

論文 / 著書情報  
Article / Book Information

題目(和文)	IoT向けLEDベースの高性能・自動化光無線給電の開発
Title(English)	LED based high-performance and automatic optical wireless power transmission for IoT
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学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

# 論文要旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	電気電子 電気電子	系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	（工学）
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要旨（英文 800 語程度）

Thesis Summary (approx.800 English Words)

This research aims to optimize the performance and functionality of optical wireless power transmission (OWPT) system, leveraging light-emitting diode (LED) based systems to enhance efficiency, transmission range, adaptability for mobile targets, and functionality in varied environments. Through analysis, design, simulation and practical implementation, we have developed a more robust, adaptable, and efficient OWPT system. The experiment results demonstrate significant advancements for powering Internet of Things (IoT) devices.

## 1. High output, high efficiency and compact LED-OWPT

The research optimizes the OWPT system's efficiency and power output. In the collimation scheme, electrical output, irradiation area, and system dimensions are three essential but interdependent factors, often involving trade-offs. In the LED array system with a small aperture imaging lens, increasing the number of LEDs only improves output power up to a saturation point. By optimizing a high-efficiency LED array OWPT, the system achieves a transmission efficiency of 72% with an output power of 0.8W from a 50×50 mm<sup>2</sup> solar cell at a 1 m transmission distance. Additionally, the system is designed to be compact and lightweight, with integration into a portable device measuring as 407g and 120×114×61 mm<sup>3</sup>. This high-efficiency, compact design makes the LED-OWPT system suitable for powering small IoT devices and other low-power electronics, advancing the feasibility of wireless power networks in a wide range of applications.

## 2. Enhanced transmission range for LED-OWPT

The research addresses the challenge of extending the LED-OWPT system's transmission range, which typically suffers from an expanded irradiation spot area over distance. A novel three-layer lens system including a converging lens, collimation lens, and imaging lens, is first designed with fixed position and focal length, and improves the electrical output at 2 to 3 m by 20%.

Building on this three-layer lens design, an improved combination of a tunable focal length lens and a depth camera allows real-time, adaptive control of the irradiation spot, maintaining precise focus across varying transmission distances. Experimental results validate this design's effectiveness, achieving an 8-fold increase in effective surface irradiation power on a 50×50 mm<sup>2</sup> PV receiver at a

3 m transmission distance, compared to previous systems with similar receiver sizes. This enhancement demonstrates the potential of LED-OWPT systems for high-efficiency wireless power transmission over longer distances.

### 3. Auto-OWPT for mobile targets

We design and demonstration the world's first LED-OWPT system capable of automatically powering small mobile devices. Based on the developed a high-power and high-efficiency optical transmission system, it utilizes a dual-axis beam aiming mechanism, designed to dynamically adjust based on the location of the mobile receiver. The beam, measuring  $\Phi 100$  mm in size, is precisely controlled by a machine vision-based receiver detection system. This ensures accurate beam alignment with the receiver, which is crucial for maintaining efficient power transmission over varying distances. The system employed a prediction algorithm based on Kalman filtering that successfully tracks mobile targets moving at speeds of up to 30 cm/s within a 4 m transmission range. Furthermore, the system's ability to track and supply power to a mobile object was evaluated comprehensively in both simulation and physical experiments. The results demonstrated not only high efficiency but also the potential for integrating this OWPT system into practical IoT applications, such as powering sensor networks, mobile IoT, and other low-energy devices, without requiring constant recharging or wiring.

### 4. Adaptive OWPT for multiple IoT devices in varying lighting conditions

The OWPT system is optimized for multi-target functionality, demonstrating its effectiveness in powering multiple IoT devices at varying distances and under different lighting conditions. The system's adaptive spot size control enables it to deliver a constant power output regardless of the target's distance or PV cell size. This adaptability is crucial for applications where power receivers vary in both dimension and location, such as in multi-sensor networks or distributed IoT systems. Furthermore, this improved OWPT optimized a vision-based detection system, which is meticulously optimized to perform effectively across varying lighting conditions, ensuring reliable operation in both highly illuminated environments (such as during daylight) and low-light or unlit environments (such as at night). the system was designed to operate seamlessly in both illuminated and dark environments, with rapid switching between day and night modes. The swift response time (less than 0.1s) ensured that the system could adapt to changing environmental conditions without disrupting power delivery. This capability not only enhances the system's practicality but also highlights its potential to support the widespread adoption of OWPT in diverse and challenging real-world settings.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note：Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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