# OWPT

## Monday, 19 April

**[OWPT-1] 13:45-15:00**
**OWPT Session 1**
Chairs: M. Matsuura
*UEC*
T. Maruyama
*Kanazawa Univ.*

**OWPT-Opening 13:45**

**Opening Remarks**

**OWPT-1-01 14:00** *Invited*

**Novel Low-cost Fabrication Method (H-VPE) of III-V Photovoltaic Devices**
Yasushi Shoji
*National Institute of Advanced Industrial Science and Technology (AIST)*
Hydride vapor phase epitaxy (HVPE) has received attention as a low-cost fabrication method for III-V solar cells, an alternative to MOVPE. The low epitaxial cost can be realized because of the use of group-III precursors generated through high-efficiency reactions involving less expensive pure metals and HCl gas. In this presentation, we report the performances of III-V solar cells grown by HVPE.

**OWPT-1-02 14:30**

**Responses of Typical Photovoltaic Cell to Dual Laser Irradiation**
Rui-Ting Chang[1,2], Cong Liu[1,2], Chen-Guang Huang[1,2], Chen-Wu Wu[1]
*[1]Institute of Mechanics, Chinese Academy of Sciences, [2]School of Engineering Science, University of Chinese Academy of Sciences*
The responses of typical photovoltaic (PV) cell to dual laser irradiation were investigated for laser power beaming. The limit tests were conducted on the PV cells illuminated simultaneously by continuous wave laser and multi-pulse laser. The failure patterns of the PV cells were characterized by optical microscope and the maximum useful power density were obtained for various combinations of the dual lasers.

**OWPT-1-03 14:45**

**Tapered Redirection Waveguide in Two Dimensionally connected PhotoRecepto-Conversion Scheme (2DPRCS)**
Akira Ishibashi, Tsuyoshi Kasai, Nobuo Sawamura
*Hokkaido University*
Demonstrated is a tapered-waveguide-based example of Two-Dimensionally connected PhotoRecepto-Conversion Scheme (2DPRCS), in which photo-harvesting/photoreception is spatially decoupled from, but two-dimensionally connected to, photoelectric conversion by thin waveguide. The 2DPRCS would serve as a key technology not only for high efficiency solar- cell systems but also for robust optical wireless power transmission or laser power beaming.

**[OWPT-2] 15:30-17:00**
**OWPT Session 2**
Chairs: T. Miyamoto
*Tokyo Tech*
M. Matsuura
*UEC*

**OWPT-2-01 15:30** *Invited*

**Free-space Laser Communication Systems**
Alexis Kudryashov
*Institute of Geosphere Dynamics RAS*
This paper presents the advantages and disadvantages of each of these approaches. The results obtained with the use of these systems are presented. Recommendation for achieving higher performance are presented.

**OWPT-2-02 16:00**

**Free Space Optical Link for Simultaneous Power and 1 Gb/s Data Transmission**
John Fakidis[1], Henning Helmers[2], Harald Haas[1]
*[1]University of Strathclyde, Light Fidelity Research and Development Centre, [2]Fraunhofer Institute for Solar Energy Systems ISE*
We study the trade-off between power and data transfer for a two-meter wireless gallium-arsenide laser and photovoltaic link. The use of orthogonal frequency-division multiplexing with adaptive bit and power loading results in a peak data rate of 1041 Mb/s. The photovoltaic receiver is shown to offer simultaneous power harvesting with 41.6% efficiency under the irradiance of 0.3 W/cm$^2$ and a data rate of 784 Mb/s.

**OWPT-2-03 16:15**

**Charging Requirements and Verification Experiments for the Introduction of Optical Wireless Power-transmission Systems for Smart Devices**
Naomi Uchiyama, Hirohito Yamada
*Tohoku University*
As an example, charging requirements of a portable media player were shown, and a verification experiment was carried out. We also investigated the wavelength of the light source. It was found that it can be charged by storing electricity in an electric double layer capacitor and the power from a solar cell was higher when using near-infrared light than when using visible light.

**OWPT-2-04 16:30**

**Optimization of Dimension and Output Power of the Portable LED-based OWPT System for Compact IoT**
Yuhuan Zhou, Mingzhi Zhao, Tomoyuki Miyamoto
*FIRST, Tokyo Institute of Technology*
Optical wireless power transmission technology, which has advantages like long distance transmission and good directionality, is still at the initial stage. Considering the relatively loose regulation and other merits, researching on LED-based OWPT system is imperative. In this research, LED-based OWPT system has been optimized in two directions, the dimension and output power.

**OWPT-2-05 16:45** *Plenary*

**The Road Towards Zero-Energy Gigabit Wireless Transceivers**
Harald Haas
*University of Strathclyde*
We demonstrate that it is possible to simultaneously transfer power and receive high-speed digital data using the same photovoltaic (PV) cell. Different PV technologies are reviewed in this context and potential use cases are highlighted. The proposed dual use of PV cells has the potential to play a major role towards net-zero wireless networks, while enabling the continuous growth in the number of connected devices, data rate performance and coverage to mitigate the digital divide.

## Tuesday, 20 April

**[OWPT-3] 9:00-10:30**
**OWPT Session 3**
Chairs: S. Uchida
*Chiba Inst. Tech.*
T. Takeuchi
*Meijo Univ.*

**OWPT-3-01 9:00** *Invited*

**Power and Spectral Range Options for Optical Power Converter Products**
Simon Fafard
*Broadcom*
High-performance Optical Power Converters (OPCs) enable more applications at new wavelengths and higher output powers. Broadcom's patented VEHSA multi-junction OPCs exhibit high-efficiency conversion at manageable external loads. This paper reviews how we extended the power outputs from 600mW to 2W and higher, and how the spectral range options extend from the 800-830nm range to other key laser diode wavelengths such as 980nm and 1500nm.

**OWPT-3-02 9:30** *Invited*

**GaN-based Solar Cells and their Application to Optical Wireless Power Transmission System**
Makoto Miyoshi
*Nagoya Institute of Technology*
To consider the application of GaN-based solar cells to the optical wireless power transmission system, their photovoltaic performance was evaluated under monochromatic light irradiations. The results predicted that their power conversion efficiency can reach to 60% or higher with a high-power light irradiation, an anti-reflection coating and the suppression of carrier recombination processes.

**OWPT-3-03 10:00**

**Fabrication and Characterization of GaP Based Photovoltaic Devices for Short Wavelength Range Optical Wireless Power Transmission**
Masakazu Arai, Akira Kushiyama, Koji Maeda
*University of Miyazaki*
We fabricated two types of GaP photovoltaic devices with different electrode shape and passivation and evaluated the characteristics. We successfully confirmed high open circuit voltage as high as 1.74 V under blue laser irradiation.

**OWPT-3-04 10:15**

**Non-Uniform Illumination Impacts on O-Band InGaAsP and Metamorphic GaInAs Photonic Power Converters**
Meghan Nicole Beattie[1], Henning Helmers[2], Christopher E. Valdivia[1], David Lackner[2], Oliver Höhn[2], Karin Hinzer[1]
*[1]SUNLAB, Centre for Research in Photonics, University of Ottawa, [2]Fraunhofer Institute for Solar Energy Systems ISE*
Single-junction photonic power converters designed for operation in the telecommunications O-band are measured under 1319-nm laser illumination with a range of beam diameters. Device performance is found to improve as the illumination becomes more uniform. Two absorber materials are evaluated in this study, InGaAsP lattice-matched to InP and metamorphic GaInAs on lattice-mismatched GaAs with maximum efficiencies of nearly 53% and 49% respectively.

**[OWPT-4] 15:30-17:00**
**OWPT Session 4**
Chairs: A. Ishibashi
*Hokkaido Univ.*
T. Yamaguchi
*Kogakuin Univ.*

**OWPT-4-01 15:30** *Invited*

**Industrial Advancement of III/V Metamorphic Technology for High Efficiency Infrared Laser Power Converters**
Victor Khorenko, Gregor Keller, Thorsten Wierzkowski
*AZUR SPACE Solar Power GmbH*
III/V semiconductors structures enable optical power converters for the infrared spectral range 800-1550 nm. For wavelengths <860 nm, GaAs is the material of choice whereas larger wavelengths need metamorphic InGaAs. The use of cost-efficient Ge substrates instead of GaAs or InP is the key for making LPCs affordable for volume applications. We successfully demonstrate this approach on 975 nm LPCs with an efficiency of 60% comparable to AZUR's 810-830 nm LPCs.

**OWPT-4-02 16:00**

**Design of AlGaAs Laser Power Converters for the First Transmission Window**
Marina Delgado Romero[1,2], Iván García Vara[1,2], Carlos Algora Del Valle[1,2]
*[1]Technical University of Madrid, [2]Instituto de Energía Solar*
We analyze the potential of increasing the bandgap using AlGaAs to minimize the energy difference between 808 nm wavelength photons and the GaAs bandgap energy. The optimum aluminum content is 7% reaching a maximum ideal efficiency of 77% at 50 W/cm$^2$.

**OWPT-4-03 16:15**

**Target Recognition for Outdoor Optical Wireless Power Transmission Using Solar-Blind Deep UV LED marker**
Shota Sato, Sicheng Lu, Alexander William Setiawan Putra, Takeo Maruyama
*The University of Kanazawa*
In optical wireless power transmission (OWPT) using camera to recognize the target. Target marker for recognition is one of the important elements. In this research, solar-blind deep UV LED is proposed as the target marker for outdoor OWPT system and the operational distance is calculated to be around 100 m. The Result means that it can potentially be used for long distance OWPT system.

**OWPT-4-04 16:30** *Invited*

**Optical Wireless Power at Eye-safe Wavelengths: Challenges and Opportunities**
Stephen J Sweeney, Timothy D Eales, Scott D Jarvis, Jayanta Mukherjee
*University of Surrey*
The potential of optical wireless power in a multitude of applications has led to a strong growth in the development of technologies to support it. However, it has also led to a strong need to develop eye-safe approaches with high efficiency. In this paper we describe some of the technical challenges associated with developing optical wireless power technologies at eye-safe wavelengths.

# OWPT

## Wednesday, 21 April

**[OWPT-5] 9:00-10:30**
**OWPT Session 5**
Chairs: H. Yamada
*Tohoku Univ.*
T. Tayagaki
*AIST*

**OWPT-5-01 9:00** ***Special***

**Augmenting the Performance of Microwave Wireless Power Networks by Incorporating Metasurface-Based Mesh Nodes**
Chris Davlantes
*Reach Labs*

Conventional microwave wireless power networks struggle to serve many devices at long distances simultaneously while maintaining a high power transfer efficiency to every node in the network. By adopting a mesh architecture enabled by adaptive metasurfaces, this work overcomes the limitations of prior WPT networks and provides a compelling avenue for further research. Theoretical calculations and simulations are presented.

**OWPT-5-02 9:30** ***Invited***

**Power Beaming and Space Applications**
Paul Jaffe
*Naval Research Laboratory*

Power beaming technology has made significant recent strides in consumer, industrial, and defense sectors. Though proposed for many decades for various space applications, few significant demonstrations of power beaming technology have taken place in space. The scale of envisioned space power beaming applications ranges from those over short distances within spacecraft, medium distances between spacecraft or platforms on celestial bodies, long distances between space and celestial bodies, and very long distances for beamed energy propulsion. Each is explored herein.

**OWPT-5-03 10:00** ***Special***

**In-wheel Motor EV and Dynamic Charging using Wireless Power Transfer**
Hiroshi Fujimoto, Osamu Shimizu
*The University of Tokyo*

In our laboratory, a second-generation wireless in-wheel motor (W-IWM2) having the capability of dynamic wireless power transfer (D-WPT) on its wheel side has been developed. The D-WPT technology can drastically extend the driving range of electric vehicles. The W-IWM3 is also developed to reduce the size and to increase the power. This talk introduces the development of the W-IWM2 and W-IWM3 with the experimental results.

**[OWPT-6] 15:30-17:00**
**OWPT Session 6**
Chairs: K. Ikeda
*CRIEPI*
M. Kohtoku
*Furukawa Electric*

**OWPT-6-01 15:30** ***Invited***

**New Frontiers in III-V Based Photonic Power Converters**
Henning Helmers
*Fraunhofer Institute for Solar Energy Systems ISE*

This paper gives an overview on research and development conducted at Fraunhofer ISE regarding III-V based photovoltaic cells used as photonic power converters (PPC).

**OWPT-6-02 16:00**

**Current Mismatch and Luminescence Coupling in Three-junction Photonic Power Converters with and without Back Reflector**
Esther Lopez[1,2], Oliver Höhn[1], Meike Schauerte[1], David Lackner[1], Michael Schachtner[1], S. Kasimir Reichmuth[1], Henning Helmers[1]
*[1]Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, Germany, [2]Instituto de Energía Solar – Universidad Politécnica de Madrid, Madrid, Spain*

In this work the coupling process efficiency in three-junction photonic power converters based on GaAs/AlGaAs rear-heterojunction subcells is experimentally quantified. A coupling process efficiency of 32 % ± 9 % from top and middle subcells to the limiting bottom subcell is found. Furthermore, it is evidenced how a back reflector affects luminescence coupling of these devices by re-directing photons that are emitted by the bottom subcell towards the upper subcells.

**OWPT-6-03 16:15**

**Power-over-Fiber Smart Sensor Fully-Connected in a Hybrid Fiber/ Power Distribution Cable**
Fabio Renato Bassan[1], Joao Batista Rosolem[1], Claudio Floridia[1], Bruno Nogueira Aires[1], Rodrigo Peres[1], Javier Francisco Aprea[2], Carlos Alexandre Meireles do Nascimento[3], Fabiano Fruett[4]
*[1]CPQD - Research and Development Center in Telecommunications, [2]IMS Power Quality, [3]CEMIG, [4]Unicamp*

This work presents the results of the field tests of an innovative utilization concept for power-over-fiber (PoF) current and voltage sensor. Using optical, optoelectronic, and electrical technology the smart sensor was tested with powering, metering, and data transmission functions performed simultaneously in a 13.8 kV hybrid aerial fiber/power distribution cable of experimental field installation.

**OWPT-6-04 16:30** ***Invited***

**High Power Single Mode Expanded Beam Fiber Optic Connectors for Power over Fiber Applications**
Andrea Tonini, Alfio Cerini, Victor Coggi
*Diamond SA*

Technologies of high-power single-mode fiber connectors for Power Over Fiber applications are explored.

## Thursday, 22 April

**[OWPT-7] 9:00-10:30**
**OWPT Session 7**
Chairs: T. Motohiro
*Nagoya Univ.*
N. Mori
*Yamashita Denso*

**OWPT-7-01 9:00** ***Invited***

**Improving Performance Metrics for Power Beaming**
Tom Nugent
*PowerLight Technologies*

System engineering-focused metrics for laser power beaming enables comparisons as systems improve and evolve to field-ready products. This paper defines metrics on efficiency, power density and specific power for laser receivers, and foreign object parameters for active safety sensing, and presents data for each of them. Requirements for use-cases and areas for improvement are described.

**OWPT-7-02 9:30** ***Invited***

**Longitudinal Current Crowding in High Power Diode Lasers**
Jenna Campbell, Michelle Labrecque, Elliot Burke, Kevin McClune, Daniel Renner, Paul Leisher
*Freedom Photonics LLC*

Longitudinal current crowding (LCC) is a power saturation effect wherein current density becomes unevenly distributed along the cavity length of high power diode lasers resulting in efficiency loss. In this work, we present theoretical modelling and experimental results characterizing the LCC effect, discuss strategies and show results on its mitigation, and report on the role of temperature nonuniformity on LCC. Mitigation of LCC is believed to be a key factor in future power and brightness scaling of diode lasers.

**OWPT-7-03 10:00**

**Improvement of Power Conversion Efficiency of VCSELs by 3D Resistance and Light Absorption Control using Proton Implantation for Use in OWPT**
Tomoyuki Miyamoto, Hayato Sakamoto
*Tokyo Institute of Technology*

Improving the power conversion efficiency (PCE) of VCSELs by 3D control of the carrier concentration, which is the main mechanism of electrical resistance and light absorption, was investigated using proton implantation technique just above the active region. The fabricated VCSELs showed an improvement in PCE of about 1.1 times without a significant deterioration of other characteristics. This technique will be useful to improve the efficiency of OWPT.

**OWPT-7-04 10:15**

**Conversion Efficiency Measurements for Optical Devices Based on Calorimetric Method**
Terubumi Saito, Takaki Chiba, Momo Karita, Shigeki Tsuchiya
*Tohoku Institute of Technology*

Conversion efficiencies of optical devices, both sources and receivers have been measured based on a calorimetric method. To automatize the operation, a negative feedback control circuit to maintain constant temperature by adjusting the electrical power to the heater has been developed and proved to work successfully.

**[OWPT-8] 11:00-12:00**
**OWPT Session 8**
Chairs: M. Arai
*Univ. of Miyazaki*
W. Kubo
*TUAT*

**OWPT-8-01 11:00**

**Beam Control Stabilization of OWPT System with Recognition Module and its Application to Multiple Light Source OWPT System**
Jing Tang, Koji Ueda, Tomoyuki Miyamoto
*Tokyo Institute of Technology*

Multiple light source systems are attractive to OWPT because of high efficient transmission capabilities. In addition, high functionalities such as selection of efficient transmission paths can be prepared by multiple light sources. In this research, we constructed an OWPT system with improved stability in both recognition and beam control, and demonstrated a system with real time switching.

**OWPT-8-02 11:15**

**Moving Target Position Prediction for Optical Wireless Power Transmission System using Machine Learning**
Sicheng Lu, Alexander William Setiawan Putra, Kosuke Imamura, Takeo Maruyama
*Kanazawa University*

In OWPT system using camera for target recognition, prediction of the next position of target which is captured by the camera is important to ensure that laser can be steered to follow moving target. Machine learning is implemented to predict next position of target on next captured frame. Using machine learning method, 75% improvement for error position has been achieved in simulation compared with linear prediction method.

**OWPT-8-03 11:30**

**Safety System of Optical Wireless Power Transmission by Suppressing Light Beam Irradiation to Human using Camera**
MA XiaoJie, Tomoyuki Miyamoto
*Tokyo Institute of Technology*

OWPT systems has some safety problems, such as unexpected, unnecessary, light irradiation to human and other objects. In this report, a moving object detection scheme based on OpenCV and python is constructed as the initial safety system of the OWPT system. The movement of multiple objects can be detected at the same time. The required operation characteristics such as response time and limitations of detection are also discussed.

**OWPT-Closing 11:45**

**Closing Remarks**

# OWPT

## Poster (Live Poster: Tue. 20 and Wed. 21 April, 11:00-12:00)

**[OWPT-P]**
**Poster Session**

### OWPT-P-01

**Numerical Analysis of Multi-particle Mie Scattering Characteristics for Improvement of Solar Cell Appearance in OWPT System**

Yu Liu, Tomoyuki Miyamoto
*Tokyo Institute of Technology*

Color filters and frosted glass can change the black surface characteristics of the solar cell of OWPT to impressive appearance. In order to improve the efficiency of OWPT even under the light scattering, we proposed application of Mie scattering which depended on incident wavelength to control the appearance of solar cell side in OWPT system. We analyzed scattering characteristics of single particle and multi particle Mie scattering.

### OWPT-P-02

**Simultaneous Fiber Transmission of Control and Mobile Communication Signals in Power-over-Fiber Drones for Airborne Base Stations**

Taiki Kobatake, Natsuki Shindo, Motoharu Matsuura
*The University of Electro-Communications*

In this work, we present a power-over-fiber drone design for air borne base stations, and experimentally demonstrate the simultaneous transmission of control and mobile communication signals using an optical fiber for air borne station applications using power-over-fiber drones.

### OWPT-P-03

**Evaluation of Wavelength Dependence in Feed light Transmission Loss of Double-Clad Fiber for Power-over-Fiber Applications**

Suguru Fujita, Tadanobu Higuchi, Hikaru Mamiya, Motoharu Matsuura
*The University of Electro-Communications*

We evaluate the feed light transmission loss of double-clad fibers for power-over-fiber applications. We also compare the wavelength dependence of the double-clad fibers. In this evaluation, we show that the wavelength dependence of the transmission loss of double-clad fibers is quite different from those of conventional optical fibers, and it depends on the structures of double-clad fibers and other factors.

### OWPT-P-04

**For Fabrication of Waveguides based on Polydimethylsiloxane for Multistriped Orthogonal Photon-Photocarrier Propagation Solar Cell (MOP3SC) System**

Xingbai Hong, Jiaxing Yu, Nobuo Sawamura, Akira Ishibashi
*Hokkaido University*

A solar cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. We propose a two-dimensional photoreceptor-conversion (2DPRC) scheme in which the photoreception part is spatially decoupled from, but is two-dimensionally connected to the photo-conversion part by a redirection waveguide (RWG). We expect the Polydimethylsiloxane may implement this system.

### OWPT-P-05

**Optical Wireless Communication and Power Transmission with Long-distance Propagation in Atmospheric Turbulence**

Konami Yada, Yui Takagi, Kayo Ogawa
*Japan Women's University*

In long-distance propagation, scintillation and beam wonder occur due to the influence of atmospheric fluctuations, so there is concern about power loss. Therefore, in this research, we proposed the LG mode multiplexing method that applies a compensation filter and LG beams in order to realize multiplex communication that is resistant to turbulence while ensuring reception intensity.

### OWPT-P-06

**Effect of Uniform Laser Irradiation on the Efficiency of GaAs Solar Cells for Optical Wireless Power Transmission**

Kazuki Kurooka, Shinya Honda, Yuki Komuro, Ryouta Warigaya, Shiro Uchida
*Chiba Institute of Technology*

We investigated the uniformity dependence of laser irradiation intensity on the conversion efficiency of solar cells. It was found that the optimum design of the electrode area changes between uniform irradiation and non-uniform irradiation.

### OWPT-P-07

**Investigation of Laser Wireless Power Transmission using Infrared InGaAsP/InGaAs 2-junction Solar Cell**

Nozomi Matsuoka[1], Tomoyuki Kato[1], Yuki Komuro[1], Li Xuefei[2], Shulong Lu[2], Shiro Uchida[1]
*[1]Chiba Institute of Technoligy, [2]Suzhou Institute of Nano-Tech and Nano-Bionics*

We irradiated an infrared InGaAsP/InGaAs 2-junction solar cell with two infrared lasers simultaneously. The photoelectric conversion efficiency of 23.8% was achieved, which was as good as that of the single-junction InGaAs solar cell.

### OWPT-P-08

**Energy Conversion Efficiency under Different Input Electrical Power Conditions in Visible LED based OWPT System**

Haruka Yokoyama[1], Naoki Yosuke[1], Tomohiro Yamaguchi[1], Tomoyuki Miyamoto[2], Takeyoshi Onuma[1], Tohru Honda[1]
*[1]Kogakuin University, [2]Tokyo Institute of Technology*

Visible-LED-based OWPT system was constructed with visible LEDs and Si solar cell. The total energy conversion efficiency in the OWPT system was investigated as a function of input electrical power for LEDs. It was found that the total energy conversion efficiency decreased with the increase in the input electrical power of LED. The tendency was well corelated with the wall plug efficiency of LED.

### OWPT-P-09

**Laser Wireless Power Transmission in Seawater Environment**

Shunki Hayashi, Yuma Aoki, Yuki Komuro, Tomoya Sudo, Tomoyuki Kato, WONG Yiu Leumg, Shiro Uchida
*Chiba Institute of Technology*

Laser wireless power transmission in seawater was tested using blue, green, orange-red lasers and a GaInP solar cell. Green laser had the highest 60.3% optical transmittance and 21.6% system efficiency with 30 cm seawater penetration.

### OWPT-P-10

**Visible Laser Wireless Power Transmission Using a Beam Expander**

Yiu Leung WONG, Taaiga Shibuya, Ryouta Warigaya, Yuki Komuro, Shunki Hayashi, Tomota Sudou, Tomoyuki Katou, Shiro Uchida
*Chiba Institute of Technology*

The long-distance optical wireless power-transmission was examined using a red-orange 609nm solid-state laser and a GaInP solar cell. We found that the incorporation of a beam expander could improve the beam reaching rates over 80m.

### OWPT-P-11

**Experimental Investigation of Electrode Design for Photovoltaic device for Laser Receiving Photovoltaic Device**

Akira Kushiyama, Masakazu Arai
*University of Miyazaki*

For high conversion efficiency of laser light receiving device, we experimentally investigated the electrode size and pitch dependence of photovoltaic characteristics of GaAs based device. Clear tendency against shadowing loss was observed under laser irradiation.