DEVELOPMENT OF NEW AIDS TO NAVIGATION SYSTEM BY LASER

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Abstract
At night, ship operators are operating ships by creating an image of the channel based on the lights from the lighted buoys interspersed on the sea.
So far, in order help them create more accurate images, the JCG has been taking such measures as to use LED lighting apparatus, increase the illuminating power, or synchronize the flashing of the lights which can improve visibility. However, recently when people have come to actively engage in marine leisure such as through the use of pleasure boats, and moreover, given the high-speeding of maritime transport, it has become necessary to let navigators identify channels more quickly and easily.
One solution is to use the characteristics of laser beams, as shown in Figure 1, to visually indicate the channel's side, central and dividing lines. This system can be expected to provide a good visual guide for navigation, greatly improving the safety of navigation and efficiency of operation. To this end, the JCG has been conducting experiments for practical application.
The use of laser beams has the following advantages.
(1) Their wavelength is uniform and are in phase.
(2) They are not easily attenuated or dispersed.
(3) The optical system is easy to control.

Résumé
La nuit, les marins dirigent le navire en créant une image du chenal à partir des feux émis par les bouées lumineuses placées à intervalles réguliers sur la mer.
Jusqu'à maintenant, pour les aider à obtenir une image plus précise, la Garde côtière japonaise prenait des mesures telles que l'utilisation de DEL, l'accroissement de la puissance du feu, ou la synchronisation des feux à éclats, ce qui permettait d'améliorer la visibilité. Récemment, toutefois, avec le développement de la navigation de plaisance et, surtout, l'accroissement de la vitesse des navires, il est devenu nécessaire de donner aux navigateurs les moyens d'identifier les chenaux plus facilement et plus rapidement.
Une des solutions possibles consiste à utiliser les caractéristiques des faisceaux laser, comme montré sur la figure 4, pour indiquer clairement les limites du chenal, sa ligne médiane et ses divisions. On attend de ce system qu'il constitue un bon guide visuel pour la navigation, ce qui permettra d'améliorer la sécurité et l'efficacité des opérations. A cette fin, la Garde côtière japonaise s'est livrée à des expériences en vue d'une application pratique.
L'utilisation des faisceaux laser présente les avantages suivants :
(1) Leur longueur d'ondes est uniforme et en phase
(2) Ils ne s'atténuent ni ne se dispersent facilement
(3) Le système optique est facile à contrôler.

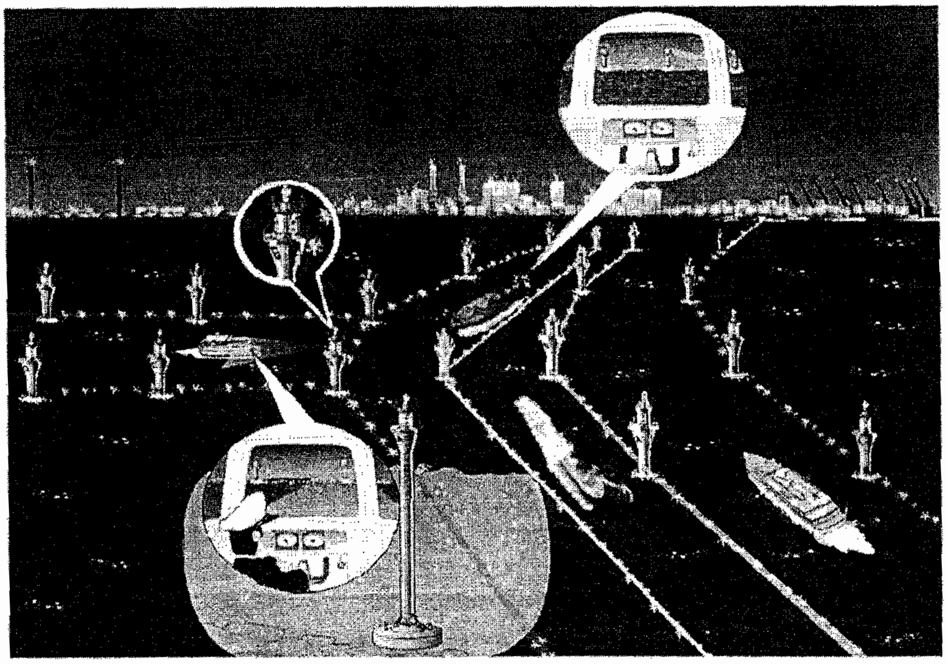

Figure 1. Future Image

ISSUES TOWARD PRACTICAL APPLICATION

1.Design policy

The fact that it is possible to create lines in space using laser beams is widely known through attractions, etc. However, when using them as navigation aids, it is necessary to ensure that the navigators can quickly and easily see them. It was therefore believed better to set the course of the beams on or near the water surface where there are relatively large quantities of suspended matter.

Also important is to ensure the safety of laser beams. This was ensured as follows. The output from the laser beam oscillator was diluted to a circular beam of a diameter of approximately 250 mm at the feeder outlet. This keeps the beam density to under the Class 3A safety level prescribed by the Japan Industrial Standards (JIS) which is compatible with the IEC (International Electrotechnical Commission) standards.

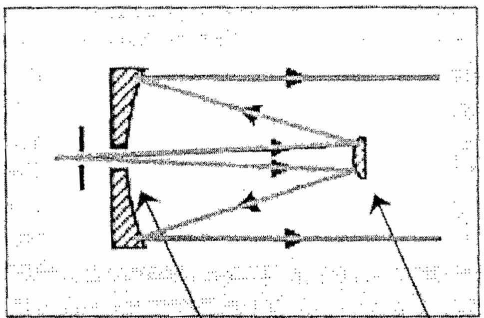

Figure 2. Principle of Large-Aperture Astronomical Telescope (Cassegrain type)

However, if someone were to intentionally watch the source of the laser beam using a telescope for instance, the risk would increase in proportion to the telescope's magnifying power which could damage the eye.

In addition, one of the requirements when using light beams as navigation aids was to generate more or less uniform parallel beams. To satisfy this requirement, the experimental system was made using a large-aperture astronomical telescope (Figure 2).

The experiment was able to dilute the beam diameter to 250 mm at the feeder outlet, and keep the diameter to 600 mm a kilometer away. The beam's radiation angle was 0.35 mrad, and the beam power, 500 mW at full beam

Figure 3 shows the system configuration of the experimental system.

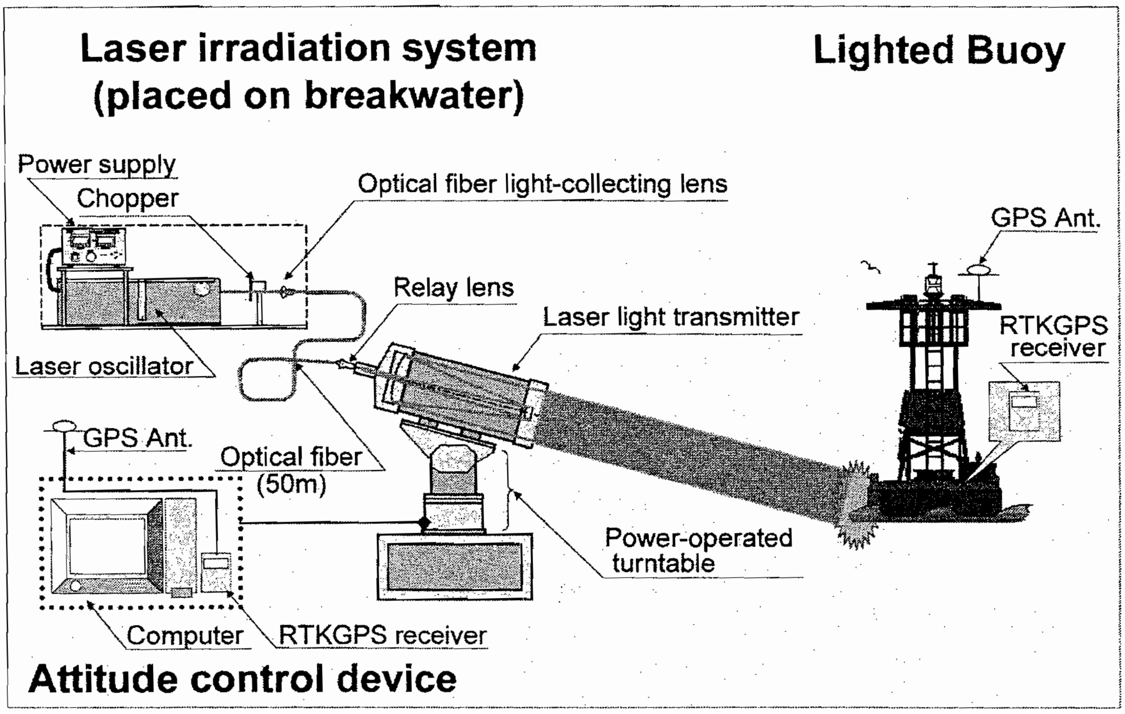

Figure 3. System Configuration of the Experimental **System**

Figure 4 shows the beam pattern. The dark section at the center is the silhouette of the auxiliary reflecting mirror and its leg.

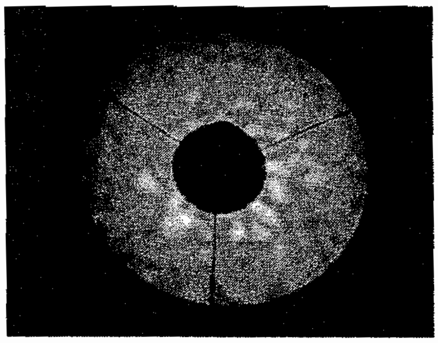

Figure 4. Beam Pattern

2.Site experiment

Based on the preliminary experiments and the results of the examinations so far, using the system as shown in Figure 3, and at the dawn of the 21st century (January 2001), the laser beam experiment was conducted for two months at Yokohama Port which is the birthplace of lighthouses in Japan.

The experiment is detailed below.
(1)The laser beams were emitted in flashes (one flash: 0.25 sec./sec.) at a lighted buoy located approximately 1,000 m away from the breakwater lighthouse.
(2)An automatic homing system was used to change the beam direction in accordance with the buoy movement.
(3)Given the nature of laser beams, the operation was restricted to nighttime.
(4)If a ship was staying in the laser beam for a certain time, the laser beam was suspended.
(5)The operations were all remote-controlled.

Photo 1 shows the site experiment conducted in the Yokohama channel.

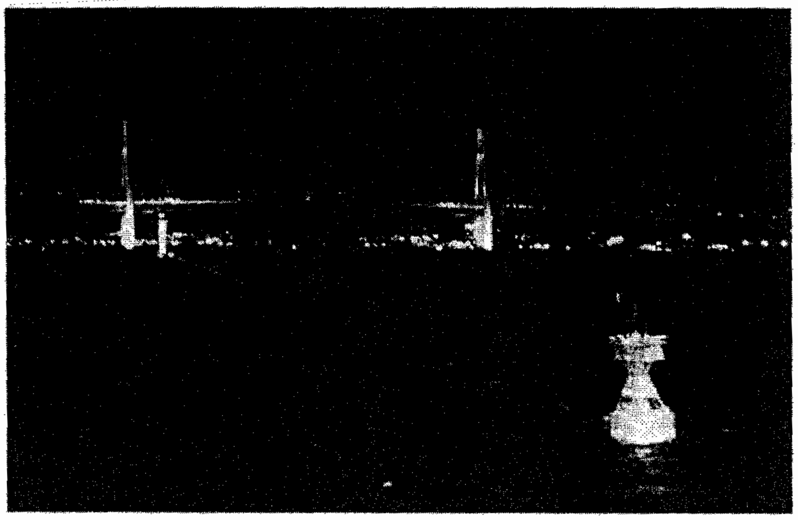

Photo 1. The experiment in Yokohama Port

During the experiment, there were no troubles to the equipment and no claims or inquiries about the experiment from the ship operators and their evaluation was good.

The results of the experiment showed that the visibility was good, the homing system worked as expected, and it was confirmed that the system was effective as an aid to navigation.

3.Laser beam visibility range

Figure 5 shows the visibility range of the laser beam when applied to the Nakanose channel where the system will officially be introduced in fiscal 2003. It shows how the beam looks depending on where one looks at it from.

These data were obtained on a hazardless beach by observing the laser beam at distances of 2.4 km, 3.6 km and 4.8 km from the source.

The laser beam has a high directionality, so that on the direct extension of the laser beam and at spots close by, the beam source appears as very bright. Depending on the distance, the source will be glaring.

In addition to ensuring the safety to the eyes, if laser beams interfere with lights from other navigation aids or navigation lights of ships in the same sea area, such will be a problem. For this reason also, it is necessary to make the beams as dark as possible.

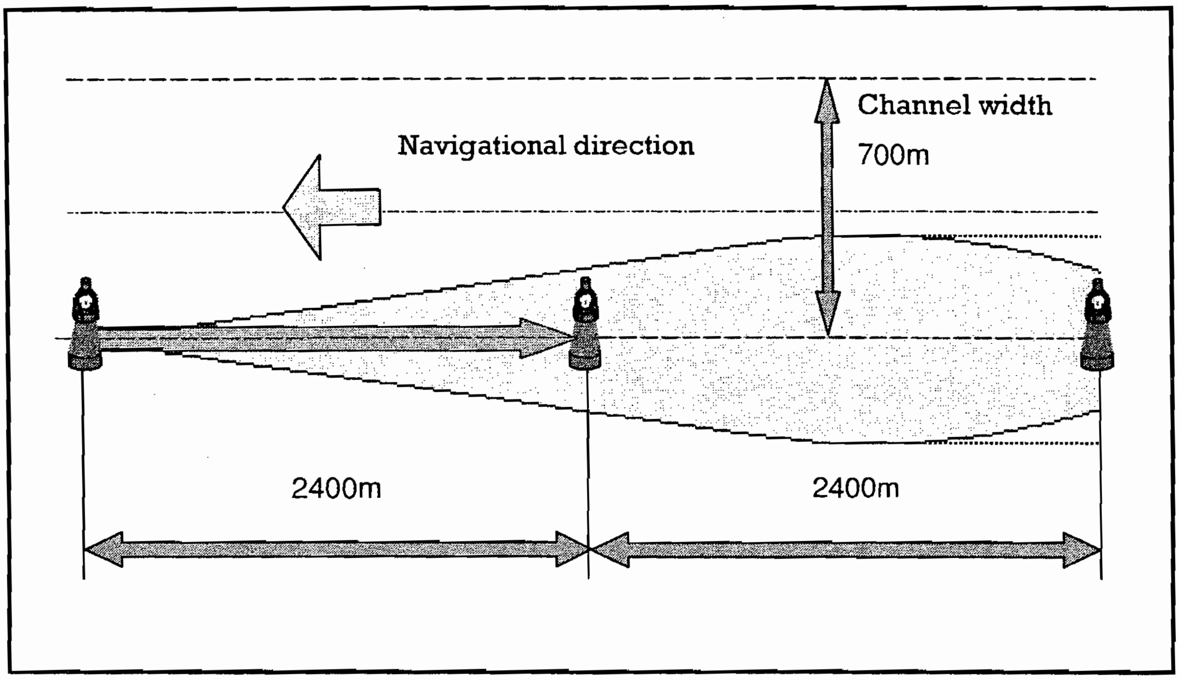

Figure 5. Visibility Range of Laser Beams

As for how the visible laser beam looks, the beam's visibility range is very limited as verified by the back-scattering theory using aerosol.

However, in cases that buoys are installed at close distances or the channel has bends, the indication of channel sidelines using laser beams is more effective.

4.Optimum flashing pattern [rhythm]

The results of the visibility experiments showed that the flashing pattern that improves the laser beams' visibility and conspicuity and minimizes the electricity consumption was either 1 flash in 1 second (ON for 0.25 second and OFF for 0.75 second) or 2 flashes in 2 seconds (ON for 0.25 sec., OFF for 0.25 sec., ON for 0.25 sec. and OFF for 1.25 sec.).

However, setting different patterns from those of the other navigation aids could affect visibility, so that whether the use of these patterns is appropriate or not remains as an issue.

5. lighted Buoy homing system

To indicate channels on the sea requires that many lighted buoys are connected using laser beams. However, lighted buoys not only move but rotate, so that to ensure that the laser beams can hit the lighted buoys for certain, the JCG plans to introduce lighted buoys that move less and do not rotate.

(1)Initial experimental system

The initial experimental system was as shown in Figure 3. The horizontal position of the lighted buoy was detected using a Kinematic GPS device installed on the lighted buoy, and the vertical position was detected using a tide calculation program.

The lighted buoy's position was thus grasped, so that the laser beams should always hit the lighted buoy.

(2)Experimental system for practical application

Now being planned is a system whereby a light source (infrared LED) is installed on the target (breakwater lighthouse), that light source is tracked using an image processing camera, so as to control the beams (to always hit the breakwater lighthouse).

An advantage of this system is that in the event of occurrence of a mist of a level that blocks the laser beam, the beams can be stopped. This will save the limited quantity of power source (supplied from storage battery) available to navigation aids.

The next experiment is scheduled for February 1-28, 2002. Figure 6 is an image diagram of the experimental system for practical application.

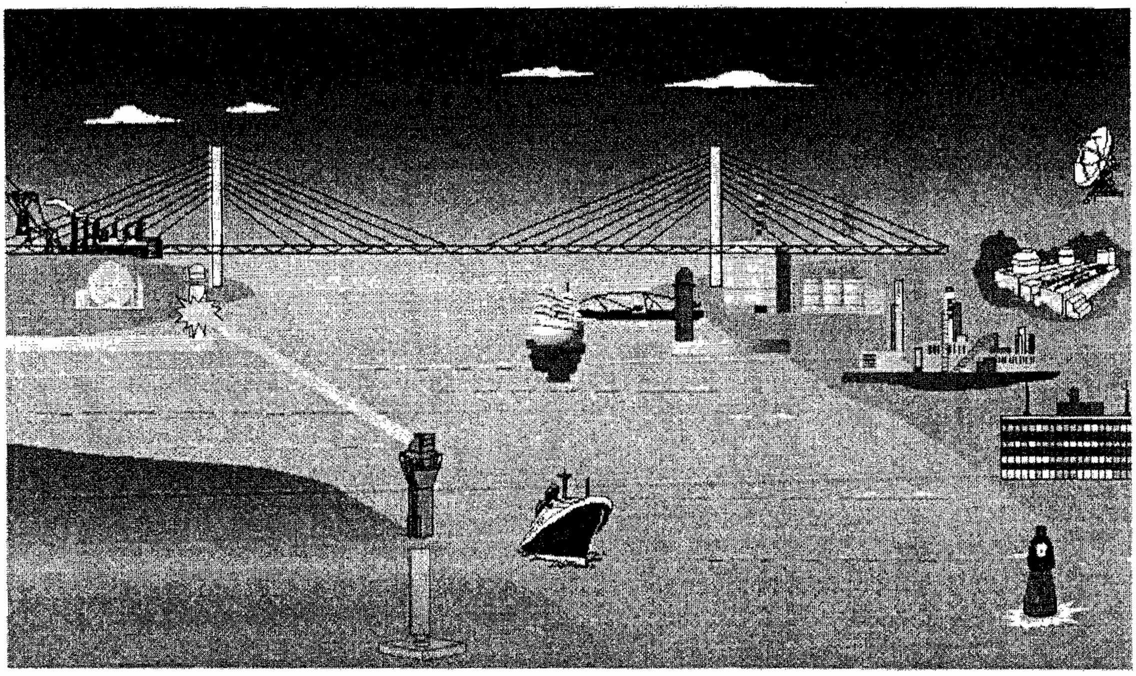

Figure 6. Image Diagram of the February 2002 Experiment

The laser beam will be a donut-shaped one with an outside diameter of 150 mm and an inside diameter of 80 mm at the muzzle, with a full-beam power of approximately 300 mW.

FUTURE ISSUES

The laser beam system has been evaluated as being "epochal and very easy to see." Based on the results of the experiments so far, the JCG plans to conduct further examinations for practical application.

In February 2002, it plans to confirm stable laser beam emission from the sea. Based on the results of this experiment, it aims for official introduction in fiscal 2003.

Check points for official introduction

(1)Optimum beam diameter
(2)Laser beam density (optical power)
(3)Visual range
(4)Beam control (tracking device)
(5)Safety
(6)The height of the beam from the sea surface
(7)Securing of power source (examination of use of natural energy sources)
(8)Examination for electricity-saving and compacting of the equipment and system as a whole
(9)Examination for red and white laser beams necessary for use on navigation aids