Research on night vision distance imaging technology of semiconductor laser

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Abstract. The semiconductor laser night vision distance imaging system introduced in this paper is an active imaging system with a laser as a light source, forming an image according to the light reflection difference of the target and the background. Compared with the passive imaging system, the active imaging system has the characteristics of strong receiving signal. Under extreme conditions, it can also realize the extraction of image key information of strong reception signal. Under extreme conditions, it can also realize the extraction of image key information through range-gated technology. It is a high anti-interference capability semiconductor laser ranging imaging technology suitable for severe weather and conditions. The system can be used in laser active imaging guidance, unmanned aircraft, guidance systems and other military fields and public security, fire control, transportation and other fields.

1. Introduction
With the continuous progress of semiconductor laser technology, especially the rapid development of semiconductor laser active imaging technology, it is not only widely used in the national defense military field, and also permeates the public security, fire protection and and fields[5]. Semiconductor laser night vision distance imaging system is a laser active imaging system using semiconductor laser as a transmitting light source, which forms an image according to the light reflection difference of the target and background[1]. Because the energy distribution of laser is concentrated, and the scattered light of the atmosphere causes serious interference to the receiving system, this kind of atmospheric scattering is particularly serious in bad weather conditions, it is the bottleneck that restricts the improvement of the imaging quality of night vision system, and the use of distance selection technology is an effective way to solve this bottleneck.

2. Laser active imaging system
Depending on whether there is a light source or not, the imaging system can be divided into active imaging and passive imaging system. The most significant feature of passive imaging is that it does not have a light source, depends on the light of the environment or target, and ultimately imaging. Such a passive imaging system, in the dark, low illumination, poor atmospheric transmission characteristics or rain, snow, fog and other bad weather conditions, due to the serious backscattering caused by suspended particles, the imaging effect is very poor. The development of active imaging technology has broken the bottleneck of this technology. Active imaging refers to the use of an artificial optical radiation source (generally a laser) and a receiver, whose receiver is used to collect and detect direct or reflected part of the light radiation of the target scene[4].

Because the laser has the advantages of high strength, high collimation, good monochromicality and easy synchronization, laser is used as a light source in the imaging system, lighting small and dark
targets in the distance, detecting laser pulse echo signal, and supplemented by distance selection technology, we can obtain high-resolution images of small and dark targets in the distance.\cite{2}

The active imaging system of laser lighting works in the same way as lidar,\cite{3} illuminates all or key features of the target by adjusting the focus state (divergence angle) of the emitting laser beam, meets the detection requirements of the receiving system, detects the laser echo, and achieves the purpose of imaging and accurate tracking of the target. Its system block diagram is shown in Figure 1.

![Collimated beam expansion](image1)

**Figure 1. A schematic diagram of the laser active imaging system**

In addition, the horizontal divergence angle of high-power semiconductor laser is about 10 degrees, the vertical divergence angle is about 40 degrees, is a typical astigmatism beam. Narrow active areas also cause poor spot uniformity, so it is necessary to greatly improve the quality of its beam before it can meet the actual requirements for use. At present, high-power semiconductor lasers are generally used in quantum trap structure, its special waveguide structure determines its output beam asymmetry and the existence of dispersion. Such beams cannot be used in ordinary optical systems to obtain high-brightness lasers, making them difficult to apply directly. For high coupling efficiency, optical elements such as microlenses are usually inserted between LD and fiber, first shaping the beam and then coupling into the fiber (so-called indirect coupling). The light energy distribution after the above optical treatment is shown in Figure 2. As can be seen from the figure, the laser energy distribution is very concentrated, the pulse laser width and repeat frequency emitted by the laser is controlled by the pulse excitation source, the pulse laser emission at the same time to start the synchronous delay circuit and gated pulse source work, they control the camera open and close according to the target distance, in order to achieve distance selection, eliminate the pulse laser backscatter and stray light interference, improve the reception signal-to-noise ratio, effectively improve the quality of the image.

![Energy distribution of typical optical fiber output](image2)

**Figure 2. Energy distribution of typical optical fiber output**
3. Range-gated technology

The laser night vision range-gated schematic is shown in Figure 3:

![Range-gated technology diagram](image)

Figure 3. Principle diagram of range-gated

Laser night vision system consists of laser emission and image reception. After laser emission, lighting emission laser and echo signal transmission in the atmospheric path, atmospheric background radiation, transmission rate, scattering and absorption and turbulence and other factors will have an impact on active lighting imaging, resulting in backward scattering. In order to overcome the above factors on the impact of imaging distance and image quality, the principle of range-gated technology is shown in Figure 2. Range-gated technology is the use of pulsed lasers and selected cameras, in order to separate the scattered light at different distances and the target's reflected light in sequence of time, so that the radiation pulse reflected by the observed target just in the camera selection working time to reach the camera and image. The laser emits a very strong short pulse, which transmits the laser to the target, irradiates the target, and returns the laser reflected by the target to the camera. When the laser pulse is on its way back and forth, the camera's range-gate closes, blocking the backward scattering of light from the suspended particles in the gas. When the reflected light reaches the camera, the range-gate opens to allow reflected light from the target to enter the camera. When the target distance is uncertain (i.e. the delay time cannot be determined), the target can be captured by adjusting the delay time. The opening duration of the selection door is consistent with the laser pulse. The resulting target image is mainly related to the reflected light in the distance selection time. Distance resolution is determined by the width of the laser pulse and the width of the detector's access door, and the width of 1ns laser pulse and width of 1ns imager combine to provide a distance resolution of 30 to 60cm. If the selection pulse width and the laser pulse width are very narrow, so that only reflected light can be detected near the target, then the signal-to-noise ratio of the echo signal can be greatly improved.

Figure 4 shows a comparison of the image effect obtained by the unselected range-gated technology and the selected range-gated technology.\[6\]
Figure 4. The same scene gets an image comparison

The key to range-gated technology lies in synchronous control, and Figure 5 is the timing relationship between laser emission pulse and gate selection.

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\text{Emission laser pulse} \quad \text{Emission laser pulse width} \\
\text{Delay time} \quad \text{Gate width} \\
\text{Range gate} \\
\]

Figure 5. Laser pulse and selection gate timing

4. Results & Discussion
After the above research, the active imaging system with semiconductor laser as the light source is used to process the all-black night images. According to the characteristics of night vision images, the range-gated technology is used to extract the key information of the images. After processing, the image better presents the key information such as vehicle type and license plate. The original and processed images are shown in Figure 6 and Figure 7.

Figure 6. The original night vision image

Figure 7. The processed image

5. Conclusion
The system can not only be used to obtain and process the key information of the image under the night, but also to process the image under the bad environment and weather. The system has a good anti-interference ability. The system can be widely used in areas such as public security, fire control, transportation and the next step, according to the characteristics of the semiconductor laser image, analysis of the advantages of laser active imaging technology, in combination with range gating technology, on the basis of further research on effective software processing and hardware processing technology, realize the real-time processing of video images, realize the breakthrough in the field of
military, It is applied to laser active imaging guidance, unmanned aerial vehicle, guidance system and other military fields.

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