Sensors & Transducers, Vol. 177, Issue 8, August 2014, pp. 24-30

Sensors & Transducers

http://www.sensorsportal.com

Research on Target Recognition Method and Information Processing in Complex Photoelectric Detection Environment

Zhiyong Lei, Zhizhen Liu
Electronic Information Engineering College, Xi'an Technological University,
Xi'an, 710032, China
E-mail: zhizhenliuxn@126.com

Received: 26 June 2014 /Accepted: 30 July 2014 /Published: 31 August 2014

Abstract: In order to solve the question that the photoelectric detection system is vulnerable to environmental factors in complex environment, which affects the detection of target recognition, and then the detection capability of the system is reduced. The double light path detection target recognition method is proposed. This research aims to study the characteristics of output signal that Raindrops affect to photoelectric detection system, analysis the differences between the raindrop signal and the target signal which affect to detection system at the same time and the target characteristics under rainfall environment, establish a target recognition algorithm, provide the design of the complex environmental targets photoelectric detection information. Through experimental simulation and analysis, the double light path detection target recognition method that can reduce the interference by environmental factors. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Double light path detection, Target recognition, Photoelectric detection, Rainfall environment.

1. Introduction

Photoelectric detection system mainly consists of laser transmitter system and photoelectric detection system. Laser system outputs pulse laser, and receiver system obtains and processes the laser signal by reflected from the target and then completing the target detection. When the target gets into the detection area of the detection system, it is changed the current of the photoelectric detector's laser reflected by target [1]. After processing amplifying and shaping circuit, the signal outputs a pulse signal which can identify target discrimination. The advantages of the laser are diversity, such as its better ability to resist electromagnetic interference, monochromatic and coherence, replacing radio to accomplish the projectile detonation point control accurately. Therefore it is widely used in various types of tactical missile and conventional ammunition [2]. However, laser photoelectric detection system is easily affected by the environmental factors (clouds, mist, rain and snow etc.), which can scatter and decay the effects of the laser signal and weaken the system performance, which can make the system failure sometimes. For example, when a pulsed laser through large diameter raindrop, going with serious backscatter randomly, incident light return to the detection system receiving field of view along the path of the signal transmission light [3]. It will make a mistake that the target echo signal when the signal reaches certain strength and meets certain conditions. So it is worth studying in extending application scope of photoelectric detection system. Based on the theory of photoelectric detection system, this thesis studies the target identification method by the double light path photoelectric detection system in the rain.

2. Target Photoelectric Detection Principle and the Optical

2.1. Target Photoelectric Detection Principle

Photoelectric detection system is mainly composed of laser transmitter system, receiving optical lens, receiving detector, amplifier and filter circuit and signal processing circuit. Laser field formed by laser system and accepting field formed by receiver system, the two fields join and build a detecting area. It means that when the target gets into the area, the echo signal can be obtained by photodetector [4]. Once the target enters into the detection area, the echo signal energy changes, what makes a change of the current on the photoelectric conversion device, and then output a signal that has been processed by amplifying and shaping circuit. At last the target information is extracted. As mentioned above, both receiving system and launch system constitute the photoelectric detection system together.

2.2. The Receiving System of the Optical Properties

2.2.1. Response Rate

Response rate is a parameter to describe the sensitivity of photoelectric diode. The so-called response rate is that diode output photocurrent when accept unit of optical power for a given wavelength of incident light. It can be given by the formula (1):

$$Q = \frac{q\eta\lambda}{hc} = 0.805\eta\lambda(\mu A/\mu W) \qquad (1)$$

where η is the quantum efficiency, λ is the wavelength light [5].

2.2.2. Spectral Noise I_N and Detection Rate D_λ

The noise of the PIN silicon photodiode is mainly determined by the dark current. Its size reflects directly the detection ability of the device for weak signal. The noise mainly for the nature of the shot noise. Represented as:

$$I_N = \sqrt{2I_d \bullet q \bullet \Delta f} \qquad (2)$$

where I_d is the dark current

The D_λ is showed that diode can able to achieve signal-to-noise ratio of unit power radiant energy in unit area when the bandwidth of the amplifier is 1 Hz. Its expression is:

$$D_\lambda = \frac{Q}{I_N}\sqrt{A \bullet \Delta f} \qquad (3)$$

2.2.3. Response Speed

Response characteristics marked the transmission of photodiode response to rapid mutation of optical signal. The three influencing factors are light carrier transit time, RC relaxation time and minority carrier diffusion time. The spread time can be negligible if the depletion layer is the main workspace [6].

3. The Interference Characteristics of Rain in Complex Environmental

3.1. Interference Principle of Detection System Caused by the Raindrops

When the photoelectric detection system applies to rainfall environment, it will be affected by different degrees of scattering with the size of a raindrop [7], which interferes seriously detection performance of detection system. The interference diagram is shown in Fig. 1 and the scattering diagram is shown in Fig. 2.

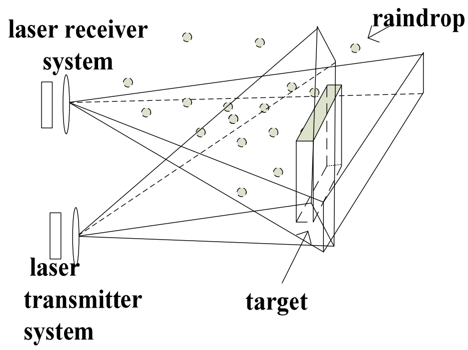

Fig. 1. Interference diagram.

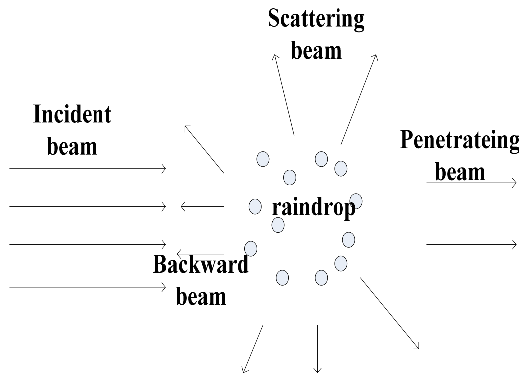

Fig. 2. Scattering diagram.

Laser scattering distribution becomes complex, when a raindrop's size is large. The big raindrops make the degree of laser scattering stronger, and collect the laser's direction within a small point of view, the scattered energy is either maximum or minimum on the other direction [8].

Therefore, when the laser emission signal enters into the rain, a part of the incident light can be made along the path of the light signal transmission back into the detection system receiving field of view because of the light scattering effect. When the signal reaches certain strength and meets certain conditions, it will be mistaken for the target echo signal.

In the detecting area, the peaks of echo signal that mingle with the reflected signal of the goal present a dynamic change due to the different distance from the raindrop to the photoelectric detector and uncertainty of backward scattering degree. Usually it is difficult to distinguish the real target signal effectively, which lead to that it can't work normally [9-10].

In order to eliminate or weaken the interference caused by the rainfall, the double light path detection method is presented in this paper, which is according to the basic structure and rainfall characteristics, which using the differences of master-slave signal detection area, thereby photoelectric detect system works well in the rainfall.

3.2. The Laser Attenuation in the Rain

When the laser transmits in the rain, it will be absorbed and scattered by the rain. Absorption loss change with the wavelength and scattering does not cause the loss of laser energy, but will change its original spatial distribution, so it will cause the attenuation of laser beam energy on the direction of propagation originally after scattering. The laser attenuation coefficient can be expressed as

$$\gamma = \mu_s(\lambda) + \mu_a(\lambda) \tag{4}$$

$$\mu_s(\lambda) = \int_{D_1}^{D_2} \sigma_s(D) N(D) dD \tag{5}$$

$$\mu_a(\lambda) = \int_{D_1}^{D_2} \sigma_a(D) N(D) dD \tag{6}$$

where $\mu_s(\lambda)$ is the raindrops scattering coefficient, $\mu_a(\lambda)$ is the raindrops absorption coefficient, $N(D)$ is the raindrop size distribution function, $\sigma_s(D)$ is the raindrops absorption cross section, $\sigma_a(D)$ is the rain scattering cross section.

By the empirical expression, rainfall intensity can be used to express the total cross section: $S_t = Kp$, the attenuation coefficient can be expressed as

$$\gamma = \int_{D_1}^{D_2} S_t N(D) dD = \int_{D_1}^{D_2} KpN(D) dD \tag{7}$$

The typical values of Constant K are as follows: in light wave band, the p < 10 mm/h, K≈0.6, for p > 10 mm/h, K≈0.2.

3.3. The Laser's Transmission Characteristics in Rainfall

In the transmitting process of the pulsed laser from laser transmitter system we should mainly consider laser scattering and absorption caused by raindrop. To build the theoretical model of laser transmission in rainfall on the basis of the above factors in the rainfall, as is shown in Fig. 3.

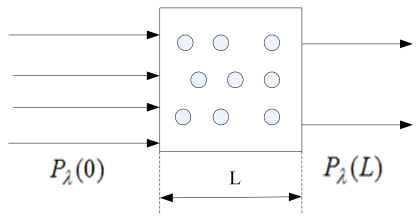

Fig. 3. Laser transmission model in the rainfall environment.

According to Bouquet Lambert [5] exponential decay law concluded that:

$$P_\lambda(L) = P_\lambda(0)\exp(-\gamma \times L) \tag{8}$$

where τ is the transmittance, $P_\lambda(L)$ is the power after laser transmission distance; $P_\lambda(0)$ is the power of distance L for zero; γ is the attenuation coefficient in the rain.

For the semiconductor pulse laser, the beam has divergence angle, so the scope of the beam is changing with the distance in the process of transmission when the light is shining on the scatter medium [11]. As a result, the beam transmission in the rain, the attenuation coefficient is a function of the beam transmission distance. For divergent beam section which is circle, its divergence angle is theta and beam transmission distance is L, then the volume of the light ray scattering medium range as follows:

$$V(\theta, L) = \frac{1}{3}\pi \times \left(\frac{\theta L}{2}\right)^2 \times L = \frac{1}{12}\pi\theta^2 L^3 \tag{9}$$

where θ is the divergence angle, L is the transmission distance .

Therefore, the attenuation coefficients of divergent beams through rainfall are as follows:

$$\gamma(\lambda) = \int_{D_1}^{D_2} ((\sigma_s(D) + \sigma_a(D)) N(D) V(\theta, L) dD \tag{10}$$

So, for a particular wavelength laser beam, the attenuation coefficient is not only related to rainfall intensity *p*, but also related to the beam divergence angle theta and transmission distance.

According to the laser attenuation coefficient in the process of rainfall from formula (4) into the above formula and we get the power when the propagation distance is d:

$$P_f = \frac{P_\lambda(d)\rho\tau_1\tau_2 S_r}{2\pi D^2} \tag{11}$$

Conclusion by reference [12], the target reflection echo power is obtained in a distance of d:

$$P_\lambda(d) = P_\lambda(0)\exp(-\gamma\times d) \tag{12}$$

In that way, the signal of target reflects as another source signals, it is concluded that the receiving power of the laser detector by (11)

$$P_I = \frac{P_\lambda(0)\rho\tau_1\tau_2 S_r}{2\pi D^2}\exp 2(-\gamma\times d) \tag{13}$$

From the (13), it is concluded that the factors that influence the detection of received power include transmission power, the size of the cross section that laser irradiate on the target, the laser emission Angle and distance. And whether the parameter P_I closely related to identifying the target or not. So it is of great significance for the experiment to calculate the relationship between received power, rainfall intensity and distance in the theory.

4. The Algorithm of Target Recognition in Rainfall Environment

4.1. Design of Eliminating the Interference from the Rain

Based on the analysis mentioned above, add a transmitter and receiver system to the photoelectric detection system, according to the characteristics of the mixed reflected signals of the target and raindrops. The A zone obtains the reflection signals of raindrops and targets at the same time, but the B zone only obtains the reflection signals of raindrops, as is shown in Fig. 4.

$$F_1(t) = f_1(t) + f_2(t) + n(t) \tag{14}$$

$$F_2(t) = f_2^{\nabla}(t) + n^{\nabla}(t) \tag{15}$$

where $f_1(t)$ is the reflected signal of target in the A zone receiver, $f_2(t)$ is the reflected signal of rainfall in the A zone receiver, $f_2^{\nabla}(t)$ is the reflected signal of rainfall in the B zone receiver, $n(t)$ is the noise signal in the A zone receiver, $n^{\nabla}(t)$ is the noise signal in the B zone receiver.

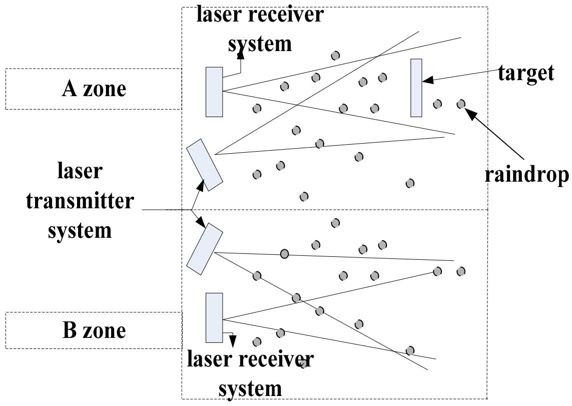

Fig. 4. Dual optical probe schematic.

If the A and B detection circuit are consistent, then $n(t) \approx n^{\nabla}(t)$, then:

$$F(t) = f_1(t) + \Delta f_2(t) + \Delta n(t) \tag{16}$$

$F(t)$ is the final output signal of the photoelectric detection system, $\Delta f_2(t)$ is the rain signal output and $\Delta n(t)$ is the noise signal output. Obviously $f_1(t) > \Delta f_2(t) + \Delta N(t)$ out, if we could make $\Delta f_2(t)$ smaller, then $F(t) \approx f_1(t) + \Delta N(t)$, so there is no rainfall reflected signal in $F(t)$. And we can select the appropriate threshold voltage to eliminate the signal $\Delta N(t)$, thereby eliminate the raindrop signal interference and correctly identify the target.

A zone is the main field of receiving area, which can produce rainfall signal as well as producing the target signal in the area, but the B zone can only produce rainfall signal [13]. The signals in the two detecting area are processed by amplifying and subtraction circuit. Thereby it can get the real target signal of main detecting area from detecting output circuit, as is show in Fig. 5. It is conclude that subtract rainfall signal of main detecting area and subordinate detecting area weaken the rainfall signal of main detecting area and retain the useful signal so that improving the ability of anti-jamming and target identification of detection system.

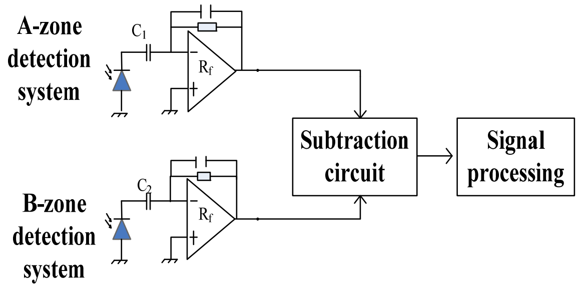

Fig. 5. Circuit of eliminating the interferences of raindrop.

4.2. Target Information Recognition

Based on the Neyman-Pearson theorem [14-15], simplifies the output results from A and B area to A $\{x[0], x[1], \ldots, x[N-1], w_R[0], w_R[1], \ldots, w_R[N-1]\}$, B: $w_R[n]$ $n = 0, 1, \cdots, N-1$. Hypothesis in the condition of H_0, $x[n] = w[n]$, in the condition of H_1, $x[n] = A + w[n]$ (A>0), and under the two hypotheses $w_R[n] = w[n]$, then the reference noise samples $w_R[n]$ can be used to eliminate the noise pollution $w[n]$. If observing the $\{x[0], x[1], \ldots, x[N-1], \ldots x[2N-1]\}$ or represents the remaining samples, so

$$H_0 : x[n] = w[n] \qquad n = 0, 1, \cdots 2N-1$$

$$H_1 : x[n] = \begin{cases} A + w[n] & n = 0, 1, \cdots, N-1 \\ w[n] & n = N, N+1, \cdots, 2N-1 \end{cases}$$

By investigating the Neyman-Pearson tested and proved, if $\frac{p(x_1, x_2; H_1)}{p(x_1, x_2; H_0)} > \gamma$, then get H_1, which becomes

$$\frac{\prod\limits_{n=0}^{N-1} \frac{1}{\sqrt{2\pi\sigma^2}} \exp[-\frac{1}{2\sigma^2}(x[n]-A)^2]}{\prod\limits_{n=0}^{N-1} \frac{1}{\sqrt{2\pi\sigma^2}} \exp[-\frac{1}{2\sigma^2} x^2[n]]} \times \frac{\prod\limits_{n=N}^{2N-1} \frac{1}{\sqrt{2\pi\sigma^2}} \exp[-\frac{1}{2\sigma^2} x^2[n]]}{\prod\limits_{n=N}^{2N-1} \frac{1}{\sqrt{2\pi\sigma^2}} \exp[-\frac{1}{2\sigma^2} x^2[n]]} > \gamma, \qquad (17)$$

which becomes

$$\frac{p(x_1; H_1)}{p(x_1; H_0)} > \gamma \qquad (18)$$

so that x_2 is irrelevant to the detection problem. So you can take the subtraction method in the design above. Based on the identification method, if the formula $F(t) \approx Af_1(t) + \Delta N(t) > f_0$ set up, then the target information is detected.

5. Test Analysis

Based on the laser transmission model in the rainfall environment in the section 3.3. Here is a simulation of that different wavelengths of laser which transmit in the rainfall environment causing transmittance changes and a actual effect diagram which use the double optical path and single photon detection method to detect in the rain environment.

From the two charts (Fig. 6 and Fig. 7), when rainfall intensity is less than l0 mm/h, the transmittance of the wavelength of the laser energy are more than 80 % or less, but the laser transmittance decreases with the increase of rainfall intensity, when rainfall intensity is less than l00 mm/h, transmittances is under 40 % and the light transmittance of infrared laser is less than blue-green wavelength laser. This is because the blue-green wavelengths laser scatters by rain only as well as the infrared laser scatters and absorbs by raindrops at the same time, and the greater the rainfall rate is, the more obvious the absorption is, which makes the infrared wave attenuation increasing and transmittance decreasing.

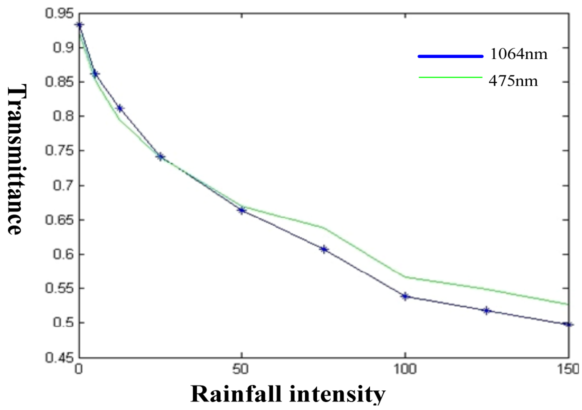

Fig. 6. 1064 nm and 475 nm wavelengths of laser which transmit in the rainfall environment causing transmittance changes.

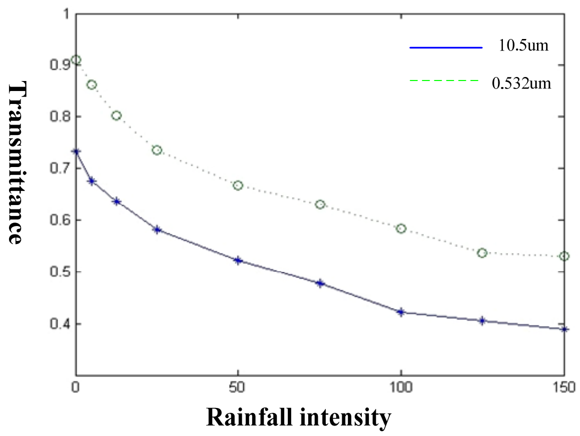

Fig. 7. 10.5 um and 523 nm wavelengths of laser which transmit in the rainfall environment causing transmittance changes.

According to the design principle described in section 4.1, experiment of double light path photoelectric detection system in the rainfall environment gets the result which is as shown in the

Fig. 8. The experiment of single light path photoelectric detection system in the rainfall environment gets the result which is as shown in the Fig. 9. It can obviously find that with the signals in the two detection areas subtracted, it retained the target signals in the detecting area, improving the photoelectric detection system for target recognition. The final signal of the system output as show in Fig. 10.

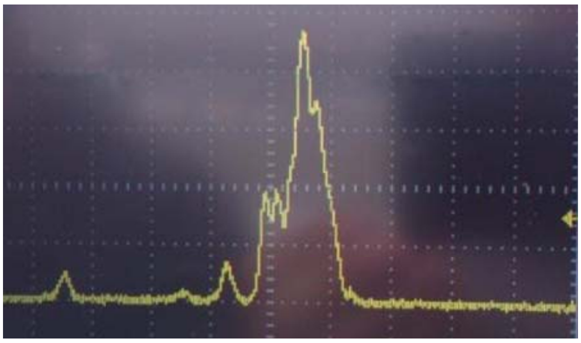

Fig.8. The result of the double path photoelectric detection system in the rainfall environment.

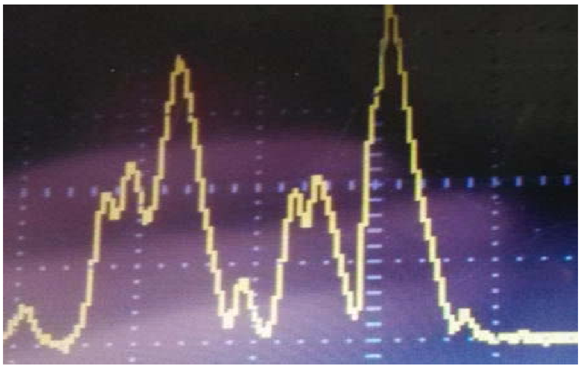

Fig. 9. The result of the single path photoelectric detection system in the rainfall environment.

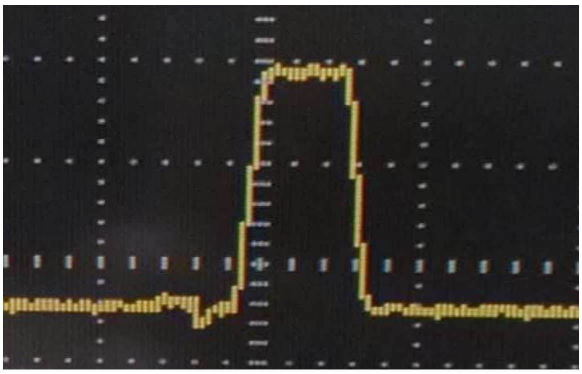

Fig. 10. The final signal of the system output.

However, it is apparent to find that the subtracting circuit introducing some interference from the Fig. 9. In practical applications; it should pay attention to the introduction of interference circuit itself and should seek to improve.

6. Conclusions

Based on the theory of photoelectric detection, the article researches the characteristics of output signal from photoelectric detection system in rainfall, studies the difference both rain signal and the target signal which effect detection system at the same time, divides detection system into A and B zone, sets up the target identification model on the basis of the relationship between raindrops signal and the target signal in the output signal detection system. Through experimental analysis, the double light path photoelectric detection system that can effectively reduce the disturbance caused by rainfall. The target signal of A zone is obviously. The target output pulse signal can be obtained through identification and information extraction processing.

References

[1]. Zhao Zhenwei, Raindrop size distribution model and prediction of rain attenuation in Guangzhou, *Chinese Journal of Radio Science*, Vol. 10, No. 4, 1995, pp. 33-37.

[2]. H. R. Prupacher and R. L. Pitter, A semi-empirical determination of the shape of clouds and rain drops, *J. Atmos. Sci.*, Vol. 28, January 1991, pp. 86-94.

[3]. Hanshan Li, Junchai Gao, Zemin Wang, Target location fire precision test technology by using intersecting photoelectric detection target, *Optik*, Vol. 125, No. 3, 2014, pp. 1325-1329.

[4]. F. T. Ulaby, R. K. Moore and A. K. Fung, Microwave remote sensing, *Addision-Westley*, Vol. 1, 1998.

[5]. Wang Lili, Ke Xizheng, Laser in the analysis and calculation of the transmission, *Chinese Journal of Light Scattering*, Vol. 17, No. 2, 2005, pp. 148-153.

[6]. Steven M. Kay, Fundamentals of statistical signal processing, Volume II: Detection Theory, *Pearson Education*, 2011.

[7]. Wang Zimeng, The principle and application of PIN silicon photodiode optical instrument, Journal *of optical instruments* ,1984 (In Chinese).

[8]. S. D. Blostein, T. S. Huang, Detecting small moving objects in image sequences using sequential hypothesis testing, *IEEE Transactions on Signal Processing*, Vol. 39, Issue 7, 1991, pp. 1611-1629.

[9]. Lv Xiaoling, Semiconductor laser rangefinder receiving system, *Changchun University of Science and Technology*, Changchun, 2006.

[10]. Y. Jon, Y. J. Shen, Z. M. Zhang, B. K. Tsai, Bidirectional reflectance distribution function of rough silicon wafers, *International Journal of Thermophysics*, Vol. 22, No. 4, 2004, pp. 561-568.

[11]. C. H. Liu, A. W. Wernik, K. C. Yeh, Propagation of pulse of trains through a random medium, *IEEE Transactions on Antennas Propagation*, Vol. 22, Issue 4, 1974, pp. 624-627.

[12]. T. Oguchi, Y. Hosoya, Scattering properties of oblate rain drops and cross polarization of radio waves due

to rain (Part II): Calculations at microwave and millimeter wave regions, *Journal of Radio Research Laboratory*, Vol. 21, No. 105, 1974, pp. 191259.

[13]. W. Yang, J. Q. Zhang, J. S. Liu, Theoretical calculation of infrared radiation of the projectile in flight, *Infrared and Laser Engineering*, Vol. 31, Issue 1, 2005, pp. 42-47.

[14]. Hanshan Li, Zhiyong Lei, Calculation research on infrared radiation characteristic on flying projectile in sky-screen, *IEEE Sensors Journal*, Vol. 13, Issue 5, 2013, pp. 1959-1964.

[15]. Wenyu Fu, Silicon photodiode linearity and signal-to-noise ratio analysis, *Journal of Photoelectric Technology*, 2003, pp. 24-29 (In Chinese).