論文 / 著書情報
Article / Book Information

題目(和文)	小型IoT向けのLED方式小型光無線給電
Title(English)	LED-based Portable Optical Wireless Power Transmission for Compact IoT
著者(和文)	周 宇環
Author(English)	Zhou Yuhuan
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第11935号, 授与年月日:2021年3月26日, 学位の種別:課程博士, 審査員:宮本 智之,小山 二三夫,植之原 裕行,德田 崇,宮島 晋介,丸山 武男
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第11935号, Conferred date:2021/3/26, Degree Type:Course doctor, Examiner:,,,,,
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

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース: Department of, Graduate major in	電気電子 系 電気電子 コース	申請学位 (専攻分野): Academic Degree Requested	博士 (工学) Doctor of
学生氏名: Student's Name	Yuhuan Zhou	指導教員（主): Academic Supervisor(main)	宮本智之
		指導教員（副): Academic Supervisor(sub)	

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Internet of things (IoT) plays an indispensable role in today's society and shows an explosive growth in many fields, and over 125 billion IoT devices are expected to be connected in next 10 years. However, the power consumption is always a critical issue of IoT devices. Wiring wiring needs laying work, laying space and wires maintenance, while power amount of battery limits devices performance, and also needs replacement or recharging. Considering the extensive increasing of connected IoT devices in the coming decade, it is very critical to study a new type of power supply method which provides the power to IoT devices easily without wiring or even installing batteries. Such novel wireless power supply technology can conveniently provide long-distance power for IoT terminals anytime and anywhere, eliminating the burden of wiring or replacing batteries. Optical wireless power transmission (OWPT) is promising candidate, and its advantages of long transmission distance, good directionality, and portable size are attractive. The OWPT technology is that the energy is propagating as the light waves and then be converted into electrical power on the receiving side. OWPT has features such as remote power supply, no electromagnetic noise interference, simple configuration, small size and high efficiency. At current stage, the research of OWPT technology is still insufficient. Moreover, the existed researches of OWPT are almost applying laser as light source, while the possible eye-hazard is a critical drawback of laser. In this research, the systematic research and analysis of the portable light emitting diode (LED) based OWPT system for the compact IoT terminals is presented.

The existing typical light source types is investigated, and analyzed whether they have the necessary characteristics for OWPT applications. As a result, LED is proved to be an excellent light source of OWPT system. From the perspectives of intensity output, wavelength, divergence angle, grid electrode pattern, package design, and uniformity of distribution, various parameters and designs of the LED are analyzed, and the most ideal characteristics of the LED as the light source of the OWPT system are discussed. Regarding the optical energy receiving devices, the single-junction GaAs solar cell has merits of high efficiency, flexibility and light weight, which is the most suitable choice for OWPT system at current stage. The plano-convex lens, aspheric lens and Fresnel lens are the proper optical components for OWPT system. The AR coating is necessary of the lenses to reduce reflection loss. The double-lens optical system can simultaneously achieve high efficiency, small irradiation spot size, and compact system dimension by adjusting various parameters, which makes it to be the most suitable choice for OWPT system. By establishing the mathematical model of the optical system, the ideal value range of the parameters of the optical system for LED-based OWPT system is provided. Confirming by simulation and experiment results, single-LED OWPT system can provide up to 200 mW output power with around 48% light utilization efficiency when the transmission distance is smaller than 1 m. The dimension of the entire system is extremely small (4cm × 3cm × 3cm), and the average irradiation size is around 2.3 cm × 2.3 cm. When the transmission distance increased to 1m, the system dimension increased a little, and efficiency increased to 52%. The output power from solar cell is 224 mW. For the 2m – 3m distance, the average irradiation size and system dimension increased. The irradiance of single-LED OWPT system roughly equals to 500-3000x ambient light. The nearby -300mm to +100mm can be seen as the tolerant distance, and the maximum tilt angle is 45 degrees.

In order to break the intensity limitation of single-LED light source, the LED-array OWPT system that applying multiple LEDs and forming a LED-array as light source is researched. A novel array method that can realize small size and high compact level

is proposed in this research. Particularly, detailed design and experimental characteristic verification were carried out for two configurations, which are simple configuration using one collimated lens (configuration A) and a highly efficient configuration using two collimated lenses (configuration B). For the experimental configuration, the configurations with two LEDs and three LEDs were prepared, and a lens configuration for irradiation at a distance of 1 m was designed. As for the lens, the lens holders made by a 3D printer were prepared. The efficiency of the lens system was 27% and 37% for two configurations in the experiment, respectively. Based on these experiments, a power output of 268 mW was obtained with the two LED configurations and 380 mW with the three LED configurations. In particular, the latter achieved the maximum power output through this research and became an example of the maximum output in the world. Moreover, the detailed analysis and instruction of solution of alignment deviation of LED-array OWPT system is discussed.

Through this research, the LED-based OWPT system is constructed and demonstrated as a highly efficient power supply method for small IoT terminals.