Chapter 2: Finger mark examination techniques within scope of ISO 17025

2.1 Visual examination

1. History

1.1. Visual examination was the first technique proposed for the detection of fingerprints, with Henry Faulds suggesting the use of finger marks in blood, impressions in clay or marks left on glass for identification of criminals in his letter to the journal *Nature* in 1880. Many of the early landmark cases in fingerprint identification involved marks detected visually [1]; in Argentina in 1892 Vucetich used a mark deposited in blood on a door frame to disprove an account of a murder; in 1897 fingerprints in blood on a book cover were used to identify a murderer in India; and in 1902 impressions of fingerprints in paint were used to identify a burglar in the first trial using fingerprint evidence in the UK.

1.2 Detection of a mark by visual examination did not necessarily mean that it could be easily captured. In many cases the lighting conditions required to detect the mark were difficult to recreate and maintain for photography, but as the use of fingerprint evidence increased a range of techniques were developed or adapted for the photography of both developed and latent marks. Those described for operational use in 1954 [2] included transmitted light, vertical/specular illumination, dark ground illumination, oblique illumination, oblique top illumination and duo filtering.

1.3 Practical examples of the use of backlighting, vertical/specular illumination and oblique illumination were presented in subsequent publications [3,4]. The detection of fingerprints in both grease and dust was demonstrated using the range of lighting techniques above. Olsen [3] also recommended visual examination of metals and firearm articles for latent prints that may not be developed by powdering, with marks occasionally being etched into metal by the fingerprint constituents or ridge impressions left in the oil coatings often found on firearms. Pfister subsequently reported the application of specular lighting techniques using a semi-silvered mirror for the capture of latent fingerprints on glossy surfaces [5].

1.4 Other photographic techniques such the use of polarising filters [6] began to be employed in the imaging of latent fingerprints, improving the contrast between the fingerprint ridges and the background by suppressing the reflections from the background regions. A combination of polarisation and specular reflection techniques has recently been suggested for the detection of latent fingerprints [7]. The use of specialist tilt/shift lenses has also been demonstrated for the capture of marks on mirrors, where the image of the mark may otherwise be obscured by background reflections [8].

1.5 It has also been proposed that marks detected by visual examination need not always be photographed in situ; if it is considered that powdering or chemical development would be of no benefit and photography is difficult, lifting of the mark may be carried out using either transparent lifting tape or gelatine lifters (black, white or transparent) [9]. Lifting of latent marks, either after visual examination or as a speculative technique, should not be carried out as an alternative to treatments such as powdering if the application of a development technique is feasible. The Home Office Centre for Applied Science and Technology (CAST) has recently carried out a comparison of the effectiveness of gel lifting and powdering for development/capture of latent marks [10] and has demonstrated that powdering is the more effective process.

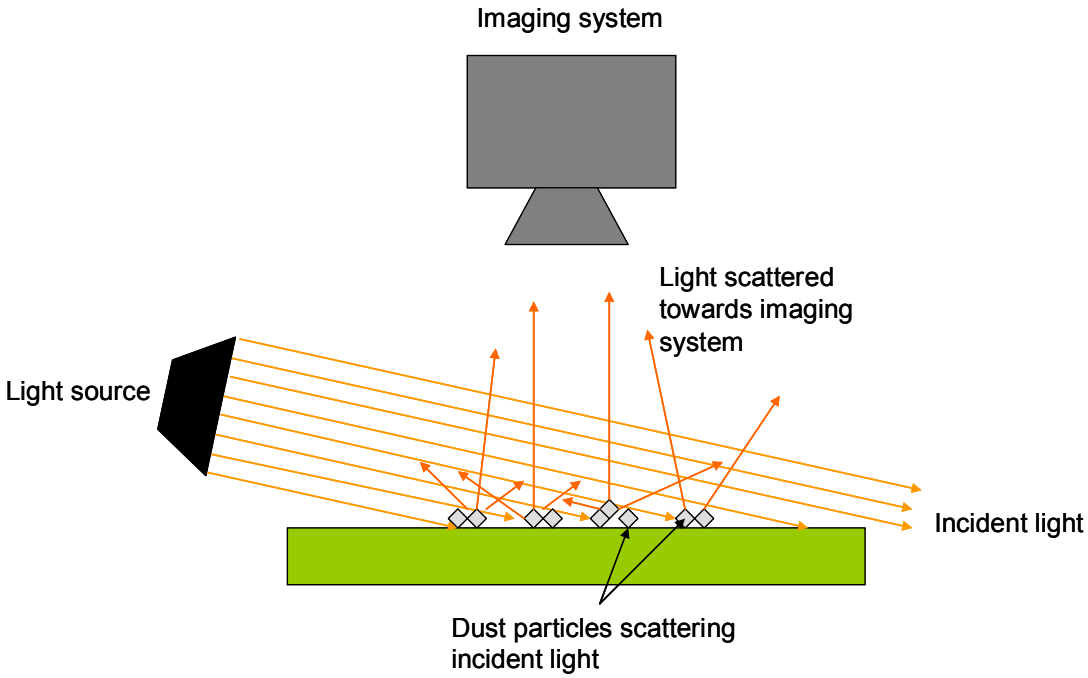
1.6 It has long been recognised that in some circumstances latent fingerprints may be developed by the environment they have been exposed to and fingerprints developed by heat have been found on paper articles at arson scenes [3]. Recent studies by CAST and others have found that there are a wide range of mechanisms by which fingerprints can be developed by the soot and heat at arson scenes [11-14], and visual examination of articles recovered from such scenes is essential.

2. Theory

2.1 The principle of visual examination is to utilise lighting in such a way as to provide as much contrast as possible between fingerprint ridges and the background, if possible suppressing any patterned backgrounds. For the initial detection of marks this is done by trying different lighting angles, but once a mark has been located there are several techniques that can be used to capture it in the optimum way. Some of these are described below, together with the situations that they are most appropriate for.

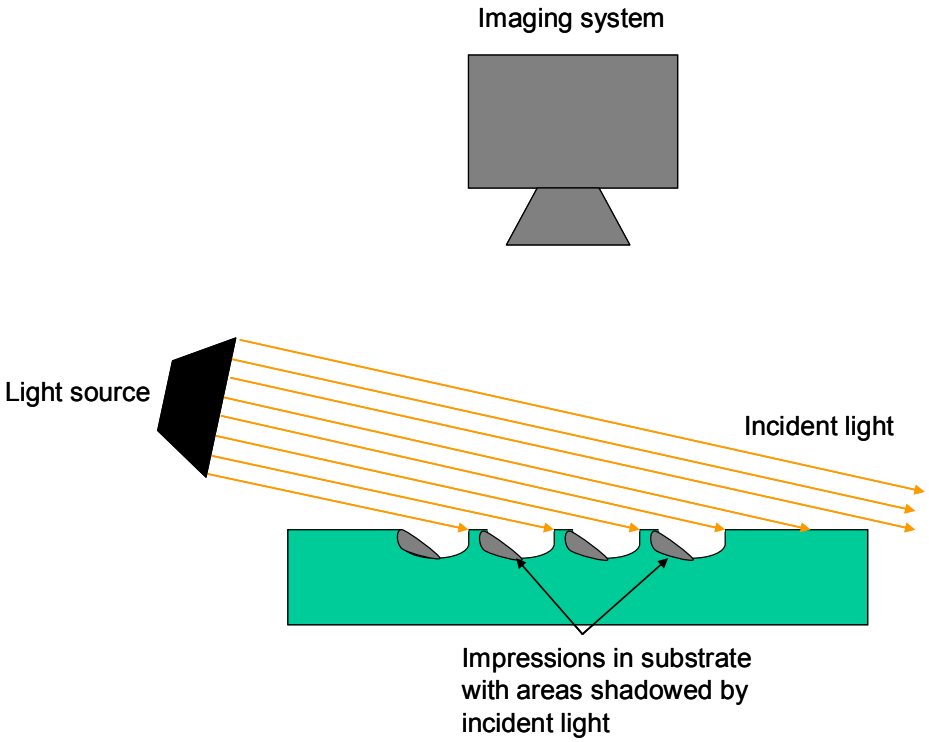
2.2 Oblique illumination

Oblique illumination may be used to capture marks where fingerprints are deposited in dust. The low angle illumination is scattered by particles of dust on the surface being examined, resulting in more light reaching the imaging system from these regions than in areas where no dust is present.



Schematic diagram illustrating the use of oblique lighting to detect marks deposited in dust

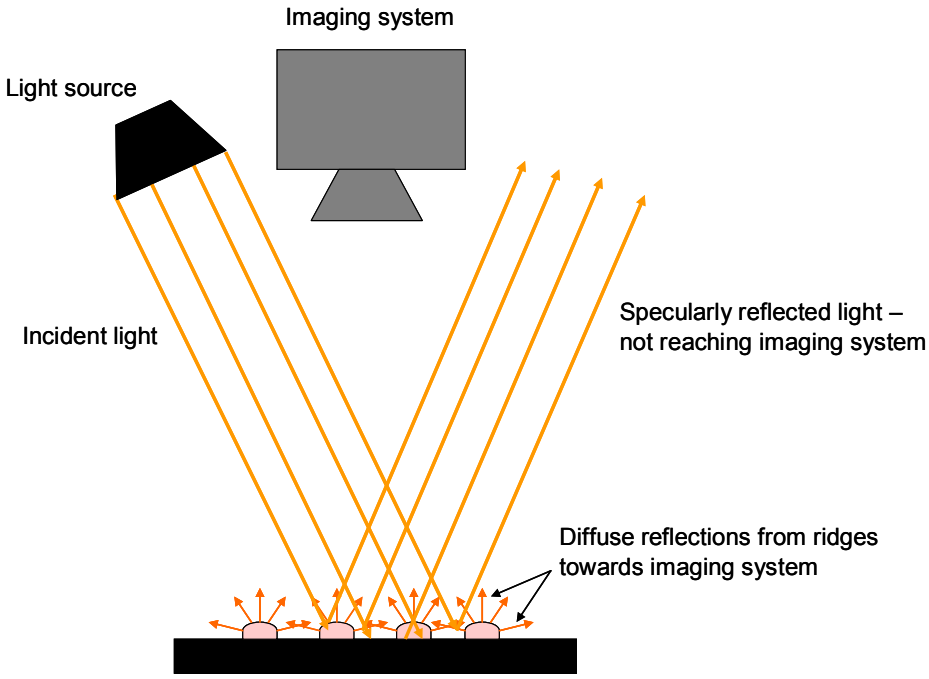
2.3 Oblique illumination can also be used in the capture of fingerprint impressions in wax or putty. In this case the low angle illumination casts shadows in the depressions left by the fingerprint ridges, thus aiding in their visualisation.



Schematic diagram illustrating the use of oblique lighting to detect marks left as impressions in a soft surface

2.4 Specular (oblique top) illumination

Specular illumination can be used for latent marks or marks in contaminant on reflective surfaces. It is essentially the opposite of oblique illumination, with the light source being placed at a high illumination angle in close proximity to the imaging system. Where light falls upon a reflective region of the background, it is specularly reflected at an angle where the reflected light does not reach the imaging system. Where light falls upon fingerprint ridges, it is either scattered or diffusely reflected, resulting in some light being reflected to the imaging system. The ridges will therefore appear lighter than the background in the image.

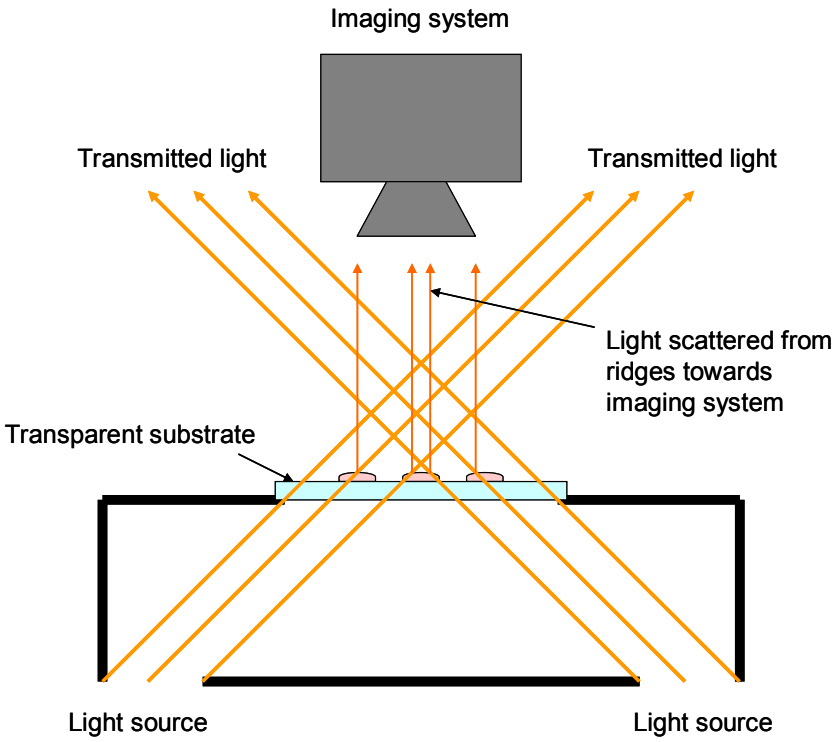


Schematic diagram illustrating the use of specular illumination to detect marks on smooth, reflective surfaces

2.5 This principle is utilised in the BVDA GLScan system, developed for the imaging of trace evidence lifted on black gelatine lifters [15].

2.6 Dark field illumination

Dark field illumination is suited to cases where fingerprints in sweat, oil or grease are present on transparent substrates, such as glass or plastic packaging. The sample is illuminated from underneath at oblique angles. In regions with no fingerprint deposit, light is transmitted and does not reach the imaging system Where there is a fingerprint deposit present the light is scattered, some of it reaching the imaging system. The resultant image shows light fingerprint ridges against a dark background.

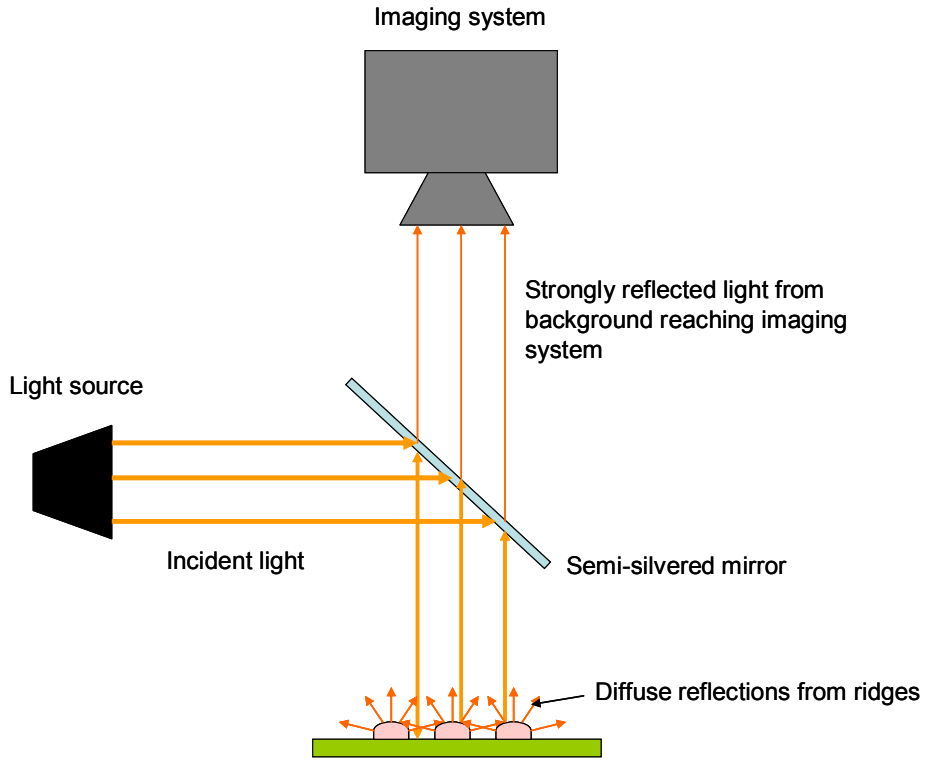


Schematic diagram illustrating the use of dark field illumination to detect marks on transparent substrates

2.7 Co-axial illumination

Co-axial illumination can be used where a latent mark or a mark in contaminant is present on a patterned, reflective background. A semi-silvered mirror at 45º to the axis of the imaging system is used essentially to provide co-axial illumination. The incident light is reflected downwards onto the sample. Where it meets the reflective surface it is strongly reflected and some passes through the semi-silvered mirror to reach the imaging system. Where the light hits ridges, it is scattered or a diffuse reflection occurs. The amount of light reflected back towards the imaging system from these regions is correspondingly less, and the fingerprint will appear as dark ridges against a light background.

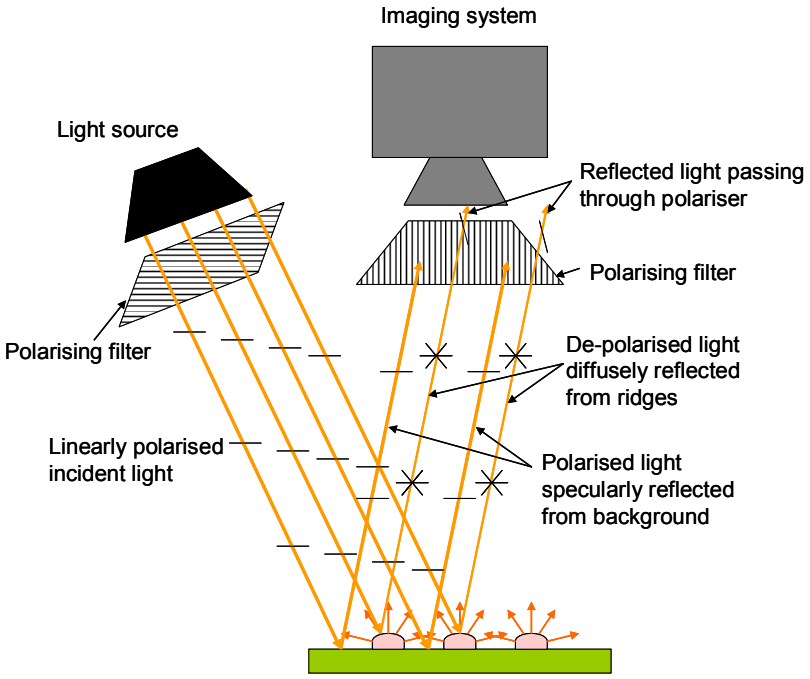
Several commercial systems have been developed incorporating co-axial or epitaxial illumination although these are mostly marketed for machine vision applications and none has been widely adopted for finger mark detection and imaging.



Schematic diagram illustrating the use of co-axial illumination to detect marks on smooth, reflective surfaces

2.8 Polarised light

Polarised light can also be used to detect a latent mark or a mark in contaminant on a reflective background. A linear polarising filter is used in front of the light source to produce linearly polarised light. When this reaches the reflective surface it is reflected and retains its polarisation. Where it hits the finger mark ridges it may be scattered or diffusely reflected, resulting in a depolarised component of light being reflected from the surface. A cross-polarised filter is placed in front of the imaging system, which blocks the specularly reflected light and allows a component of the de-polarised light through, resulting in an image with light ridges against a dark background.



Schematic diagram illustrating use of cross-polarised light to detect marks on reflective backgrounds

3. CAST processes

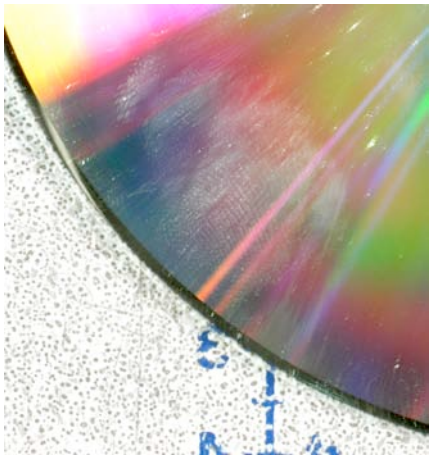
3.1 The CAST *Manual of Fingerprint Development Techniques* [9] identifies five generic types of fingerprint that may be visible.

- Type 1 – where the fingerprint is present in a semi-transparent material, such as sweat, oil or grease.
- Type 2 – where the fingerprint is deposited in a coloured material, such as blood, ink or paint.
- Type 3 – where the fingerprint is in dust.
- Type 4 – where the fingerprint is present as a result of a reaction between a fingerprint and the surface, e.g. fingerprints visible on ferrous, silver and copper articles as a result of surface corrosion or tarnishing.
- Type 5 – where there are fingerprint impressions in wax or putty.

Subsequent to the work carried out on articles recovered from an arson scene [11-14], a further type is proposed.

- Type 6 – where fingerprints have been developed by the effects of an environment the article has been exposed to, e.g. fingerprints developed on paper by the action of heat.

Examples of all these types of mark are illustrated below.



a)

b)

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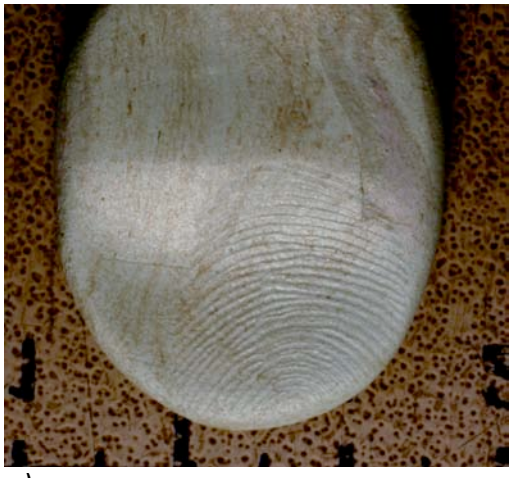

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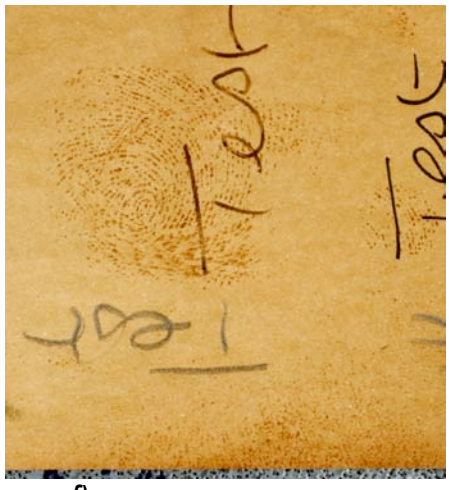


f)

Different types of marks that may be detected by visual examination a) Type 1 mark in grease on CD b) Type 2 mark in soot on mug c) Type 3 mark in dust d) Type 4 mark on metal sheet e) Type 5 mark in plasticine f) Type 6 mark developed by heat on paper.

3.2 The process recommended by CAST for all of these types of marks consists of examination under natural light, turning the article so that illumination falls on it from different angles. This should be followed by an examination using an even, white light source, again altering the angle of illumination from perpendicular to the exhibit to oblique.

3.3 Any fingerprints detected using this examination process should be imaged using the most appropriate technique outlined in the 'Theory' section above.

4. Critical issues

4.1 Visual examination must be performed before commencing any other form of examination or chemical treatment because potentially useful marks may otherwise be missed.

5. Application

5.1 Suitable surfaces: Visual examination is applicable to all types of surface, but will yield most marks on non-porous surfaces.

5.2 Visual examination can be applied to all types of articles, including examination of surfaces at crime scenes. Because it is a non-destructive technique and marks detected in this way may not be subsequently developed by any chemical/physical process, it should be the first stage in any sequential treatment process and any marks found should be imaged before proceeding.

5.3 Because there are a wide range of mechanisms by which latent marks or impressions may occur on articles, a thorough examination using different lighting conditions should be carried out, using both natural light and an even illumination from a white light held at different angles.

6. Alternative formulations and processes

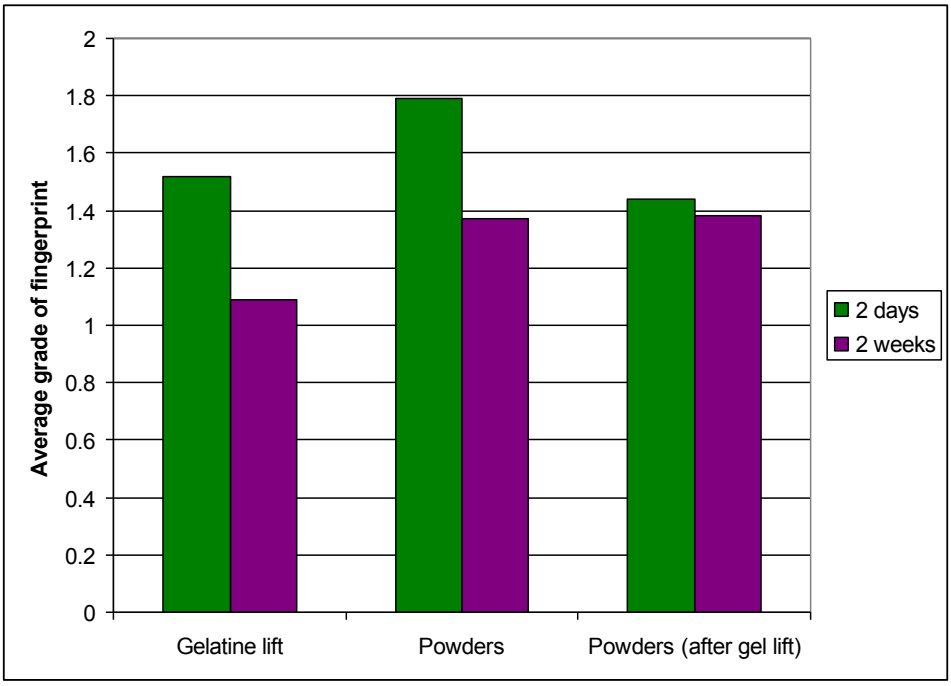
6.1 There are no alternative treatments or processes to those described in this section.

7. Post-treatments

7.1 If the latent mark detected is thought to be eccrine or sebaceous in nature, appropriate chemical/physical development techniques should be selected from the manual [9] taking into account the surface it has been deposited on. Similarly, if the mark is thought to be in blood or another

contaminant that could be developed by techniques in the manual, an appropriate sequential treatment regime should be selected.

7.2 For other types of contaminant/particulate, marks found by visual examination may be lifted using adhesive tape or gelatine lifts. However, this should only be carried out if the type of mark or surface precludes the use of subsequent development techniques, and/or the mark has already been captured, or cannot be captured in situ. The results of a comparative study between gel-lifting of latent marks and powdering are illustrated below, based on 1,260 graded marks.



Relative effectiveness of powders and gelatine lifts for fingerprint recovery from a range of surfaces

7.3 It can be seen that gel-lifting latent prints is less effective than powdering and can be detrimental to subsequent powder application, especially on fresher marks where the deposits are more easily lifted by the gel. On older marks where the deposits are more robust, gel-lifting appears to be less detrimental to subsequent powdering but in general gel-lifting should only be carried out in exceptional circumstances.

7.4 Impressed marks can also be cast and lifted using silicone rubber casting compounds, and the ridges of such casts enhanced by the application of black ink.

7.5 For marks on paper that have been developed by heat, subsequent fluorescence examination using the Quaser 473–548 excitation band and 549 viewing/camera filters may reveal additional detail [12-14].

8. Validation and operational experience

8.1 Because visual examination is a non-destructive process and should be used as the first stage in any sequential treatment regime, few documented operational trials have been carried out. There are many reported examples of where visual examination has revealed fingerprints at crime scenes and on articles in laboratories, and it is not considered necessary to extensively validate what should be an intuitive process.

8.2 Recently, studies have been carried out by Hampshire Constabulary and the Metropolitan Police [16], using a wide range of light sources to examine exhibits prior to chemical treatments. Both of these studies incorporated white light sources and visual examination. Results indicate that visual examination will detect marks that are not found by any other light source or developed by subsequent chemical treatment. In the Hampshire study 11% of marks were only detected by a combination of visual and fluorescence examination, and of this visual examination using white light was the sole means of detection for 3% of marks.

8.3 A summary of the results obtained from the study on operational work at Hampshire Constabulary is given in the tables below.

Surface type	Articles	White light	Quaser 2500	Laser (532nm)	Laser (577nm)	Chemical treatment
Porous	169	3	10	42	15	240
Non-porous	192	43	36	34	54	277
All	361	46	46	76	69	517

Summary of the performance of different light sources on porous and non-porous surfaces.

8.4 The types of article that marks were detected on using visual examination included cowlings and knife blades for non-porous items, and marks in dirt on paper for porous items. The results indicate that, as expected, subsequent chemical treatment develops appreciably more marks. However, it is also of interest to consider the number of unique fingerprints attributable to each process. In this analysis, the following information is obtained.

Light source	Total fingerprints	Not developed chemically	Unique fingerprints to process
White light	46	18	18
Quaser 2500	46	27	8
Laser (532nm)	76	46	36
Laser (577nm)	69	39	24

Detailed analysis of fingerprints detected by different light sources.

8.5 As stated above, it is evident that although visual examination detects comparatively few fingerprints (<10% of all marks detected), 40% of the marks that are detected by visual examination are unique to that process and it is therefore an essential element in a sequential treatment regime.

8.6 The Metropolitan Police study indicated that use of light sources accounted for ~8% of all marks detected on over 1,000 exhibits, although this included white light, long-wave ultraviolet and laser examination. On some non-porous surfaces (e.g. vehicle bodywork), the number of unique marks found by visual examination with a white light source was much higher than the average value above and reinforces the recommendation that visual examination should ideally be carried out before commencing any chemical treatment sequence.

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2.2 Fluorescence examination

1. History

1.1 The use of fluorescence examination for the enhancement of developed fingerprints was being considered as early as the 1930s, with materials such as anthracene and zinc sulphide being proposed for use as fingerprint development powders. Both of these powders fluoresced when illuminated with ultraviolet (UV) radiation and could be used to enhance the contrast of the mark against the background. In the case of zinc sulphide, the longer term phosphorescence of the material could also be utilised by imaging the mark once the light source had been removed. In 1954, Cherrill [1] described the use of barrier filters in combination with fluorescent powders to reduce reflected light from the background.

1.2 Most early investigators used UV radiation to produce fluorescence in fingerprints. In 1970 Ohki [2] carried out an investigation into the constituents of fingerprints and found several components that had inherent fluorescence when illuminated with UV radiation. Developments in chemical reagents for fingerprint development in the mid-1970s identified several systems that produced reaction products with fluorescence in the visible region when illuminated in the UV, including fluorescamine and o-phthaladehyde. However, these reagents did not provide any advantages in performance over ninhydrin and were not widely adopted.

1.3 The most significant development in fingerprint detection by fluorescence examination was the observation by Dalrymple *et al.* [3] that latent, untreated fingerprints could be detected on a range of substrates using a 1.5W argon ion laser line at 514.5nm with an appropriate barrier filter. Duff and Menzel were working in the Xerox Mississauga research laboratory and were also involved in using dye lasers in the same laboratory. It is now thought that the high success rates initially observed in these studies may have been attributable to some latent fingerprints being contaminated with laser dyes. Fluorescence was also observed by the same authors using a filtered xenon arc lamp, but this light source was of lower power (filtered output measured at 0.5W) and the fluorescence was correspondingly weaker. The authors recognised the future potential of fluorescent stains and powders, and attempted to enhance marks by powdering with the fluorescent Coumarin 6. Initially this did not reveal any ridge detail, but subsequent spraying with methanol and laser examination showed some powder preferentially adhering to the ridges. Thornton [4] was more successful, dissolving Coumarin 6 in ethanol, mixing with a black powder and then evaporating the ethanol to produce a fluorescent tagged dusting powder.

1.4 This prompted further studies into development techniques compatible with laser examination and Menzel and Duff investigated a range of fluorescent powders and chemical reagents [5] and the use of

phosphorescent powders in combination with a light chopper to reduce the interfering effect of background fluorescence [6]. This 'time resolved imaging' approach was later explored using a range of substances with long fluorescence decay times.

1.5 Laser examination was also becoming used on operational work and in 1979 Dalrymple [7] was able to record casework successes where laser examination had revealed marks by fluorescence that were not subsequently developed by chemical treatment. Dalrymple also identified the potential of fluorescing the background to enhance the contrast with a non-fluorescent fingerprint.

1.6 The published papers attracted worldwide interest in the technique and in 1979 a Police Scientific Development Branch (PSDB) delegation visited Duff and Menzel at the Xerox laboratories and the FBI [8] to assess the technique on a range of test substrates and to discuss its operational applications. Fluorescent marks were detected on low density polyethylene and matt aluminium, and some fainter marks seen on paper and adhesive tape. Overall the process performed poorly in comparison with traditional methods on 19 surfaces and 300 fingerprints. The PSDB group concluded that the coherent output of the laser was not essential to promote fluorescence, just the output power and wavelength specificity, and this initiated the programme of work into filtered light sources that ultimately led to the production of the Quaser 30 in the early 1980s, followed in turn by the Quaser 80, 100, 40 and finally the Quaser 2000.

a) b)

Different generations of Quaser, a) Quaser 80 and b) Quaser 2000.

1.7 PSDB demonstrated a prototype lamp system to Professor Warrener from Australia and John Watkin from Canada in 1980/81. These other groups also recognised the potential and the significantly lower cost of filtered light sources and research programmes to develop these systems were initiated in both Canada [9] and Australia [10,11]. Comparisons carried out between a filtered light source and a laser [11]

indicated little difference in performance between the systems available at that time.

1.8 The PSDB research programme investigated the constituents of fingerprints, in particular those fluorescing under UV and green light [12,13]. Several constituents that fluoresced under laser illumination were detected although it was not possible to conclusively identify all of them. PSDB (by now part of the Home Office Scientific Research and Development Branch) also began a comprehensive programme to assess the optimum excitation and viewing filter combinations for the Quaser filtered light sources, and to devise health and safety guidelines for use with all types of light sources that could be used for fluorescence examination. This included work in close consultation with leading ophthalmologists to ensure that the safety guidance given was directly relevant to the light sources used and to the end application. The culmination of this work was *Fingerprint Detection by Fluorescence Examination – A Guide to Operational Implementation* [14].

1.9 Another advance in fluorescence examination was made by Herod and Menzel [15] during studies into techniques for enhancing fingerprints developed using ninhydrin. It was already known that complexes formed between some metal ions and ninhydrin could result in colour changes to the mark, but not that some of these products were fluorescent. Herod and Menzel found that spraying the ninhydrin marks with zinc chloride resulted in a colour change in the fingerprint from purple to orange, and the formation of a fluorescent reaction product excited by the 488nm line of the argon laser. Subsequent studies showed that zinc toning used after ninhydrin detected significant numbers of additional marks and this became an important sequential processing technique until somewhat superseded by the development of reagents such as 1,8-diazafluoren-9-one (DFO) and 1,2 indandione, which yielded inherently fluorescent reaction products.

1.10 Other refinements considered to the fluorescence examination process were the use of a scanning laser spot to build up a fluorescence intensity map of a surface by Herod and Menzel [16] and the use of narrow bandpass filters in combination with a long-pass barrier filter to improve the contrast between the fluorescing mark and the background by Dalrymple [17].

1.11 Other types of laser were also considered for fluorescence examination and reviews of the options available were made by Menzel [18,19]. By the early 1980s copper vapour and neodymium:yttrium aluminium garnet (Nd:YAG) lasers had become available and although the copper vapour laser had similar attributes to the argon laser, the Nd:YAG laser was more portable (albeit with much lower output power at that time) and could be taken to crime scenes.

1.12 Research was also conducted into the use of time-resolved fluorescence imaging, combined with the assessment of reagents with longer

fluorescence decay time compatible with this technology. Europium compounds [20] and other lanthanides [21] were proposed by Menzel for this purpose, the potential advantage of the technique being that background fluorescence can be separated from the fluorescence of the fingerprint by the difference in decay time.

1.13 Since the early 1980s, advances in fingerprint development techniques have meant that fluorescence examination has become an integral process in sequential treatment regimes, being used to detect latent fingerprints and to enhance developed fingerprints. Fluorescent dyes have been developed for use with superglue, DFO is available as a technique for developing fluorescent marks on porous surfaces, acid yellow 7 can be used as a fluorescent blood dye on dark surfaces and marks developed using basic violet 3 may also be enhanced by fluorescence. All of these processes are described in greater detail in Chapters 3.1, 3.2 and 3.3, respectively.

1.14 Most recently, the advances made in light emitting diode (LED) technology have resulted in hand-held torches with equivalent output power to some filtered arc lamp systems. However, the output spectra of LEDs are typically broader than filtered systems and usually require additional filtering to avoid reflected light from the light source passing through the viewing filter. Further increases in LED power are anticipated and such systems are already becoming useful tools in fluorescence examination.

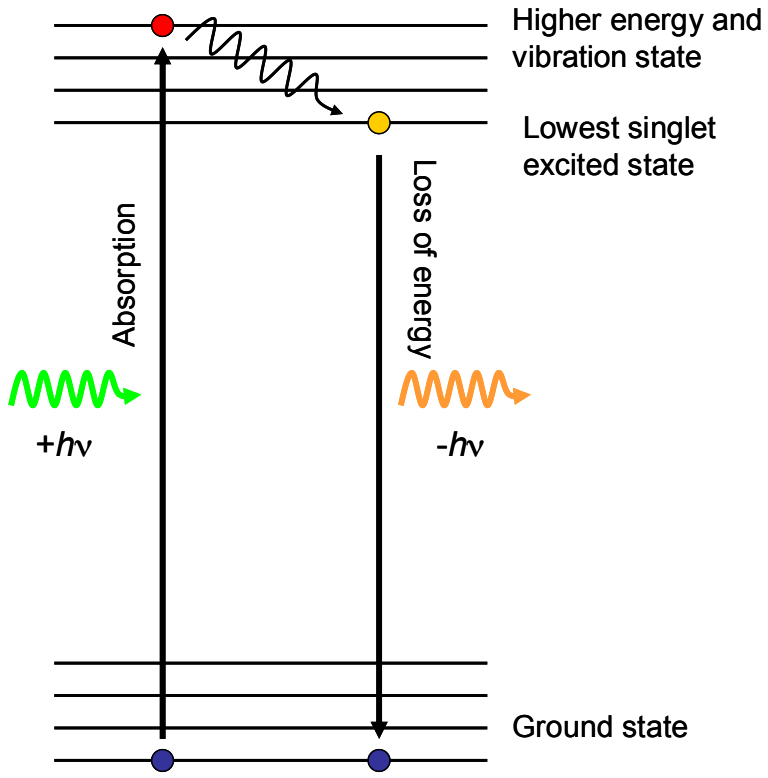
1.15 Lasers have also become more lightweight and portable, and scene portable, suitcase-sized Nd:YAG (and semiconductor diode) green lasers with output powers up to 8W are now available. Semiconductor lasers with outputs of 2W in the blue and 5W in the yellow regions of the spectrum have also been developed; both of these have been demonstrated to detect marks (and other types of forensic evidence) not found by the green laser. The use of as many different light sources as possible is therefore recommended to maximise evidence recovery.

2. Theory

2.1 Fluorescence is one of a number of processes that are broadly described by the term ‘luminescence’, which means that a substance emits light in response to an external stimulus. Other examples include chemiluminescence, where light is emitted as a result of a chemical reaction (as in the blood detection technique luminol) and triboluminescence, where light is emitted as a result of a material being rubbed, broken or abraded.

2.2 In fluorescent chemicals, light of a specific colour is absorbed and some of this absorbed energy is subsequently emitted as light of a different colour and longer wavelength. This can occur because the molecule has potential electronic energy excited states with levels compatible with the

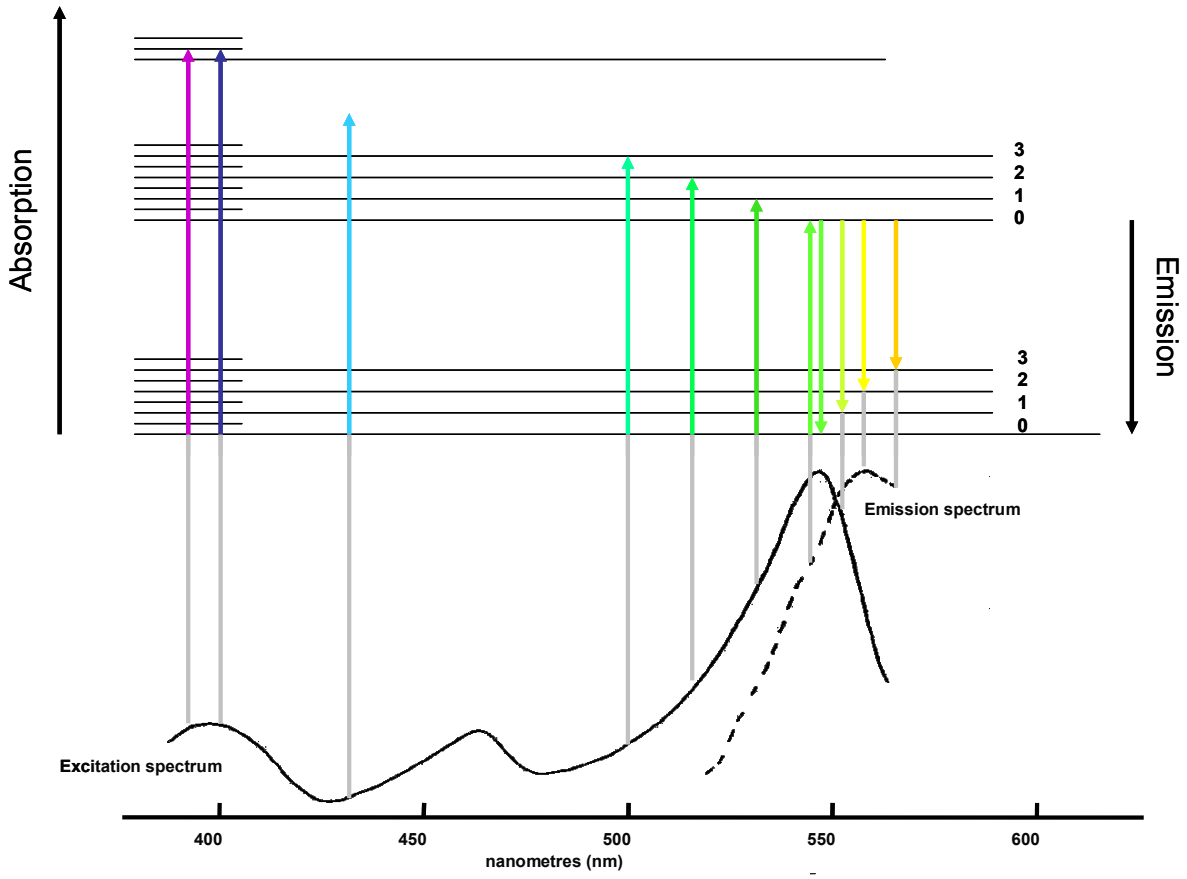
absorption and emission of visible light. The mechanism of fluorescence is shown schematically below.



Schematic diagram showing the mechanism by which fluorescence occurs.

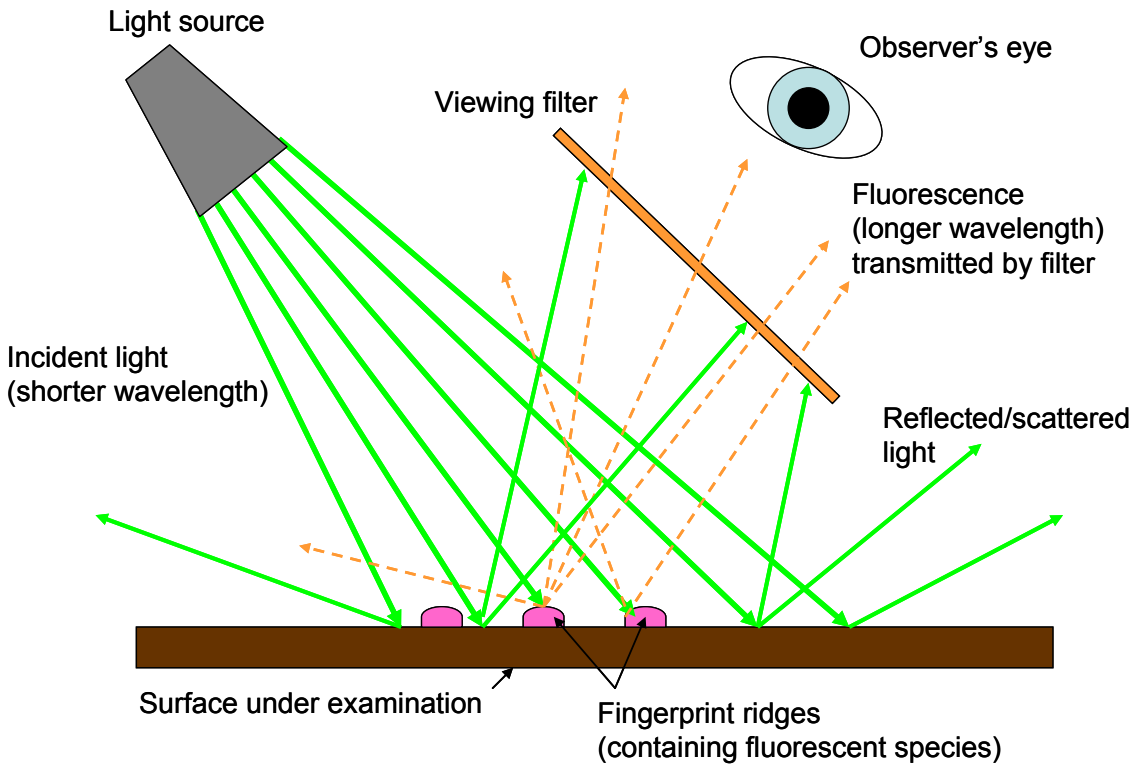
2.3 When a fluorescent molecule is excited with light of an appropriate wavelength, the electrons absorb energy from the light and are promoted from the ground state to a higher energy electronic state. Radiationless energy loss transitions resulting the vibrational energy level of the excited electron dropping. The electron then drops to a lower electronic level with the emission of a photon of a lower energy and lower wavelength than the original absorbed photon. If the transition between excitation and emission takes place in less than 10-8 seconds it is generally regarded as fluorescence. There are other 'delayed fluorescence' and phosphorescence mechanisms that can occur in ome molecules.

2.4 There are in practice several excited states to which electrons can be promoted and several ground states to which they can return, so that absorption and emission actually occur over ranges of the electromagnetic spectrum. A schematic illustration of a representative emission and absorption spectrum and the corresponding excited states is shown below.



Representation of excitation/emission spectra of a chemical with corresponding transitions between excited and ground states.

2.5 Typically, light in the UV, blue, green or yellow parts of the spectrum is used to excite fluorescence, which may result in the emission of light in the yellow, orange, red or infra-red (IR) regions. Most of the illuminating light is not absorbed but scattered or reflected from the surface being examined. Filters that transmit the fluorescence but not the illuminating light are therefore placed in front of the eye and/or image capture device to enable the fluorescence to be seen and recorded. This is shown schematically below.



Schematic diagram illustrating the viewing of fluorescence from fingerprint ridges containing a fluorescent species

2.6 In optimising fluorescence examination it is essential to ensure that the illuminating wavelengths of light correspond closely to the excitation of the fluorescent species present (if known), and that the viewing filter used blocks all illuminating wavelengths and transmits the maximum emission peak of the fluorescent species.

2.7 It is this philosophy that has been used to determine the excitation wavelengths and corresponding viewing filters recommended in the 'CAST processes' section below.

3. CAST processes

3.1 Comprehensive descriptions of the processes used for fluorescence examination are given in the HOSDB publication *Fingerprint Detection by Fluorescence Examination – A Guide to Operational Implementation* [14]. A shorter summary is given here. This section does not cover the use of UV radiation for the detection of fingerprints, which is dealt with in greater detail in Chapter 4.1, Ultraviolet imaging.

3.2 In common with visual examination, there are many ways in which fluorescence examination can used to detect fingerprints. There are two principal forms of examination, subdivided into eight types, which are described below.

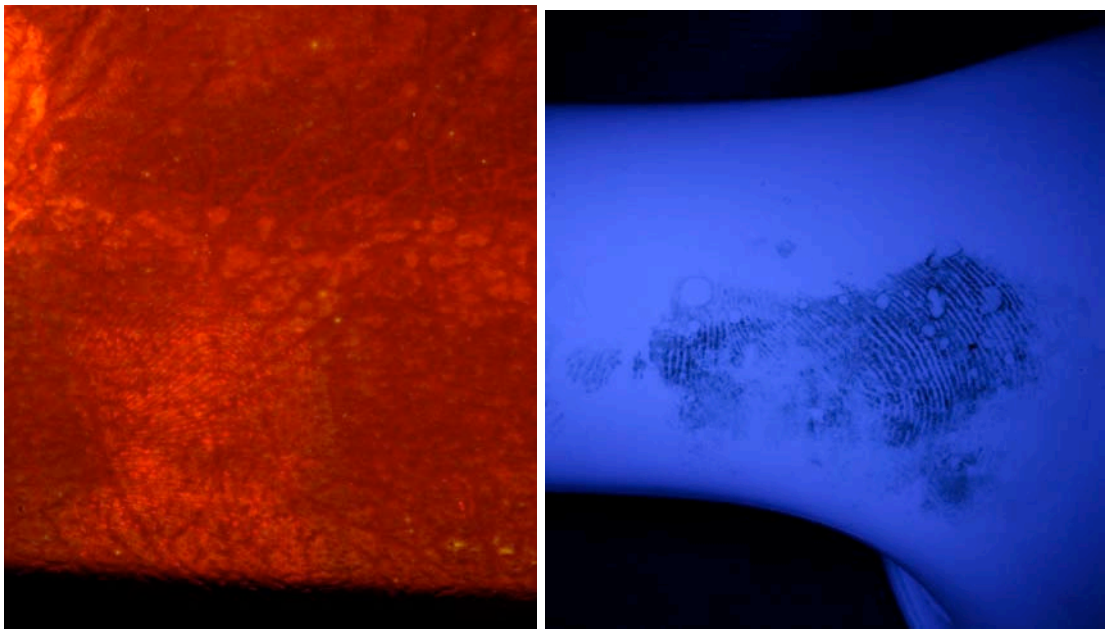
3.3 Initial examination of untreated fingerprints

3.3.1 Fluorescence examination is an essentially non-destructive process and may be used as the initial stage in a sequential processing regime. There are three types of fingerprints which may be revealed during initial examination.

Type 1 – Fingerprints may be detected due to the inherent fluorescence of constituents that may be present in sweat.

Type 2 – Contaminants present in the fingerprint, such as ink, drugs or grease, may exhibit enhanced fluorescence over those consisting of sweat alone.

Type 3 – Some surfaces, such as paper or cardboard, may exhibit background fluorescence, which can improve the contrast of fingerprints contaminated with substances such as blood or dirt that absorb light and appear dark against the light fluorescing background.



a) b)

Marks detected during initial examination a) Type 1 or 2 mark detected by inherent fluorescence of fingerprint and b) mark in blood revealed against fluorescent background.

3.4 Enhancement of developed fingerprints

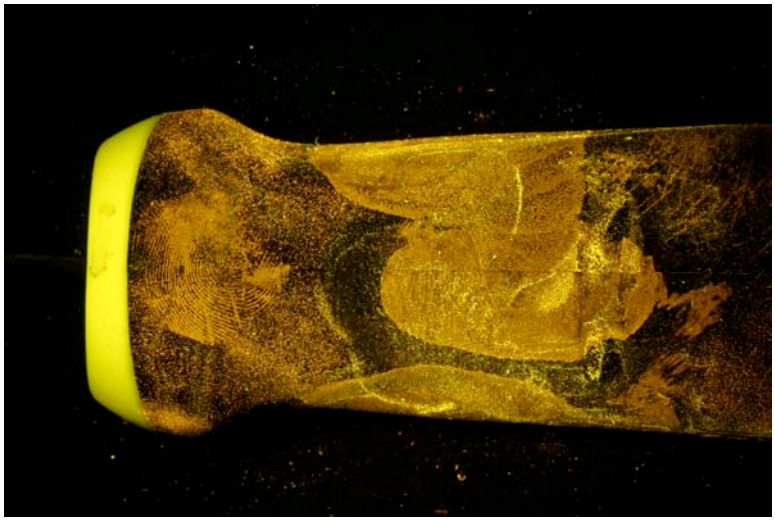
3.4.1 Fluorescence examination may also be used as a method of improving the contrast of fingerprints developed with other processes. There are four principal types of fingerprint to which fluorescence examination can be applied.

Type 4 – The treated fingerprint may itself fluoresce because the chemical used to stain it is fluorescent, examples being basic violet 3 and acid yellow 7. In this way, fingerprints that are faint or invisible under normal light may be revealed by fluorescence. However, heavy blood deposits or heavily stained fingerprints may quench fluorescence.

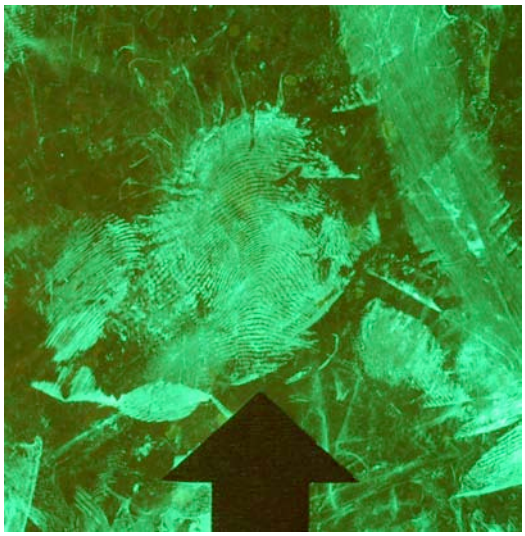
Type 5 – The background surface may fluoresce and the fingerprint may absorb or scatter the incident light and appear black. Examples of this may be seen for ninhydrin and physical developer.

Type 6 – The treated fingerprint may be treated with a secondary reagent or stain prior to fluorescence examination. This converts it from a non-fluorescent to a fluorescent mark, thus improving the detail that can be imaged. Examples of this include the zinc salt toning of ninhydrin marks and the staining of superglue marks with fluorescent dyes.

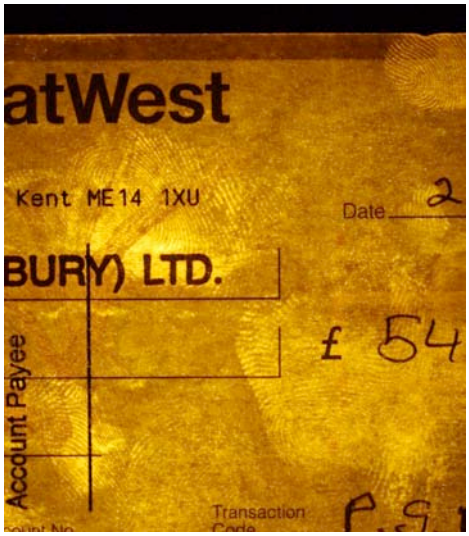
Type 7 – The reagent used may react directly with fingerprint constituents to form a fluorescent product, e.g. DFO and 1,2 indandione. Fluorescent fingerprint powders also fall into this category.



a)



b)

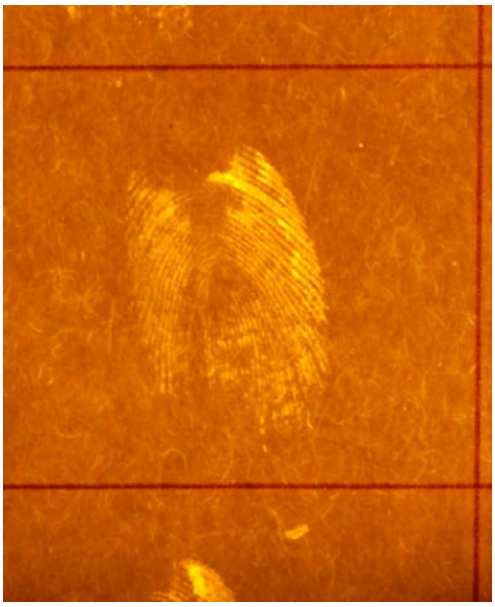


c)

Fingerprints enhanced using fluorescence examination a) Type 4 mark, mark in blood enhanced using acid yellow 7 b) Type 6 mark, superglue stained with basic yellow 40 and c) Type 7 mark, fingerprints developed using 1,8-diazafluoren-9-one.

3.4.2 More recently, work on the recovery of fingerprints from arson scenes has revealed a further category of mark that can be revealed or enhanced by fluorescence examination.

Type 8 – The action of the environment (e.g. heat) on a latent fingerprint may result in the formation of fluorescent products.



Type 8 mark – eccrine mark on paper becoming fluorescent after exposed to 150ºC.

3.4.3 The excitation and viewing conditions recommended for these situations by HOSDB are summarised below.

3.5 Nd:YAG laser (single wavelength)

3.5.1 Initial examination and enhancement of developed fingerprints

Application	**Excitation wavelength (nm)**	**Schott viewing filter**
Examination of all surfaces	532	OG570
DFO	532	OG570
Superglue dyed with basic red 14	532	OG570

Data given are for the Coherent 'Tracer' green laser, and the Laser Innovations 'Revelation' green laser.

3.6 Yellow semiconductor laser (single wavelength)

3.6.1 Initial examination and enhancement of developed fingerprints.

Application	**Excitation wavelength (nm)**	**Schott viewing filter**
Examination of all surfaces	577	RG610
Basic violet 3	577	RG610
DFO (on backgrounds highly fluorescing under green illumination)	577	RG610

Data given are for the Coherent 'Tracer' yellow laser.

3.7 Blue semiconductor laser (single wavelength)

3.7.1 Initial examination and enhancement of developed fingerprints.

Application	**Excitation wavelength (nm)**	**Schott viewing filter**
Examination of all surfaces	460	GG495
Marks contaminated with body fluids	460	GG495
Superglue dyed with basic yellow 40	460	GG495

Data given are for the Coherent 'Tracer' blue laser.

3.8 Argon Ion Laser (multiple, selectable wavelengths)

3.8.1 Initial examination.

Application	**Excitation wavelength (nm)**	**Schott viewing filter**
Examination of all surfaces	514.5	OG550
Surfaces with low background	488.0	OG530

fluorescence		
Fingerprints in dark materials, e.g. blood, where fluorescence of background may improve contrast	488.0	OG530

3.8.2Enhancing developed fingerprints.

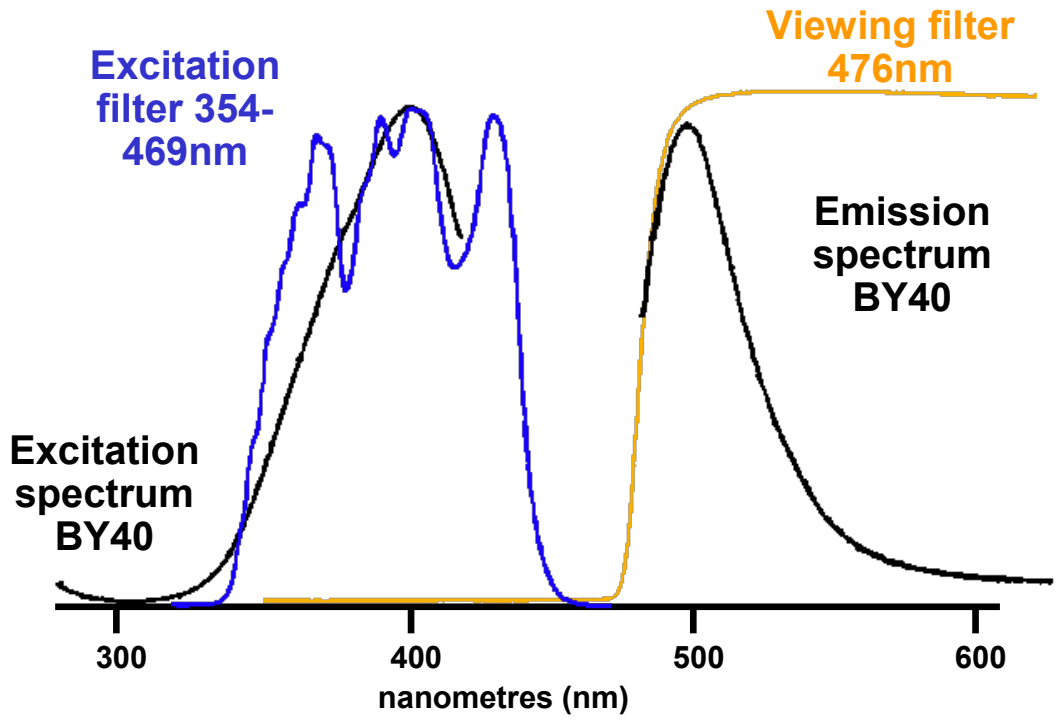
Application	**Excitation wavelength (nm)**	**Schott viewing filter**
Absorbing treatments, e.g. ninhydrin, acid black 1, acid violet 17, Powders (background fluorescence)	457.9 or 476.5 or 488.0	GG495 OG515 OG530
Acid yellow 7	514.5	OG550
DFO	514.5	OG550
Basic violet 3	528.7 or 514.5	RG610 OG550
Ninhydrin toned with zinc salts	488.0	OG530
Superglue dyed with basic yellow 40	457.9 or 476.5 or 488.0	GG495 OG515 OG530
Superglue dyed with basic red 2	514.5	OG550

Where alternative wavelengths are given, users should investigate which is the best combination for their particular laser.

Data obtained from Hardwick *et al.* [14].

3.9 Quaser (multiple, selectable excitation bands)

3.9.1An example of excitation and viewing filter selection for different applications is illustrated below.



Selection of appropriate Quaser filters to fit with excitation/emission of basic yellow 40 dye.

3.9.2Initial examination.

Application	**Excitation filter (nm)**		**Viewing filter (1% transmission point)**	
Examination of all surfaces. Background fluorescence may obscure some fingerprints	Blue	352–509 385–509 354–519 385–519 400–519	Yellow/ Orange Orange	510 or 515 529
Reduces background fluorescence	Blue/ Green	468–526	Orange	529
Reduces background fluorescence further	Green	473–548	Orange	549
Detects some fingerprints on polythene packaging and possibly other surfaces	Green	491–548	Orange	549
Fingerprints in dark materials, e.g. blood, where background fluorescence may improve contrast	Violet/ Blue	350–469 385–469 400–469	Yellow	476
Fingerprints in dark materials, e.g. blood, where background fluorescence may improve contrast. Some fingerprints in oils and greases and some	Ultra-violet	280–413 340–413	Yellow	415

absorbing fingerprints on glossy papers				

Where multiple excitation filters are listed, the set supplied will depend on the Quaser system used.

3.9.3Enhancing developed fingerprints.

Application	**Excitation filter (nm)**		**Viewing filter (1% transmission point)**	
Absorbing treatments, e.g. ninhydrin, acid black 1, acid violet 17, powders (background fluorescence)	Violet/ Blue	350–469 385–469 400–469	Yellow	476
Acid yellow 7	Blue	352–509 385–509 354–519 385–519 400–519	Yellow/ Orange Orange	510 or 515 529
DFO for maximum contrast on most types of paper	Green	473–548	Orange	549
DFO to reduce background fluorescence	Green	491–548	Orange	549
DFO to reduce background fluorescence further	Green/ Yellow	503–591	Red	591
Basic violet 3	Green/ Yellow	503–591	Red	591
Ninhydrin toned with zinc salts	Blue/ Green	468–526	Orange	529
Superglue dyed with basic yellow 40	Violet/ Blue	350–469 385–469 400–469	Yellow	476
Superglue dyed with basic red 14	Green	473–548	Orange	549

Where multiple excitation filters are listed, the set supplied will depend on the Quaser system used.

Data obtained from Hardwick *et al.* [14] and from the CAST *Manual of Fingerprint Development Techniques* [22].

3.10 LED light sources

3.10.1 Data given are for Foster and Freeman ‘Crime-lite 80S’ range, correct as of 28/01/2010

3.10.2 Initial examination.

Application	**Excitation filter (nm)**		**Viewing filter (1% transmission point)**	
Examination of all surfaces.	Blue	430–470	Yellow	476

Background fluorescence may obscure some fingerprints				
Reduces background fluorescence	Blue/ Green	460–510	Orange	529
Reduces background fluorescence further	Green	500–550	Orange	549
Detects some fingerprints on polythene packaging and possibly other surfaces	Green	500–550	Orange	549
Fingerprints in dark materials, e.g. blood, where background fluorescence may improve contrast	Violet/ Blue	395–425 430–470	Yellow	476

3.10.3 Enhancing developed fingerprints.

Application	**LED colour and excitation (nm)**		**Viewing filter (1% transmission point)**	
Absorbing treatments, e.g. ninhydrin, acid black 1, acid violet 17, powders (background fluorescence)	Violet	395–425	Yellow	476
Acid yellow 7	Blue	430–470	Yellow	476
DFO for maximum contrast on most types of paper	Green	500–550	Orange	549
Ninhydrin toned with zinc salts	Blue/ Green	460–510	Orange	529
Superglue dyed with basic yellow 40	Blue	430–470	Yellow	476
Superglue dyed with basic red 14	Green	500–550	Orange	549

4. Critical issues

4.1 There are several issues that need to be considered and addressed when performing fluorescence examination, some concerned with technique effectiveness and other relating to health and safety.

4.2 The light source used must output at a wavelength or spectral bandwidth that overlaps with the absorption bands of the dyes/contaminants in the fingerprint and thus excite the fingerprint into a state where it can fluoresce.

4.3 The light source used must have an effective radiated power that produces a sufficient intensity of fluorescence in the mark for it to be detected and captured.

4.4 The filters used for both viewing and capture of fluorescent marks must be correctly designed and selected so that they block all of the

wavelengths output by the illumination source, and transmit as much of the fluorescence output from the mark as possible.

4.5 The potential background fluorescence of the surface should be considered. It may be necessary to move to other wavelengths or wavebands to reduce the impact of background fluorescence, even though these may not be optimum for exciting the fluorescent constituents in the mark.

4.6 It is essential to carry out a full safety assessment prior to carrying out fluorescence examination to ensure that all operators are wearing appropriate protective eyewear and that unprotected personnel cannot be accidentally exposed to harmful levels of stray light. Safety procedures should be put in place to enforce this.

4.7 The light levels needed to detect weakly fluorescent materials present serious hazards to the eyes and in some cases the skin. It is possible to cause retinal burns in less than the eye blink response time of ¼ second. Some of the light source and filter systems marketed are potentially hazardous and may have inadequate or incorrect safety advice. Those providing safety features to avoid accidental exposure to harmful levels of light are preferable.

4.8 Changes to the wavelength, power, barrier filter or light delivery optical system may dramatically affect the risks to human eyes. The only effective way to carry out a safety assessment of a system is by calculation, and/or by measurement of the radiance levels for visible light systems and irradiance for UV or IR systems.

5. Application

5.1 Suitable surfaces: Fluorescence examination can be used for detection of latent fingerprints on all types of untreated surface, but success rates are higher on non-porous articles. Fluorescence examination is also useful on all types of surface after chemical treatment provided that an appropriate fluorescent chemical has been used to develop the fingerprint, or the surface has appreciable background fluorescence while the chemically treated print absorbs.

5.2 Fluorescence examination has two principal applications in fingerprint detection, firstly in the detection of latent fingerprints prior to commencing a sequence of chemical treatments and secondly in the enhancement of marks that have either been treated to produce fluorescent products or are absorbing on a fluorescent background.

5.3 In the first role, fluorescence can be an invaluable tool because it may detect marks that contain small quantities of fluorescent contaminants. Because fingerprint development processes primarily target natural

secretions, many of these marks will never be found during subsequent chemical treatment.

5.4 Fluorescence examination may also detect marks present in contaminants, such as blood. Many surfaces fluoresce when excited by high-intensity light in the UV and violet regions of the spectrum. This is coincidently where the haem group in blood is most absorbent, with a peak around 421nm (known as the Soret Band) [23] and why blood-contaminated fingerprints will appear dark against a light background. Fluorescence examination may be used before any other fingerprint enhancement techniques as it is non-destructive, and if long-wave UV or violet light (350–450nm) is used then DNA typing is also unaffected.

5.5 In the enhancement of chemically treated fluorescent marks, fluorescence examination is used to reveal marks that may not be visible to the eye and to enhance the contrast between ridges and background. More powerful light sources (of the correct excitation wavelength) will cause even very weakly developed marks to fluoresce sufficiently for imaging.

5.6 Marks in blood may also be detected by fluorescence, even though the original chemical treatment is not intended to produce fluorescence. If haem-specific enhancement processes are used, the use of a strong organic acid in conjunction with hydrogen peroxide breaks up the haem group so that it is no longer as effective at absorbing light. When subsequently excited by green (500–550nm) light it will fluoresce orange. This effect has also been noted as blood ages.

5.7 Wherever possible, fluorescence examination should be carried out in a darkened room free of highly fluorescent articles and surfaces, and users should allow themselves to become dark adapted before commencing examination. All safety precautions appropriate to the light source being used should be taken [14] to ensure the safety of both the operator and others in the vicinity. The light source should be passed slowly over the article to be examined, taking care to minimise exposure time on articles that may be damaged by the heat associated with some high-power light sources. Handling of the article during examination should be minimised to avoid damage to any marks present on the surface. Any marks detected should be photographed using an imaging system fitted with an appropriate barrier filter.

5.8 Fluorescence examination can be carried out both in a laboratory and at a crime scene, provided that appropriate health and safety precautions are taken. For optimum results, it is essential that the operator takes time to become fully dark adapted before commencing examination.

Examination of a crime scene using a portable laser.

6. Alternative formulations and processes

6.1 There are many suppliers of light sources, covering the range of lasers, filtered arc lamps and LEDs, but regardless of which is selected the essential examination process is the same. The light source should be selected to provide maximum illumination in the excitation region of the fluorescent chemical (if known), and the viewing filter selected to block the illumination wavelengths and transmit the excitation wavelengths of the chemical. Provided that this approach is adopted, many different combinations of fluorescent dye, illumination light source and viewing filters can be successfully employed in fluorescence examination.

7. Post-treatments

7.1 There are no post-treatments used in fluorescence examination.

8. Validation and operational experience

8.1 Because fluorescence examination is essentially a non-destructive examination technique and is recommended for use as the second stage in a sequential treatment (after visual examination), its operational implementation for this purpose should not require extensive validation.

8.2 Laboratory trials

8.2.1 Few laboratory trials have been conducted using deliberately deposited fingerprints. This is because it is known that the proportion of marks that will be detected in this way is low, but this is accepted for operational use

because fluorescence examination is non-destructive and will find marks in contaminants not developed by chemical reagents.

8.2.2 A limited study has been carried out by CAST to compare the effectiveness of fluorescence examination with other non-destructive examination techniques, including short-wave UV imaging on porous surfaces. These results are reported in Chapter 4.1, Ultraviolet imaging, and illustrate that both green and yellow lasers will detect marks not found by any other light source, although they are not particularly effective on most porous surfaces.

8.3 Pseudo-operational trials and operational experience

8.3.1 Data are available that demonstrate the benefit of fluorescence examination in sequential treatments. As early as 1979, the FBI reported that from 1,500 articles examined using an argon ion laser, 76 fingerprints were found that were not subsequently developed by any other process [8].

8.3.2 Creer reported early results from the use of an argon ion laser at the Serious Crime Unit of the Metropolitan Police in 1983 [24], stating that from 396 exhibits examined, 121 identifiable fingerprints had been found. Many of these exhibits had been considered unsuitable for other treatments due to surface scratches or patterned backgrounds, which would make conventional photography difficult. Creer also noted that in some cases on plastic bags, the laser detected marks that were totally different to those subsequently developed by vacuum metal deposition. The broader forensic applications of the laser were also presented.

8.3.3 More recently CAST has purchased a 5W, 532nm green laser and have loaned it to police forces for trials on operational work. The laser has been compared with the Quaser 100 operating in the green excitation band for both initial fluorescence examination and for examination of marks developed using DFO [25]. The results of this trial, conducted on articles from over 70 cases, are summarised below.

Application	**Total number of marks found**	
	Quaser 100	**Nd:YAG laser**
Initial examination	10	52
DFO enhancement	70	77

Summary of results obtained using a laser compared with a Quaser 100.

8.3.4 It can be seen that the higher power and higher wavelength specificity of the laser compared with the Quaser 100 provide benefits in the number of marks detected using fluorescence examination. Similar successes have been reported from the use of the laser at crime scenes.

8.3.5 On a limited number of operational cases processed by CAST [26], similar observations to those of Creer [24] were made in that marks were

detected on plastic bags using fluorescence examination that differed totally from those developed by subsequent vacuum metal deposition. One set were identified to a householder, the other to a suspect. This type of result demonstrates that fluorescence examination is a complementary tool to chemical treatments, and fully justifies its position within a sequential treatment process.

8.3.6 As prototypes of lasers operating at different wavelengths became available, CAST carried out a small-scale pseudo-operational trial examining items recovered from waste bins and in and around the laboratory. These items were examined using four different light sources and the number of fingerprints recorded. The results of this study are recorded below.

	Blue laser (460nm)	**Green laser (532nm)**	**Yellow laser (577nm)**	**Quaser 101 (503–587nm)**
Items	56	56	56	56
Total fingerprints	2	15	20	16
Common fingerprints	1	13	12	16
Missed fingerprints	0	0	4	0
Unique fingerprints	1	3	8	0

Summary of results obtained from different light sources in a laboratory trial.

8.3.7 These results suggested that the green and yellow lasers were effective in detecting fingerprints, with the yellow laser finding more fingerprints, and more unique fingerprints overall. Even though the blue laser found very few fingerprints, it was still capable of finding marks not detected by other light sources.

8.3.8 More recently, studies have been carried out by Hampshire Constabulary and the Metropolitan Police [27], using a wide range of light sources to examine exhibits prior to chemical treatments. Both of these studies incorporated fluorescence examination at different wavelengths using a range of light sources. Results confirmed that fluorescence examination will detect marks that are not developed by subsequent chemical treatment. In the Hampshire study, reported in Chapter 2.1 Visual examination, fluorescence examination was the sole means of detection for ~8% of marks recovered from 361 exhibits over a period of 6 months. In contrast to the earlier CAST study, the green laser was found to be most effective in detecting marks on operational exhibits, although both green and yellow lasers found marks not detected by other techniques.

8.3.9 CAST also included fluorescence examination as the initial stage in a pseudo-operational trial to establish the optimum processing sequence

for plastic bags. In this study, 100 plastic bags of varying types (e.g. supermarket bags, black bin bags, clear magazine wrappings) were divided into quarters and each quarter was assessed using a different fluorescence examination regime followed by a different chemical treatment sequence. The total number of fingerprints and the number of fingerprints unique to each process were recorded. The fluorescence examination regimes used were: exclusively laser examination, using green, yellow (and blue when available) lasers; exclusively Quaser examination, using each waveband of a Quaser 101; solely LED examination, using a green Crime-lite 80S; and finally a full examination using all of the light sources available. The results of this exercise are summarised below.

Light source(s)	Total fingerprints found with light source	Total developed chemically	Unique fingerprints to light source
Laser sequence (460, 532, 577nm)	46	379	24
Quaser 101	34	335	10
Green Crime-lite	19	392	5
Full (Quaser, Crime-lite, lasers)	65	380	21

Summary of results obtained using fluorescence examination during a pseudo-operational trial on 100 plastic bags.

8.3.10 It can be seen that on plastic bags, fluorescence examination sequences utilising lasers typically recover ~10–15% of the marks found overall, with up to 50% of the marks found by fluorescence examination not being subsequently developed by any other process. The lower power Quaser and Crime-lite sources are less effective, but still find several unique marks.

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