Study on the damage effect of optical detector irradiated by CW laser

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Abstract. In order to study the damage effect of continuous laser on optical detectors, an equivalent experimental method of laser irradiated optical detectors was designed and constructed in the laboratory. The damage mechanism and phenomenon of the laser are analyzed through experiments, and the power density of the laser to the target and the size of the saturated spot on the surface of the detector are measured, and the corresponding relationship between the saturation of a single pixel of the detector and the power of the laser to the target is obtained, which reveals the influence of laser power on detection. The influence law of the interference characteristic of the device. The experimental results show that under the condition that the diameter of the laser beam and the distance to the target are the same, as the power of the laser to the target increases, the saturated spot size of the detector (that is, the number of saturated pixels) increases, and the saturated spot size increases with the power within the error range. The relationship is approximately linear; for a typical optical detector, the laser power at which the pixels are disturbed by saturation is a fixed value. Increasing the laser power can increase the number of saturated pixels, and the area disturbed by laser saturation is further expanded.

1. Introduction
With the continuous development of laser technology, more and more attention has been paid to the study of laser damage effects. The research on the radiation effect of laser on optical detector (CCD) mainly focuses on two aspects of laser damage and interference. However, due to the current limitation of laser power density, laser can only achieve interference effects on long-distance targets. Therefore, the interference effect of laser irradiation has always been a research hotspot. Laser interference means that when the laser is irradiated, the optical detector reaches saturation and cannot work normally; after the laser is irradiated, the photodetector can work normally.

The earlier systematic study of the damage effect of laser on the detector was the Becker and Zhang team of the University of Texas at Austin[1-2]. In 2005, Zhang Zhen of the National University of Defense Technology [3] studied the radiation effects of high-repetition frequency (5k Hz) 532 nm, 1064 nm, and 1319 nm pulsed lasers on DALSA IL-P3 visible light array detectors. Experiments found that after 4.1 W/cm² high frequency (5 kHz) 532 nm pulsed laser irradiation, some photosensitive elements in the visible light array detector could not resume normal operation. In 2013, Zhu Zhiwu of National University of Defense Technology [4] carried out nanosecond (1064 nm, 33 ns), picosecond (1064 nm, 25 ps), and femtosecond (800 nm, 100 fs) pulsed lasers to optical detectors (sony. The damage effect of ICX405AL visible light detector is studied, and the energy density threshold value of the optical detector when the optical detector reaches the white point damage, white line damage and complete failure state under three pulse frequencies is obtained by experiment.
There are many research results on laser-irradiated optical detectors at home and abroad, but there is no research result on the relationship between the saturation of a single pixel of the detector and the power of the laser to the target, and it cannot answer whether the accumulation of laser power can expand the area of the interference spot. Therefore, this paper constructs an equivalent experimental analysis method for laser-irradiated optical detectors. The experiment analyzes the influence of different laser power and distance to the target on the saturation interference threshold of optical detectors, and provides a theory for the application of laser interference interference optical detectors stand by.

2. Experimental system
A laser irradiation detector experimental system was designed and constructed in a laboratory environment. The schematic diagram of the principle is shown in Figure 1. The laser light source passes through the spot adjustment mirror to achieve the effect of beam reduction or focusing; and then adjusts to the target power after the iris and power attenuation device, so that the detector detects the power and the appropriate spot, and finally passes through the computer connected to the detector Obtain the distribution information of the entire spot.

Due to the limited detection area of the detector, an iris diaphragm is required to be placed in front of the detector to adjust the size of the laser spot. Since the output power of the laser light source is relatively large, it needs to be attenuated by a fan attenuator and then irradiated to the detector. The experiment uses an optical detector to perform detailed measurement and calibration of the laser response process threshold at a wavelength of 1.5 μm (mid-infrared band). The experimental system is shown in Figure 2.

3. Laser irradiation experiment
Based on the laser irradiation detector experimental method, the detector is used to test the detection response process threshold of the 1.5 μm laser (mid-infrared light source). Through data recording and analysis, the corresponding relationship between a single pixel point and the power of the laser to the target is obtained.

3.1. Experimental program
Averaging for multiple tests. Under the condition of different distance L, change the diaphragm to change the light spot on the detector detection panel, repeat the experiment steps, measure the
saturation threshold power of each pixel of the detector under different conditions, and obtain detection at different distances through multiple tests. The driving current and power threshold for pixel saturation of the sensor are shown in Figure 3.

![Figure 3. Detector pixel saturation driving current and power threshold at different distances](image)

3.2. Analysis of spot power response process

The experiment mainly used to change the power of the laser to the target and the spot size, revealing the corresponding relationship between the saturation of a single pixel of the detector and the laser power. Among them, the spot size from the laser to the target is mainly determined by the distance $L$ between the detector and the focusing lens and the size of the diaphragm, which will be introduced separately below.

(1) The distance $L$ between the detector and the focusing lens

The distance $L$ between the detector and the focusing mirror directly affects the spot size from the laser to the target, and the response process of the spot power at different powers can be obtained by changing the driving current. In the experiment, the distances $L=100$ mm, $80$ mm, and $60$ mm were designed to obtain light spots of different sizes. Fig. 4 is a schematic diagram of the laser with a current intensity of 10 mA reaching the target light spot when the distance $L=80$ mm. It can be seen from the figure that the color of the spot changes from white to red from the center to the edge. It is generally considered that the red part of the spot color is not saturated (the image can still be taken), and the white and purple parts of the detector are saturated, so the experiment is calibrated. The saturated spot size is white and purple.

![Fig. 4 Saturated spot detector with a distance L of 80 mm and current I 10mA](image)
Use the detector's own testing software to measure the diameter $D$ of the light spot, and calculate the area $S$ of the saturated pixel of the detector. The pixel size of the detector is 2.50×2.50 μm. Divide the area of the saturated part of the light spot by the minimum detection area to calculate the saturated pixel point of the detection surface. In this way, the threshold value of the saturation response process of the detector to the single pixel point detection of the 1.5 μm laser is calculated.

Figure 5 show the relationship between the number of saturated pixels and the power. It can be seen from the figure that under the same focal length, as the 1.5 μm incident laser current slowly increases, until the target power increases, the number of saturated pixels in the detection area increases. The experimentally measured spot size at different distances $L$ is also different. For example, under the driving current 100 mA current output condition, when $L=100$ mm, the saturated spot size is 735.93 μm; when $L=80$ mm, the saturated spot size is 725.3 μm; When $L=60$ mm, the saturated spot size is 714.1 μm. The relationship between the saturation threshold power and the 63% power of a single pixel is shown in Figure 6.

![Figure 5](image5.png)

**Figure 5.** The number of saturated pixels varies with power

![Figure 6](image6.png)

**Figure 6.** 63% power of a single pixel point vs. power change

It can be seen from the figure that the calculated results are analyzed. Due to the error of testing and data processing, the threshold values of the saturated single pixel point response process obtained by the three sets of measurements are slightly different, and as the incident laser power increases, the detector saturation spot size As the number of pixels increases, the detector responds to a single pixel of 1.5 μm laser, and the threshold of the detection response process is about 10−7W. The reason for choosing 63% power is that the far-field integrated spot is generally Gaussian-like. When the intensity
of the Gaussian beam drops to 1/e, the energy in the ring is 63%. When calculating the average power
density, take the 63% energy area. The average power density can reflect the value of the central area.

(2) Change the size of the diaphragm
The size of the aperture can affect the size of the light spot on the detector detection panel. Changing
the aperture of the diaphragm can change the size of the light spot incident on the detector, and
obtain the response threshold power of the light spot of different sizes. Figure 7 shows the
statistics of the spot size, the number of saturated pixels, and the power change of the laser to the
target caused by changing the aperture of the diaphragm 15 times in the figure. It can be seen from the
figure that as the incident laser power increases, the saturated spot size of the detector increases, the
spot size increases from 729.85 μm to 4022.41 μm, the number of saturated spot pixels increases, and
the spot size increases, and the spot size increases approximately with the power. It is linear.

![Figure 7. Variation of different spot sizes with power](image)

4. Summary
Based on the review of previous studies, this article explains the phenomenon and mechanism of laser
interference of optical detectors, points out the importance of studying laser interference effects, and
constructs an equivalent experimental analysis method under laboratory conditions. Irradiation
experiments were carried out to analyze the influence of the laser beam diameter and the distance to
the target on the saturated spot size and the number of pixels. The main conclusions are as follows:

(1) Under the condition that the beam size and the distance to the target are the same, as the power
of the laser to the target increases, the saturated spot size of the detector (that is, the number of
saturated pixels) increases, and within the error range, the saturated spot size approximately increases
with the power Linear relationship

(2) For a typical optical detector, the laser power at which pixels are disturbed by saturation is a
fixed value. Increasing the laser power can increase the number of saturated pixels, and the area
disturbed by laser saturation is further expanded.

(3) When multiple laser beams irradiate the optical detector at the same time, the overlapping part
of the laser will be enhanced due to the power accumulation, which will further expand the saturation
area of the detector and achieve the purpose of increasing the interference area.

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