donors

SALIVA ON BROWN CARDBOARD

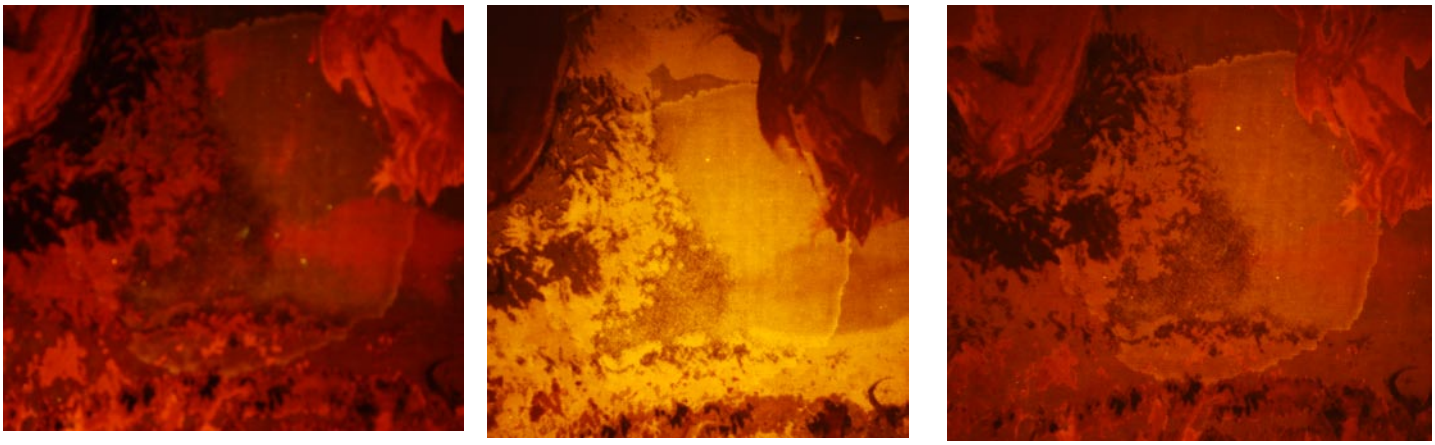
LASER 450NM 505NM

DONOR A

DONOR B

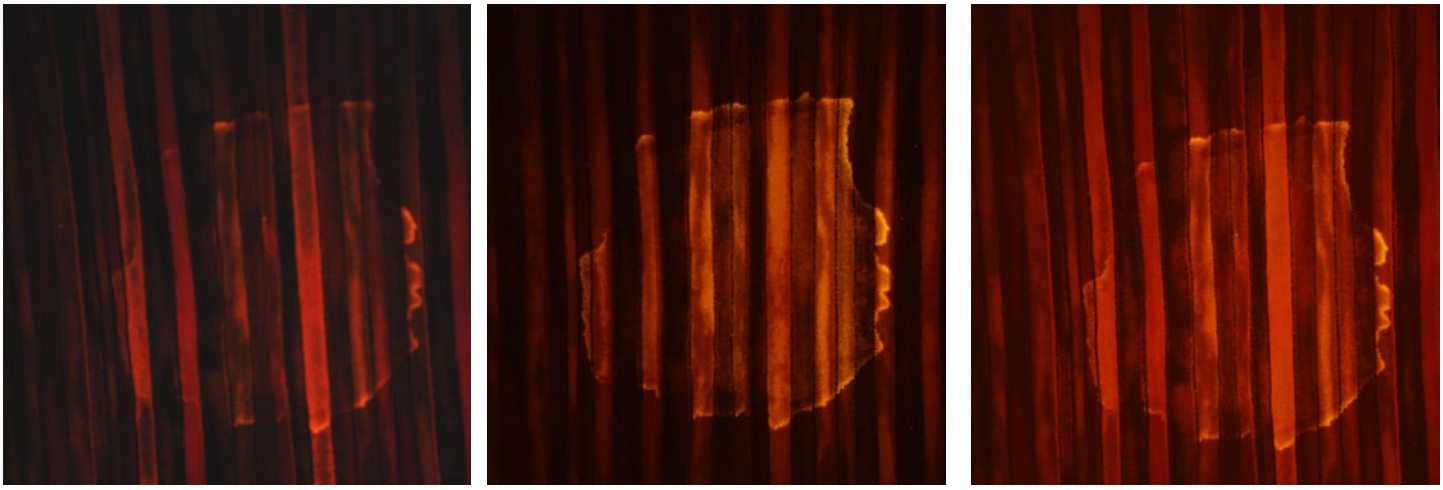
Figure 2 Saliva on Brown Cardboard, Two Donors

SEMEN ON MULTI-COLORED CLOTH



LASER 450NM 505NM

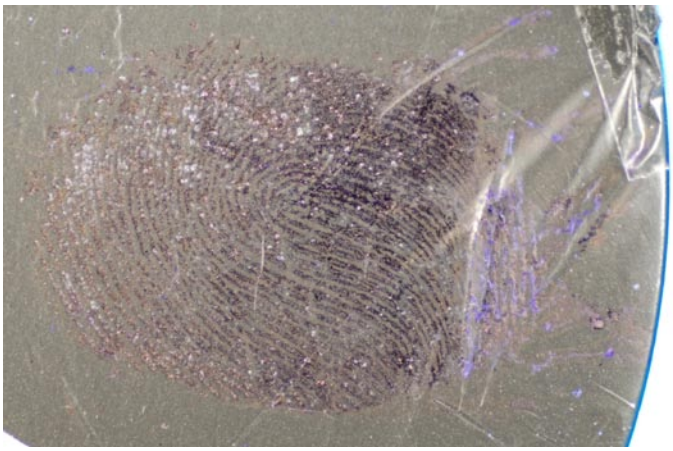
Figure 3 Semen On Multi-Colored Cloth, (Note Different Substrate Response)



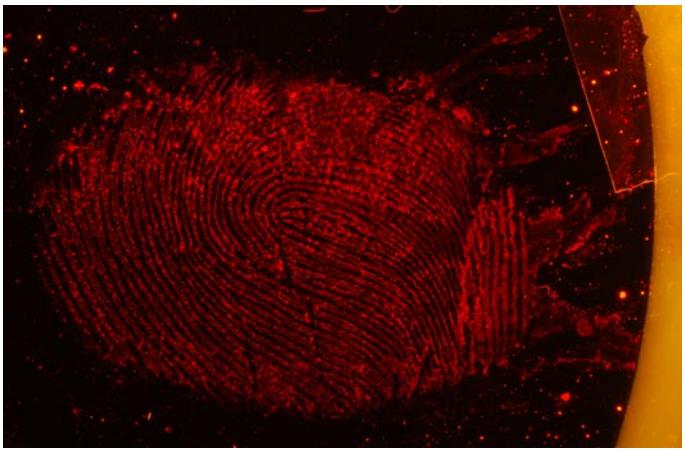
LASER 450NM 505NM

Figure 4 Semen on Striped Cloth

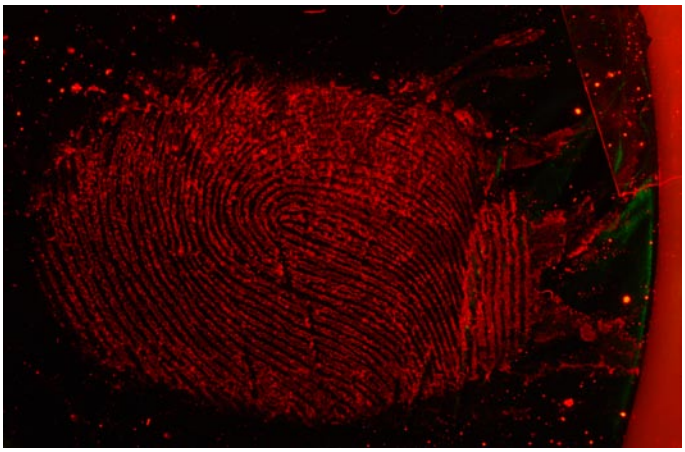
LCV ON GREEN GARBAGE BAG



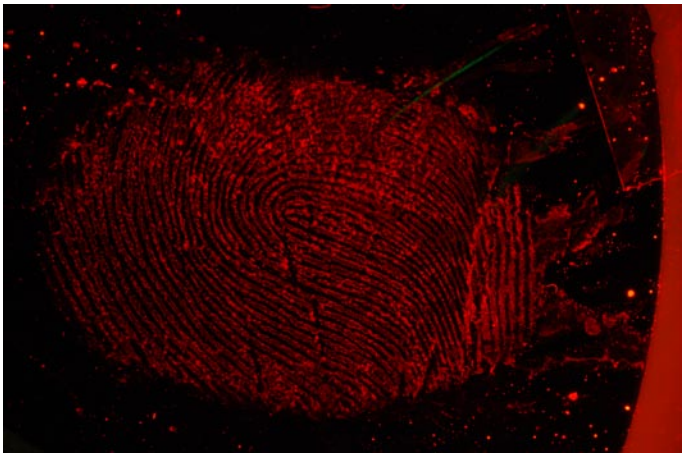
WHITE LIGHT



LASER WITH ORANGE BARRIER FILTER



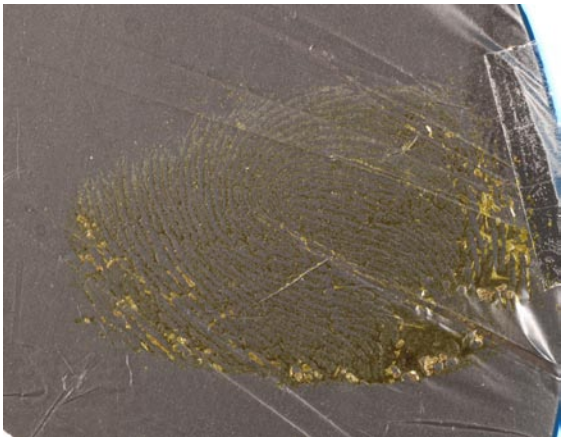
LASER WITH RED BARRIER FILTER



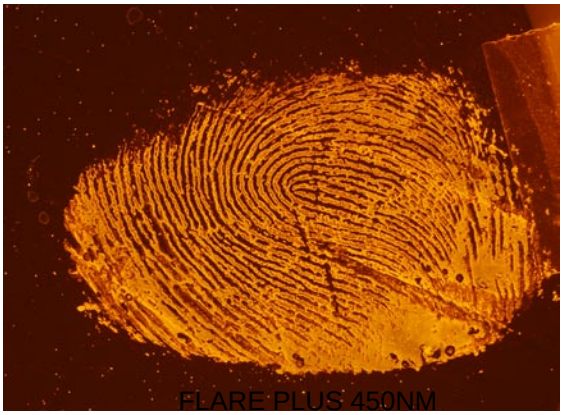
FLARE PLUS 530NM WITH RED BARRIER FILTER

Figure 5 LCV – White Light, Laser W/Orange Filter, Laser W/Red Filter, Flare Plus 530 W/Red Filter

ACID YELLOW ON GREEN GARBAGE BAG



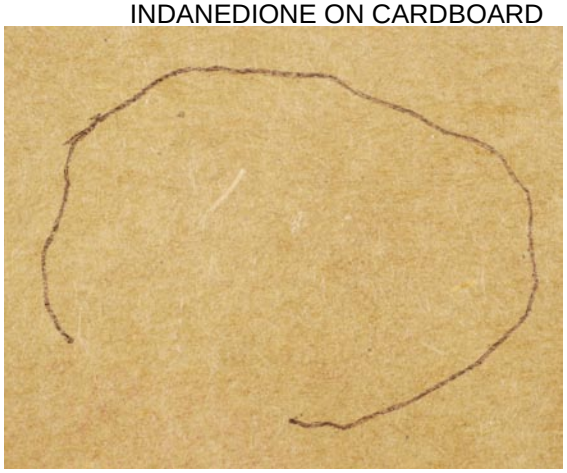
WHITE LIGHT



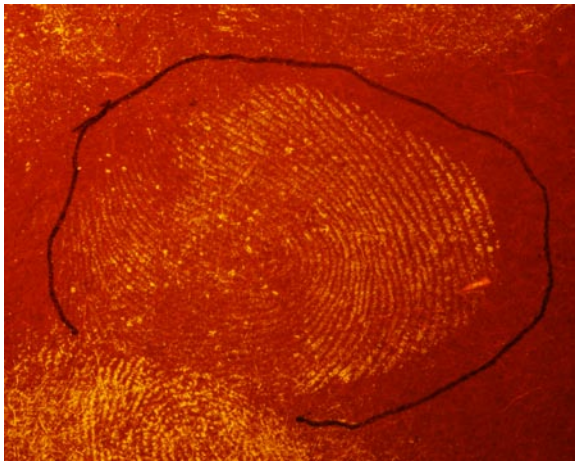
LASER

Figure 6 Acid Yellow On Green Garbage Bag, White Light, Flare Plus 450, Laser

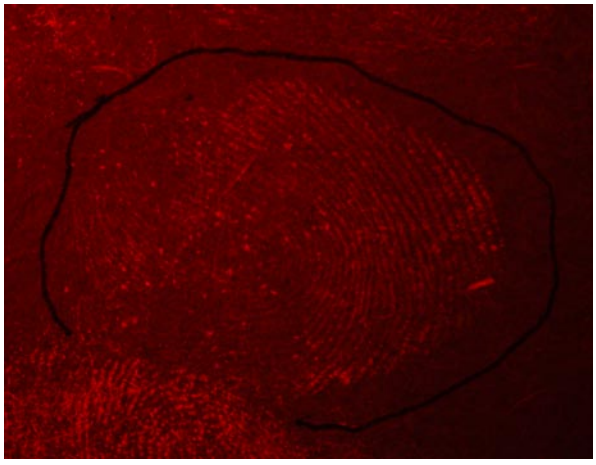
INDANEDIONE ON CARDBOARD



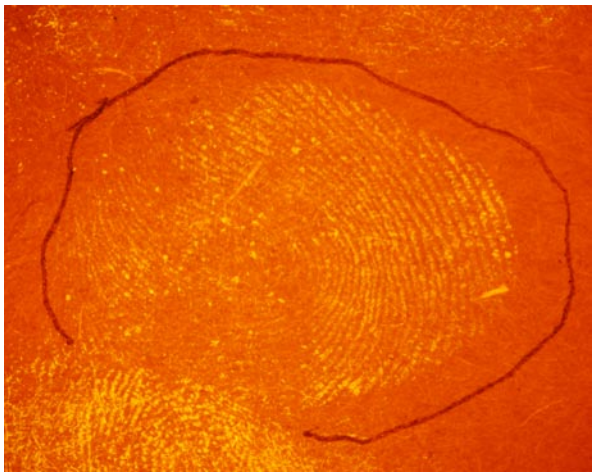
WHITE LIGHT



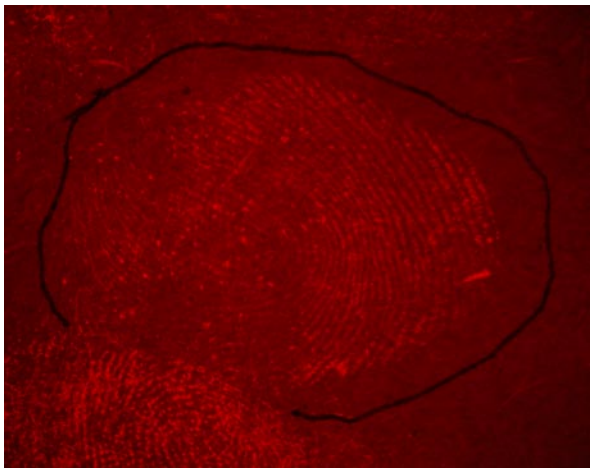
LASER – ORANGE FILTER



LASER – RED FILTER



FLARE PLUS 505 NM

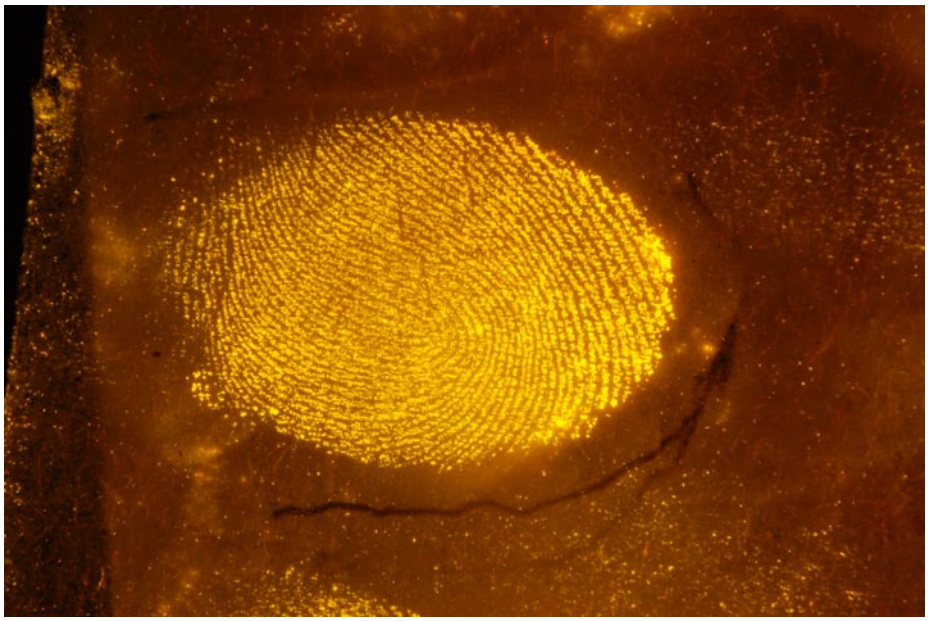


FLARE PLUS 530NM WITH – RED FILTER

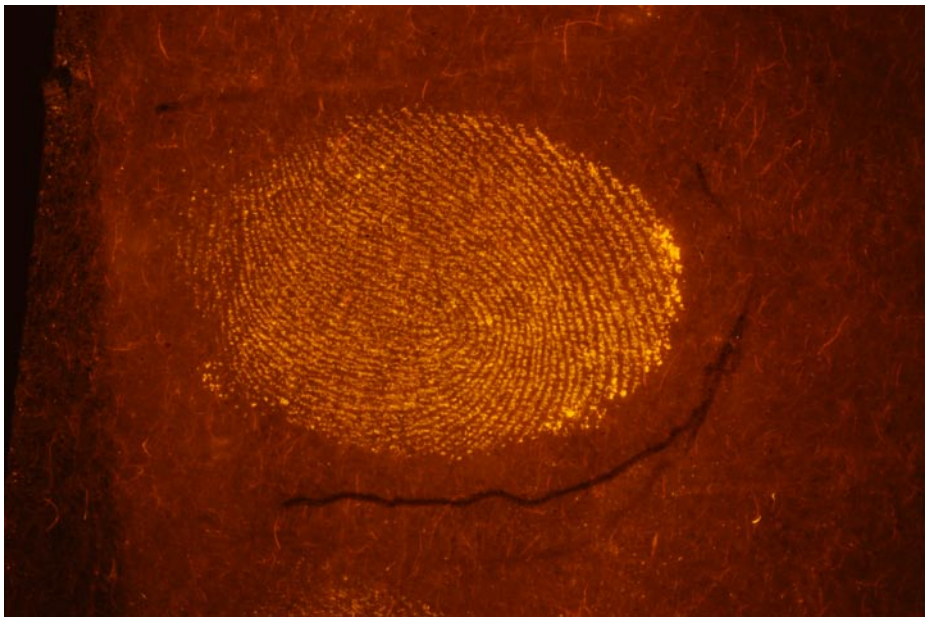
Figure 7 Indanedione on Brown Cardboard, White Light, Laser W/Orange Filter, Laser W/Red Filter, Flare Plus 505 W/Orange Filter, Flare Plus 530 W/Red Filter

INDANEDIONE ON KLEENEX

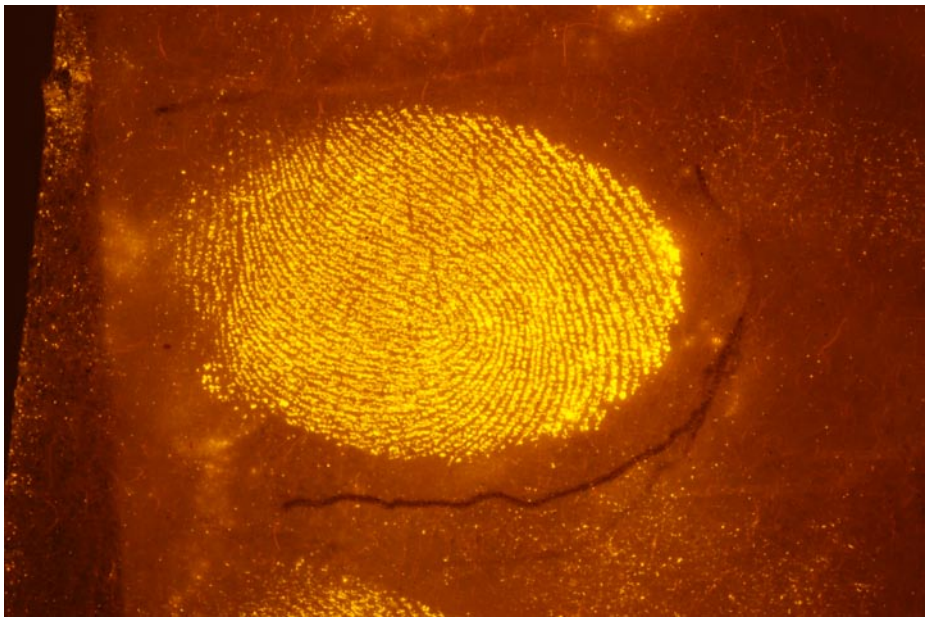
WHITE LIGHT



LASER

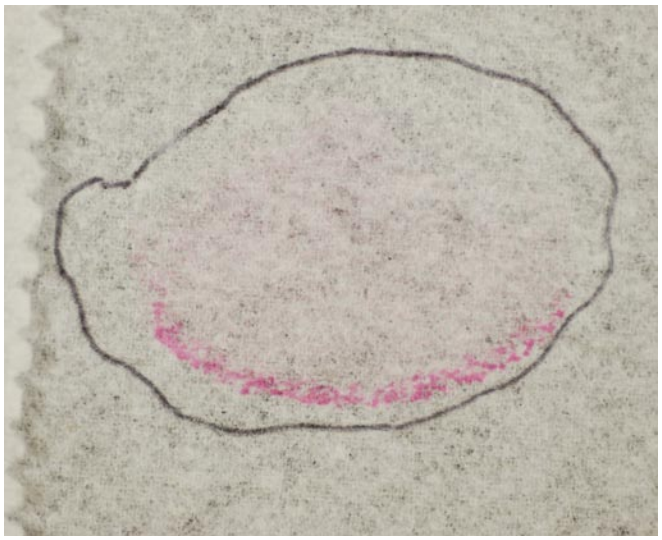


FLARE 450NM

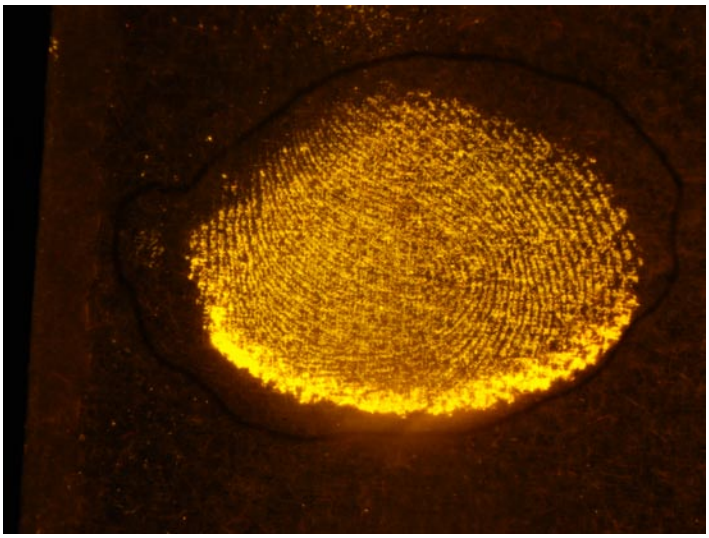


FLARE 505

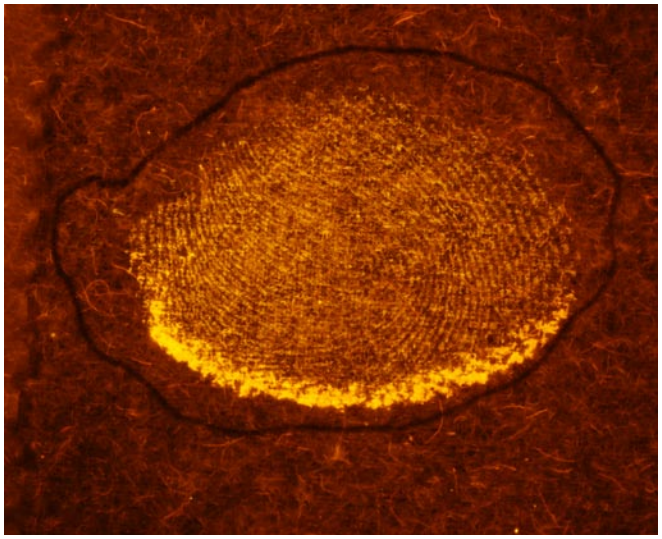
Figure 8 Indanedione on Kleenex, White Light, Laser, Flare Plus 450, Flare Plus 505 PAPER TOWEL



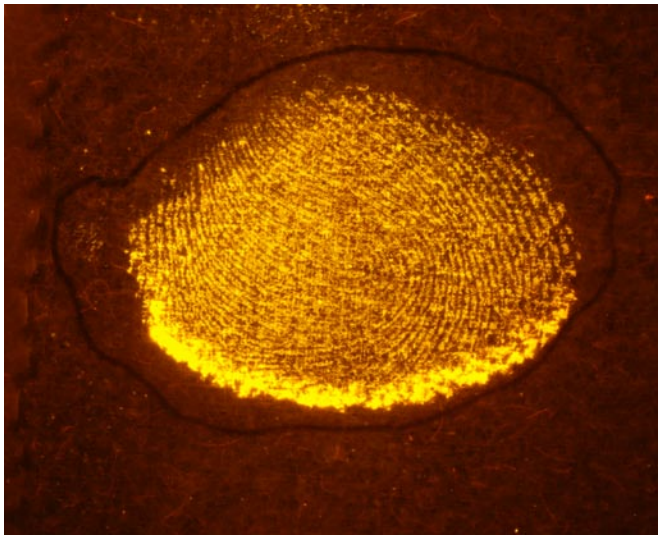
WHITE LIGHT



LASER



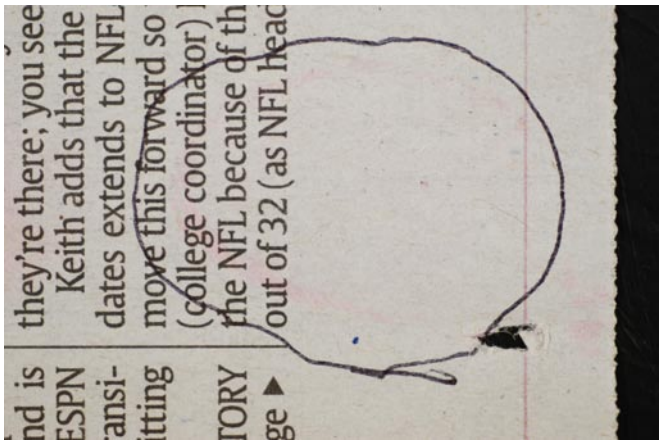
FLARE PLUS 450 NM



FLARE PLUS 505 NM

Figure 9 Indanedione on Paper Towel, White Light, Laser, Flare Plus 450, Flare Plus 505

NEWSPRINT



WHITE LIGHT

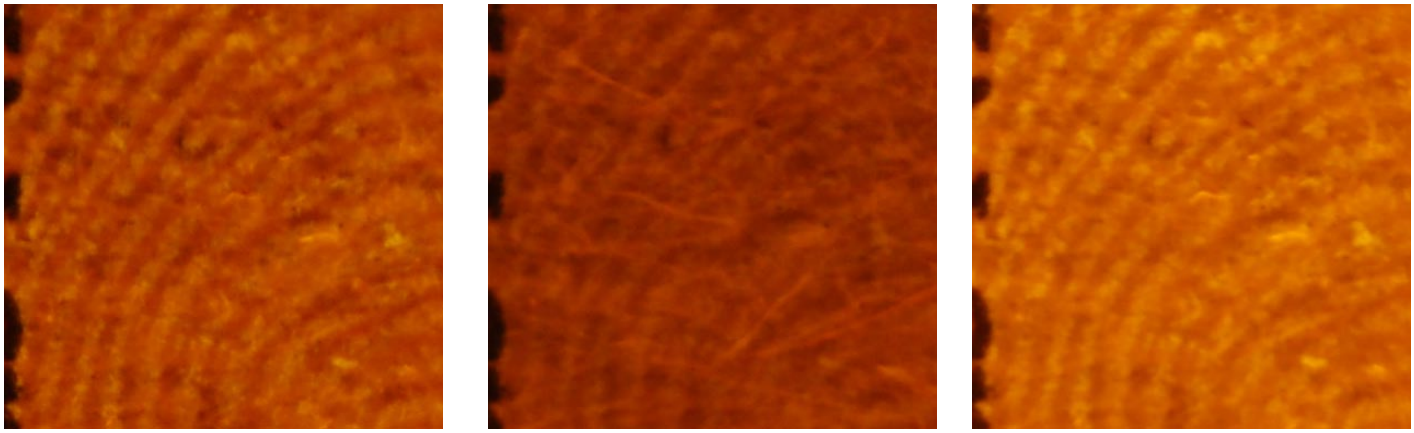
LASER

FLARE PLUS 450

FLARE PLUS 505

Figure 10 Indanedione On Newsprint, White Light, Laser, Flare Plus 450, Flare Plus 505

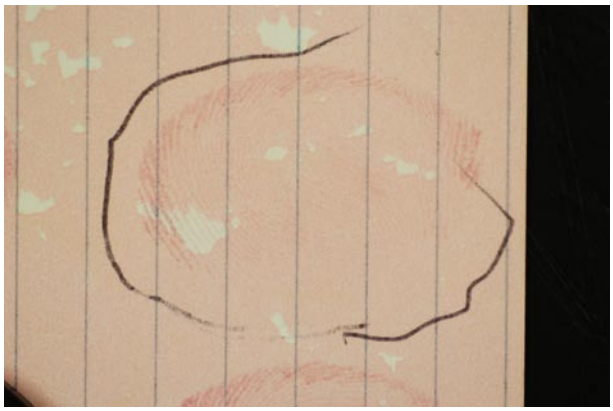
ENLARGEMENT



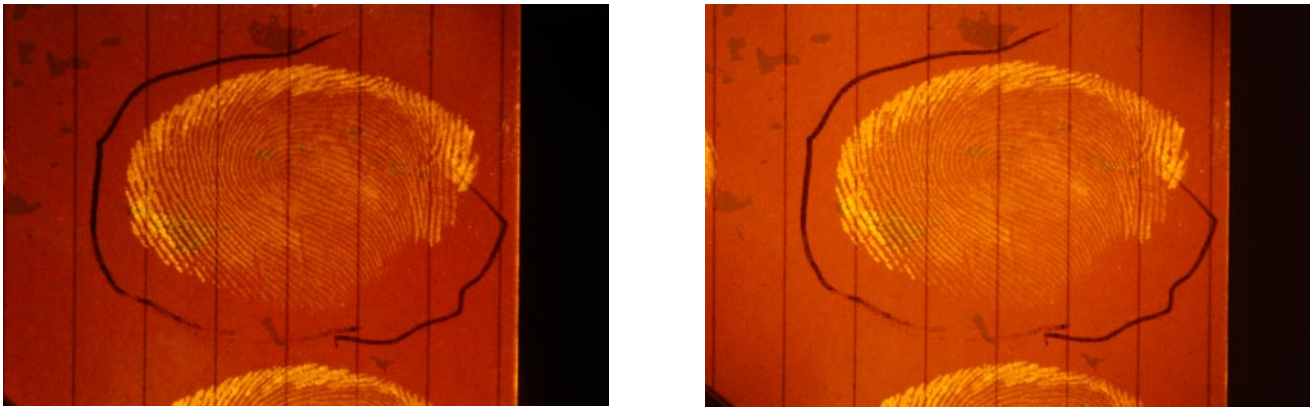
LASER | FLARE PLUS 450NM | FLARE PLUS 505NM

Figure 11 Enlargement of Indanedione on Newsprint – Laser, Flare Plus 450, Flare Plus 505

PINK INDEX CARD



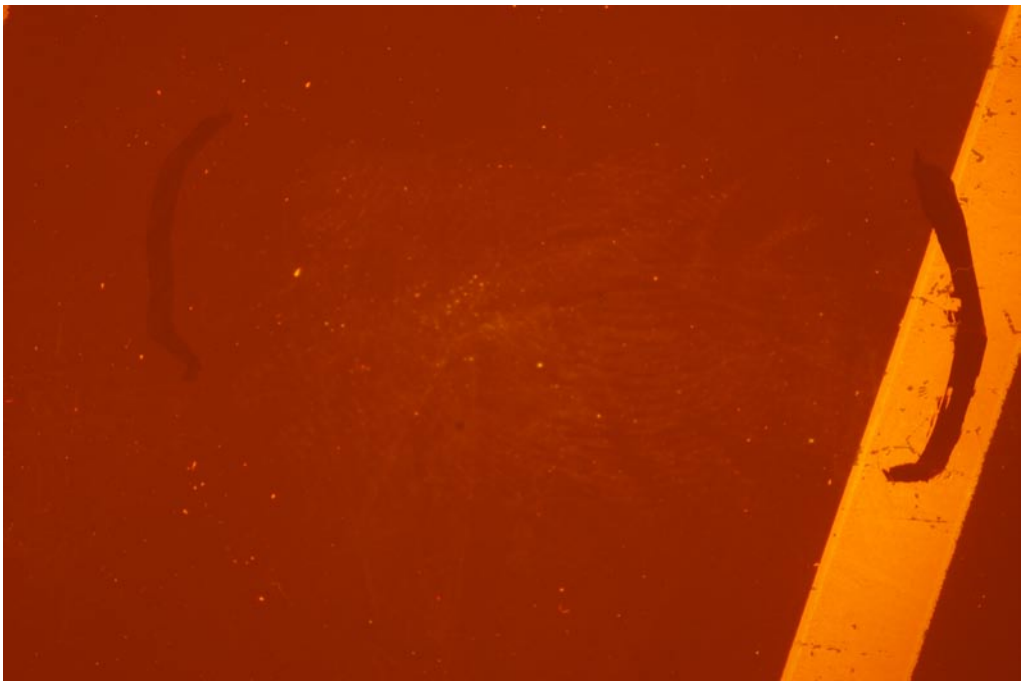
WHITE LIGHT



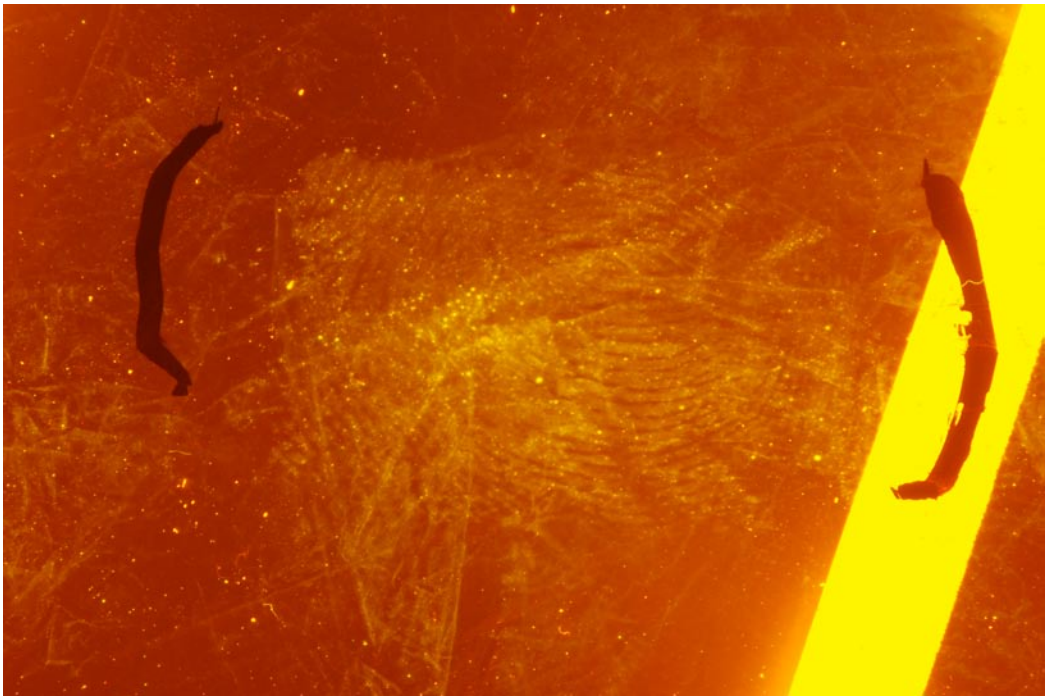
LASER | FLARE 505 NM

Figure 12 Indanedione On Pink Index Card, White Light, Laser, Flare Plus 505

UNTREATED FINGERPRINTS ON PLASTIC BAGS

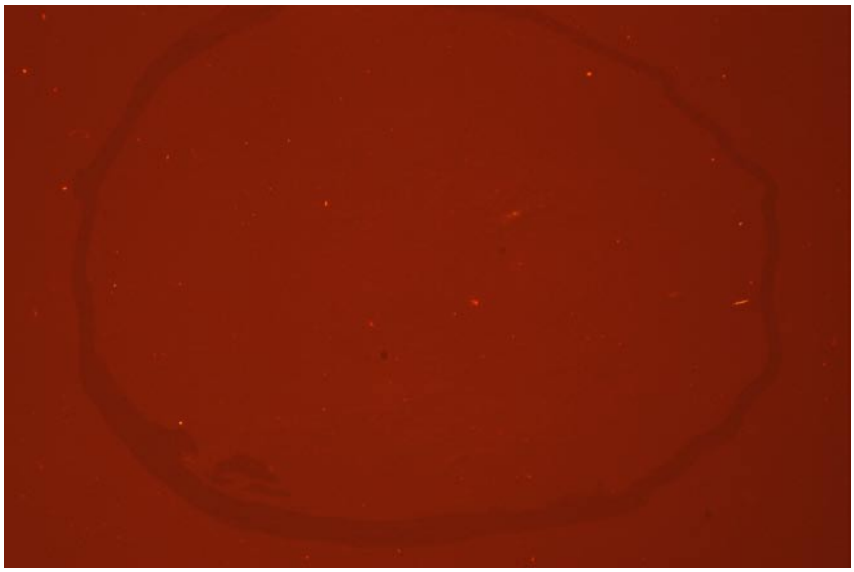


FLARE PLUS 505 NM

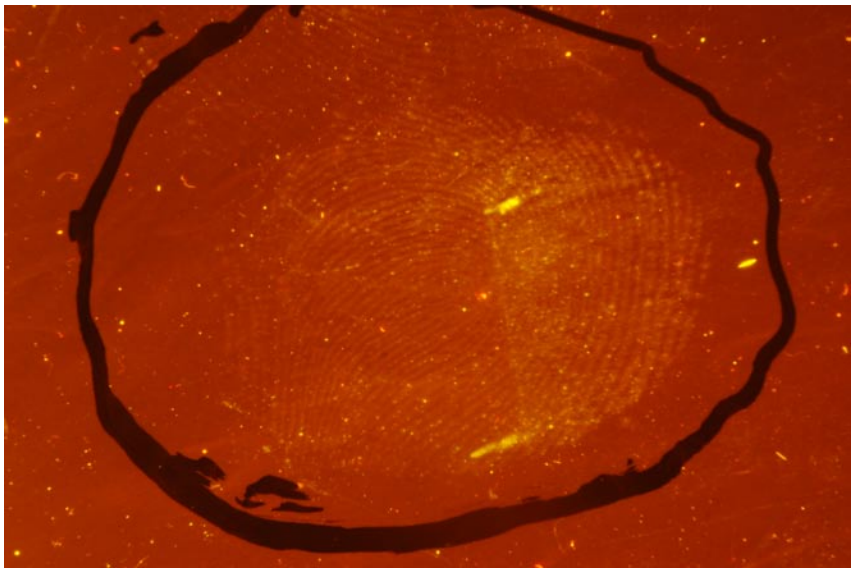


LASER 532 NM

Figure 13 Untreated Print on Plastic Bag A, Flare Plus 505, Laser

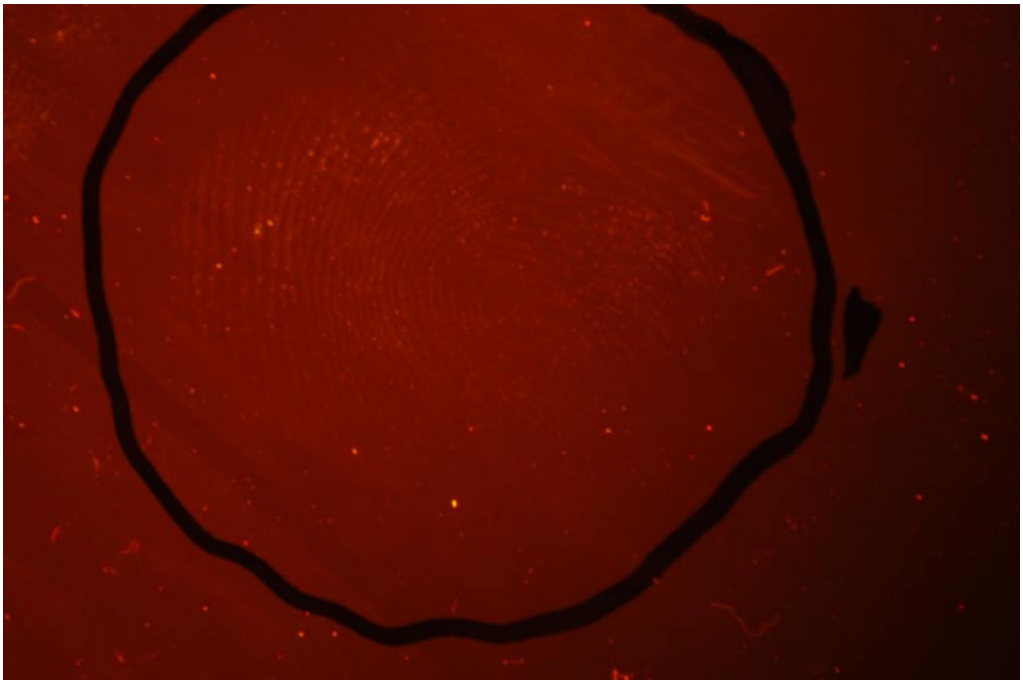


FLARE PLUS 505 NM

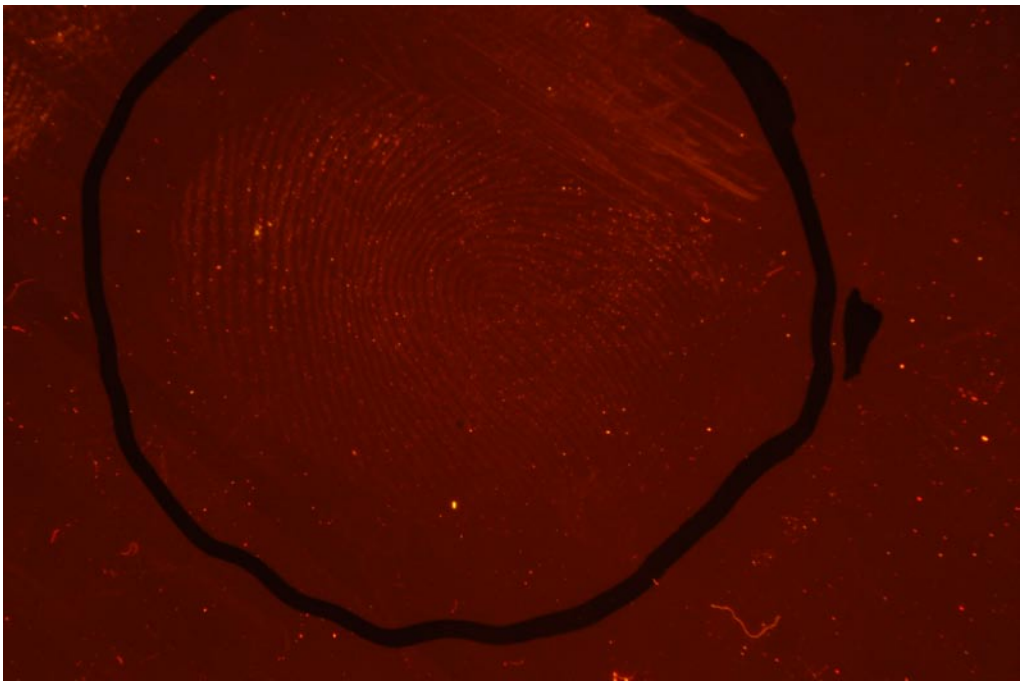


LASER 532 NM

Figure 14 Untreated Print on Plastic Bag B, Flare Plus 505, Laser



FLARE PLUS 505 NM



LASER 532 NM

Figure 15 Untreated Print on Plastic Bag C, Flare Plus 505, Laser