Light Receiving Characteristics in case of Air to Underwater Optical Wireless Power Transmission

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1. Introduction

Optical wireless power transmission (OWPT) is a method of transmitting power by using light over long distances. One important characteristic is the power transmission efficiency even for in-air use. However, there are some new problems which can influence the system efficiency that appear in underwater OWPT system. One of these problems is the presence of waves when light passes through the interface between air and water.

In the last report, the analysis of an initial simple model of a 1D waves was discussed [1]. In this report, 2D light distribution was simulated, and an experiment of this model was done for practical characterization.

2. Simulation of Light Distribution

We assumed that the solar cell was placed underwater, light was incident through the water directly above the solar cell and there were waves. Since sin-function like wave is more common, we assumed that water waves are superposition of 2-axis sin waves.

To figure out how light is distributed underwater, we simulated light ray trace as showing in Fig. 1. In this simulation, we set the wave height to 0.2 cm, the wavelength to 1.4 cm, the size of the light source to 10 cm, and the depth of water to 30 cm. I traced 100 thousand shares of light and simulated which part of the solar cell the light beam would enter to find the light distribution under the influence of waves.

From Fig. 1, the light distribution pattern is not uniform and is widely spread compared to the light source size. For efficient receiving, a large solar cell module is required as described in [1]. As the characteristics of solar cells are limited by the region where the light intensity is weak, even if region with strong light intensity exists, the power from the strong light cannot be extracted well, especially for a typical series connected solar cell module. As a result, although it also depends on the configuration of the solar cell module, considering that only the weak light region can limit output electricity, the efficiency might be much lower.

3. Experiment of light incident from air to water

To experimentally characterize the influence of waves in an underwater OWPT system, we set up the apparatus as shown in Fig. 2. In this model, a Si solar cell module with 10 cm square is underwater and LED light is incident on the solar cell. We changed the depth of water from 6.5 cm to 30 cm. The beam size is 7 cm square at the solar cell position when water is not poured.

Figure 3 shows the I-V characteristics under the influence of waves in an underwater OWPT system. From the result, the I-V graph was fluctuated because the irradiation pattern on the solar cell is time dependent by the wave. Therefore, waves influences not only to the light region spread but also unstable power transmission.

With the water goes deep, some light should be absorbed by the water, but since the short circuit current does not differ so much, the influence of light absorption may be small. This is because the light used is a white LED and the absorption coefficient of the wavelengths range is small.

Acknowledgment

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References

[1] J. Li and T. Miyamoto, JSAP2019spring, 11p-W611-6.

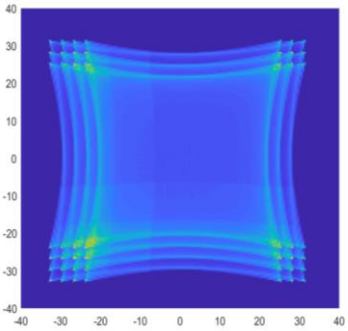

Fig. 1 Simulation result of light distribution

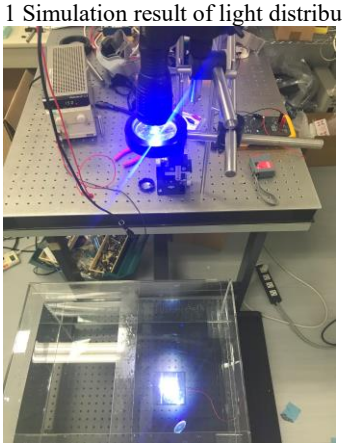

Fig. 2 Experimental setup

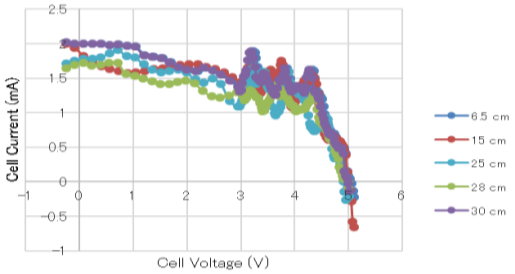

Fig. 3 I-V characteristics of Si solar cell in different depth of water with waves