Study on Laser Spot Affecting the Accuracy of Transient Angle Test System Based on PSD

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***Abstract*—Aimed at the problem that PSD output position is not the laser spot center coordinate formed on PSD in the measurement of transient angle, factors affecting the accuracy of testing system is analysed in this paper. from the work principle of PSD and detection experiment, the energy distribution and light spot position have a close relationship can be seen.**

Keywords- PSD; laser; transient angle; measurement

I. INTRODUCTION

The working principle of transient angle test system based on PSD is: a plane reflecting device was installed in the measured position of gun tube, when a semiconductor laser (LD) transmit pulsed laser irradiated the gun tube, the pulsed laser was also reflected from the reflecting device, laser will carry information on the gun barrel vibration. The laser signal with high precision photoelectric position sensor (PSD) is converted into current signal, then the signal amplification, filtering, processing, and using the formula of calculating coordinate of PSD devices, and the displacement of laser spot on the photosensitive surface is obtained, then according to the calculation formula of optical imaging, thus obtains the dynamic displacement curve of firing angle. The test block diagram shows in figure 1.

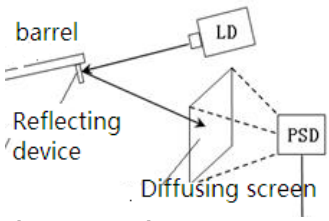

Figure 1. The transient angle measurement principle diagram

II. ANALYSIS OF FACTORS AFFECTING THE ACCURACY OF TESTING SYSTEM [1,2,3]

As shown in figure 2, in the measurement of transient angle, as the muzzle disturbance, angle of laser light irradiation on PSD are different, thus spot formed on the PSD is different. From the chart we can see that the laser spot of semiconductor laser is not a small point infinitely, and the energy distribution of the spot of is uneven from literature, there is the energy center, the PSD output position is not the spot center coordinate but energy barycenter coordinate. Because the laser energy distribution is not uniform, but multimode structure or more strength, the actual effect is equivalent to the photosensitive surface of multi beam at the same time to PSD. So the PSD detection is affected, the changes in the energy center of laser spot energy distribution caused by one of the factors affecting the PSD positioning accuracy. These factors may influence the displacement measurement accuracy of transient angle.

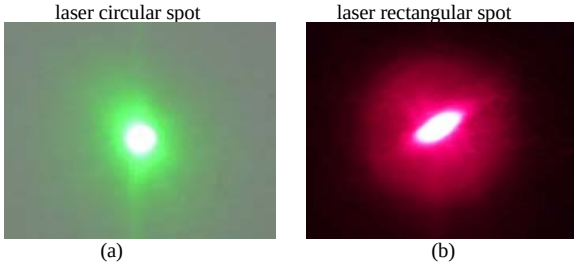

Figure 2. Laser spot formed on the PSD

This paper mainly from the work principle of PSD, and the laser light source is equivalent to multi-beam acting on a PSD photosensitive surface at the same time, to explore the effect of spot for precision measurement of transient emission angle (research assumes that the influence of the external environment can be ignored, only consider the influence of incident light source).

III. THEORETICAL STUDY OF DOUBLE-BEAM EFFECT ON PSD POSITIONING

A. Study On Double-Beam Linear Array (One-Dimensional) PSD Localization[1]

The total light beam current is A function in the PSD generated when the total current is $k_A I_0$, light beam B on PSD generated for $k_B I_0$.

Optical beam A alone act on the electrode 1 and electrode 2 to collect flow respectively:

$$\begin{cases} I_{1A} = k_A I_0 (L - x_A)/(2L) \\ I_{2A} = k_A I_0 (L + x_A)/(2L) \end{cases} \quad (1)$$

Optical beam B alone. Electrode 1 and electrode 2 collected flow by (1) respectively:

$$\begin{cases} I_{1B} = k_B I_0 (L - x_B)/(2L) \\ I_{2B} = k_B I_0 (L + x_B)/(2L) \end{cases} \quad (2)$$

Interaction of A and B in the one-dimensional beam on PSD, according to the current principle of superposition, the photoelectric electrode 1 and an electrode 2 collected flow by (1) respectively:

$$\begin{cases} I_1 = I_{1A} + I_{2A} = [k_A (L - x_A) + k_B (L - x_B)]/(2L) \times I_0 \\ I_1 = I_{2A} + I_{2B} = [k_A (L + x_A) + k_B (L + x_B)]/(2L) \times I_0 \end{cases} \quad (3)$$

Position coordinate interaction of A and B beam of light, the total current, then:

$$\begin{cases} I_1 = (L - x_{AB})/(2L) \times I_{AB} = (L - x_{AB})/(2L) \times (k_A + k_B) I_0 \\ I_1 = (L + x_{AB})/(2L) \times I_{AB} = (L + x_{AB})/(2L) \times (k_A + k_B) I_0 \end{cases} \quad (4)$$

By type (3) and type (4) are equal:

$$x_{AB} = k_A x_A /(k_A + k_B) + k_A x_B (k_A + k_B) \quad (5)$$

As the beam A, B common role line array PSD coordinate value expression, expressed as the ratio of weight of beam energy multiplied by the respective coordinates.

B. Dual Beam Array (2D) Positioning of PSD

The total photocurrent generated a beam in two-dimensional PSD A function of total light beam current, a role of B in the two-dimensional PSD generated for.

1) Beam A alone, equation (1) can be rewritten as:

$$\begin{cases} [(I_{xA2} + I_{yA1}) - (I_{xA1} + I_{yA2})]/(I_{xA2} + I_{yA1} + I_{xA1} + I_{yA2}) = x_A / L \\ [(I_{xA2} + I_{yA2}) - (I_{xA1} + I_{yA1})]/(I_{xA2} + I_{yA1} + I_{xA1} + I_{yA2}) = y_A / L \end{cases} \quad (6)$$

2) Beam B alone, equation (2) type also can be rewritten as:

$$\begin{cases} [(I_{xB2} + I_{yB1}) - (I_{xB1} + I_{yB2})]/(I_{xB2} + I_{yB1} + I_{xB1} + I_{yB2}) = x_B / L \\ [(I_{xB2} + I_{yB2}) - (I_{xB1} + I_{yB1})]/(I_{xB2} + I_{yB1} + I_{xB1} + I_{yB2}) = y_B / L \end{cases} \quad (7)$$

3) Beams A, B common role of two-dimensional PSD, according to the current principle of superposition, then:

$$\begin{cases} \dfrac{[I_{xA2} + I_{xB2} + I_{xA1} + I_{yB1}] - [I_{xA1} + I_{xB1} + I_{yA2} + I_{yB2}]}{k_A I_0 + k_B I_0} = \dfrac{x_{AB}}{L} \\ \dfrac{[I_{xA2} + I_{xB2} + I_{yA2} + I_{yB2}] - [I_{xA1} + I_{xB1} + I_{xA1} + I_{yB1}]}{k_A I_0 + k_B I_0} = \dfrac{y_{AB}}{L} \end{cases} \quad (8)$$

Similarly with the one dimension PSD, then (6) + (7) = (8) type available:

$$\begin{cases} x_{AB} = k_A x_A /(k_A + k_B) + k_B x_B (k_A + k_B) \\ y_{AB} = k_A y_A /(k_A + k_B) + k_B y_B (k_A + k_B) \end{cases} \quad (9)$$

Equation (9) for laser beam A, B interaction in two-dimensional PSD position coordinate value expression, expressed as light weight than coordinate multiplied by their respective value. If the beam of A, B energy equal and at the same time to PSD, PSD coordinates of the midpoint of the output value of A and B alone, if the beam of A, B energy is not equal, the PSD position output value should be partial to one side of the beam energy.

IV. THE DETECTION EXPERIMENT OF DIMENSIONAL PSD ON DUAL BEAM POSITION

According to the mathematical model, we set up a 2D PSD on dual beam position detection experiment platform, and did a corresponding experimental verification. The experimental device mainly comprises a two-dimensional PSD, the signal processing circuit, semiconductor laser, computer, application software. During the experiment, the PSD and semiconductor laser in optical platform, the principle block diagram is shown in Figure 8, figure 9 is a test platform for the laboratory. The laser emits a laser beam expander, the collimated light beam from a uniform distribution, through the diaphragm reached: (1) two equal energy point light sources; (2) the two point light energy is not equal, the size of the energy is controlled through the aperture size. For the two point light which energy are equal: first let the aperture A passed "O", measure the energy K_A to the PSD on the diaphragm A incident, and to record the time point coordinates in the PSD value (x_A, y_A), the same, only the diaphragm B, measuring out the energy K_B to the PSD on the diaphragm B incident, remember the time coordinate recorded on the PSD value (x_B， y_B); and then measure the diaphragm A, B and PSD on the incident energy K_{AB}, also recorded the same energy two spot in the PSD coordinates (x_{AB},y_{AB}), according to the (5) formula (x_{AB},y_{AB}), the experimental results is shown in table 1. The two asymmetric point light sources: the methods and the same, the experimental results is shown in table 2.

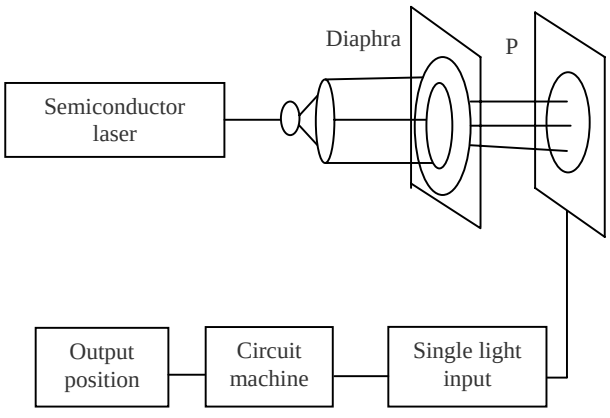

Figure3. The principle of dimensional PSD on dual beam position

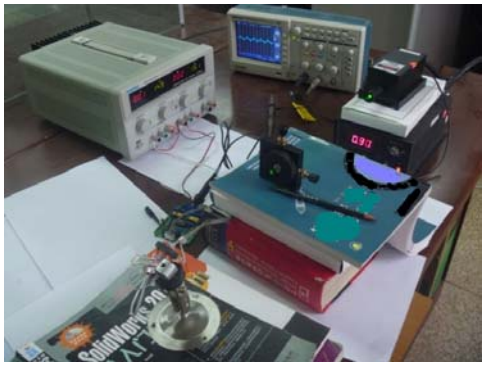

Figure4. The test platform in the laboratory

TABLE Ⅰ. THE DISTRIBUTION OF TWO EQUAL ENERGY LIGHTS

	Diaphragm A passed	**Diaphragm B passed**	**Diaphragm A and B passed**	**Theoretical value**
x_A	-1.682			
y_A	0.031			
k_A	0.300			
x_B		1.624		
y_B		0.034		
k_B		0.300		
x_{AB}			0.000	0.025
y_{AB}			0.001	0.024
k_{AB}			0.596	

TABLE Ⅱ. THE DISTRIBUTION OF TWO UNEQUAL ENERGY LIGHTS

	Diaphragm A passed	Diaphragm B passed	Diaphragm A and B passed	Theoretical value
x_A	-1.551			
y_A	0.050			
k_A	0.310			
x_B		0.760		
y_B		0.070		
k_B		0.114		
x_{AB}			-0.933	-0.945
y_{AB}			0.044	0.052
k_{AB}			0.410	

From table 1 and table 2 shows, theoretical calculation results and the experimental results are only difference is within 0.025mm, the cause of this error are: power semiconductor laser with a floating, resulting in even uniform spot with time change; not completely reach the laboratory darkroom conditions, with effect of some external light; impact of human error.

V. CONCLUSION

From the one-dimensional and two-dimensional PSD in the A B energy beam, relationship between the uniform and non-uniform when pushing energy and light spot position coordinates derived can be seen, the energy distribution of light spot position and have a close relationship, but also from the experimental results also validate this relationship.

PSD position and beam energy is closely related to weight distribution, therefore, attention should be paid to in the measurement:

1) Beam spot should be as small as possible, so that the energy remains constant, while ensuring a diffraction phenomenon, to destroy the energy center;

2) Replace the laser light source, should do before and after passing through an aperture energy remains constant, or it will change the absolute measurement value;

3) Plus the aperture should also pay attention to when each time the assembly of the diaphragm may not gravity center of the geometric center and the beam aperture fully coincide, it will influence the accuracy of measurement;

4) Should minimize the effect of background light and diffuse stray light, which is equivalent to the effect of the PSD photosensitive surface effect a spot, because of its existence will cause the position offset, so as to reduce the measurement accuracy.

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