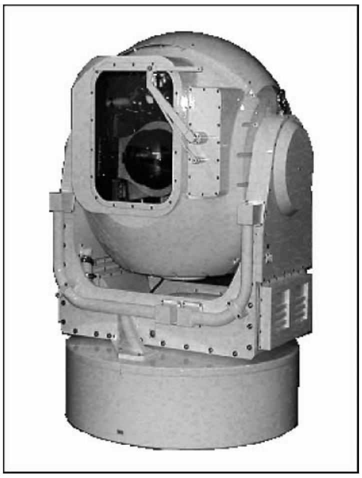

Development of the Laser Radar Surveillance System Technology at Long-distances with High-resolution Under Inclement Weather

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Mitsubishi Heavy Industries, Ltd. (MHI) has commercialized laser radar surveillance system that enables simultaneous long-distance high-resolution surveillance at night and in inclement weather such as rain. Active imaging uses invisible laser light and high imaging performance. Long-distance operation includes character recognition at night and distance measurement while ensuring safety security and concealing properties with high surveillance.

1. Introduction

Surveillance and security considerations around the globe have grown since the Sept. 11 terrorist attacks in New York and an unidentified boat was spotted in the Japan Sea.

Surveillance is especially important at night and in inclement weather, when conventional surveillance using passive sensors, such as highly sensitive and infrared cameras, deteriorates dramatically.

MHI has commercialized surveillance that simultaneously enables long-distance observation at high resolution even in inclement conditions. We introduce operating principles and features of our proposal, the system configuration, and sample images under inclement conditions.

2. Operating principles and features

2.1 Operating principles

We have developed active imaging using the range gate method and invisible laser beams. Operating principles are shown in **Fig. 1**. With the range gate method, a pulse laser beam is illuminated planarly on an object and imaging is conducted when light reflected from the object reaches the system. Repeating laser beam illumination and imaging at 30 Hz yields real-time animated images similar to ordinary camera images. Unlike conventional highly sensitive and infrared cameras, our system eliminates the effects of disturbing scattered and reflected light from outside the target object, dramatically reducing disturbance effects in imaging (scattered light from suspended particulates in space between the system and target), and outputs the distance obtained by the time the reflected light signal reaches the system.

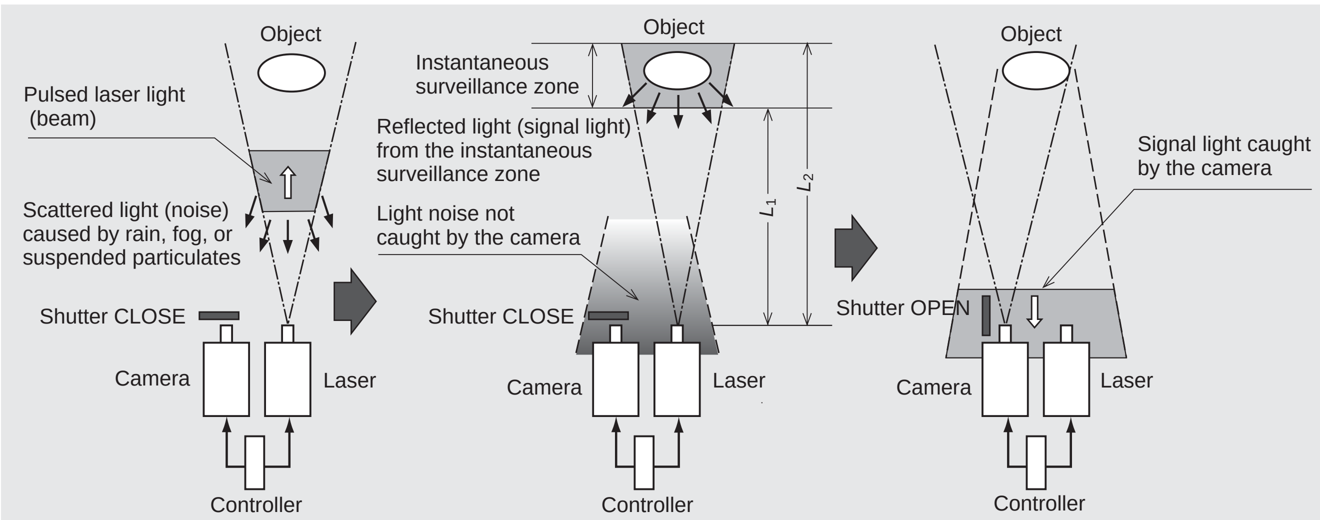

Fig. 1 Operating principles
Pulsed laser light is irradiated and imaging is conducted only when reflected light reaches the camera.

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2.2 System components and features

Figure 2 shows the system block diagram, which consists of (1) imaging unit and (2) controller/lasers unit, detailed below.

(1) Imaging Unit

Imaging unit consists of a laser-transmission lens, light-reception lens, ICCD camera, and color-visible camera. Reflected light received through the light-reception lens is amplified and converted to image data by ICCD camera before being sent to the controller. The color-visible camera operates in the daytime.

Laser-transmission lens and light-reception lens control ensures that the laser-transmission and imaging zones are identified. Effects on the body are reduced through zone-control operation based on JIS standards.

(2) Controller/laser Unit

The controller/laser unit, consisting of controllers, PCs, operator panel, etc., processes image data from imaging before displaying results. The direction of observation, zones (regions), etc., are set using the control user interface.

Figure. 3 shows a shipborne system in which imaging on the oscillation stabilizer corrects oscillation in rough seas, ensuring stable images regardless of wave height and ship movement.

2.3 Features

The system has the following features:

(1) Imaging is possible in two modes – color-mode during the day using a color-visible camera and laser-mode at night using laser irradiation and the ICCD camera – enabling monitoring in all time zones.

(2) Character recognition not possible using conventional infrared cameras is enabled, as is imaging through glass (**Fig. 4**[1]).

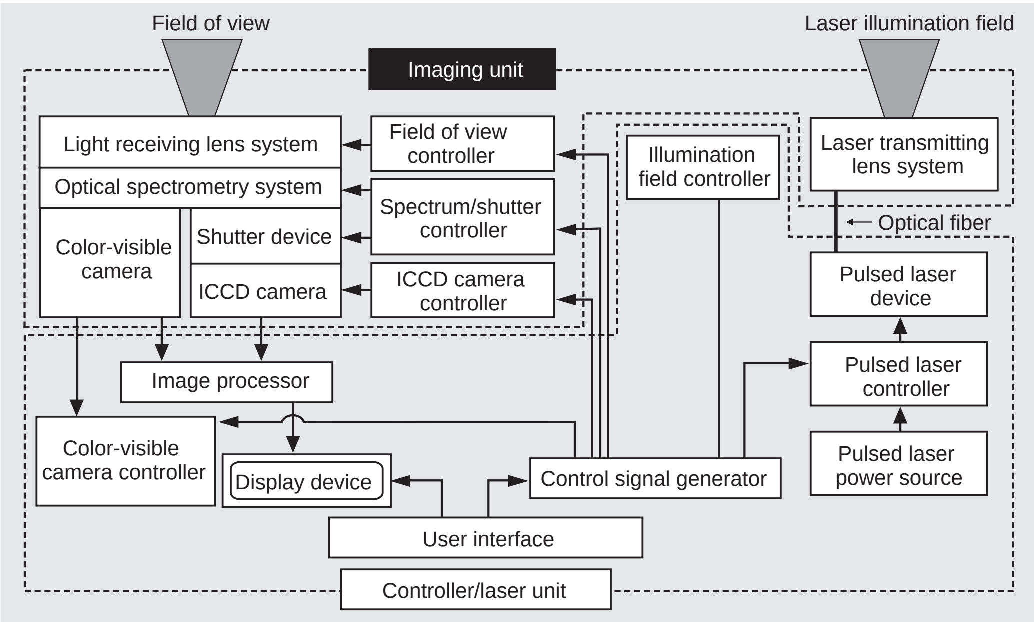


Fig. 2 System block diagram

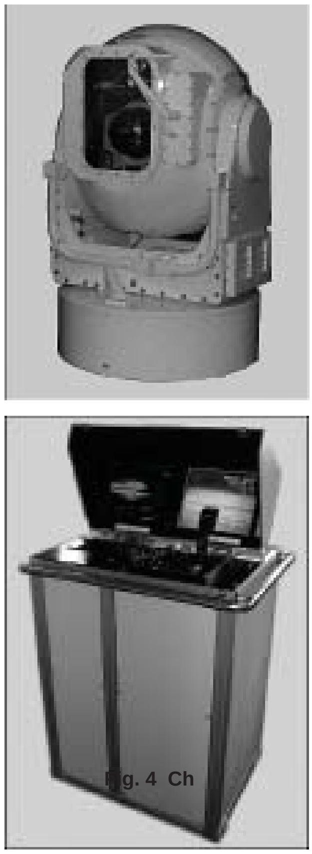


Fig. 3 System
The shipborne system consists of imaging and a controller, with the imaging function of collecting vessel oscillation.

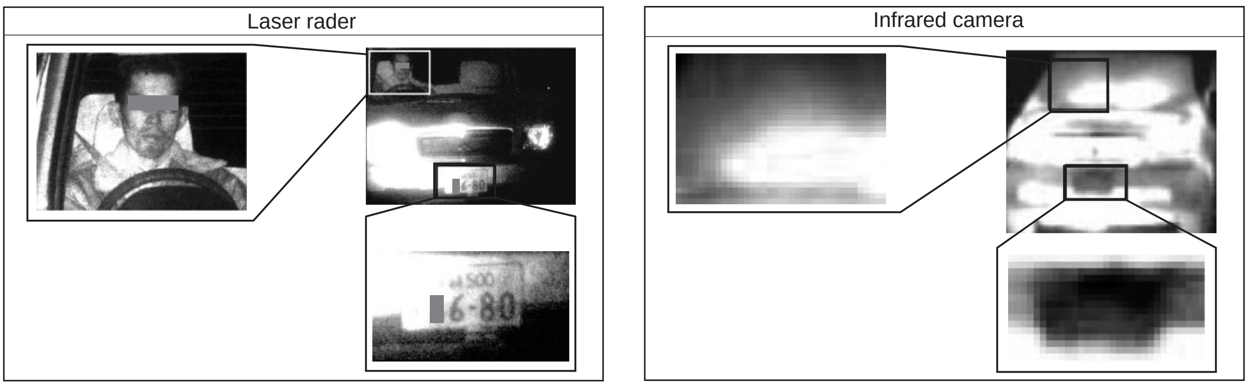


Fig. 4 Character recognition: Sample image taken through glass
Number plates and drivers are photographed – an accomplishment not possible using conventional infrared cameras.

(3) Monitoring is enabled even in inclement weather using laser mode.
(4) Invisible laser light enables monitoring ensuring high concealment even in laser mode.
(5) Imaging is possible with range gate image (**Fig. 5**) by shutter control (close/open) in laser mode.
(6) Deviation-free images are output by using planer laser irradiation and images as in the strobe photography.

3. Sample images

3.1 Sample images in inclement weather

(1) Sample images under simulated weather conditions

Figure 6 shows sample images under simulated weather conditions with the object — a black-and-white lattice plate — about 1 000 m away and photographed under precipitation equivalent to 10 mm/h and a visibility range in fog equivalent to 400 m. The result shows that despite conditions severe for ordinary visible and infrared cameras, our new system ensures dramatic reduction in adverse environmental effects while enabling imaging.

(2) Sample images under weather conditions

Figure 7 shows sample images of an observation stand 1 000 m away in fine weather and in precipitation of 5 mm/h[2]. Images at the top in Fig. 7 are from the visible camera without laser illumination jointly set in the new system. Images at the center are from the system in laser mode. Images at the bottom are from the infrared camera at the same position. Imaging at night and in rain, difficult for an infrared camera, is possible using our new system.

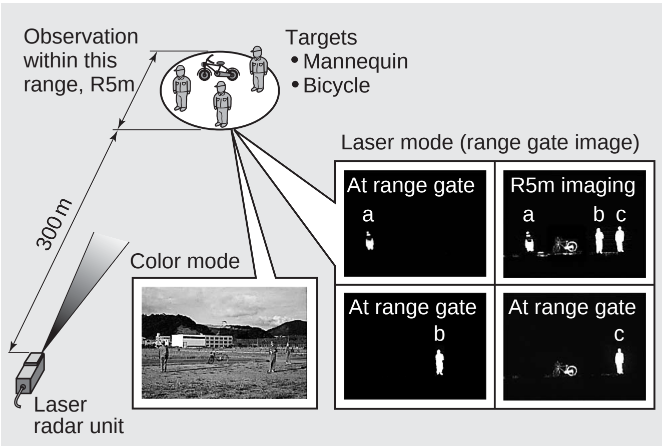


Fig. 5 Sample of range gate image
Objects at different distances are photographed independently through arbitrary zone selection.

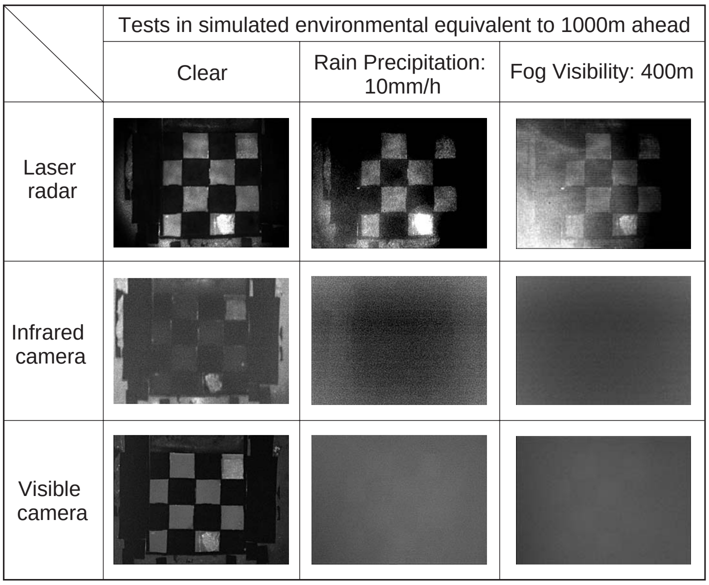


Fig. 6 Sample images under simulated weather conditions
Our system dramatically reduces environmental effects of rain, fog, etc., ensuring good imaging.

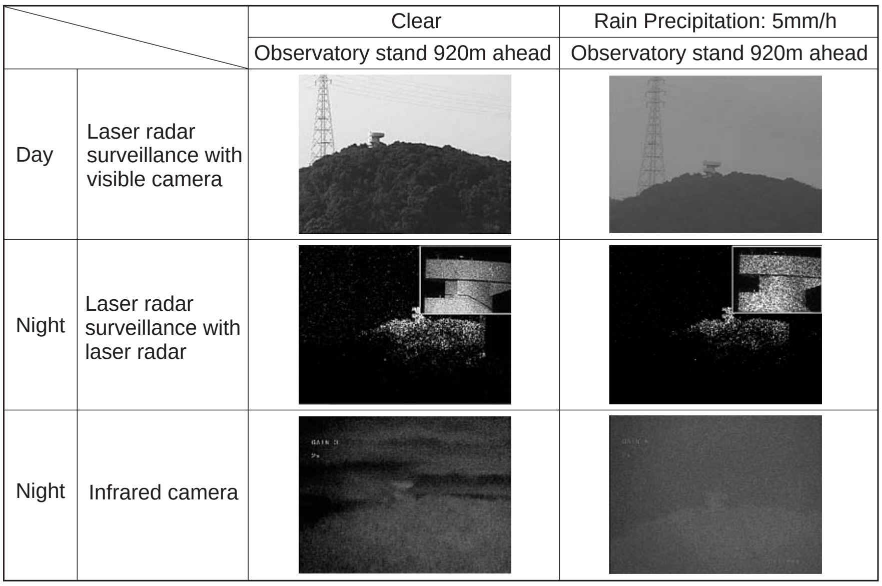


Fig. 7 Sample images in actual weather conditions
Our system ensures imaging even in conditions difficult for infrared cameras to photograph.

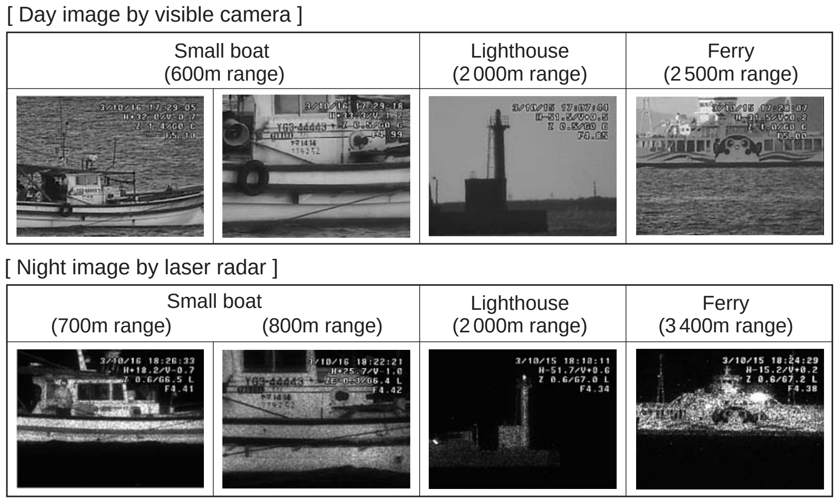
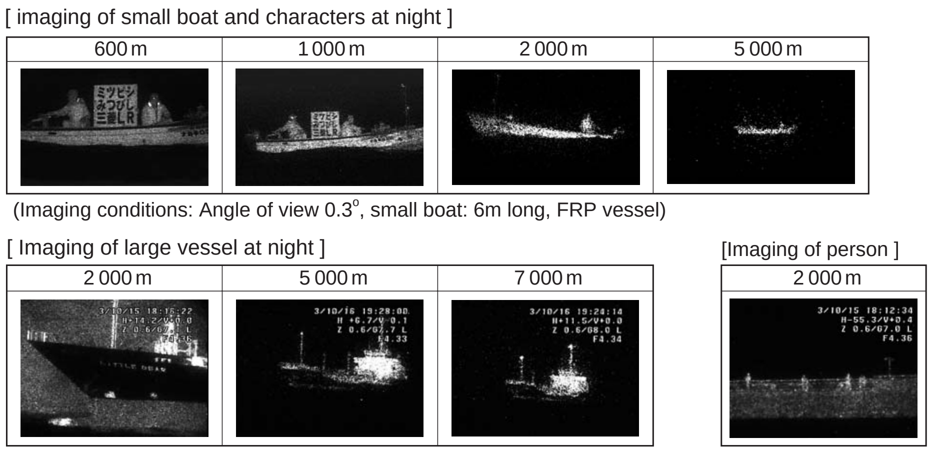


Fig. 8 Sample images of objects at sea



(Imaging conditions: Angle of view 0.3°, small boat: 6m long, FRP vessel)

(Imaging conditions: Angle of view 0.6°)

(Imaging conditions: Angle of view 0.6°)

Fig. 9 Sample images at long distance

MHI confirmed observation of a small boat at over 5000 m and of a large ferry at over 7000 m, recognition of 25 cm square characters at over 1000 m, and human movement observed at over 2000 m.

3.2 Sample images of objects in sea

Figure 8 shows sample images of objects at sea — a small boat, a lighthouse, and a large marine ferry(2). Images at the top were taken using the color visible camera during the day and those at the bottom taken at night using laser mode. Long-distance verification images of a small boat (top) and a large ship (bottom) taken at night are shown in **Fig. 9**, with a board with 25 cm square black characters against a white background located on the small boat at the top to verify character recognition performance. Verification was also confirmed for human movement recognition performance, at right in Fig. 9. Night-time detection was confirmed to exceed 5 000 m for the small boat and 7 000 m for the large vessel. The 25 cm square character identification performance exceeded 1 000 m and human movement recognition 2 000 m.

4. Conclusions

We have commercialized surveillance technology that simultaneously realizes long-distance observation and high resolution at night and in inclement weather. Our active imaging technology uses invisible laser light to ensure safety and high concealment. We applied it to laser radar surveillance with high imaging performance, including character recognition at night, distance measurement, and high surveillance. Our customer has implemented a shipborne application in practical operation, demonstrating the system's full capacity. MHI is promoting the development of ground systems, etc., to contribute to building and maintaining a highly secure society.

References

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