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Target detection probability calculation model and performance analysis on photoelectric detection target

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To scientifically evaluate the detection performance of photoelectric detection target, based on the working principle of photoelectric detection target, combing with the characteristic of the detection screen of photoelectric detection target using multi-element array photoelectric detector, this paper proposes a new calculation method of target detection probability of photoelectric detection target. We take the central area of the detection screen as the center, and the detection screen is divided into several regions. At the same detection distance, the distance between the projectile passing through each region and the photoelectric detector is different; according to the influence of detection blind area on target irradiance under different detection distance conditions, the calculation model of target signal is established in different region state. The distribution characteristics of target signal and external noise distributed in the whole detection screen are analyzed; the detection probability calculation function is derived. To increase the target radiant energy, laser is applied in photoelectric detection target. The experimental results show that the detection probability obtained by the experiment is consistent with the detection probability model established in this paper. By adding the laser in the photoelectric detection target, the detection ability of the system can be effectively improved, and the detection performance of the photoelectric detection target is stable.

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Keywords: Light field camera, Micro lens array, Warhead fragment, Refocus, Inversion

1. Introduction

The photoelectric detection target has the characteristics of flexible field layout and high test accuracy, and is one of the important testing equipment for testing flying projectile parameters in weapon range. In order to obtain multiple parameters of flying projectile, the multiple photoelectric detection targets are arranged according to a certain spatial geometric relations of detection screens, such as: the four detection screen intersection test system, assuming that the projectile passes through the detection screen vertically, according to the spatial geometric relationship of four detection screens, the flying velocity and spatial position of the projectile can be obtained by the calculation model [1]. The six detection screen intersection test system is used to measure the velocity, spatial position and attitude angle of flying projectile at the ballistic [2]. The seven detection screen intersection test system can obtain parameters of flying projectile when the projectile flied in the variable curve motion state, this test method can obtain more accurate flying trajectory of projectile [3], and so on. However, in the field of weapon range testing, the traditional photoelectric detection target consists of optical system, photoelectric detector, signal processing circuit, and slit aperture, and which uses the unit photoelectric detector as the detection device, although the detection ability of the system can be guaranteed, the detection field of view of the system is also small due to the small size of the unit photoelectric detector [4]. To meet the requirement of large field of view, the multi-element array photoelectric detector is used to make photoelectric detection target have a large field of view, because the photoelectric detector is composed of multiple unit photoelectric detectors, there is detection blind area in the whole detection screen because of the blind area between the unit photoelectric detectors; meantime, with the increase of the detection distance, the width of blind area in the detection screen is increased [5]; The detection mechanism of photoelectric detection target is that when the projectile passes through the detection screen, the surface of the projectile reflects the natural light and radiates to the photoelectric detector, causing the change of light flux of the photoelectric detector, the recognizable projectile signal is obtained by the signal processing circuit [6]. Once the projectile passes through the blind area of detection screen, the proportion of the projectile's surface in the blind area affects the detection ability of the system. The larger the proportion of the blind area is, the more obvious the decline of the detection ability of the system is. Especially in the condition of farther detection distance, because the width of the blind area is wider, the influence of the blind area is more significant, and the detected projectile signal is lost, resulting in the instability of detection performance of the system [7]. In order to scientifically evaluate the detection performance of photoelectric detection target, it is necessary to establish the detection probability calculation model. At present, previous work had been done for the detection probability model of photoelectric detection target, for example, from the perspective of the optical characteristics of target, based on the detection principle of photoelectric detection target, the detection probability model of photoelectric detection target is established [8]. By analyzing the radiant illumination of the target and the background in the photoelectric detection target, the relationship between threshold signal-to-noise ratio and false alarm probability are studied, the calculation model of detection probability of the system is derived [9]. Reference [10] proposes a method to calculate target detection probability quantitatively for an infrared and visible image fusion system, and establishes a corresponding calculation model. To solve the problem that the detection sensitivity of the sky screen is reduced by the external environment, the sensitivity of the sky screen is proposed based on the automatic control principle; this method makes the detection probability of the system improve [11]. For the photoelectric detection system, much work had established the detection probability model mainly from the characteristics of the target and the photoelectric detector, the detection circuit and the size of target; the characteristics of the detection screen of the photoelectric detection target are not fully considered. According to the characteristics of the detection screen of the photoelectric detection target with multi-element array photoelectric detector, this paper divides the detection screen into several areas, the influence of the width of detection blind area, detection region of projection passing through the detection screen, the threshold limitation of false alarm probability and external environment are considered, the new detection probability calculation model of the photoelectric detection target are established, which provides an effective scientific basis for the research, and design of the photoelectric detection target.

2. Detection probability modeling of photoelectric detection target

In the photoelectric detection target, the threshold is set the system, when the target passes through the detection screen, if the detected target signal amplitude is greater than the threshold, we think that the photoelectric detection target can detect the target signal, the probability that the target signal amplitude is greater than the threshold, which can also be expressed as the detection probability of the system, at the same time, since the core of photoelectric detection target is to detect the target by relying on the radiation energy of external natural light to the target, it is easy to be affected by the external environment. If the width characteristic of interference signal is similar to the target signal, once the amplitude of interference signal exceeds the target signal, the system mistakenly thinks that the target signal is detected; there is a certain false alarm probability in the process of detecting the target [12-14]. In order to obtain the detection probability of the system, we need to analyze the probability density distribution curve of the noise signal; the noise signal probability density of the photoelectric detection target follows Gaussian distribution, as shown in Fig. 1. Therefore, the calculation model of false alarm probability is expressed as:

$$P_X = \int_{V_{SNT}}^{\infty} \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(V-\mu)^2}{2\sigma^2}} dV = 1-\Phi\left(\frac{V_{SNT}-\mu}{\sigma}\right) \quad (1)$$

here, V is the target signal, $\Phi\left(\frac{V_{SNT}-\mu}{\sigma}\right)$ is the distribution function, V_{SNT} is the threshold value, μ is the mean value of noise signal, and σ is the variance of noise signal.

Assuming that the false alarm probability is a constant in the photoelectric detection target [15], so, $\frac{V_{SNT}-\mu}{\sigma}$ should also be a constant, we denoted as $\kappa = \frac{V_{SNT}-\mu}{\sigma}$, combined with the false alarm probability, the threshold can be deduced as follows:

$$V_{SNT} = \kappa\sigma + \mu \quad (2)$$

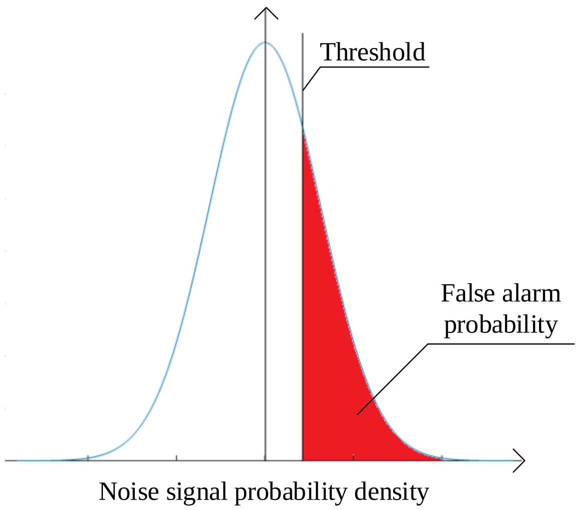

Fig. 1. Relationship diagram of noise signal probability density and false alarm probability (color online)

There is no target passing through the detection screen of the photoelectric detection target, multi-element array photoelectric detectors output the signal, and then the output signal of a plurality of unit photoelectric detectors is processed by a signal processing circuit, this signal is the noise signal; when the target passed through the detection screen of the photoelectric detection target, and the target radiation energy enters to some unit photoelectric detector, and then photoelectric detector output the target signal by using a signal processing circuit, at this time, the output noise signal contains the projectile signal when the projectile passes through the detection screen; so the target signal is quite different of the noise signal target signal. Because multi-element array photoelectric detector is applied in the photoelectric detection target, the detection field of view is larger than that of the photoelectric detection target with unit photoelectric detector. When the detection distance is same, the distance from different field of view to the photoelectric detector is different, resulting in different target radiation characteristics; due to the existence of detection blind area between two unit photoelectric detectors, if the target's size has been determined, the proportion of detection blind area to target's size is different under different detection distance conditions, and the impact on target radiation energy is also different. In order to analyze the target signal characteristics in the whole detection screen in detail, the detection screen is artificially divided, as shown in Fig. 2.

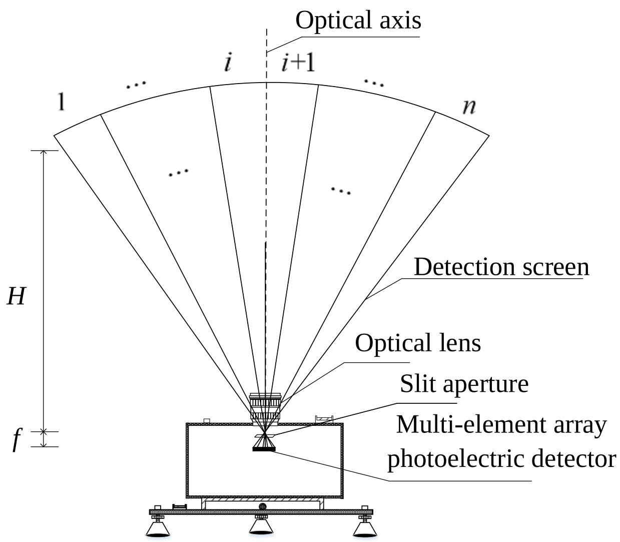

Fig. 2. The divided detection field of view of photoelectric detection target

In Fig. 2, the detection sensor of the photoelectric detection target uses the multi-element array photoelectric detector, combined with the optical lens and the slit aperture, a fan-shaped detection screen with a certain thickness is formed in space. The thickness of the detection screen is determined by the width of the slit aperture, and the width of the detection screen is determined by the multi-element array photoelectric detector and the optical lens. As can be seen from Fig. 2, the detection screen is divided into unit detection region with the same width region, and the number of detection regions is 1 to *n* clock-wise in the whole detection screen, the *i*-th and *i*+1-th detection regions are the center of detection regions.

For the photoelectric detection target, the thermal noise is not considered; the mean value of noise signal is mainly related to the photosensitive surface of photoelectric detector, the background illumination, the dark current, the natural light illumination and the average density of dust particles in the air [16-17]. The calculation model of the mean value of noise signal is shown as:

$$\mu=(2b\tau\pi\lambda\delta\beta(1-\eta x)LK\sum_{i=1}^{\frac{n}{2}}\int_0^{a_1}\cos^4(-\arctan\frac{\frac{a_0}{2}-ia_1-(i-1)a_2+\Delta a}{v})\,d\Delta a+I_1)R \tag{3}$$

In (3), b is the width of slit diaphragm, τ is the transmission coefficient of the optical lens to natural light, λ is the fading coefficient of photosensitive surface of photoelectric detector, δ is the influence coefficient of the average density of dust particles in the air on the noise signal, β is the magnification of detection circuit, η is the flux attenuation coefficient caused by the defocusing dispersion method, x is the defocus, L is the background brightness, K is sensitivity of photoelectric detector, a_1 is the length of unit photoelectric detector, a_0 is the length of the effective photosensitive surface of multi-element array photoelectric detector, a_2 is the width of blind area between two unit photoelectric detectors at a certain detection distance, v is the object distance, I_1 is dark current of background noise, and R is the equivalent resistance of detection circuit.

When the target passes through the detection screen, there are two relationships between the diameter of target and the thickness of detection screen. If the detection distance is small, one case is that the length of target is greater than the thickness of detection screen; on the contrary, another case is that the length of target is smaller than the thickness of detection screen. The width of detection blind area is different at different detection distance, so the target radiation energy radiated to the photosensitive surface of the photoelectric detector is affected by the detection distance, the thickness of detection screen, the detection blind area, the transmittance and edge effect of optical lens. The calculation model of the target signal output by the system when the target passes through the different detection region is established:

$$V_s=\begin{cases}\dfrac{\tau\pi\lambda Lb(d-a_2')Dx\cos^4\omega}{H}(1-\eta x)K\beta R & l\geq K_h\\ \dfrac{\tau\pi\lambda L(d-a_2')lD^2x^2\cos^4\omega}{H^2}(1-\eta x)K\beta R & l<K_h\end{cases} \tag{4}$$

In (4), d is the diameter of target, a_2' is the width of the target falling into the detection blind area, D is the aperture of optical lens, ω is the angle between the position of target passing through the detection screen and the optical axis of optical lens, H is the detection distance, l is the length of target, and K_h is the thickness of detection screen.

Because two unit photoelectric detectors have a certain blind area, which leads to multiple detection blind areas in the whole detection screen. With the increase of detection distance, the width of the blind area becomes larger. When the target passed through the detection screen, if the yaw angle of the target is smaller, the proportion of blind area width to target diameter is the main factor affecting the target radiation energy. If the proportion is larger, some target radiation energy radiated to the photoelectric detector will be lost, causing the target signal outputted by the system is small, even lose to the target signal, at this time, the target signal cannot be identified, and the detection probability is decreased. If the target passes through any position of the whole detection screen, the angle between the position and the optical axis is different at different detection regions, the schematic diagram is shown in Fig. 3.

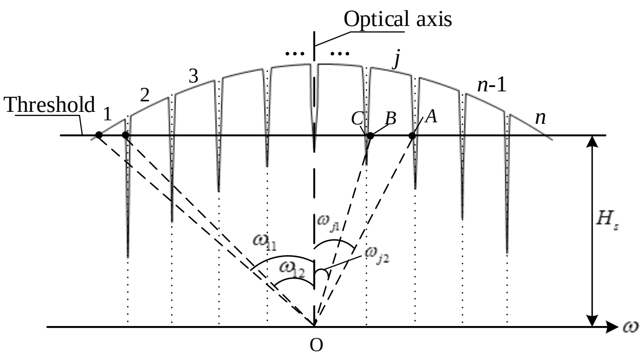

Fig. 3. The schematic diagram of the target passing through any position of the whole detection screen

In Fig. 3, if the target signal amplitude exceeds the threshold, and the detection distance is H_s, ω_{11} and ω_{12} represent the angle between the position and the optical axis when the target passes through the first detection region, in the same way, ω_{j1} and ω_{j2} represent the angle between the position and the optical axis when the target passes through the *j*-th detection region. In order to better describe the detection region, the target detectable region at *j*-th detection region is marked as *A* and *B*, the edge of detection blind area at *j*-th detection region is marked as *C*, that is, the total width of *j*-th detection region is *AC*, *AB* is the width of target detectable region, *BC* is the width of target undetectable region (detection blind area). In the actual test process, the wooden target is used to obtain the data of the position of target passing through the detection screen, if the position is obtained, according the characteristics of detection screen, the ω_{j1} and ω_{j2} can be calculated, and $j = 1, 2, \cdots, n$, the output signal of the system is calculated at different detection field of view and detection distances, the detection probability calculation model at the divided unit detection region can be given:

$$P_i = \frac{(f + x)\,|\tan\omega_{j1} - \tan\omega_{j2}|}{a_1 + a_2} \tag{5}$$

Based on (5), the detection probability calculation model in the whole detection screen of the photoelectric detection target is established:

$$P = \sum_{j=1}^{n} \frac{(f + x)\,|\tan\omega_{j1} - \tan\omega_{j2}|}{n(a_1 + a_2)} \tag{6}$$

According to the (4)-(6), we can found that the greater the target radiation energy, the higher the target signal amplitude of the photoelectric detection target and the greater the detection probability of the system. Therefore, in order to improve the detection probability of photoelectric detection target, we should consider the method of increasing the target radiation energy. Laser is used in the photoelectric detection target, the laser through the optical lens can form the laser emission screen in air, which is same thickness as the detection screen of the photoelectric detection target. The laser emission screen is overlapped with the detection screen of the photoelectric detection target by calibration, when the target passes through the detection screen, the laser emission screen illuminates the target's surface, which makes the radiation energy of the target entering the photosensitive surface of the photoelectric detector be improved [18-19]. The calculation model of target radiation energy is given:

$$\Delta\Phi_1 = \vartheta \tilde{P} S_g \tag{7}$$

here, ϑ is the reflectivity of the target to the laser, $\tilde{P}$ is the laser emission power, and S_g is the area of the reflected laser on the target's surface.

3. Simulation analysis and experimental analysis

3.1. Simulation analysis

According to the detection principle of photoelectric detection target, the detection probability of photoelectric detection target is related to the position of target passing through detection region, target's diameter, background illumination and detection distance; in order to verify the detection probability model established in this paper, according to (5) and (6), the relation of background illumination, detection distance and detection probability is given, as shown in Fig. 4. The relation of detection distance, target's diameter and detection probability is shown in Fig. 5. The relation of target's diameter, detection region and detection probability is shown in Fig. 6.

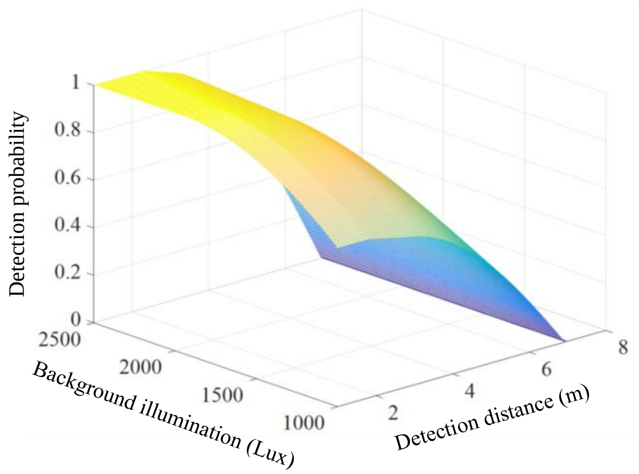

Fig. 4. The relation of background illumination, detection distance and detection probability (color online)

It can be seen from the variation of Fig. 4, when the detection distance is fixed, the background illumination is less than 1000Lux, and the detection probability is proportional to the background illumination. When the background illumination is more than 2000Lux, the detection probability is slowly increased with the background illumination. When the background illumination is fixed, the detection distance is less than a certain detection distance, and the target signal amplitude is greater than the threshold, and the detection probability is higher. On the contrary, the detection probability is evidently decreased with the increase of detection distance, at the same time, the blind area at the corresponding detection region will gradually widen, also causes the detection probability reduced.

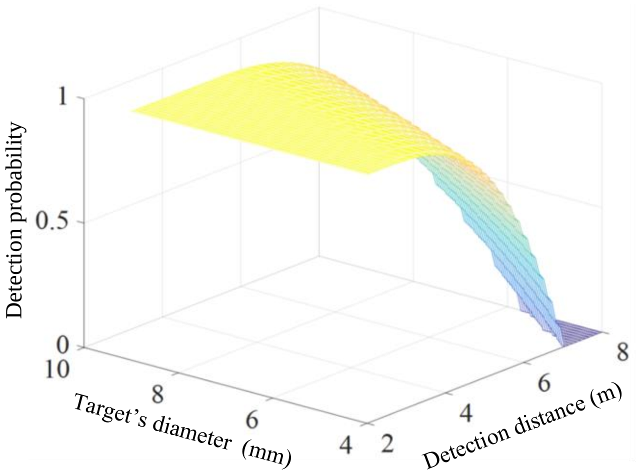

Fig. 5. The relation of detection distance, target's diameter and detection probability (color online)

In Fig. 5, we can found that the detection probability still follows the trend that the larger the detection distance, the smaller the detection probability. If the detection distance is fixed, according to the Gaussian imaging principle, the target imaging area is proportional to the target's diameter, the target signal amplitude is proportional to the target imaging area, namely, the target's diameter is larger, the target signal amplitude is higher, and the detection probability is higher, therefore, the detection probability is affected by the target's diameter.

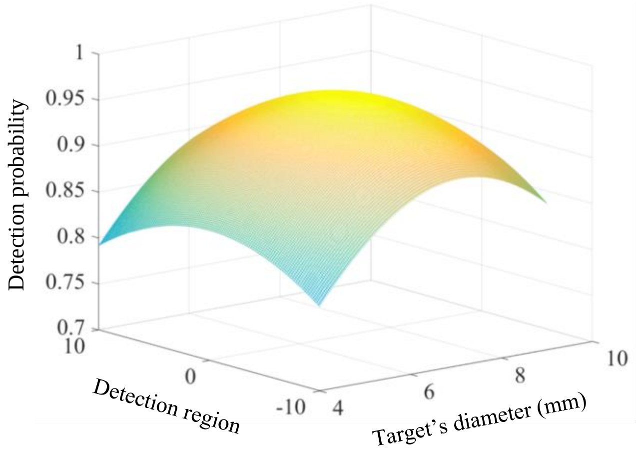

Fig. 6. The relation of detection region, target's diameter and detection probability (color online)

Because of the edge effect of optical lens, when the target passes through the detection screen, and the attenuation of the target signal amplitude is increased from the optical axis to the edge of the detection screen. According to the change curve of Fig. 6, the detection probability is decreased from the optical axis to the edge region. Moreover, if the target's diameter is smaller, the influence of the detection probability at the edge region is greater especially in the limiting detection distance of the system. The limiting detection distance refers to the detection distance when the projectile signal meets the lowest detection signal to noise ratio, in generally, the signal-noise-rate of photoelectric detection target is 1.5.

The detection probability of photoelectric detection target without laser and with laser is obtained at different detection distances respectively, as shown in Fig. 7. If the detection region is different, the detection probability of photoelectric detection target without laser and with laser is also different, as shown in Fig. 8.

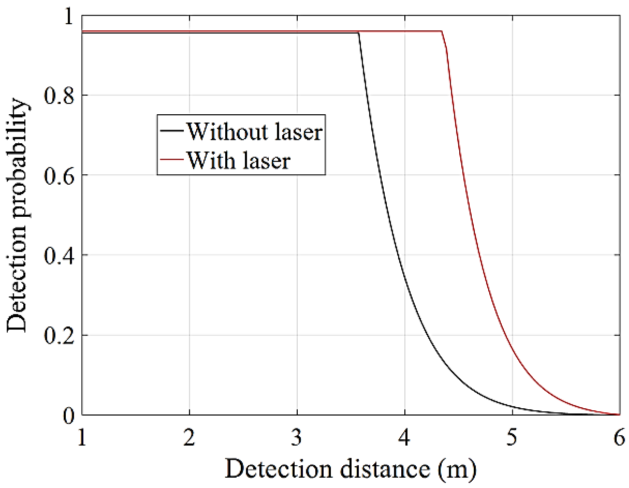

Fig. 7. Detection probability of photoelectric detection target at different detection distances (color online)

According to the results of Fig. 7, the detection probability of the photoelectric detection target is no longer 100% when the detection distance of the photoelectric detection target without laser is greater than 3.6 m. When the detection distance of the photoelectric detection target with laser is greater than 4.3 m, the detection probability of the photoelectric detection target begins to decline. The results show that the laser is applied in the photoelectric detection target, the detection ability of the system is increased, the limiting detection distance is significantly improved, so the detection probability at certain detection distance is also improved by adding active light source.

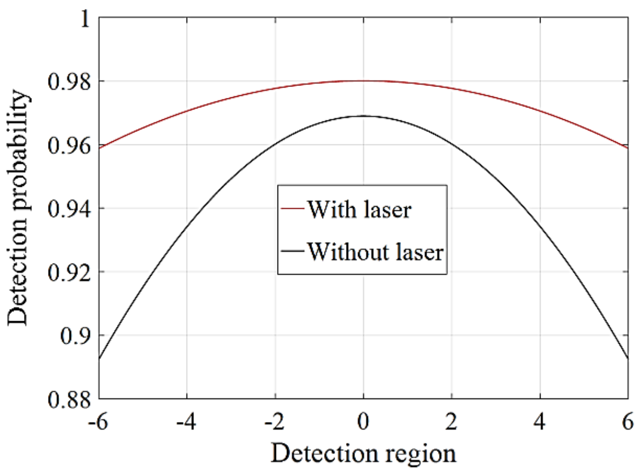

Fig. 8. Detection probability of photoelectric detection target at different detection regions (color online)

According to the results of Fig. 8, the detection probability of the photoelectric detection target without laser at the edge region and the optical axis has a big difference; by adding the laser, the detection probability has significantly improved under the same detection distance, and the difference between the detection probability at the edge region and the optical axis is smaller, especially the detection probability at edge region is significantly improved. The main reason is that the photoelectric detection target is a short-range detection, and the attenuation of laser emission power is not obvious because of the short detection distance. Under the same detection distance, the energy attenuation of laser radiation to the target's surface in the whole detection area is small.

3.2. Experimental analysis

The limiting detection distance of the photoelectric detection target can reaches 800 times of the target's diameter, the photoelectric detector used in the photoelectric detection target is 12 element array photoelectric detectors, the size of photoelectric detector is $0.3\text{mm}\times 40\text{mm}$, and the optical lens is 50 mm. To measure the position of the target passing through the target, a wooden target is set up 2 m away from the photoelectric detection target, the detection screen of photoelectric detection target is perpendicular to the ground, a wooden target and detection screen are parallel each other. Based on the position data of the wooden target, the detection distance and detection region of the target passing through the detection screen is obtained. The projectile with diameter of 4.5 mm and 7.62 mm is used for testing, to compare the impact of projectile's diameter on detection probability. In addition, the photoelectric detection target and the photoelectric detection target with laser are used to carry out test at different background conditions, detection distances, and detection regions. The experimental conditions are shown in Table 1.

Table 1. The experimental conditions

Parameter	Value
Detection distance/m	(2,3.5)
Detection region/m	(-1.4,1.4)
Projectile's diameter/mm	4.5 and 7.62

In the first experiment, two different diameters of projectile are shot at same time period and detection distance and detection region, the diameters of projectile are 4.5 mm and 7.62 mm, respectively. the shooting position is the central of detection screen as the origin, the detection region of the detection screen is -0.24 m to 0.24 m at the detection distance of 3.5 m, the detection distance and the detection region are recorded by the position that the projectile hitting the wooden target, because the background illumination at each time interval is not exactly the same, the detection probability under different background illumination is obtained, as shown in the Fig. 9.

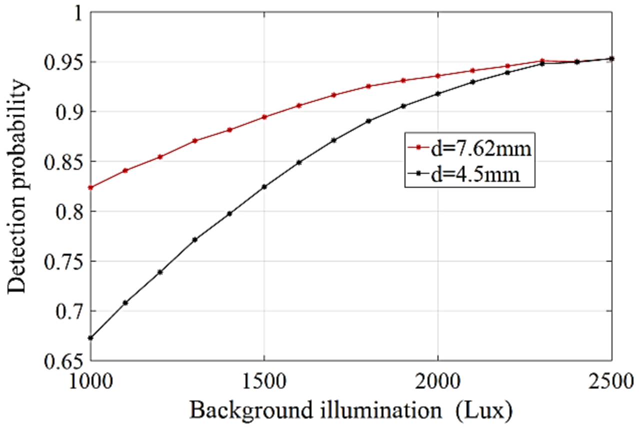

Fig. 9. Detection probability under different background illuminations (color online)

As can be seen from Fig. 9, with the increase of background illumination, the detection probability also increases at a certain extent; under the same background illumination, when the detection distance is determined, the diameter of the projectile is bigger, the greater the projectile radiation energy radiates to the photoelectric detector, so that the projectile signal amplitude is larger, and the detection probability is higher. The experimental results verify the influence of projectile's diameter and background illumination on the detection probability.

In the second experiment, the projectile with a diameter of 4.5 mm is used to shot at different detection region, when the detection distance is 3.5 m, the width of detection area is about 2.8 m. The detection screen is divided into 12 detection region according to the distribution of array photoelectric detectors, the corresponding width of divided each detection region is about 0.23 m, according to the position of the projectile hitting the wooden target, the detection distance and the detection region of the projectile passing through the detection screen is obtained; when the detection distance is decreased to 2 m, use the same test method, obtain and record the test data, Table 2 shows the a part of test data at different detection regions and detection distances. According the all test data at different detection regions and detection distances, Fig. 10 shows the change curve of the detection probability at different detection regions and detection distances. At this time, the noise signal amplitude of the system is about 1.1V, and the maximum value of the projectile signal is 11.8 V.

Table 2. The test data at different detection regions and detection distances

No.	Detection region (m)	Detection distance (m)	Projectile signal amplitude (V)
1	0.18	3.47	8.72
2	0.35	3.62	8.36
3	0.62	3.39	8.31
4	0.89	3.45	7.25
5	1.10	3.54	6.97
6	1.34	3.55	6.83
7	0.09	2.08	10.93
8	0.21	2.09	10.89
9	0.34	1.91	10.84
10	0.49	1.95	10.76
11	0.58	2.04	10.65
12	0.74	1.93	10.52

In the actual test process, even if the projectile is shot at the same position, the position of each projectile passing through the detection screen is not exactly the same, as can be seen from Table 2. From the results of Table 2, we can found that the projectile signal gradually decreases with the increase of the detection distance. When the shooting position moves to the edge region of the detection screen, the projectile signal is the smallest in the edge region of detection area; when the detection distance is about 2 m, the difference of the projectile signal between the edge region and the center region is small; when the detection distance is increased to 3.5 m, the difference of the projectile signal between the edge region and the center region is large. The main reason is that for the projectile's diameter of 4.5 mm, the limiting detection distance of the system is 3.6 m. When the detection distance is 3.5 m, once the projectile passes through the edge region of detection screen, the distance between the projectile and the photoelectric detector is about 3.7 m, which is slightly larger than the limiting detection distance of the system, so that the attenuation of the projectile signal is more, and is relatively small amplitude, the experimental results are consistent with the simulation results of the theoretical model.

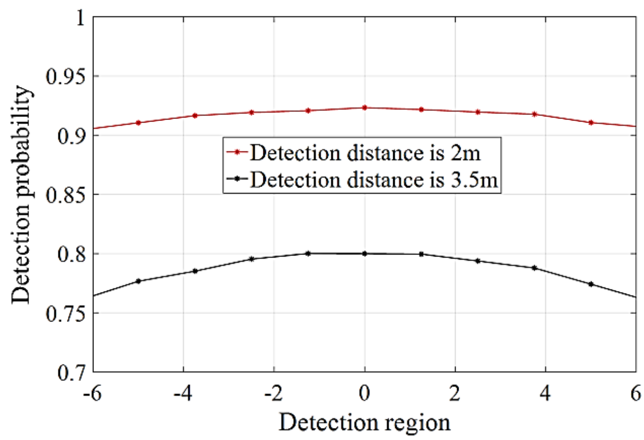

Fig. 10. The change curve of the detection probability at different detection regions (color online)

From the result of Fig. 10, when the detection distance and projectile's diameter are determined, the detection ability of the photoelectric detection target is the largest in the central area of the detection screen, because the distance between the projectile and the photoelectric detector is the shortest in this detection region, and the detection probability is the largest. When the projectile's diameter is same, the smaller the detection distance is, the greater the detection probability is. Although the detection screen on both side are basically symmetrical, the natural environment and the target with uncertain attitude affect the projectile radiation energy in the actual test, the projectile signal from the symmetrical region of the detection screen is not completely consistent, the detection probability is not completely the same at symmetrical region of the detection screen.

In the complex test environment, the detection probability of photoelectric detection system is related to signal-to-noise ratio and false alarm probability [20], the calculation model of detection probability is as follows:

$$P' = \frac{1}{2} + \frac{1}{2} erf\left[\left(\frac{1}{2} + SNR\right)^{\frac{1}{2}} - ln^{\frac{1}{2}}\left(\frac{1}{P_X}\right)\right] \quad (8)$$

In (8), *SNR* is the signal-to-noise ratio, which is the ratio of the projectile signal to the noise signal.

In order to verify that the calculation model of detection probability established in this paper is advanced and the detection ability of photoelectric detection target by using the laser is improved; combined with the formula (8), the results of two different calculation models of detection probability are given under the same test conditions. Therefore, in the third experiment, two set photoelectric detection targets are used for test, a set of test equipment has a laser as light source, and the laser emission power is about 10 W; Through calibration, the laser emission screen is overlapped with the detection screen of photoelectric detection target, the distance between two set photoelectric detection targets is about 0.5m, and the two set photoelectric detection targets are adjusted to make the two detection screens parallel and perpendicular to the ground. In the central detection region of the detection screen, the detection distance is 2 m as the initial detection distance, increase 0.2 m each time until the detection distance is 3.6 m, the target's diameter is 4.5 mm, we shot 100 projectiles at each detection distance, the test data at different detection distances is recorded, as shown in Tables 3 and 4. At this time, the noise signal of the photoelectric detection target is about 1.2 V, the noise signal of the photoelectric detection target with laser is about 0.94 V, $\overline{P}$ is the actual test results.

Table 3. The test data of photoelectric detection target with laser

No.	Average detection distance (m)	Average projectile signal amplitude (V)	P	P'	$\overline{P}$
1	1.97	11.63	0.95	0.97	0.95
2	2.16	11.58	0.95	0.96	0.95
3	2.42	11.51	0.95	0.96	0.95
4	2.56	11.48	0.94	0.96	0.95
5	2.83	11.35	0.94	0.96	0.94
6	3.04	11.21	0.93	0.96	0.94
7	3.17	11.02	0.92	0.95	0.93
8	3.46	10.93	0.91	0.95	0.92
9	3.59	10.86	0.91	0.95	0.92

Table 4. The test data of photoelectric detection target without laser

No.	Average detection distance (m)	Average projectile signal amplitude (V)	P	P'	$\overline{P}$
1	1.97	10.82	0.94	0.87	0.92
2	2.16	10.68	0.93	0.86	0.91
3	2.42	10.21	0.92	0.84	0.91
4	2.56	9.85	0.92	0.82	0.90
5	2.83	9.19	0.91	0.78	0.88
6	3.04	8.46	0.89	0.74	0.87
7	3.17	8.01	0.86	0.70	0.85
8	3.46	7.38	0.81	0.65	0.82
9	3.59	6.89	0.73	0.61	0.75

From the test results in Tables 3 and 4, we can find that with the increase of the detection distance, the detection probability has a downward trend, and the closer the detection distance is to the limiting detection distance, the decrease of the detection probability is more obvious, the results are verified from the test data in Table 4. For the photoelectric detection target without laser, the limiting detection distance of the system is about 3.6 m, so when the detection distance is 3.59 m, the projectile signal is significantly reduced, so that the detection probability is also low; Form the test data of Table 3, we can see that when the laser is added in the photoelectric detection target, the detection distance is 3.59 m, the projectile signal is large, and the detection probability is also large; the results mean that the detection ability of the system is improved by adding active light source in the photoelectric detection target. At the same time, according to the calculation results of detection probability in Tables 3 and 4, it can be seen that the calculation result of detection probability in formula (8) has a larger deviation from the actual test result, especially for the photoelectric detection target without laser, its detection probability has a larger deviation from the actual test result; The results of detection probability in this paper are closer to the actual test results, which shows that the detection probability model established in this paper is more consistent with the detection performance of photoelectric detection target. In addition, in order to stabilize the detection performance of the system, an active light source is added, further research on target radiation energy, so as to provide design ideas and basis for effectively improving the detection ability of photoelectric detection target.

4. Conclusions

In this paper, the photoelectric detection target uses the multi-element array photoelectric detector, make the detection screen has large field of view; because of the detection blind area of unit photoelectric detectors, there are multiple detection blind areas in the whole detection screen of photoelectric detection target; the detection screen is divided into several regions, combined with the influence of detection blind area on target irradiance under different detection distance conditions, the target signal calculation model is established in different region state, and the detection probability calculation function is derived. In order to improve the detection ability, the laser is applied in the photoelectric detection target; the target radiant energy calculation function is established. Through many experiments, the feasibility of the detection probability calculation model established in this paper is verified. The research in this paper provides a certain practical value and research significance for the design of photoelectric detection target.

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