Research on Testing Technology of Gunshot Residues on Textile by Infrared Spectroscopic Imaging

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Abstract. The research work of infrared spectroscopic imaging technology in the field of forensic science is still in its infancy. In the process of exploring the detection of material evidence by infrared spectral imaging, we find that this technology is a new method to test the invisible material evidence by the naked eye. In this study, the modified infrared imaging spectrometer is used to collect the spectral image set of the tested textiles, and analyze the spectral image set. The results show that the infrared spectroscopic imaging technology can be used to detect the gunshot residues on textiles, and the infrared spectroscopic imaging technology can be used for the qualitative analysis and inspection of gunshot residues on textiles.

1. Introduction
So far, nondestructive spectral imaging inspection technology is still one of the most attractive and effective inspection methods in the field of forensic science, and plays an important role in the inspection and identification of various types of material evidence. By the use of an imaging spectrometer, hyperspectral imaging captures a serial of images of reflective light or fluorescent light from examined object, and forms a data set of spectral image which contains intensity and spectral information of the object[1]. It is a new content of infrared spectrum imaging method to study the infrared spectroscopic imaging technology in the detection of gunshot residues. Therefore, it is necessary to carry out experimental research on the infrared spectroscopic imaging technology and method. It is found that this technology is a new method to test the gunshot residues. In this paper, experiments are carried out to explore this technique. As demonstrated in the results, infrared spectroscopic imaging has potential to be defined as a novel method for detecting gunshot residues on textiles.

2. Experimental principle
When the object are irradiated by infrared light with continuous frequency variations, its molecules absorb radiation at some frequencies, and its vibration or rotational motion causes the change of dipole moment. Some vibrational and rotational modes are triggered, resulting in the intensity of transmitted light in these absorption regions is weakened [2-3]. Because of the infrared spectrum can be obtained by recording the relationship between the transmittance of infrared light and wave number and wavelength, different substances have different infrared spectrum.

The principle of image acquisition by imaging spectrometer is according to the preset parameter to achieve automatic operation of CCD camera by special computer software. With the liquid crystal adjustable wavelength filter it is coupled with CCD camera to record the brightness distribution of the corresponding waveband of the samples, and record ten monochromatic images at one time. After image
collection, many monochromatic images are stored in the computer in “TIFF”, then a spectral image set is formed for further analysis and processing[4].

The absorption capacity of gunshot residues in visible light area is on par with that of textiles but differs greatly in the infrared range. This difference forms the basis of infrared spectroscopic imaging.

3. Experimental conditions

3.1 Experimental equipment

The equipment and specifications used in the experiment were: (1) Nuance multispectral imaging system (CRI, USA); (2) Varispec400 Liquid crystal infrared filter; (3) Samsung notebook, processing software for Nuance developed by CRI, and the processing software by Xingbo; (4) mini400 multi-band light source; (5) iodine tungsten lamp; and, (6) Jingguang Type-I multi-functional light source.

3.2 Modification of the infrared spectroscopic imaging system

The liquid crystal infrared filter is placed at the front of the objective lens of the spectral imager, and the channel is placed in “white”. The spectral readings changed subsequently to 00-680 nm, 450-700 nm, 500-750 nm, 550-800 nm, 600-900 nm, and 700-950 nm. The modification of the infrared spectroscopic imaging system as shown in Figure 1.

![Figure 1 Infrared spectral imager is composed of infrared liquid crystal filter, CCD and computer](image)

3.3 Test sample

3.3.1 Experimental materials. The shooting vestige carrier are Four types of textiles (synthetic knitting, Satin, Polyester, Nylon) with different textures and patterns. Each of the 4 pieces of textile has a size of 20 cm × 15 cm. "64" type 7.62mm handgun, electric measuring tape, target plate, earmuff, goggles, etc.

3.3.2 Test sample preparation. Take 4 pieces of textiles of the same fabric, use the "64" type experimental handgun to aim and shoot them at the distance of 5 cm, 30 cm, 60 cm and 150 cm respectively, and obtain four samples as a group. In the same way, samples were made on textiles of different fabrics according to the above operation, and a total of 16 samples were obtained from 4 groups. Details of the sample preparation procedure can be found in Table 1.

| Sample number | Sample texture | Number of samples at each shooting distance | Subtotal |
|---------------|---------------|-------------------------------------------|----------|
|               |               | 5 cm | 30 cm | 60 cm | 150 cm |               |

Table 1. Fabric texture and shooting distance of gunshot residue samples.
3.4 Experimental procedure

3.4.1 Image acquisition.
Image acquisition was carried out at room temperature. Put the experimental sample on the photographic platform, select two 200W halogen iodine tungsten symmetrical light distribution, at an angle of incidence of approximately 45 degrees, then Aim at the corresponding position of the experimental sample, adjust the sample position, magnify the magnification and lens focal length until the clear image of the part to be tested appears on the computer display screen.

3.4.2 Image scans.
Set a series of parameters such as scanning range and resolution in CRI software spectral scanning interface. Then open the Vs software, set the corresponding scanning range, scanning time and other series of parameters. In this experiment, the scanning range of Vs software is set to 650-1100 nm, the scanning interval is set to 20 nm and the scanning time is set to 5000ms. In order to synchronize the two systems the scanning range of CRI processing software is set at 420-720nm. In the image scanning interface, infrared scanning is carried out in the two wavelength range of the inspected area. The exposure time is determined by the image recording software of the imaging system.

3.4.3 Image analysis. The software of CRI can de-mixing analysis and adjustment the information of image entered. After the sample is scanned, the spectral image is obtained, that is a pseudo color image synthesized automatically by spectrometer. Each wavelength interval selection can form multiple tricolor combinations and generate multiple pseudo color images, and the software of CRI can display them in turn for analysis.

4. Results

4.1. Detection rate of gunshot residues
Aiming at the shooting traces of different texture objects at different set distances, image acquisition, image scanning and importing into software database, computer pseudo color image synthesis and analysis were carried out respectively, and the detection results of gunshot residues were compared with the observation results under stereomicro-scope, as shown in Table 2.

| Sample number | Synthetic knitting (black) | Satin (ivory) | Wool knitting (dark red) | Nylon (coffee, shadow pattern) | Synthetic knits (black) |
|---------------|----------------------------|---------------|--------------------------|--------------------------------|------------------------|
| 5cm Stereomicroscope | +                          | --            | --                       | +                              | --                     |
| 30cm Stereomicroscope | --                         | --            | --                       | --                             | --                     |

Table 2. Detection of gunshot residues at different firing distances
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Spectroscopic imaging + + + +

Note: “+” gunshot residues can be detected, “-” gunshot residues are faintly visible, and “--” gunshot residues cannot be detected.

As can be seen from the experimental statistics in the table 2, the gunshot residues detected by both stereomicroscope and spectral imaging are related to shooting distance. The results of different texture and color of textiles are observed under stereomicroscope show that the color of textiles has great influence on the detection of gunshot residues and some dark textiles can not identify the presence of gunshot residues even at a distance of 5cm. However, the pseudo color image of infrared spectrum can be clearly distinguished the gunshot residues on dark textiles at different shooting distance. Representative images are shown below for comparison.

4.2 Gunshot residues detection on different textiles

4.2.1 Comparison of gunshot residues detection on Nylon fabric (coffee, shadow pattern). At the distance of 60cm, irradiated by iodine tungsten lamp, the gunshot residues on nylon fabric are infrared spectrum imaging, and the residues are clearly visible (Figure 2). An analysis of the spectroscopic image is shown in Figure 3.

![Figure 2](image_url)

Figure 2. Gunshot residues left on nylon fabric (coffee, shadow pattern) from 60 cm away, as seen on the image formed by scanning the sample at 780nm wavelength.
4.2.2 Comparison of gunshot residues detection on Wool knitting (dark red). At a shooting distance of 30 cm, because of fabric fiber interference, gunshot residues on wool knitting are not immediately obvious (Figure 4). But irradiated by iodine tungsten lamp, it can be found that there are obvious granular distribution traces formed by gunshot residues on wool knitting through the infrared spectrum imaging (Figure 5). An analysis of the spectroscopic image is shown in Figure 6.

Figure 3. 60cm shooting spectrum imaging and spectrum curve on nylon fabric (coffee, shadow pattern).

Figure 4. Gunshot residues left on wool knitting (dark red) from 30 cm away, as seen under natural light.

Figure 5. Gunshot residues left on wool knitting (dark red) from 30 cm away, as seen on the image formed by scanning the sample at 810 nm wavelength.
4.2.3 Precautions of the experiment.

- After obtaining the experimental samples, the samples should be stored separately in file bags, so as to avoid mutual contamination;
  - When using CRI software and Vs software to set the scanning range and scanning time, the two systems should be synchronized;
  - For de-mixing of the input image using the software developed by CRI, several reference points should be selected among the gunshot residue pixels of the pseudo-color image and one in the background.

5 Conclusions

- There are few reports on the use of infrared imaging technology in the physical evidence examination, and it is urgent to develop the infrared spectroscopy imaging technology in the detection of trace physical evidence such as shooting residue in court science. Especially, combined with the application of special infrared all-band liquid crystal adjustable wavelength filter, it will open up a new research direction for the detection technology of shooting residue and infrared spectroscopic imaging technology.
  - This article proposes the infrared spectroscopic imaging technology can use to detect the shooting residue. It is a new convenient and rapid method to detect the shooting residue, that a clear outline and distribution of the chemical composition of the shooting residue can be obtained. Thus the characterization of specific target components can be achieved by stoichiometric methods.
  - Gunshot residues are almost always found on the scene when shooting takes place within a certain distance. However, little shooting residue could be extracted due to shooting distances, extraction methods, and other factors. Direct observation of the residues is also difficult. Infrared spectroscopic imaging is a quick and intuitive method that allows for the easy and accurate detection of shooting, and the inspection of the state of gunshot residues. It provides a basis for analyzing the shooting distance, gun type, gun power, and muzzle devices.
  - Common shooting residue detection methods used at present include the paraffin method, neutron activation analysis, atomic absorption, and scanning electron microscopy/Energy-dispersive X-ray spectroscopy (SEM-EDX) [5]. These techniques all have their strengths but are also difficult to implement. Infrared spectroscopic imaging does not place high requirements on samples, and sample
collection could be performed in a variety of ways. The detection is also simple and fast. Compared with other methods, it offers more comprehensive information, and can be used in the cross-verification with traditional methods, giving it unique advantages

- Infrared spectroscopic imaging has features of fast speed, high efficiency, the sample does not need to be pretreated, good repeatability and so on. The test results are rarely affected by anthropic factors, so nondestructive testing can be realized.

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