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# Feasibility analysis of laser detection and positioning for unmanned aerial vehicles

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**Abstract.** In order to carry out effective anti-reconnaissance for unmanned aerial vehicles (UAV), the feasibility of effective monitoring of UAV by laser detection system has been analyzed. The models of laser transmitting and receiving system and the photoelectric imaging system on UAV are established. The characteristics of specular scattering and focal plane reflection of UAV imaging lens are simulated. Taking the UAV located at a height of 10,000 m as an example, the feasibility of the application of two detection systems under reflected light has been analyzed. The range of incident angle of the detection laser, the distribution characteristics of light intensity on the photosensitive surface of the detection system and the variation characteristics of return light of the detection laser during dynamic scanning have been obtained respectively. The results show that the focal plane reflected light intensity of the UAV imaging lens is much higher than that of the specular scattered light intensity, and has a good return characteristic. Within the field coverage of the UAV imaging system, the focus plane reflected light can be used to effectively detect and locate the UAV target.

## 1. Introduction

With the continuous improvement of the overall performance and its unique advantages, UAV will become an important means of aerial reconnaissance in the future high-tech local wars. However, UAV has adopted stealth technology which cannot be detected by radar normally, so the laser detection method appears. Laser detection is aimed at the CCD camera and infrared imaging device carried by the unmanned reconnaissance plane for reconnaissance, so it is less affected by the stealth characteristics of the UAV, which can also interfere with the target's imaging device while detecting it, making its normal reconnaissance ability lost[1]. Compared with other passive detection methods, laser detection is more advantageous in that the echo intensity generated by laser irradiation on the target optical lens is much higher than that of diffuse reflection. However, whether this reflected light can be used by the laser detection system, and what conditions are necessary for the detection are still key problems must be solved. This paper will simulate the optical lens of laser irradiated UAV and analyze the feasibility of anti-reconnaissance of UAV by laser detection means.

## 2. Principle of Detection

The basic principle of laser detection and radar detection is the same, they rely on receiving the echo of the target to detect [1-2]. Target optical system can be generally equivalent to the combination of a single lens and a reflective surface. Transmission of the laser through atmosphere to the target optical system is approximately the parallel light incidence. Due to the focal plane imaging optical system is generally equipped with detectors of 1% ~ 5% reflectivity, which makes the incident laser can be in accordance with the original road return, namely "cat's eye effect". This kind of light echo has good



characteristics of the original return, which is received and signal processed by the coaxial receiving system to complete the detection and positioning task [3-4]. In addition, the window glass of the optical lens and the shell of the aircraft have a certain reflectivity, and the backscatter light intensity is generally very small, but its space coverage is very wide. In laser detection, scattered light can be used for initial scanning detection, and then the original return light of focal plane can be used for accurate detection and positioning.

### 3. Simulation Analysis

#### 3.1. Model establishment

To carry out feasibility study, the simulation model should be established first. In order to obtain a general rule, the target lens in the simulation model is an ideal single lens, and the focal plane reflecting element is a full mirror. In the simulation, the reflectivity is set as 0.01. Since the transmitting system only plays the role of adjusting the divergence angle of the transmitting laser, the parameters of the incident laser beam can be directly adjusted in the simulation, without modeling the transmitting system. The receiving system adopts the large-caliber reflection receiving system. The established simulation model is shown in figure 1.

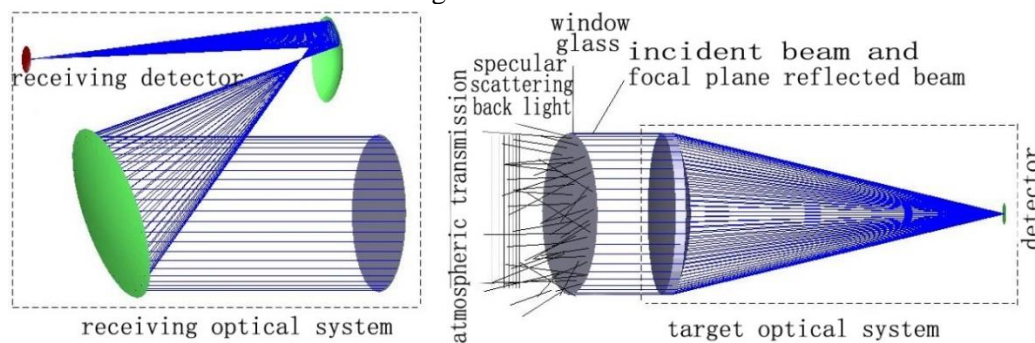


Figure 1. Simulation model.

Specific parameters: the objective lens diameter is 150 mm, the equivalent focal length is 300 mm, the viewing angle is  $3^\circ$ , the focal plane detector photosensitive surface diameter is 19.76 mm, coke quantity is 0, effective aperture of the receiving system is 1 m, the equivalent focal length is 2 m; The incident laser beam is a gaussian beam with a wavelength of 1.06 m, a far field divergence angle (all) of 0.1 mrad, a total energy of 100 W, a maximum power density of  $3.4931 \times 10^{-1} \text{ W/mm}^2$ , transmitting distance from the receiving system to the target system is 10 km. Due to the long operating distance, the spot diameter of the detection laser beam at the target lens is much larger than the lens aperture. Only the atmospheric propagation law and diffraction propagation law of laser beam are considered, and the beam is propagated according to the propagation law of physical optics and gaussian optics, without considering the influence of atmospheric turbulence and other factors.

#### 3.2. Specular scattering back light analysis

First consider the scattering light from the window glass. Since each lens surface of the target system generally has a certain curvature, the scattered backlight of the target system will soon diverge, which is of no value [5-6]. Assuming the reflectivity of the window glass surface (possibly flat glass) is 0.001, the scattering light characteristics that can be received by the receiving system at different incident angles are shown in table 1.

Table 1. Reflection characteristics of specular scattering with different incident angles

incidence angle / ( $^\circ$ )	total power the receiving system receives /W	the highest power density of receiving detector / ( $\text{W} \cdot \text{mm}^{-2}$ )
0	$1.233 \ 9 \times 10^{-2}$	29.557
0.001	$1.555 \ 8 \times 10^{-2}$	0.864 0
0.003	$2.917 \ 0 \times 10^{-3}$	$6.091 \ 9 \times 10^{-3}$

0.005	$7.0725 \times 10^{-5}$	$6.0551 \times 10^{-7}$
0.01	$6.4394 \times 10^{-6}$	$1.9050 \times 10^{-9}$

As can be seen from table 1, since the specular scattered light does not have the characteristics of the original return, the receiving system has a high detectable power density only when the incident angle is 0. However, each plane of the aircraft needs to generate scattered light, so when using scattered light for rough detection, the range of available incidence angle is large and the warning area is wide. When the aircraft enters the detectable warning area, it can be detected in advance, but the precise positioning is not enough.

### 3.3. Focal plane reflection analysis

According to the cat-eye effect principle of optical lens, the reflected light of focal plane has the characteristic of returning in the original way. The simulation results show that when the UAV is located at a height of 10 km, the light spot of the receiving system is shown in figure 2.

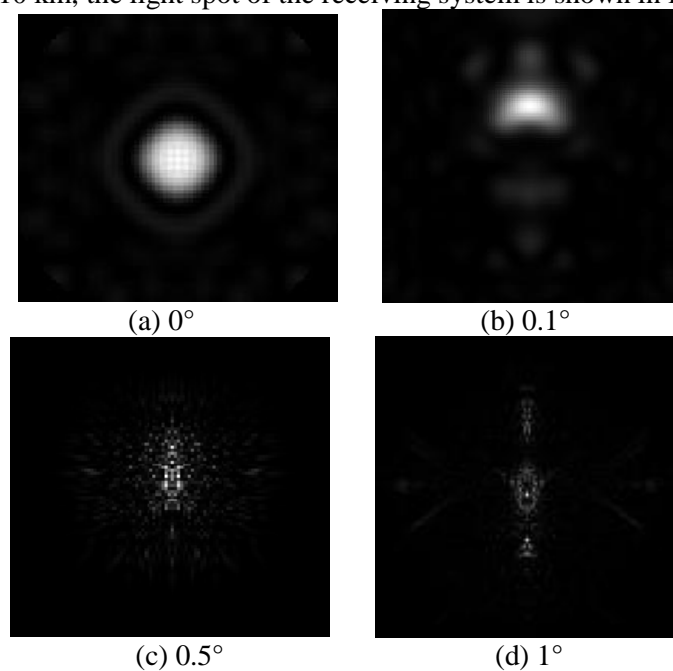


Figure 2. Light intensity distribution of far-field light spot when incident angle increases gradually.

As can be seen from figure 2, with the increase of the incident angle, the energy concentration of the far-field light spot decreases rapidly, and the tilt and divergence of the light spot lead to a huge loss of light energy. Figure 3 and 4 show the curve of divergence angle and energy change with the change of incident angle.

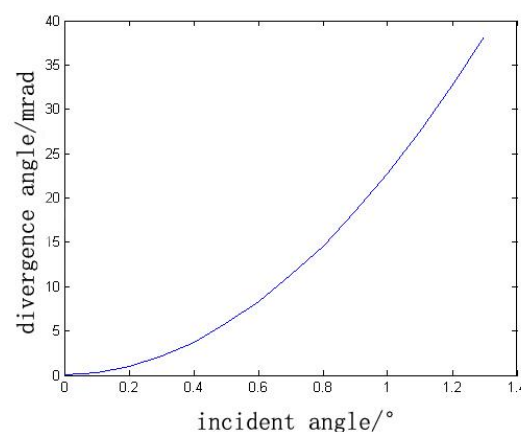


Figure 3. Divergence angle of backward reflection beam at different incident angles.

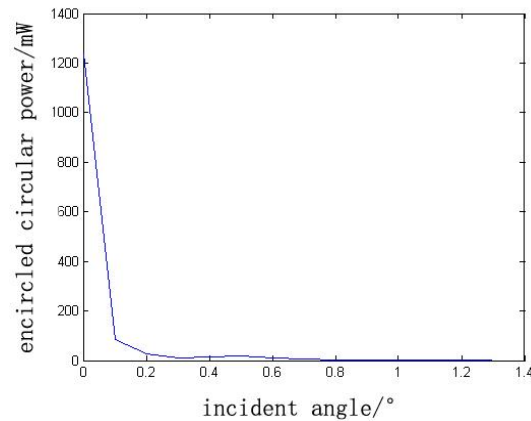


Figure 4. Girth power at different incident angles.

It can be concluded from the analysis that the far-field energy characteristics of the backward reflected light are mainly determined by the divergence angle of the backward reflected light. When the incident angle increases, the divergence angle of the reflected beam increases rapidly, because the tilted gaussian beam does not match the field of view of the target lens, resulting in defocusing. With the increase of the incident angle, the far field light energy decreases rapidly (which is quite different from the normal incidence).

Figure 5 is the graph of the girth power that can be received by the receiving system located at the return of the original circuit when the detection distance is different. It can be seen that the receivable power of the receiving system basically has a negative square decreasing relationship with the detection distance. Under the simulation condition, the detection distance can reach about 30 km.

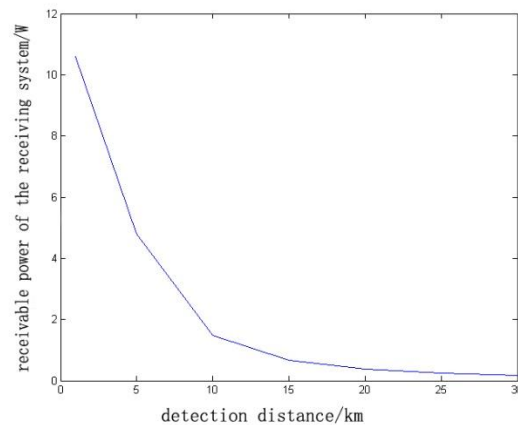


Figure 5. Received power at different detection distances.

### 3.4. Overall analysis of the detection system

From the above analysis, it is feasible to use the reflected light of focal plane to detect. As long as our detection laser is in the target's field of view, it can basically receive the original return light. According to the subsequent information processing and analysis of the receiving system, it can determine the target's speed, direction, distance and other information. Figure 6 is a schematic diagram of the principle of using laser to detect and locate the high-altitude UAV.

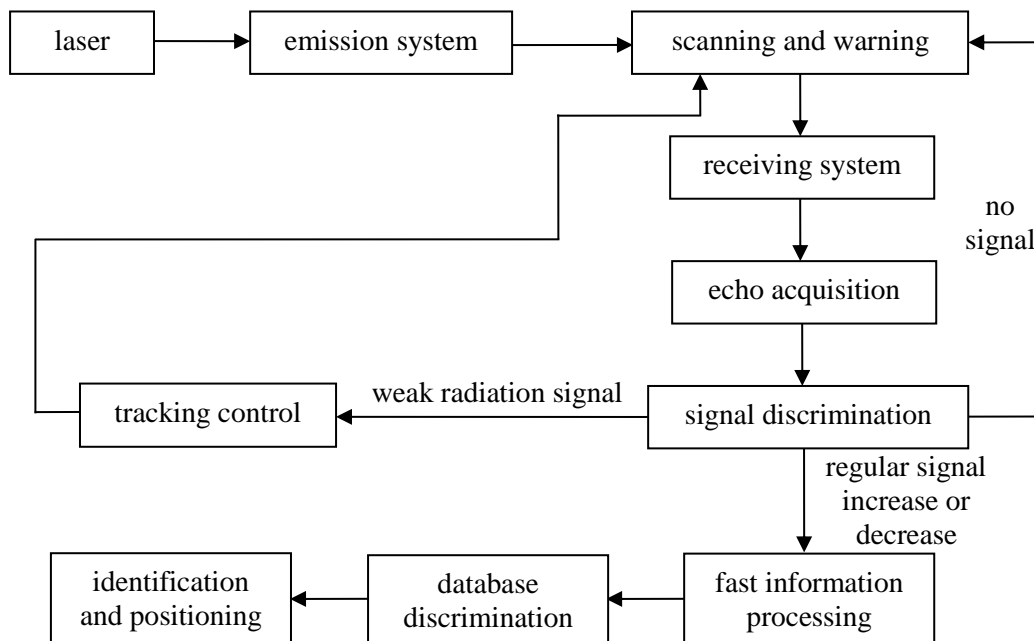


Figure 6. Schematic diagram of laser detection device.

When laser is used to detect UAV, the detection system can work all day and keep the scanning and warning status. Due to the wide detection domain of radiation light, after detecting weak radiation signals, the system control will track servo equipment into standby. As a result, when the signal appears regularity, targets enter the detectable domain of the focal plane reflected light, by subsequent information processing module analyzing the characteristic of the echo signal, comparing the magnitude data in the database to determine target characteristics, we can determine its dynamic information to achieve the purpose of position detecting [6-8].

#### 4. Conclusion

Unmanned reconnaissance aircraft carries photoelectric reconnaissance equipment for high-altitude operation with a relatively long visual range. However, it is generally used for ground reconnaissance. It can be easily controlled to detect the laser incidence angle by using active laser to detect it. According to the analysis results, as long as our laser reconnaissance equipment is in the view of UAV, the detection mission can be completed quickly. Under the premise of fully improving the quality of the launching beam of launching system, reasonably selecting the launching position, and lifting the detection ability of the detection system, laser reconnaissance has shown more and more development potential in UAV confrontation.

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