Theoretical Study on Fingerprint Development by Laser

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Keywords: Laser, Fingerprint, Intrinsic fluorescence

Abstract: Because of their special physiological structures and stable characteristic systems, fingerprints are widely concerned by departments and scholars of many disciplines all over the world; they are especially important in the field of forensic science. So far, fingerprinting is still the first choice of evidence for most investigation departments in identifying individuals; it is also the focus of researchers in forensic science. Using the non-destructive optical method to reveal latent fingerprints is the preferred method to extract fingerprints. However, in practical work, inspectors on the scene are still unable to quickly discover and extract some old and difficult fingerprints, which leads to the failure of the work. In this paper, the application of laser photography technology and the development of fingerprints by laser are studied to provide a theoretical basis for the study of methods which can enhance the effect of fingerprint development, and effectively improve the efficiency of fingerprint manifesting.

1. Introduction

Laser technology is a new technology developed on the basis of electronic physics, quantum physics, optical technologies and electronics in the mid-20th century. Due to the excellent characteristics of laser, laser technology is widely used in national defense, medical and health, agriculture, industrial engineering and other fields. At the same time, the emergence of laser technology provides new technical means for forensic science and new methods for the appearance of some difficult substances.

2. Overview of the Laser Photography Technology

2.1 Principle and Characteristics of Laser

A laser is a coherent light excited by stimulated radiation. When the particle number is inversely distributed, the photon will pass through the medium with the inversion distribution of particle number, and the photon energy will be exactly equal to the corresponding energy level difference of two energies. Under that situation, the received radiation will be dominant. At this time, the output light is stimulated and amplified, and the energy exceeds the energy of the incident light, thus forming the laser. Compared with traditional light sources, the laser has following characteristics.

First, it is highly directional. In general, the emission angle of the laser beam is very small, which makes the output energy of the laser source more concentrated. At the same time, in the process of shooting the evidence, this characteristic can help the laser to avoid the direction of reflected light, and eliminate the reflective point and the reflective band.[1]

Second, the laser has high brightness. Due to the short luminescence time and strong directivity of visible lasers, their brightness is very high. The high concentration of laser energy can be used to excite the intrinsic fluorescence of materials, which provides convenience for the search and extraction of physical evidence.

Third, the laser has good monochromaticity. The optical wavelength of light emitted by ordinary light sources has wide range, while the optical wavelength of light emitted by the laser is narrow and the frequency is single. In forensic experiments, we often use the good monochromaticity of laser to photograph objects with weak contrasts or similar colors, which can enhance the effect of traces

  DOI: 10.25236/mmmce.2020.019

manifesting.

Fourth, the laser has good coherence. Since the laser is generated by the amplification of stimulated radiation, the luminous centers are related, and there is a constant phase difference which forms stable interference fringes. In the research of forensic science, we can use the good coherence of lasers to carry out hologram photography and identification for some stereoscopic traces.

2.2 Principle of Laser Photoluminescence Photography

Photoluminescence (PL) is a phenomenon. After absorbing the light energy from an external excited light source, atoms or molecules can transfer from one electronic state to another and produce light radiation. In the process of photoluminescence, the emission can be divided into fluorescence and phosphorescence according to the length of the fluorescent lifetime of atoms or molecules. If the luminescence goes out within 10-8s after the exciting light disappears, it is called as fluorescence; if the luminescence is not extinguished after 10-8s after removing the exciting light, it is called as phosphorescence. Figure 1 shows the energy level transition of photoluminescence molecules.[2]

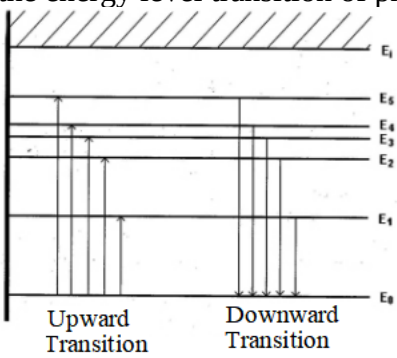

Fig.1 Energy Level State and Energy Level Transition of Molecules and Atoms

According to the Stokes Rule, the fluorescence wavelength is greater than or equal to the wavelength of the excitation light, while the photon energy of the light emission of the matter is less than or equal to the energy of the photon of the excited light radiation. The law points out that there is a shift in the direction of long wavelength, i.e. the Stokes shift, between the peak wavelength of light emission and the peak wavelength of absorption of the matter. It is an important parameter of photoluminescence and has a great influence on the test method.

Photoluminescence photography is a process in which the laser is used as excitation light source to make the object emit fluorescence and record it with camera. In practical work, ultraviolet and visible photoluminescence are widely used.

2.3 The Principle of Visible Fluorescence Photography

According to the Stokes Rule, the laser visible fluorescence photography uses the blue-green light output from the laser device as the excitation source to receive and record the fluorescence brightness distribution of the object in the orange-red region. The absorption filter can absorb the blue-green light while passing through the orange-red light; the blue-green light reflected by the material will be absorbed by the filter, and the orange-red fluorescence emitted by the material will enter the lens for imaging through the absorption filter and be recorded on the photosensitive element. Figure 2 is a schematic diagram of a laser visible fluorescence camera.

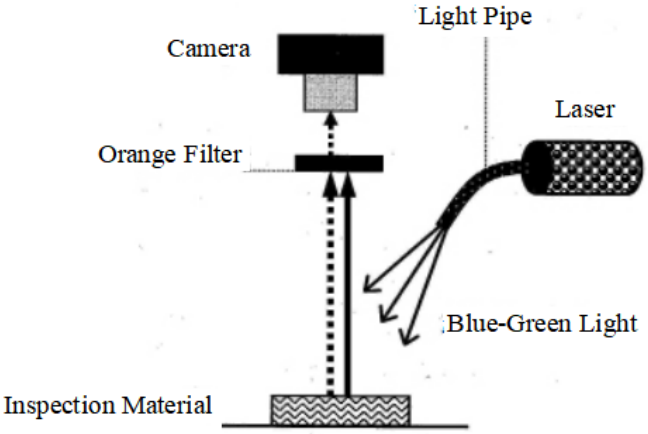

Fig.2 The Laser Visible Fluorescence Photography Attachment.

In the fingerprint test, the blue-green laser excites the foreign matter in the fingerprint to produce fluorescence in the orange-red optical band. However, the traditional experiments show that the efficiency of inherent fluorescence is not high in fingerprint development. Taking sweat fingerprints as an example, the development efficiency is only about 10% to 20%, and the inherent fluorescence brightness of fingerprints is relatively weak. Because the absorption peak band and emission peak band of the main material are in the short wave ultraviolet region and the long wave ultraviolet region respectively, which does not match the blue-green band laser. For a few fingerprints showing "intrinsic fluorescence", although there is controversy, many scholars believe that it is caused by foreign substances mixed in sweat fingerprints.

3. Progress in the Research of Fingerprint Development by Laser

3.1 Research Progress Abroad

In the field of forensic image technology, the visible fluorescence photography technology is an important way to display fingerprints without damage. In 1977, Duff and E.R. Menzel of Xerox Canada and Dalrymple of Ontario Provincial Police firstly reported the method of using lasers to show latent fingerprints, pointing out a new way for optical fingerprint inspection.

In many cases, the intrinsic fluorescence of fingerprints is weak and the background fluorescence is strong. Researchers began to explore a new mode which combines physicochemical fluorescence processing with the laser photography technology. In 1978, Thornton first proposed the method of preparing fluorescent powders with coumarin 6, which was used in the pre-treatment of fingerprints and develop fingerprints with laser photography. In 1979, Salares, Eve and Carey firstly studied the excitation effect of NBD chlorine by the argon laser at 457.9 nm. In 1981, Almog and other scholars firstly proposed the pretreatment of latent fingerprints with gaseous dyes. A year later, Menzel put forward the method of evaporation staining combined with the argon laser to show fingerprints on the skin, and achieved certain results. In 1983, Kobus and other scholars used the gentian violet and coumarin 540 to enhance the latent fingerprint staining after ethyl cyanoacrylate fumigation under the excitation of orange light. In the same year, Stoilovic and his colleagues proposed to use cadmium nitrate to post-process the fingerprints of ninhydrin, and to observe the fluorescence characteristics by the xenon arc lamp illumination in liquid nitrogen at low temperature. In 1986, based on the research of Almog, Lennard and other scholars combined benzoninhydrin, a homologue of ninhydrin with zinc chloride. The method is very effective in the fluorescence detection of latent fingerprints. In 1990, Pounds and other scholars synthesized DFO in the experiment. It reacts with amino acids in fingerprint and can produce strong fluorescence under the blue and green light. Up to now, DFO is still one of the most commonly used methods to show latent fingerprints with sweat on permeable objects.[3] In 2000, the Menzel working group of the United States took the lead in using Cds nanocrystals as photoluminescent agents in fingerprint development, opening up a new path for

fingerprint development.

Although above physical and chemical methods are effective in many cases, the secondary fluorescence of fingerprints has following disadvantages. First, organic solvents need to be used together with fluorescent dyes, which may damage the characteristics of fingerprint lines. Second, organic solvents used for the secondary fluorescence may damage the biological evidence in fingerprints. Third, some dyeing methods have high technical requirements. For example, sometimes rinsing is required in fingermark development, which will not only weaken the fluorescence effect, but also run the risk of removing the fingermarks together. Therefore, as the preferred method of laser photography, researchers have never stopped to study the intrinsic fluorescence of fingerprints.

In addition, researchers used the difference of luminescent life between materials to adjust and control the contrast of fluorescence brightness between fingerprint lines and the object background, which is called the Time-Resolved Imaging technology. As early as 1979, Professor Menzel of the United States studied luminescent fingerprint powders that emit phosphorescence or hysteretic fluorescence, and proposed that the time-resolved imaging can improve the detecability of fingerprints. Although relevant research has made great progress, it has not been widely used in public security departments because of the high requirements for equipment and operating conditions.

3.2 Domestic Research Progress

In China, the research of laser photography began in the late 1970s and early 1980s. In 1982, Yuzhi Dong of Jilin Provincial Public Security Department published *Brief Discussion on Argon Ion Laser Photography*. For the first time, the application of lasers as a light source in the field of criminal science and technology became the focus of this exchange meeting. However, most of the researches focused on the displaying of handwriting in documents, rather than fingerprint development. In 1993, at the Third National Criminal Technology Exchange Conference, researchers developed the ND: YAG double frequency laser to the replace argon ion laser in fluorescence photography. At the same time, the methods to improve the fluorescence efficiency of fingerprints in photoluminescence photography were also discussed. In 2001, Bainian Chang, a researcher from the Second Research Institute of the Ministry of Public Security used multiple bands light sources to detect the inherent fluorescence of fingerprints. The results showed that the development rate of fingerprints with longer storage time was higher than that with shorter preservation time.

In the long-term practice of public security departments and criminal technicians in our country, through repeated experiments, they summed up the working procedures of laser photography to show fingerprints and in cooperation with conventional methods.

4. Application Status and Development Trend of Fingerprint Development by Laser

Photofluorescence photography is a non-destructive optical inspection method, which can show fingerprints on the surface of specific objects. With the popularization of multiple bands light sources as well as the miniaturization and portability of laser light sources, laser light sources will play an increasingly important role in the field of investigation. In the laboratory inspection, using the laser photography to check fingerprints will also become an essential link. This method is relatively simple, and has unique advantages in showing some fingerprints, especially old fingerprints, on the background of non fluorescent objects. However, it also has shortcomings. First, the laser light source is not popular in the grass-roots. Although there are some relevant portable laser light sources in the market, they are mainly designed for the search of biological evidence on the spot; their role in fingerprint development is not prominent. Secondly, as a substitute for the laser light source, multiple bands light sources are more popular at the grass-roots level, but the intensity and monochromaticity of the output light can not be compared with that of laser light sources. Therefore, when using the photoluminescence method to shoot fingerprints, the expected effect may not be achieved.

In the aspect of displaying technology, although researchers focus on the development of

fluorescent agents and dyeing reagents in recent years, there is still room for the further research on traditional intrinsic fluorescence. First, some difficult objects, such as fingerprints on the skin of corpses and fingerprints on textiles, cannot be revealed by the laser photography. Second, substances causing fluorescence in the fingerprint precipitates cannot be fully explained. It is also a technical problem to determine the time of fingerprints according to the luminous components found. Third, the laser photography can be combined with other instruments (such as the spectral imaging system) to improve the imaging sensitivity.

In general, there are still some deficiencies in the current laser photography, and the technology of laser fingerprint development needs to be further improved. Researchers should pay attention to the application of inherent fluorescence of fingerprints while developing non-toxic, non-destructive and cheap fluorescent agents. With the progress of science and technology, some laser photography technology will be popularized and applied in the actual work of public security developments. In recent years, with the promotion and popularization of portable laser search equipment in public security organs, portable and small laser light sources appear in the market, which will further promote the application of photoluminescence photography in the field of forensic science.

5. Summary

Laser method is an effective way of fingerprint development. The laser visible fluorescence photography has good manifestation effects on old fingerprints with oil and sweat and latent fingerprints on some non-smooth and permeable objects. The preliminary research shows that the laser method can enhance the fingerprint development, effectively improve the development efficiency of fingerprints on the spot, and has high research values.

Acknowledgement

This paper is supported by the Foundation for the Academic Innovation Team of Young Teachers in Forensic Evidence Research of Shandong University of Political Science and Law.

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