Target-recognition of laser fuze based on polarization detection

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Abstract: In this paper, laser polarization detection principle were expounded laser, and a new technical approach for laser fuze to recognized target using different polarized characteristics of different target on laser background scattering were invented. Experimental system were designed, the different objectives polarization test were completed. The test results are that smooth surface of metal objects have high degree of polarization, rough surface of objects have low degree of polarization. The realization scheme of polarization detection laser fuze is proposed, and the target discrimination technology is verified through prototype design.

Key words: polarization laser fuze; depolarization degree; target-recognize

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偏振探测激光引信目标判别技术

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摘 要: 阐述了激光偏振探测的原理,提出利用偏振激光对目标、目标背景散射的退偏度差异性,进行激光引信探测目标识别的一种新的技术途径。通过设计实验系统,完成了不同目标的偏特性测试,给出在一般情况下,表面光滑金属物体偏振度最高、粗糙表面物体偏振度最低的测试结果,提出偏振探测激光引信的实现方案,通过样机设计对目标判别技术进行验证。

关键词: 偏振激光引信; 偏振度; 目标判别

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0 Introduction

Laser fuze has been used extensively in military application for its advantages of anti-electromagnetic interference capability, high resolution, and robust operability. But the performance is compromised by the background environment such as fog. In order to realize the full potential of laser fuze, it's critical to analysis the characteristic of target object and interference[1-3].

It would be helpful to achieve good target detection, identification and anti-interference capabilities, if the feature could be extracted from the return signal as much as possible. Polarization of light could be taken as an important feature to extend the conventional 4D information (intensity, spectrum, space) into seven dimension (intensity, spectrum, space, polarization degree). This paper focus on polarization laser fuze, and presents a novel mechanism of anti-interference which would provide a different solution to improve the accuracy of target identification and the robustness to the inferences[4-6].

1 Polarization characteristic of reflected laser

When the light arrive the interface of two medium, two phenomenon of reflection and refraction would result. The relationship between reflected and refracted lights (these lights are shown in Fig.1) comply to Fresnel equation. Fresnel refraction equation, which describe the phase and amplitude relationship between incident and reflected light at the boundary two mediums, is written as follows:

$$r_s=\frac{A_{1s}'}{A_{1s}}=-\frac{\sin(\theta_1-\theta_2)}{\sin(\theta_1+\theta_2)}=\frac{n_1\cos\theta_1-n_2\cos\theta_2}{n_1\cos\theta_1+n_2\cos\theta_2} \tag{1}$$

$$r_p=\frac{A_{1p}'}{A_{1p}}=\frac{\tan(\theta_1-\theta_2)}{\tan(\theta_1+\theta_2)}=\frac{n_2\cos\theta_1-n_1\cos\theta_2}{n_2\cos\theta_1+n_1\cos\theta_2} \tag{2}$$

where n_1, n_2 are the refractive indexes of medium 1 and medium 2 respectively; the angles of incident light, reflected light and refracted light are pural.

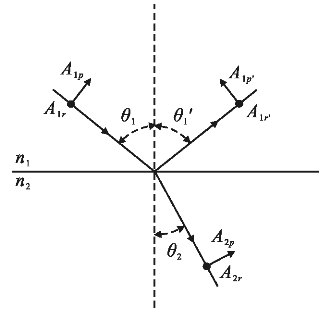

Fig.1 Refraction and reflection of light on two kinds of dielectric

Usually, the dielectric constant and refractive index are defined complex number. If we replace the real refractive index, real angle of refractive light with its complex counterpart, the complex form of Fresnel equation is obtained.

$$\hat{r}_s=\frac{A_{1s}'}{A_{1s}}=-\frac{\sin(\theta_1-\hat{\theta}_2)}{\sin(\theta_1+\hat{\theta}_2)} \tag{3}$$

$$\hat{r}_p=\frac{A_{1p}'}{A_{1p}}=\frac{\tan(\theta_1-\hat{\theta}_2)}{\tan(\theta_1+\hat{\theta}_2)} \tag{4}$$

From the perspective of microscopic view, each single incident light in diffuse reflection also comply to Fresnel theory. As shown in Fig.2, when linearly polarized light hit rough surface at the boundary, the deviation of reflected light from the incident light in direction A/B is small. Due to the roughness of the surface, incident light would be reflected two or more times. In this case, even the reflected light is parallel with the incident light, it is possible that depolarization effect would take place.

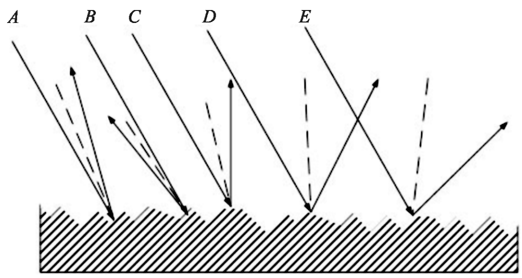

Fig.2 Reflection of light on coarse interface

When linearly polarized light hit the opaque surface, the polarization degree of reflected light is function of surface roughness. The smoother the surface is, the larger the polarization degree of reflected light presents.

2 Description of polarized light

The measurement and judgment of polarization light is required by the characteristics that the transmission light intensity presents when it passes through the polarizing elements. The maximum and minimum light intensity I_{max} and I_{min} are obtained by rotating the polarizer for a circle. Define the degree of polarizationp is as follows:

$$p=\frac{I_{max}-I_{min}}{I_{max}+I_{min}} \tag{5}$$

Depolarization is transforming the polarized light into unpolarized one. If the incident light is completely polarized light, then the depolarization happens when the polarization degree of the outgoing light is less than 1. For fully depolarized devices, the polarized light can be converted into completely unpolarized light; for partial polarizer, it can be converted into polarized light. For the case of P=l, the optical target has no depolarization, which we call complete polarization. Targets that do exhibit no depolarization are referred to non-depolarizing devices.

3 Target polarization test

The experimental program of polarization detection is presented in Fig.3. Firstly, fix the polarization direction of the polarizing prism. Secondly, install the analyzer prism with the same polarization direction as the polarizing prism and record echo intensityImax. Afterwards, adjust the polarization direction of the prism perpendicular to that of the polarizing prism with echo intensity I_{min} being recorded. Repeat the same steps and calculate the echo polarizability in various targets, distances and angles of incident.

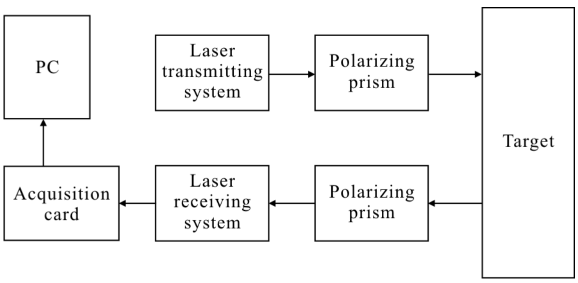

Fig.3 Experimental program of polarization detection on different targets

4 Test results of polarized laser detection

Tests of polarization characteristics to different targets are performed in the polarized laser fuze test system. The experimental results indicate that for the polarized laser fuze, the echo polarization characteristics of the laser targets vary little with the change of working distance and incident angle. Specifically, the polarization characteristics of different laser beams differ largely, as shown in Tab.1. In terms of polarization degree of target echo, artificial metal reaches the highest, while rough natural target reaches the lowest. The echo polarization degree of grassland, trees and mud is below 0.5, while metal target reaches 0.7 or more.

Tab.1 Experimental result of polarization detection fuze

Target	Echo polarization/(°)	Target	Echo polarization/(°)
Cars with various colors	0.95	Tiled wall	0.29
Copper	0.74	Water brushing stone wall	0.28
Glass beads	0.71	Three-ply board	0.40
Matt coated aluminum	0.95	White paper	0.13
Black painted aluminum	0.94	Rough cardboard	0.09
Steel plate	0.89	Dead leaves	0.06
Stainless steel plate	0.94	Grass	0.346
Green paint aluminum	0.93	Unit of air conditioner	0.40
Water surface	0.99	Mud	0.423

5 Laser fuze design for polarization detection

According to the difference of light polarization between target reflection and background scattering, a laser fuze based on optical polarization detection is designed. In principle, this scheme not only has the ability of target recognition and passive interference resistance, but also possesses certain ability of resisting laser active interference. The active laser interference source can be judged by the magnitude of the echo amplitude of the two detectors. The completely linearly polarized light is generated when laser emitted by polarized laser fuzepass through the horizontal inspection polarizer. However, depolarization effect occurs as the linearly polarized light is reflected (scattered) caused by the target. Typically, the amplitude of the echo passing through the horizontal analyzer is greater than that of the vertical analyzer. But when the polarized laser fuze encounters active laser interference sources, the echo amplitude passing through the horizontal analyzer is approximately equal to that of the vertical analyzer.

The block diagram of polarization detection laser fuze is shown in Fig.4. Polarization detection laser fuze system is mainly composed of laser emitting circuit, emission optics, analyzer, receiving optics, information processing circuit, detonating execution circuit and power circuit. Laser beam is emitted by the analyzer as designed and reflected back by the target or target background. Laser echo is converted to electrical signals after the horizontal and vertical deflection by the receiver. Therefore, polarization degree of the laser echocan be calculated. According to the difference of depolarization degree between the specific target and the typical natural background such as the land, the sea, the cloud, the target can be correctly judged and the explosion point can be accurately calculated, which will detonate the warhead timely.

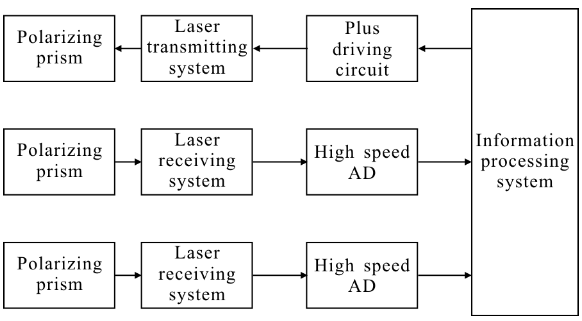

Fig.4 Composition of polarization laser fuze

6 Target discrimination verification for polarization laser fuze prototype

After the application of polarized laser fuze to different targets, the digitized waveforms acquired by FPGA in the fuze are storedand uploaded to the computer via the Chip Scope Pro. Take the mud and metal sheet as an example to verify the target discrimination.

The echo signal of polarization detection fuze on aluminium sheet acquired by FPGA is presented in Fig.5, in which the red curve represents the echo in the parallel direction to the polarized light while the blue light represents the vertical one. By extracting the amplitude of two echoes, calculating the degree of polarization and comparing the degree with threshold, the target can be verified eventually.

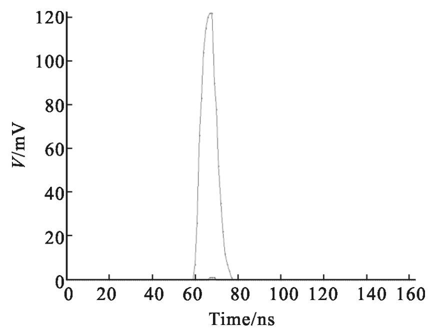

Fig.5 Echo signal of polarization detection fuze on aluminium sheet

Figure 6 presents the echo of mud sheet acquired by FPGA. Interference can be judged due to the fact that the degree of polarization of the mud sheet is lower than the set threshold.

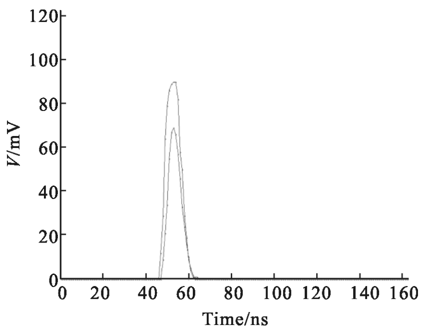

Fig.6 Echo signal of polarization detection fuze on mud and grass sheet

7 Conclusion

Laser fuze for polarization detection utilizes the difference of echo polarization degree so that not only does it possess target recognition ability with anti-passive interference, but also the laser anti-active interference performance is excellent.

References:

[1] Schneider M, Wurm G. Experiments on light scattering and extinction by small, icrometer-sized aggregates of spheres[J]. ***Appl Opt***, 2012, 41(6): 1175-1180.

[2] Shen N, Zhang X J, Guo J. Attenuation of laser fuze through fog [J]. ***Opt Precision Eng***, 2013, 21 (4): 864-869. (in Chinese)

[3] Zhang J G, Liang X G, Liu J X, et al. Cloud and fog backscattering laser signal affected by baseline distance[J]. ***Journal of Detection & Control***, 2012, 34 (6): 1-5. (in Chinese)

[4] Zhang Q X, Li Y D, Deng X J, et al. Experimental determination of scattering matrix of fire smoke particles at 532 nm [J]. ***Acta Physica Sinica***, 2011, 60(8): 084216. (in Chinese)

[5] Wu X T, Lu J F, He B G, et al. Fast restoration of haze-degraded image [J]. ***Chinese Optics***, 2013, 6(6): 892-899. (in Chinese)

[6] Liang S Y, Wang J A, Zong S G, et al. Laser detection method of ship wake bubbles based on multiple scattering intensity and polarization characteristics [J]. ***Acta Physica Sinica***, 2013, 62(6): 060704. (in Chinese)