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# Laser Fingerprint Detection Under Background Light Interference

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**ABSTRACT:** A gateable, image-intensified laser system that permits detection of latent fingerprints under high background light is described. The system is intended for crime-scene work and for daylight conditions.

**KEYWORDS:** criminalistics, fingerprints, lasers, gated imaging

Laser fingerprint detection has become a conventional method of fingerprint development since its discovery in 1976 by E. Roland Menzel [*1,2*]. Because of simplicity, sensitivity, and nondestructiveness, portable fingerprint lasers are particularly suited to crime-scene work. For this reason, the frequency-doubled Nd:YAG (2 ω YAG) and air-cooled argon-ion ($Ar^+$) lasers became commercially available in the mid 1980s. In 1987, we reported [*3–5*] some applications to case work with a 2 ω YAG laser system built in our laboratory. Our techniques are raising growing interest in criminal detective divisions and they are very hopeful that these techniques can be used in daylight conditions in instances where latent fingerprints or palm prints are located on items difficult to move, such as furniture, doors, walls, window frames, etc. Because of strong ambient light interference, laser detection at crime scenes can presently be carried out only at night or under local shading. In 1987, Menzel [*6*] presented a time-resolved luminescence imaging method using a light chopper together with an $Ar^+$-laser and a gateable digital camera for suppression of strong background fluorescence. Later, he suggested that this approach may decrease daylight interference as well. A similar approach, using a TV camera synchronized with a (pulsed) copper vapor laser, was suggested by Almog also [*7*]. According to these suggestions, a gateable image intensified laser fingerprint detection system has been established in our laboratory during the last two years. Its principle of operation and experimental results are presented in this paper.

## Principle

### *Features of Background Light*

In crime scene work, one faces three kinds of background: room (sun) light, outdoor light (usually in shaded places) and lamp illumination. Table 1 gives some typical bright-

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TABLE 1—*Brightness of various environments (lux).*

| Field | | Balcony | | Room | | Lamp Illumination (40W) | |
|---|---|---|---|---|---|---|---|
| Sunny sky | 92 000 | sun-illuminated wall | 32 000 | entrance | 8000 | 0.5 m away | 6000 |
| Full-moon sky | 0.2 | shaded wall | 9 000 | inside door | 1030 | 0.15 m | 1800 |
| Starry sky | $3 \times 10^{-4}$ | corner | 6 000 | corner | 291 | 0.30 m | 400 |
| | | | | | | 0.45 m | 160 |

ness values, which were measured on a sunny day in Guangzhou City. Figure 1 shows the spectral distributions of sunlight, tungsten lamp, and fluorescent tube. Spectra were measured by a PDA photometer calibrated for spectral detector response. An arrow placed on the horizontal axis of Fig. 1 points out the detecting wavelength of inherent fingerprint fluorescence.

*Ratio of Fluorescence Signal to Background Noise*

In the case of visual inspection for laser development in a room light environment, the background will decrease the contrast of the image, and in extreme conditions, it will submerge the fluorescence pattern altogether. Thus, the main problem is how to improve the fluorescent signal to background noise in daylight environments.

In general, the intensity of laser induced fluorescence is proportional to excitation power or power density (that is, brightness). Menzel reported the comparison of Argon-ion, Copper-vapor and 2 ω YAG lasers for latent fingerprint development [*8*]. The author indicated that an $Ar^+$-laser operating at 5145A with 750 mW gives equal perception of brightness as a 140 mW 2 ω YAG laser. The 2 ω YAG laser light is very intense (700 kW) but operates in very short pulses (20 ns long) at low repetition rate (20 Hz), whereas the $Ar^+$-laser operates in the continuous wave (CW), i.e., not pulsed, mode. Integrated over time, that is, over many pulses, which is what the eye perceives or a photographic film records, the above two illuminations produce comparable results because now the average power of the 2 ω YAG laser (140 mW) is pertinent. However, the temporary fluorescence intensities produced by the two laser differ greatly because the excitation power in a pulse duration is 700 kW for the YAG laser, but 750 mW still for the Ar-

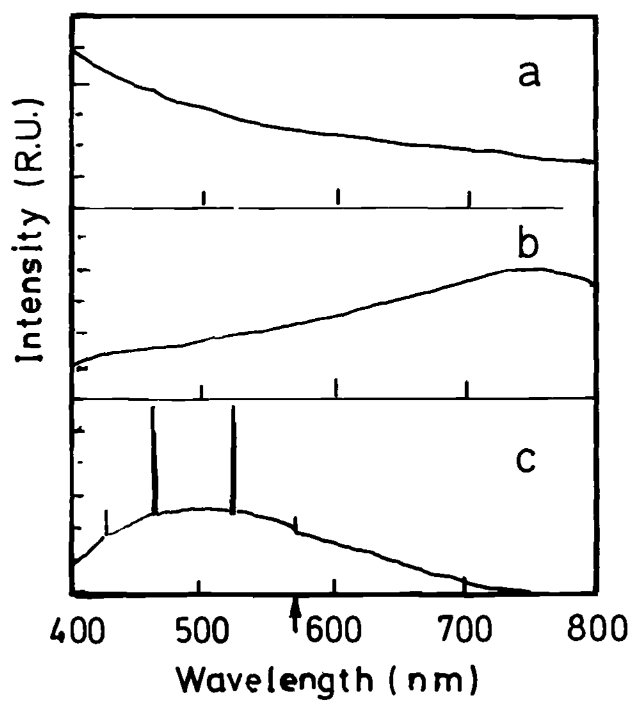


FIG. 1—*Spectral distribution of sun light (a), tungsten lamp light (b) and fluorescent tube (c). Arrow marks detecting wavelength (550) of laser fingerprint technique.*

laser. The ratio between them is up to $10^6$ fold. When the background level is equal to inherent fluorescence, it would be difficult to visually distinguish the signal and noise from each other. In this case, for CW $Ar^+$ illumination, S/N is 1. For 2 ω YAG illumination on account of duty ratio (about $2 \times 10^{-7}$), the average S/N is about 5, but temporary S/N during the pulse duration is up to $10^6$. This is very important to note and indicated to us that one can use gateable techniques to suppress the background interference as schematically depicted in Fig. 2, where the fluorescence duration is 20 ns and duty duration is 0.05 s (for 20 Hz). For a gated aperture of 100 ns, noise would be suppressed by 5 orders of magnitude (see Table 2).

For excitation by green light, a long wavelength-pass orange filter or narrow band filter are always put in front of the camera's lens. In practice, these filters also play a role in decreasing background light due to wavelength selection. Figure 3 shows the continuous spectral distribution of sun-light and lamp light calculated with the Planck formula. In addition we have calculated the integrated intensity ratio R between the orange filter ($\lambda$ from 550 to 800 nm) and total intensity from 400 to 800 nm. For sunlight ($T_1$ = 10 000 $K$), $R(T_1)$ is 44.1% and lamp light ($T_2$ = 3000 $K$) $R(T_2)$ is 84%. For a narrow band ($\lambda_{max}$ = 550 nm, 20 nm bandpass) filter, $R(T_1)$ is 3.8% and $R(T_2)$ is 5.5%. These values are quite interesting. The spectral distribution of sunlight shows pronounced blue content while the tungsten lamp has strong red content. A narrow band filter of about 70% peak transmittance will suppress background light by two orders.

Taking advantage of the above two factors: time gating and wavelength selecting, background interference can be depressed at least 6 to 7 orders. Under mercury (street) lamp illumination, a strong Hg 546.1 nm line will give rather high interference, however.

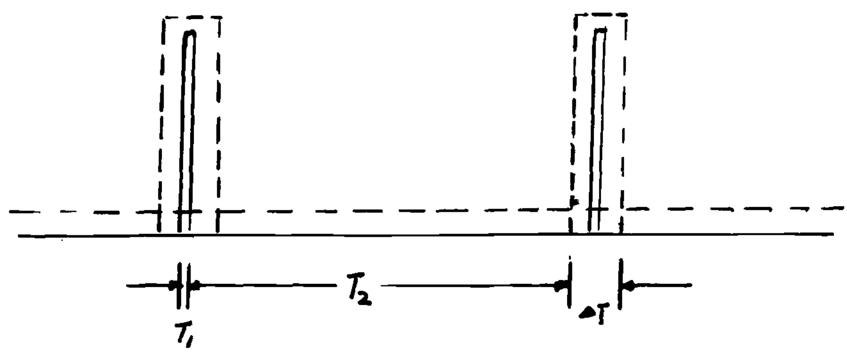


FIG. 2—*Time duration of 2 ω YAG laser.* $T_1$ = *fluorescence duration,* $T_2$ = *duty duration and* $\Delta T$ = *gate aperture.*

TABLE 2—*Comparison of lasers.*

| Laser | 2 ω YAG(700kW at 20 Hz) | | CW $Ar^+$ | (700 mW) |
|---|---|---|---|---|
| Spot area | 3 cm | 5 cm | 3 cm | 5 cm |
| Temporary brightness (lux) | $5.9 \times 10^{11}$ | $2.1 \times 10^{11}$ | | |
| Time average | $8.4 \times 10^5$ | $2.3 \times 10^5$ | $5.9 \times 10^5$ | $2.1 \times 10^5$ |
| Surface emittance of latent fingerprint fluorescence (0.5% quantum yield) | | | | |
| Temporary | $3 \times 10^9$ | $1.1 \times 10^9$ | | |
| Time average | $1.2 \times 10^3$ | $4.2 \times 10^2$ | $3 \times 10^3$ | $1.1 \times 10^3$ |
| With Rh6G treatment (3% quantum yield) | | | | |
| Temporary | $1.8 \times 10^{10}$ | $6.3 \times 10^9$ | | |
| Time average | $7.0 \times 10^3$ | $2.5 \times 10^3$ | $1.8 \times 10^3$ | $6.3 \times 10^3$ |

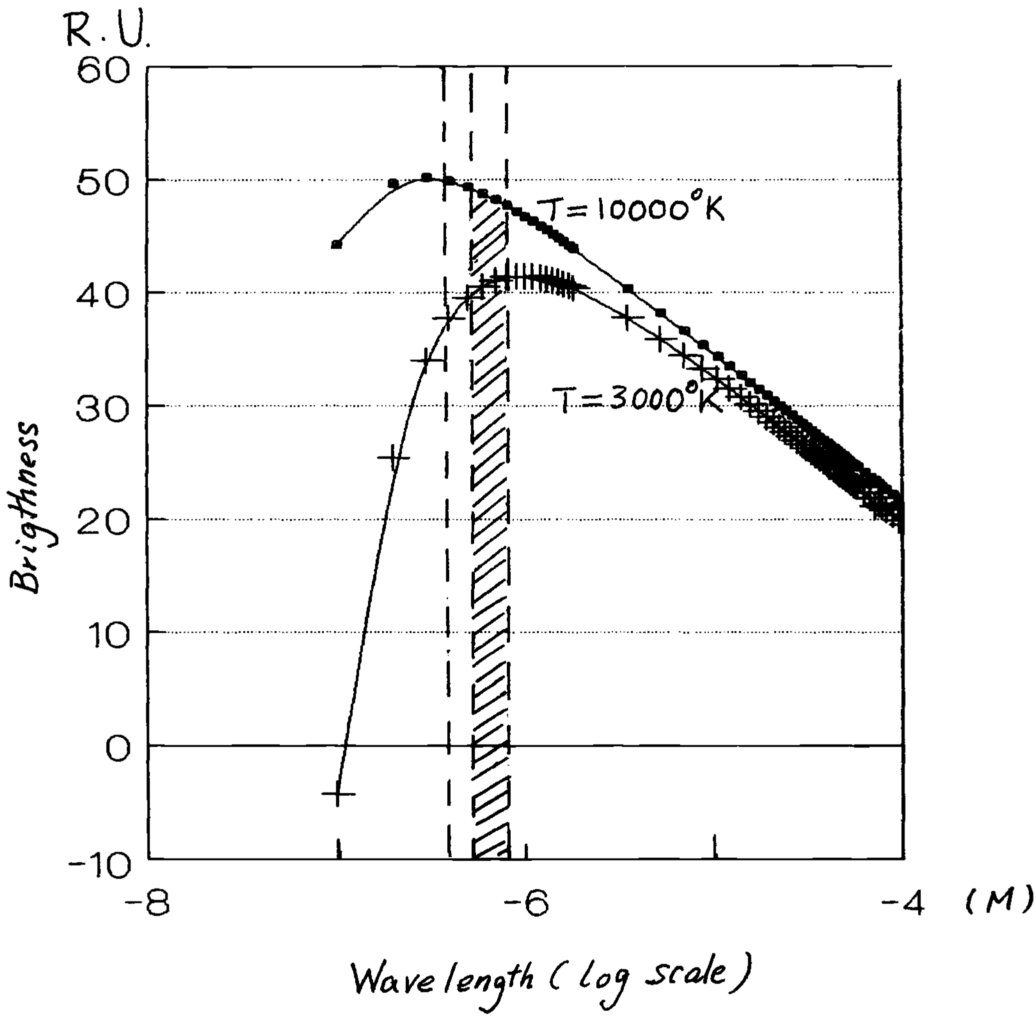


FIG. 3—*Spectral distribution of sun light and lamp light.*

*Experimental Set-Up*

According to the previous principle, a gateable intensified laser fingerprint detection system has been established in our laboratory. The experimental set-up is shown in Fig. 4. The green light (532 nm) from the 2 ω YAG laser was transferred and expanded by an optical fiber cable to illuminate an area of about 3 to 10 cm in diameter. The detection system consists of four parts: search lens, gateable intensifier device, recording camera and high-speed synchronized photoelectronic gate unit.

*Optics*—In common crime-scene work, fingerprint pictures are taken in 1:1 magnification with an expander ring. In a dark environment, one can directly search by eye, wearing protective glasses with a special filter. In our system, the signal first passes through the lens onto the detector window. After gated intensification, one should use an eyepiece lens to watch the image on the phosphor screen of the tube. Obviously, the

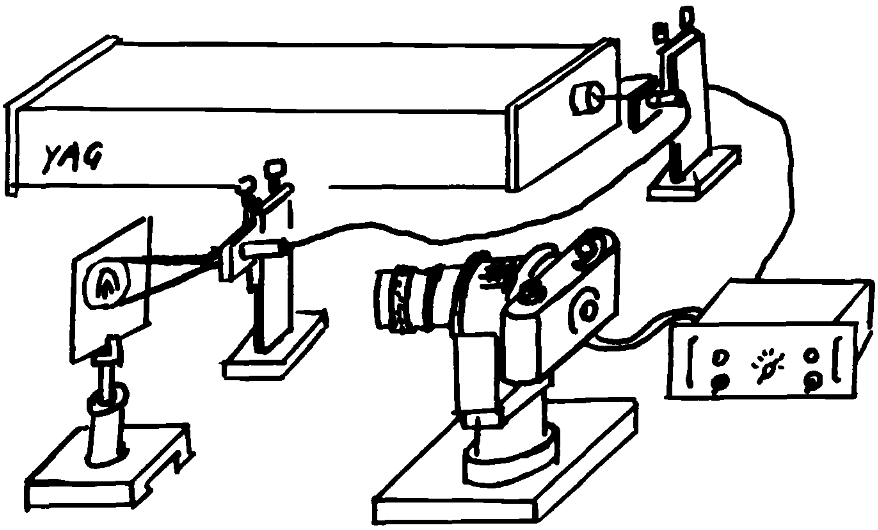


FIG. 4—*Gateable intensified laser fingerprint detection system.*

optical equipment is not as flexible in focusing ability as the eye. Thus, the focusing lens should have some improvement for search operation. As is well known in optical designing, the pinhole gives an image for any object distance, but its focus plane is a spherical coverage, and the spatial resolution is dependent on the pinhole diameter. The smaller the hole, the better the resolution, but the weaker the condensing power. A standard lens has state of the art image quality and condensing power. But in case of expander added (for close distance imaging), depth of focusing and depth of field are very short. It will thus be very difficult to catch a sharp image in practical operation. For this reason, we designed a hybrid lens for our system. Consideration was given to advantages of pinhole and standard lens. The hybrid lens can easily catch a fine image at distances between 10 to 100 cm. A special eyepiece (7X) and a camera box can be exchanged with each other conveniently for visual image inspection or photography of the phosphor screen image.

*Electronics Unit*—The electronics unit consists of two parts. The first part is the fundamental power supply for the intensifier tube. The second part is a synchronized high speed photoelectronic gate. As shown in Fig. 5, the tube is operated in the gate-on mode.

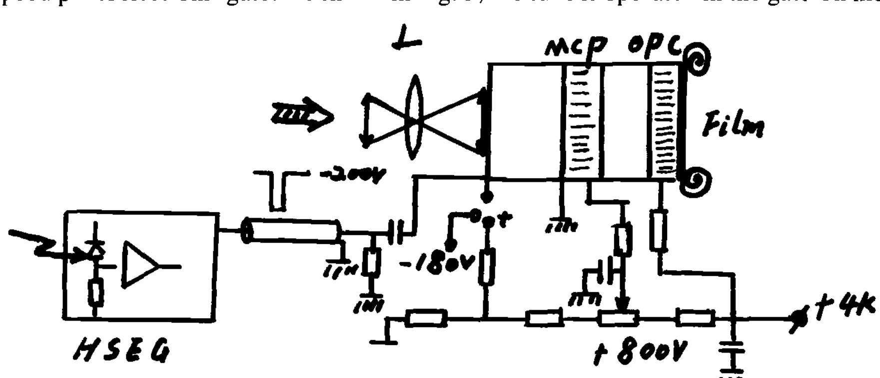


FIG. 5—*Electronic Unit. HSEG: high speed electronic gate, MCP: micro-channel photomultiplier, OCP: optical fiber coupling plane, L: lens.*

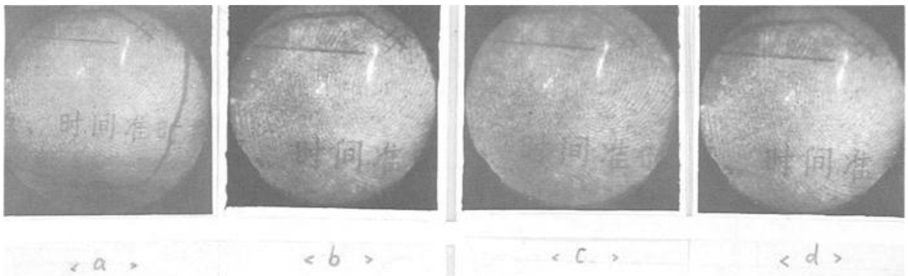


FIG. 6—*Fingerprint pattern under background light interference; (a) dark room; (b) (c) and (d) taken under lamp illumination at 200, 5000, and 100 000 lux, respectively.*

A portion of the light-on signal from the laser is fed by an optical fiber to an ultrafast photodiode (rise time 100 ps) for triggering. The total delay of the gate unit is about 5 to 8 ns. Four gate-on durations, 20 ns, 500 ns, 1 μs, and 2 μs have been used in our experiments.

## Results and Discussion

Figure 6 shows a series of pictures of a latent fingerprint that was located on a plane ticket that was over 5 years old. Inherent fluorescence was excited by 1.5 mJ (532 nm) 15 ns high repetition rate YAG laser. Figure 6*a* is taken in a dark room with the image intensifier ungated, Figs. 6*b*, 6*c*, and 6*d* were taken under tungsten lamp illumination as background interference with 200, 5000, and 10 000 lux brightness, respectively. All pictures are clear. The fingerprint could be observed visually well in a dark room, but was submerged at about 500 lux background interference. In our case, interference is up to 10 000 lux now, and yet the fingerprint pattern is still as clear as in dark room visual inspection. This indicates that the background suppression efficiency of our system is very high. As shown in the data of Table 1, the system can be used in daylight environment for crime-scene work.

Due to combined time resolving and wavelength selecting, background suppression of 6 to 8 orders of magnitude can be achieved.

For high reliability of time gating, one must ensure good photoelectronic synchronization. In general, the variation of YAG pulse repetition is about ±10%, causing trigger jitter and thereby decreasing the reliability of synchronization. Broadening $\Delta T$ would give more reliable triggering but would decrease background suppression. For matching well with our system, the YAG laser should have repetition rate stability of ±5%.

### *Acknowledgment*

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