S8-3 Range-Imaging using the two-micron base Eye-Safe Laser Radar

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Eye-safe laser radars with range capabilities from several dozens meters to several kilometers has been developed for range-imaging applications such as obstacle avoidance (wire detection) and target profiling. The development effort has been made under the Cooperative Eye-safe Laser Radar Project (CELRAP) between 2nd Research Center, TRDI, Japan Defense Agency, and Night Vision and Electronic Sensors Directorate (NVESD), U.S. Army Communications-Electronics Command. To avoid technical duplication, the 2nd Research Center designs, constructs, and tests the 2-μm base eye-safe laser radar system[1], and on the other hand the NVESD promotes the 1.5-μm base system[2]. In this work, the Japanese 2-μm base system will be outlined with some test results obtained to date.

Shown in Fig. 1 is the transmitter/receiver of the 2-μm base eye-safe laser radar system. A laser source and its cooler are also contained in the enclosure. The laser source of the system is a diode-pumped Tm, Ho:YLF laser capable of operating with a peak power of more than 10 kW at a pulse repetition frequency of 10.5 kHz in ~20 nsec of the pulse duration. A laser pulse is successively transmitted in the Palmer scan pattern, and returned pulse energy is collected by a 14.5-cm diameter telescope, focused on a single InGaAs p-i-n detector. The output from the detector is conveyed to a signal processor to determine the range. Range measurements that are recorded for each pulse are repeatedly performed in different beam positions. In order to produce an image, the recorded data are transferred to the off-line processor that registers each range data to a pixel. Image size can be varied, depending upon the preset Field-Of-View and the laser beam divergence. In typical test conditions, a FOV of $^{AZ}48^{\circ} \times {}^{EL}12^{\circ}$ and 1.3 mrad of the divergence are chosen so that an image size becomes 640 x 160 pixels. The system can produce such a wide FOV image within ~24 sec.

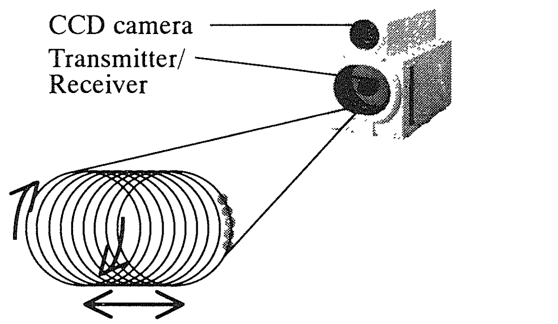
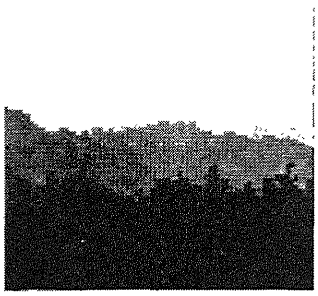
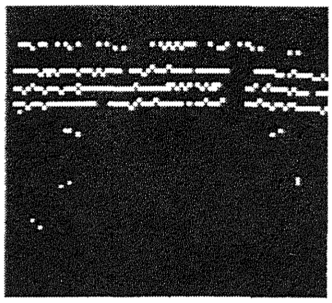


Fig. 1 Transmitter/receiver of 2-μm base eye-safe laser radar system on which a visible CCD camera is mounted. The laser pulses are transmitted on the Palmer scan pattern.

For obstacle avoidance, a laser radar system is required to be able to detect wire-like obstacles typically at several hundreds meters and to show them with separation from background. We have been collecting range images with the system for various scenes including wires and cables during the ground tests. Such range images are utilized as samples for optimization of our wire detection algorithm to increase detection probability with low false alarms[3]. Fig. 2(a) shows a typical range image consisting of a tower, cables and woods with a FOV of 6° x 6°. The tower is located at a distance of ~600 m from the system. The top line running horizontally is a 11-mm diameter metal communication cable, and the other three are 22-mm diameter twisted power cables made of aluminum. After applying the algorithm to the image, in Fig. 2(b) one can clearly see only the cables with elimination of woods and the ground, although several false alarm pixels still appear. Optimization of the algorithm is underway to lower the false alarms.





(a) (b)

Fig. 2(a) Typical range image including power cables obtained by 2-μm base laser radar system (b) Cables extracted by wire detection algorithm

Target profiling requires that a laser radar system can provide a three-dimensional image of a vehicle deployed at several kilometers with high relative range accuracy. For evaluation of the relative range accuracy, range measurements were repeatedly performed to a reference plate placed at distances of nominal 300 and 1000 m for various returned intensities. As shown in Fig. 3, discrepancies of measured ranges with respect to the nominal ranges do not exceed 50 cm over the receiver's dynamic range. Hence, the relative range accuracy is estimated to be less than 50 cm, although the range precision corresponding to each point's error is much smaller. This is reasonably good for target profiling.

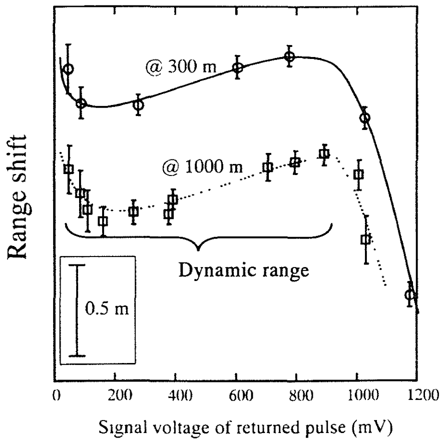


Fig. 3 Dependency of measured range upon return signal voltage, indicating relative range accuracy of < 50 cm. Saturation of returned signal starts at ~1 V.

It is widely accepted for reliable recognition and identification that a vehicle's image should contain, at least, hundreds of pixels. Our approach to meet it is to make a beam sharper in conjunction with use of a scan pattern that partially overlaps each consecutive beam spot by scanning with slower speed. This increases the number of registered pixels per unit solid angle. The current system can drive the scanner both vertically and horizontally with one-third of the normal scan in speed, so that the number of registered pixels per unit solid angle is increased to a factor of nine higher.

Usefulness of the overlapping scan is demonstrated as shown in Fig. 4. From the segmented range image obtained by the overlapping scan with a beam divergence of 1.3 mrad, one can easily recognize a recreational vehicle at ~300 m, while the normal scan provides a poorly resolved shape. Target imagery tests in longer range with a sharper beam divergence of several hundreds μrad are planned.

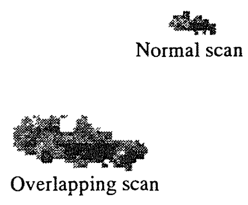


Fig. 4 Comparison of segmented range images of a recreational vehicle at ~300 m with a beam divergence of 1.3 mrad.

REFERENCES

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