Numerical Analysis of Maximum Output in LED-based Optical Wireless Power Transmission System

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1. Introduction

LED-based optical wireless power transmission (OWPT) system has been attractive as a possible solution for remote power transmission.[1] A handy size 3-LED-array OWPT system for small IoT terminal based on the collimation scheme achieved 500 mW class electricity output at 1 m.[2]

In this research, the maximum output of handy size LED-array-OWPT will be numerically analysed with a 100×100 mm^2 size imaging lens and a 50×50 mm^2 solar cell at 1 m transmission distance.

2. Analysis condition of the maximum output

Figure 1 shows the LEDs OWPT system based on the collimation scheme. Arrayed LEDs are formed the light source and are placed at the front focal points of the arrayed collimation lenses. The parallel beams are focused on the solar cell by an imaging lens. It has been proved that, in the collimation scheme with the fixed imaging (transmission) distance, only the focal length of the collimation lens affects the irradiation spot size and they are inverse proportional relationship.[2]

In the case of increasing LEDs number for increasing output in the collimation scheme, more collimation lenses are applied. However, to maintain the imaging lens aperture, the aperture of each collimation lens is decreased. Accordingly, its focal length should be decreased to avoid the beam leakage. Therefore, the irradiation spot size is enlarged and the beam leakage occurs at the fixed light receiver. Thus, even if LED numbers are increased, the total electricity output from this receiver is not increased anymore.

Since the LED array arrangements are quite complex when LED number is larger than 5, and different parameters of collimation lens complicate the performance analysis. Therefore, to calculate the maximum output of LED-OWPT system, n×n LEDs array are assumed to simplify the numerical analysis.

3. Analysis and discussion

A software, Zemax, was used for the numerical analysis of collimation scheme. A high-performance LED (OSRAM SFH4715AS, 850 nm, 1.53 W) is applied to form the LED array. As for the lens system, an imaging lens is 100×100 mm^2 aperture and 1 m focal length. A 50×50 mm^2 detector is applied at 1 m away from imaging lens as the light receiver.

It was confirmed that by changing the focal length and radius of collimation lens, during $5 < r \leqslant 10$ mm, f = 25 mm collimation lens has the local optimal value, besides, during $10 < r \leqslant 25$ mm interval, f = 30 mm has the optimal output. The relationship between collimation lens radius (r) and 50×50 mm^2 size surface irradiation power (I) and their regression equations are shown in Fig. 2.

Because of the fixed 100×100 mm^2 aperture imaging lens and n×n array LED light source, each collimation lens radius is equal to 100 mm/2n, thus, the relation between surface irradiation I and LEDs number (n×n) is shown as followings.

$$I = -16.5\,n^2 + 345\,n + 3750 \quad (5 < n \leq 10) \quad (1)$$

$$I = -192\,n^2 + 1965\,n \quad (2 < n \leq 5) \quad (2)$$

The vertex coordinates are (n=5.1, I=5017) and (n=10.4, I=5553) respectively. Although the intensity difference is relatively small, considering the integer number of n, 10×10 LEDs with f = 25 mm collimation lenses perform the optimal output. 5415 mW surface irradiation on 50×50 mm^2 receiver and 2166 mW electricity output (40% conversion efficiency) are expected as the saturated values.

4. Conclusion

In the LED-OWPT collimation scheme, with 100×100 mm^2 size imaging lens and 50×50 mm^2 solar cell at 1 m transmission distance, 2166 mW electricity output is expected by 10×10 LEDs as the maximum value based on the numerical analysis.

Reference

1) Y. Zhou and T. Miyamoto, "200mW-class LED based optical wireless power transmission for compact IoT," JJAP, 58, SJJC04, 2019.

2) M. Zhao and T. Miyamoto, “Optimization for compact and high output LED-based optical wireless power transmission system.” MDPI-Photonics, 2022; 9 (1), 14.

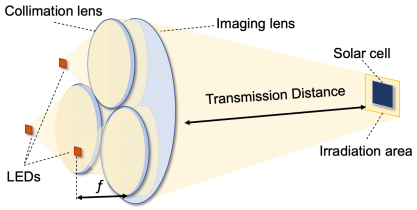

Fig. 1. Collimation scheme of LED-array OWPT.

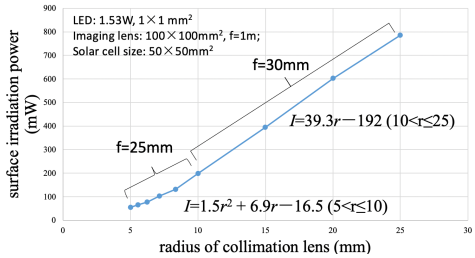

Fig. 2. Surface irradiation power of a set of 1-LED and lens.