Laser Energy Transmission for a Wireless Energy Supply to Robots

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***Abstract*—The importance of the wireless energy transmission is emphasized for the actual operation of robots. Examples of application such as a lunar rover mission for the ice exploration, rescue robot for nuclear accident and laser driven kite plane are shown. Problems to be solved are discussed for more extensive utilization of the technology.**

***Index Terms*— laser, energy transmission, solar cell, laser diode, rescue robot, lunar rover.**

I. Introduction

For rescue activities, the robot is considered as a very hopeful tool, however, right now, the robot is not used actually for the rescue activity. It is clear that once it is actually used, how to keep supplying energy is very important. The wireless energy supply is mandatory. In most cased, it is considered that the rechargeable battery is most easy to solve it.

However, for example, in nuclear power plant accident or chemical weapon disaster due to terrorism, once the robot enters into the contaminated area, it is almost impossible to return for the battery recharging. Wireless energy transmission is mandatory.

Even for those robots working in the area where only robots can enter and can return for the refueling, the wireless energy transmission is required when the robot malfunctions and cannot return.

Moreover, some rescue activity's urgent need may not allow the robot to return for the refueling, then the wireless energy transmission is also very useful.

To realize the wireless energy supply, either the microwave or laser energy transmission is considered most hopeful. The microwave energy transmission has an advantage of higher energy conversion efficiency and can be used through the cloud, but it is not easy to concentrate the power in a small region. It is considered as a useful tool for the power transmission from the space power station (SPS) to the earth.

Laser is easy to focus the beam in a small area and the mirror can be used to transmit energy behind a blind corner. Since the development of laser diodes (LD), a very compact laser transmitter system can be constructed For the robot use, the laser is more advantageous over the microwave system.

This research is done as one of " Open Research Center (2001-2006)" project and also supported partly by "University-Industry Joint Research (2004-2009)" for Private Universities : matching fund subsidy from MEXT.

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II. Development of Laser Energy Transmission Technology

A. Lunar ice exploration rover

We have started the laser energy transmission technology development from 1997 to apply to a rover to explore the presence of ice in the bottom of craters in the lunar polar region, where no sun light is available. The solar radiation at the periphery of the crater is converted into the laser light through the electric energy and it is transmitted to the rover working at the bottom of the crater.

A proto-type model has been constructed as shown in Fig. 1 (a) and (b). The laser system consists of a 200 W Laser Diode system and the laser is output through a 400 micrometer fiber with NA= 0.22. The laser light is focused in 70 cm at the distance of 1 km using a mirror of 25 cm in diameter. The laser beam is received by a solar cell panel of 70 cm in diameter on the rover. The rover can easily be driven at the power more than 10 W.

Though the lunar exploration mission based on this experiment is not yet realized as the actual space mission, the energy transmission to more than 1 km has successfully been done on the ground to drive an actual size rover with an conversion efficiency more than 20 % (Fig.2).

Fig. 1(a). Laser system for the lunar rover mission

Fig. 1(b). Lunar rover to explore the presence of ice in the lunar polar region

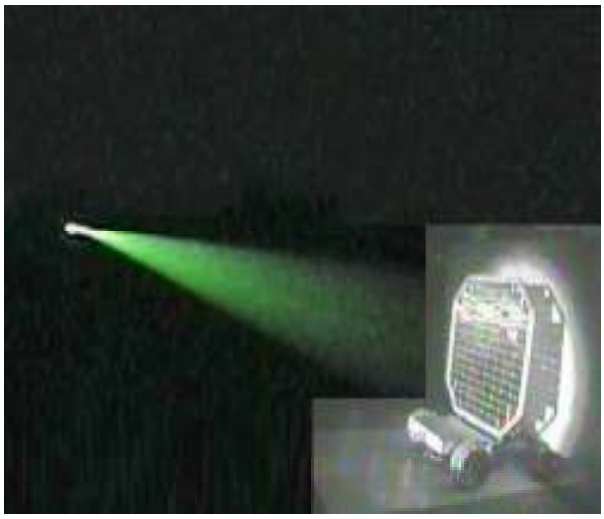

Fig. 2. 1 km laser energy transmission experiment

B. Robot

As a spin-off of the technology developed for the space mission described above, we are now developing a laser energy transmission system to an actual robot. The robot is constructed using the parallel mechanism (Fig. 3). Particular emphasis is put on the application to a rescue robot.

Currently, the power required to drive the robot itself is more than 120 W and the laser power can only drive the motion of an arm and fingers.

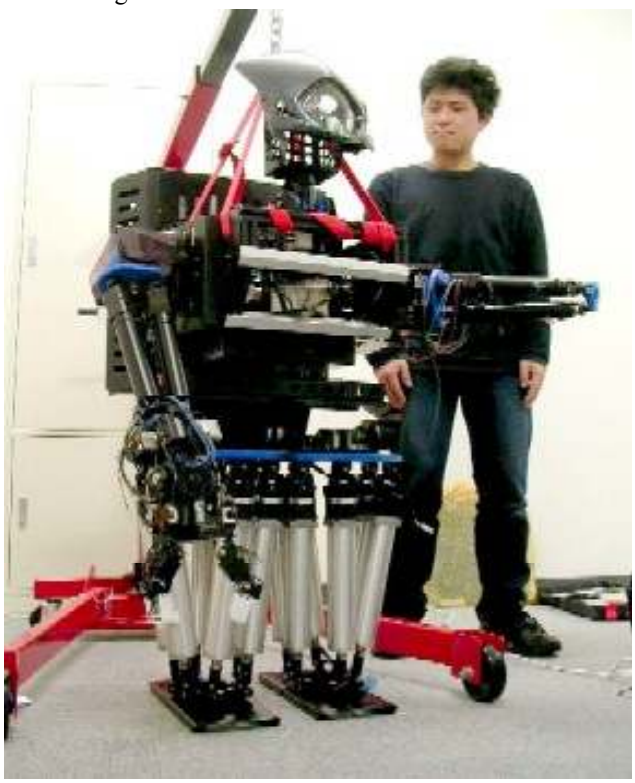

Fig. 3 Rescue robot

C. Small airplanes

The laser energy transmission technology is also applied to the small airplane for environment monitoring, surveillance of natural disaster such as flood, volcano eruption etc, broadcasting etc.

A kite plane developed by ATRIM Inc. as shown in Fig. 4 is one of candidates. It is considered that the kite plane has a better flight stability in worse wind conditions compared with other small airplanes.

The initial step of the development is to drive the kite plane making a circular orbit at the height of 50 m above with a radius of 10 m. The maximum speed shall be less than 10 m/sec. The plane shall not consume the electric power more than 40 W. and shall have a payload capability more than 300 g including a receiving solar panel of 30 cm in diameter.

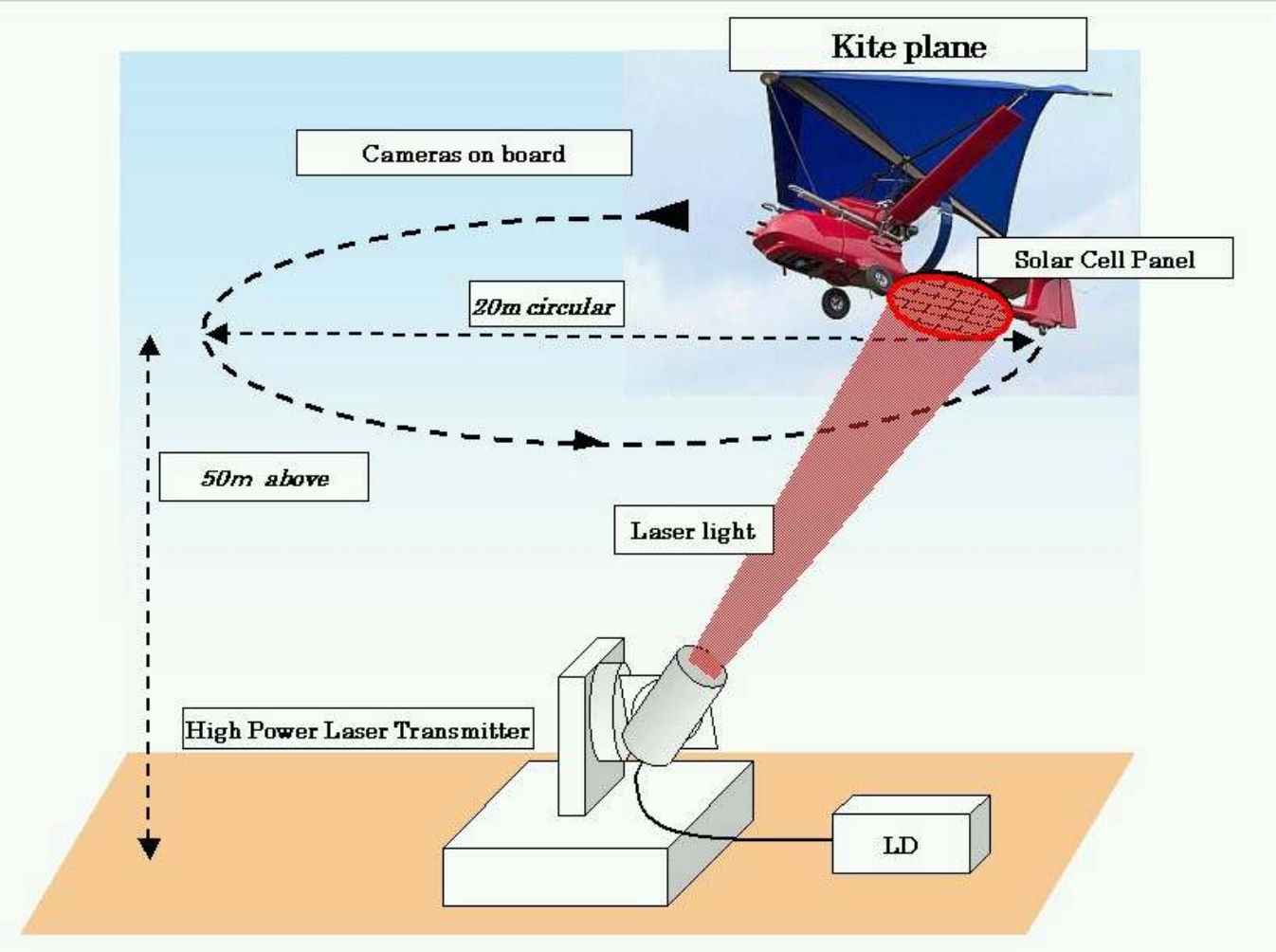

Fig. 4 Laser driven kite plane

The same 200 W LD system is used. The tracking system has been developed to keep the laser beam within the accuracy of 1 cm on the solar panel on board (the accuracy of 0.2 mrad).

Though this requirement is not yet fulfilled, we are now repeating the flight test improving the flight stability.

The second stage target is to send the laser power to the plane above more than a couple of hundred meters.

III. PROBLEMS TO BE SOLVED

A. Increase of the Conversion efficiency of LD

The laser diode is very compact and have a high conversion efficiency more than 30 % , however, when the output power is more than hundred watts, the dissipated heat is quite large and the cooling system is not anymore compact. More increase of the conversion efficiency is strongly required.

B. Efficient cooling system

Right now, for a laser diode of the power less than 100 W, the Peltier cooling system can be used. For a higher power, the water cooling system is used and it is not at all compact. More efficient compact cooling system is required.

C. Increase of the conversion efficiency of the solar cell to the electric energy

We are now using a solar cell of single junction GaAs of Spectrolab Inc. U.S.A. having a single cell conversion efficiency more than 40 %. However, the overall efficiency of the solar panel is less than 25 %. The reason why is that there is an open space between cells on the panel and also the intensity distribution is not uniform so that all the cells cannot receive the laser light at the optimum operation condition. Some cell has an conversion efficiency more than 60 % and higher efficiency cell is strongly needed.

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