Irradiation Performances Analysis of Multi-LED Optical Wireless Power Transmission System Based on Collimation Scheme

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1. Introduction

LED-based optical wireless power transmission (OWPT) systems are a novel technology for remote power transmission with the advantages of safety, long distance, high directionality, and no EMI. An OWPT system based on the collimation scheme with a single LED chip has been reported, and the length of the integrated light source module can be decreased by 50%.[1] However, with current LED device manufacturing technology, the output power of a single LED of the same chip size is difficult to increase. On the other hand, applying multiple LEDs is an effective way to increase total output.

In this research, the improvement of OWPT irradiation performance will be reported based on the collimation scheme using multiple LEDs.

2. Analysis of irradiation size

Figure 1 shows the proposed LEDs array system using the collimation scheme. The ideal irradiation spots overlapped, and the spot size is the same as a single LED chip schema. In this collimation scheme, the LED is placed at the front focal point of the collimation lens. The parallel beam can be focused on the solar cell by an imaging lens. Because of the parallel beam, the distance between the two lenses can be arranged as short as possible. The system dimension, which contains the distance between the LED and the imaging lens, depends only on the focal length of the collimation lens. Therefore, the irradiation size of a multi-LED collimation scheme can be analyzed with a combination of a regular double lens and a single LED as shown in Fig. 2.

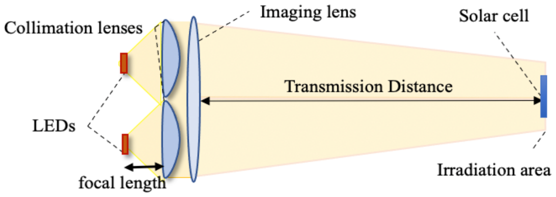

Fig. 1. The collimation scheme of multi-LED OWPT system.

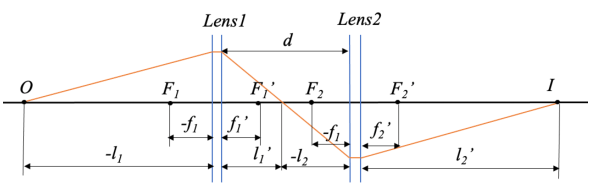

Fig. 2. Optical path of double lenses system.

Based on the optical path and Gaussian formula, the total horizontal magnification of the double lenses system can be calculated as;

$$\beta = \beta_1\beta_2 = \frac{f'_1 f_1}{(f'_1 f_1 - d(l_1 - f_1))}\frac{l'_2}{l_1}. \qquad (1)$$

In a collimation scheme, which the focal length value of the collimation lens is equal to the object distance, the horizontal magnification can be simplified as;

$$\beta = \frac{l'_2}{f_1}. \qquad (2)$$

Here, l'_2 is the system image distance, f_1 is the front focal length of the collimation lens. From this formula, in the collimation scheme with the fixed image distance, only the focal length of the collimation lens affects the irradiation size and is inversely proportional.

3. Analysis of multi-LED irradiation power

Three high-intensity NIR LEDs (Osram SFH-4703AS, 810 nm, 1040 mW) were assumed to form the LED array. Because of its 40° divergence angle, ideally, the focal length of the collimation lens is half of its aperture. With fixed lens aperture, the longer focal length of the collimation lens causes beam leakage more critically. With maintaining the aperture of the collimation lens at 50 mm, the relationship between the focal length of the collimation lens and the simulated irradiation power (Zemax) is shown as Fig. 3. When the size of the solar cell is limited to small, a collimation lens with *f*=30 mm shows preferred performance.

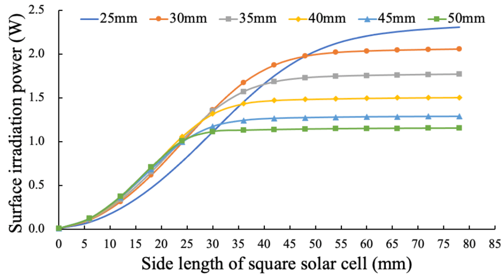

Fig. 3. Simulated irradiation power at 1 m with different focal length of collimation lens.

4. Conclusion

In an LED-OWPT system based on the collimation scheme, the shorter focal length of the collimation lens causes not only the larger irradiation size but also the higher output under the same lens aperture. The experimentally evaluated results will be shown in the presentation.

Reference

1) M. Zhao, Y. Zhou, and T. Miyamoto, JSAP2021 spring, 19a-Z22-10.