Systems and Control Theory as Fundamental Technologies of the IoT Era

Internet of Things (**IoT**) is a concept which means that anything can be connected via the Internet. In an IoT society, a large amount of information is collected from physical space into cyberspace. The collected information is then analyzed to create added value. Finally, these results are utilized in physical space to provide smarter social services, for example, smart grids, smart cities and intelligent transport systems.

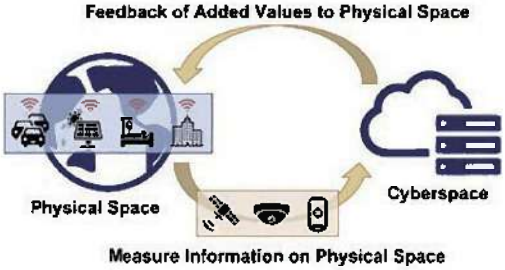
Systems and control theory can provide us with **methods for collecting, analyzing and utilizing information in an IoT society**. However, there are many technical issues regarding controlling **IoT** systems, as follows:

(1) **IoT** systems are large and complex.

(2) There are many constraints on communication networks, for example, communication delays, communication volume and privacy.

(3) There are many requirements for IoT systems, for example, automation, optimization and energy conservation.

In our work, we aim to create theoretical frameworks that will solve the above issues for next-generation societies.



Measure Information on Physical Space and Create Added Value in Cyberspace, then Feed Back to Physical Space

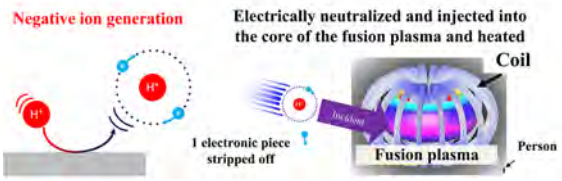
About Researcher

ADACHI Ryosuke, Ph.D.

Ph.D., 2019, Hokkaido University

Fundamental Research on and Prospects of Hydrogen Negative Ion Production and Its Applications

Plasma is one of the four fundamental states of matter, alongside solid, liquid, and gas. It is often referred to as the "fourth state of matter." Plasma is composed of charged particles, including ions and electrons. In a plasma, some atoms or molecules are stripped of their electrons, resulting in a mixture of positively charged ions and free electrons. Plasmas are commonly found in environments with a large amount of energy, such as stars (like our sun), lightning, and certain types of flames. An ion is an atom or molecule that has gained or lost electrons, resulting in a net electrical charge. When an atom gains one or more electrons, it becomes negatively charged and is referred to as a **negative ion** under certain conditions. One common method of injecting negative ions into a plasma is through neutral beam injection. Negative ions are accelerated to high energies and then neutralized before entering a plasma. **Negative ions neutralize more efficiently** than positive ions, making them an appealing choice for improving energy supplies in fusion devices. We focus on generating negative ions, specifically hydrogen negative ions. **Understanding their generation process** within a hydrogen plasma is directly aligned with the goals of advancing plasma heating and fusion applications.



Overview of Negative Ion Generation and Its Applications in Fusion Reactors

About Researcher

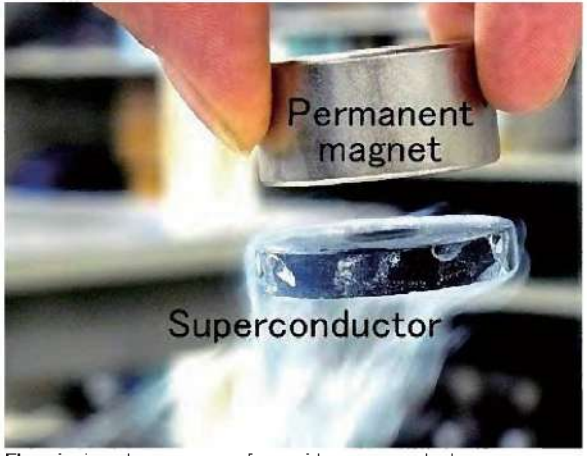
FENG Shuangyuan, Ph.D.

Ph.D., 2021, Nagoya University

WEB ≫ http://www.eee.yamaguchi-u.ac.jp/lab/1273/

Research into the Application of Superconductivity to Energy Technologies

Superconductivity is a phenomenon in which electrical resistance is reduced to zero when certain materials are cooled with very low-temperature liquid helium or liquid nitrogen. Since its discovery approximately a century ago, superconductivity has been observed in many metals, alloys, and oxides. Owing to its advantage of **zero electrical resistance**, there is the expectation that superconductivity will be applied in developing electrical energy technologies. Examples of fourth-year undergraduate research and postgraduate research on superconductivity include the study of **superconducting coil** designs that take advantage of the characteristics of superconducting oxide materials; fabrication of **superconducting wires** using MgB_2; manipulation of microscopic thin superconducting films; and research into levitation devices using superconducting bulk magnets. As a technology of the 21st century, superconductivity is being used in the research and development of magnetic levitation trains, power transmission lines, and superconducting magnetic power storage systems.



Flux-pinning phenomenon of an oxide superconductor

About Researcher

HARADA Naoyuki, Ph.D.

Ph.D., 1991, Kyushu University

Development of a High-Performance Wireless Power Transfer System

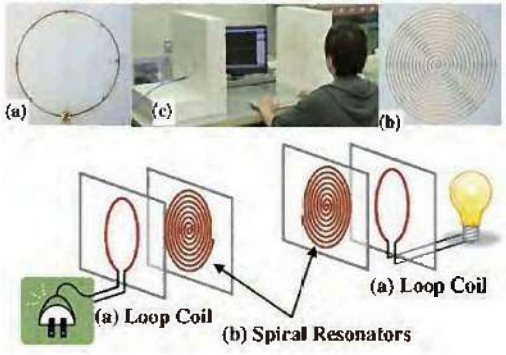
A **Wireless Power Transfer (WPT) System** would be a promising candidate as a power supplier for electrically moving objects without batteries in the near future, such as electric vehicles and capsule endoscopes for medically inspecting the human body. Our current research interest is the development of an **easy-handling** and **high-efficiency** WPT system which can be used where lossy materials exist along a power transmission path. Specifically, we are conducting the following research;

1) Development of resonators which forming the electromagnetic field distributions with the desired shape.

2) Establishment of a method to **easily recover** the power transmission efficiency declined by a positioning misalignment of system elements.

3) Investigation of a suitable power transfer setup that can **maintain efficient power transmission** even in the presence of water or dielectric materials with dielectric or conductive losses in the transmission path. We also aim to develop a method to avoid the decay of electromagnetic energy in WPT systems by **water with high ionic contents**, such as seawater.

In addition to the above theme, we have also analyzed the modes in anisotropic single-negative waveguide composed of the metamaterials.



Wireless Power Transfer System
(a) Loop Coil (I/O Ports), (b) Resonators, (c) System Overview

About Researcher

HOTTA Masashi, Dr.Eng.

Dr Eng., 1995, Osaka Prefectural University

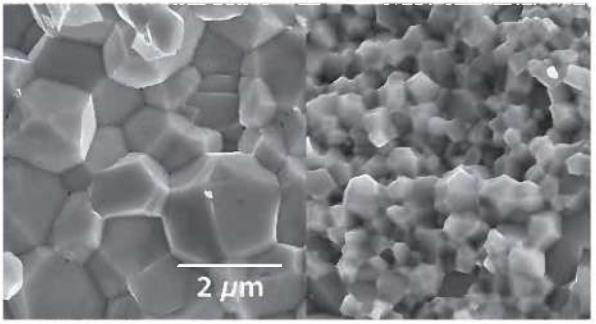
Development of Thermoelectric Materials

My research interest is in thermoelectric technology. Since this technology can make electricity from waste heat, it is useful for energy-saving. I have been developing thermoelectric materials with high efficiency in terms of their crystal and band structures, which govern electron and phonon transports. The following are my areas of research:

1) **Microstructured** or **nanostructured** materials such as sintered alloys that have a fine grain size and layered compounds. Such structures are expected to increase thermoelectric properties.

2) Semiconducting inorganic compounds such as **clathrates** and silicides. Unlike conventional materials such as Bi_2Te_3 and PbTe, type-II clathrates $(K,Ba)_{24}(Ga,Sn)_{136}$ do not contain toxic elements but have just as high efficiency.

3) **Thermoelectric conversion modules** that use materials being developed.



Micro- and nano-structured alloys with fine grain sizes. Grain boundaries scatter phonons effectively, leading to an enhancement of thermoelectric properties

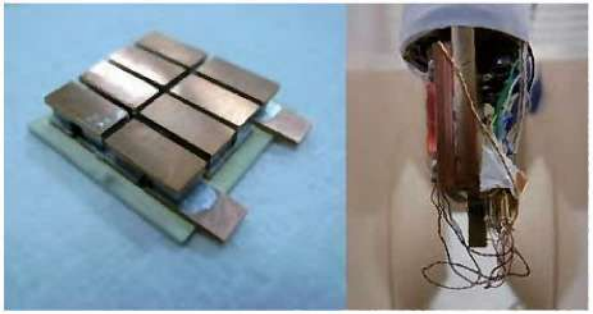
About Researcher

KISHIMOTO Kengo, Dr.Eng.

Dr.Eng., 2003, Yamaguchi University

Thermoelectric Technology Using the Ordinary Seebeck Effect and New Spin-Related Effects

In our study of **thermoelectric (TE) technology**, our research has ranged from TE materials to the fabrication of TE modules, which enables the direct conversion of thermal energy to electrical energy. This technology has been interesting from the viewpoint of energy recycling and harvesting. Our research into TE materials has mainly focused on **clathrate compounds**, which are formed by the inclusion of ions into cavities in the crystal lattices. We have developed TE modules by using clathrate sintered materials to achieve higher energy conversion efficiency. We are also researching a new TE technologies based on the **spin Seebeck effect** and the **anomalous Nernst effect**, to which much attention has been recently given as a new field in spin electronics. These effects are attributed to the nature of conduction electron spins. We have researched these effects for magnetic insulator yttrium iron garnet (YIG) films prepared by metal-organic decomposition (MOD) and magnetic semiconductor $Ge_{1-x}Mn_xTe$ films prepared by molecular beam epitaxy (MBE). In order to study these new effects, we developed a new measurement system.



TE module and sample holder for new measurement system

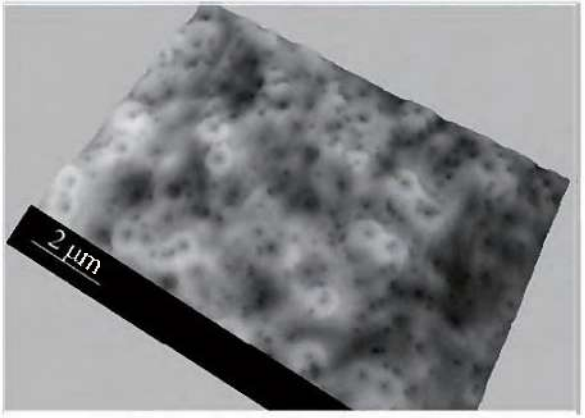
About Researcher

KOYANAGI Tsuyoshi, Ph.D.

Ph.D., 1990, Kyoto University

Nanoscopic Spectroscopy of Semiconductor Alloys for High Efficiency Light Emitters

My research has focused on semiconductor optics, especially the **nanoscopic spatial distribution of luminescence from semiconductor alloys** and its contribution to emission processes. Semiconductor alloys, which are used for active layers of optoelectronic devices, are useful due to the controllability of their material properties by changing the alloy compositions. For example, in a AlGaInN material system, it is possible to control band gap energy from the ultraviolet to the infrared spectral region. However, semiconductor alloys have complex characteristics associated with their **inhomogeneity**, including defects and compositional fluctuations. Spectroscopic information from the nano-sized areas, which is an issue important to understanding inhomogeneous semiconductor alloys, can be measured by using fine-focused electron beams or near-field light through a nano-sized aperture on the tip of an optical fiber used as the excitation source. The relation between the compositional fluctuation, carrier diffusion and localization, and the defects inhibiting radiative recombination has been revealed from the map of nanoscopic spectroscopy, leading to **improved quantum efficiency** for light emitters.



Direct observation of nanoscopic emission distribution of InGaN semiconductor alloy by Cathodoluminescence mapping

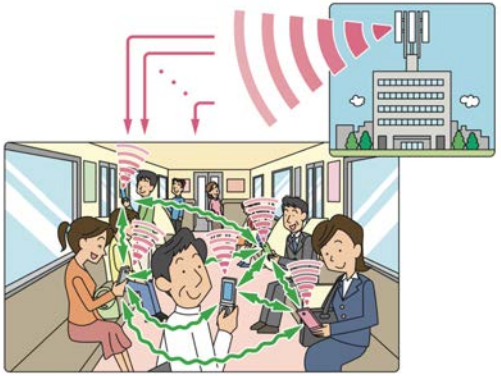
About Researcher

KURAI Satoshi, Ph.D.

Ph.D., 1998, University of Tokushima

Mobile Terminal Collaboration for Future Wireless Communications

Wireless communication services such as smartphones and wireless LAN (Wi-Fi) have become indispensable in our daily lives. We feel as if we cannot do anything without a wireless connection to the Internet. Today's smartphones and wireless LANs communicate with base stations and access points on a one-to-one basis. This one-to-one communication has been taken for granted until now, but in this form, other smartphones in the vicinity become **competitors**, and the transmission speed decreases in proportion to the number of competitors. However, a relatively recent theory has shown that the **transmission speed** can be increased in proportion to the number of smartphones in the vicinity when they cooperate. By taking advantage of this feature, it is possible to realize wireless communications that do not degrade in transmission speed even if the number of smartphone users increases. Our goal is to realize such a **wireless system that cooperates with other smartphones**, which used to be competitors, to increase the overall transmission speed.



Mobile terminal collaboration to enhance the transmission performance.

About Researcher

MURATA Hidekazu, Dr. Eng.

M.E., 1993, Kyoto University

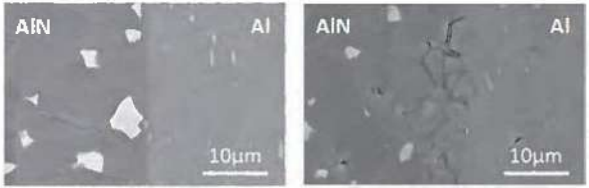
WEB ≫ http://www.eee.yamaguchi-u.ac.jp/lab/bunya_3/2898/

Joining Electronic Materials and Activation of Water Purification Flocculants Using Electrolysis

My research interest extends to two different fields that are leading areas of study concerning "**electrolysis of water (electrolysis)**". Both have been patented.

(i) The figure shows an SEM (Scanning Electron Microscope) image depicting the **joint** interface of ceramics with high thermal conductivity and metal with high electrical conductivity. Using electrolysis on the metal changes the joint interface morphology from platelet to interlocking projections, strengthening the joint by several magnitudes.

(ii) To purify dammed lake or river water for use as drinking water, the Al-based metal salt flocculent PAC (Poly-Aluminum Chloride) or Fe-based PSI (Poly Silicato Iron) is used by strictly adjusting the mix concentration to that of everyday water sources. The electrolytic pretreatment of the **flocculent** broadens the adequate mix concentration, expanding the range of application for this technology.



Electron microscope image of a ceramic-metal joint interface

About Researcher

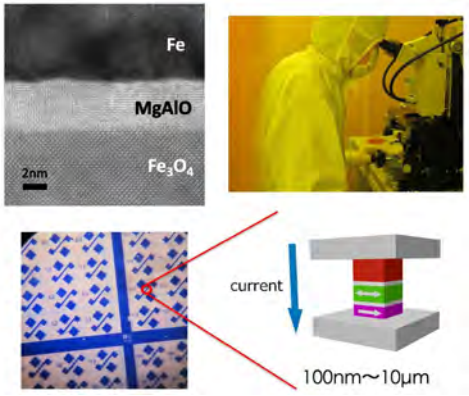
MURATA Takuya, Ph.D.

Ph.D., 1994, Yamaguchi University

Spintronics : Physical Properties Involving Charge-Spin-Orbit and Their Application to New Functional Devices

Electrons carry an electric charge and possess the intriguing property of spin. The phenomenon of spin flow in materials, referred to as a "**spin current**," provides various electronic functionalities and characteristics. The objective of our laboratory's research is to explore and elucidate novel functionalities by fabricating high-quality multilayer films controlled at the atomic scale using epitaxial growth techniques. This research field is known as **spintronics**, and its energy-efficient feature is expected to contribute significantly to addressing global energy challenges. Our research group is investigating a novel functional device that ingeniously combines a **magnetic tunnel junction** device-a prospective next-generation memory component-with a highly advanced magnetic oxide.

In addition, materials with topological electronic states have recently garnered considerable attention. To develop the topological materials, we are exploring magnetic alloy thin films, which have unique physical properties, such as the giant anomalous Hall effect and anomalous Nernst effect, arising from the presence of topological electronic states.



Cross sectional TEM image of oxide-metal hetero structure and schematic image of tunnel junction devices

About Researcher

NAGAHAMA Taro, Dr. Sci.

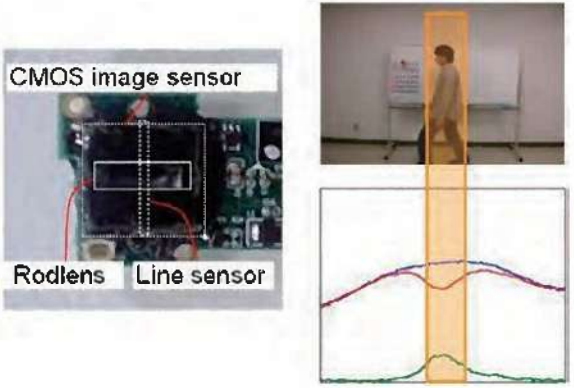
Dr. Sci., 2000, Kyoto University

WEB ≫ https://researchmap.jp/tnagahama

Intelligent Sensing System

Elderly people sometimes fall down in restrooms or bath areas and can—in the worst-case scenario—die. Using cameras for observation can be effective in avoiding such tragedies. However, privacy concerns prohibit cameras from being used in such places. To address the situation, we propose a sensor that can **convert two-dimensional images into a one-dimensional brightness distribution**.

Our proposed technology is a sensor system for **detecting a person's condition without violating his or her privacy**. Such an achievement is possible because **the sensor obtains only a one-dimensional brightness distribution** from natural light. Such sensors can therefore be installed and operated in restrooms or bath areas without violating privacy. Given the simple, low cost of such devices, we also hope to see these sensors installed in nursing homes with private rooms as well as the homes of elderly people living alone.



Care system using obrid-sensor without invading privacy

About Researcher

NAKASHIMA Shota, Ph.D.

Ph.D., 2010, Kyushu Institute of Technology

Eye-Gaze-Independent Brain Machine Interface

Our research interests include **biological signal processing** and its application to the biomedical engineering and life support technology fields, particularly to the development of **brain machine/computer interfaces** without control of eye-movement including eye-gaze and eye-opening/closing for people with eye impairments, as well as research into the response of electroencephalograms to various stressors and acute light aerobic exercises for the development of a **stress measurement** modality. Our research is focused on the following four projects:
1) Brain machine interface using event-related modulation of steady-state visually evoked potential in electroencephalograms during the performance of mental tasks ; 2) Auditory brain machine interface in terms of stochastic resonance in auditory steady-state responses in electroencephalograms; 3) Brain machine interface using event-related desynchronization of alpha wave refreshed with aromatic odors; and 4) Effect of acute light aerobic exercise and rest on electroencephalograms after mental tasks.
The range of application of the brain machine interface has been extended to hands-free and voice-free games and control of home electronics such as television channel changing.

Measurement by electroencephalogram for muscle-free communication

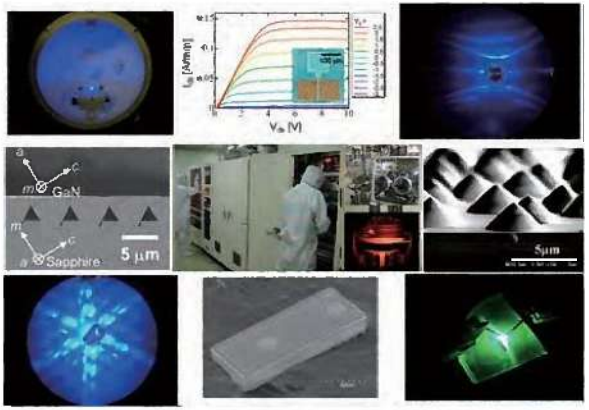
About Researcher

NISHIFUJI Seiji, Dr.Eng.

Dr.Eng., 1993, Kyushu University

Fabrication of High-Quality GaN and Its Application to Light-Emitting Diodes and Power Devices

GaN and related materials (III-nitride semiconductors) are attracting greater attention as a means to save energy after the Nobel Prize was given for the development of blue **light-emitting diodes (LEDs)** on a sapphire substrate. In the III-nitride semiconductor field, high-quality GaN substrates are currently in great demand due to a need for high-performance LEDs and **power devices**. Hydride vapor phase epitaxy (HVPE) is one of the most promising candidates for obtaining high-quality GaN substrates, and the fabrication of the GaN substrate is the major target of our research in terms of original techniques being developed. Our research group employs cutting-edge techniques to fabricate patterned sapphire substrates (PSSs). These are used to develop high performance LEDs and were demonstrated for the first time in the world by fellow lab member Prof. Tadatomo. In addition, this technique, PSS, makes it possible to fabricate various plane directions of GaN substrates with the potential to realize novel functions. Based on these techniques, we focus on the fabrication of high-quality GaN substrates by HPVE and their application to high-performance LEDs and power devices.



Research in our laboratory

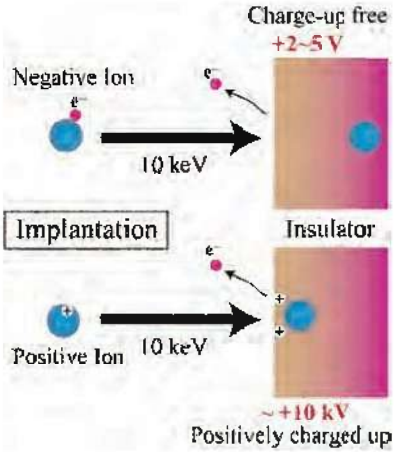
About Researcher

OKADA Narihito, Ph.D.

Ph.D., 2008, Meijo University

Efficient Production of Negative Hydrogen Ions on Metal Surfaces and the Application of Ionic Plasma

Ion implantation is a materials engineering process by which ions of a certain material are accelerated in an electrical field and impacted into a solid. Ion implantation is used in various applications in materials science research. Negative ion sources for ion implantation play an important and unique role in the ion source universe. The kinds of applications for which the sources are used are all significantly different from all the positive ion sources because the negative ion beam carries an energy, a material, and a negative charge. The charging by secondary electron emission can be suppressed even if negative ions are implanted on non-metallic materials. We are trying to efficiently produce **negative hydrogen ions** on metal surfaces without cesium adsorption. Furthermore, we are also researching the collective properties in **ionic plasmas** consisting of only positive and negative ions. In particular, we are very interested in **a hydrogen pair-ion plasma**.



Charging of non-metallic surfaces owing to the implantation of negative and positive ions

About Researcher

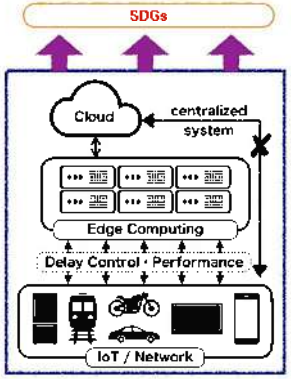
OOHARA Wataru, Ph.D.

Ph.D., 1999, Tohoku University

Optimization Analysis Based on AI for Edge Computing

At present, IT companies such as GAFA offer a broad range of cloud services. Several areas in the environment for internet networking will dramatically change in the future, with various internet services based on 5G technology and edge computing already being introduced around the world. Operational management and reliability assessments are extremely important for managing the local infrastructure of cloud services and edge computing. While the technologies behind 5G, cloud services, and edge computing are useful for many people, their failure will lead to various damages occurring and private information being leaked. Therefore, the management technologies of cloud services based on edge computing and 5G are important to maintain our convenient lifestyles. Considering optimization based on edge computing, the maintenance technologies for edge computing services are important to manage the information infrastructure.

Our research group focuses on the problems relating to infrastructure, the environment, lifestyle, and health such as SDGs. We propose several optimization methods based on AI in terms of maintenance and assessment for edge computing.



The Relationship between Edge Computing and Optimization

About Researcher

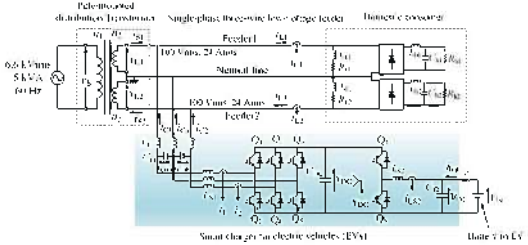
TAMURA Yoshinobu, Ph.D.

Ph.D., 2003, Tottori University

WEB ☞ http://www.tam.eee.yamaguchi-u.ac.jp/

Smart Charger for Electric Vehicles in Single-Phase Three-Wire Low-Voltage Feeders with Power Quality Compensator

Smart meters can report the power-consumption conditions of each domestic consumer to the power companies. The figure shows a power circuit diagram of a domestic consumer in single-phase three-wire low-voltage feeders (SPTWLVFs), which are generally used for domestic consumers in Japan. Load1 and Load2 correspond to home appliances used in a domestic consumer. The load currents i_{L1} and i_{L2} are always unbalanced and distorted with a lower power factor. These unbalanced and distorted source-current conditions increase losses in pole-mounted distribution transformers (PMDTs). Each domestic consumer should be responsible for improving power consumption conditions on their own. We have thus proposed **smart charger (SC)** for electric vehicles (EVs) with **active power quality compensator (APQC)**. In that figure, the colored area shows the proposed SC with an APQC. The proposed SC can obtain the balanced and sinusoidal source currents with a unity power factor in the SPTWLVF on the secondary side of the PMDT during both the battery charging and discharging operations in EVs. Improving power quality with the proposed SC reduces losses in the PMDT. There are a large number of the PMDTs in Japan. The proposed SC helps the achievement of a significant reduction in power losses. Thus, it is concluded that the proposed SC achieves a more **environment-friendly society** reducing **CO_2 emissions** in the World.



Power circuit diagram of proposed SC with APQC for EVs in SPTWLVFs

About Researcher

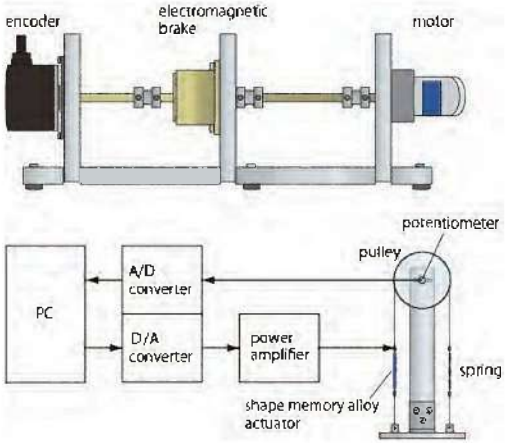
TANAKA Toshihiko, Ph.D.

Ph.D., 1995, Okayama University
Fellow of IEEJ
IEEJ-IAS Technical Achievement Award (2021)

WEB ≫ http://pelab.eee.yamaguchi-u.ac.jp/

Control of the Dynamical Behavior of Devices and Phenomena

In order to efficiently operate **dynamical systems** such as automobiles and robots, we need to properly control their individual elements, including engines and motors. In most cases, these elements are controlled electrically. My laboratory constructed an experimental system for motor control as shown in the figure and researched **control technology** to control the motor in an optimal and efficient manner. My research interests include not only actual devices but also dynamical phenomena such as shape memory alloy actuators which are known as artificial muscle. The shape memory alloy actuators present contraction phenomena and function by electrifying them. However, they are difficult to control precisely due to their complicated behavior. We have developed a simple and effective control method using an experimental system of shape memory alloy actuators. I am also interested in the efficient control of inverters, traffic signal systems, and smart grids. I deal with a variety of topics of control and **optimization** for dynamical behavior from both theoretical and practical perspectives.



Experimental control systems for motors and shape memory alloy actuators

About Researcher

WAKASA Yuji, Ph.D.

Ph.D. 2000, Kyoto University

Power Electronics for Renewable Energy and Energy Saving

My research interest is **power electronics** for renewable energy and energy saving. My main research topics are as follows:

1) Multi-Level Cascade Converter Based Wind Power Generation System with Tip Speed Ratio Control

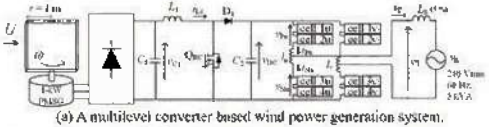
We have constructed a modular multi-level cascade converter based **wind power generation system** with tip speed ratio control. We are currently working on simplifying the control method.

2) High-Power LED Drivers for Industrial Fields

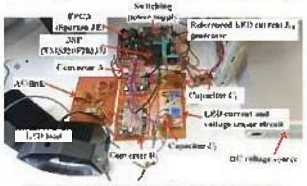
We are working on expanding the current control range of **high-power LED drivers** for many intended applications in fields such as fishery and agriculture.

3) Maximum Power Point Tracking Method for Vibration and Thermoelectric Power Generation

We are currently working on simplifying the control method for **energy harvesting**.



(a) A multilevel converter based wind power generation system.



(b) An LED driver for high-speed turn-off.

(c) A piezoelectric element for vibration power generation.

Our proposed power supplies and one of the energy harvesting devices.

About Researcher

YAMADA Hiroaki, Dr.Eng.

Dr.Eng., 2007, Yamaguchi University

WEB ≫ http://pelab.eee.yamaguchi-u.ac.jp/

Laser Spectroscopy of Wide Bandgap Semiconductors

Our research interest is to understand the optical properties of wide bandgap semiconductors for applications to solid-state light sources such as light-emitting diodes and laser diodes. We maintain a particular focus on **excitonics (exciton engineering)** in researching the dense excitonic properties of semiconductor low-dimensional quantum structures by means of time- and space-resolved laser spectroscopy. Our main research subjects are as follows:

1) The many-body effects of excitons, including the formation of biexcitons (excitonic molecules), the inelastic scattering of excitons, and the optical functionality of dense excitonic systems in highly-excited AlGaN ternary alloys and AlGaN-based quantum well structures by means of photoluminescence (PL) and PL excitation spectroscopy; 2) Radiative and nonradiative recombination dynamics of excitons in InGaN-based light-emitting devices by means of **time-resolved PL spectroscopy** with a temporal resolution as fast as 2 ps; 3) Optical inhomogeneity and the mechanism of high quantum efficiency in InGaN ternary alloys and InGaN-based quantum well structures by means of **scanning near-field optical microscopy** with a spatial resolution as high as 30 nm.

Our laser system for time-resolved PL measurements

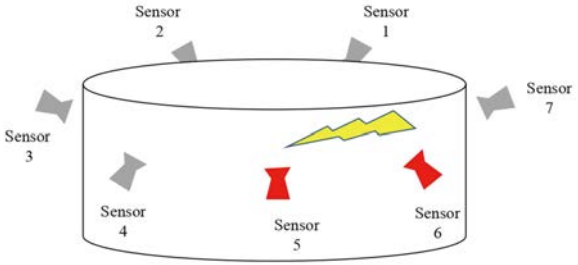
About Researcher

YAMADA Yoichi, Ph.D.

Ph.D., 1993, University of Tsukuba

Research on Design and Maintenance Policies for Complex Systems

As most of industrial systems become more complex and multiple-function oriented, such as aircrafts, submarines, military systems, and nuclear systems, it is extremely important to prevent accidents and reduce the causes of failure, which can be dangerous or disastrous. As a result, monitoring and evaluating the performance of the system is essential to ensure the normal operation. In reliability engineering, **maintenance** plays an important role during the operation phase. The main objective of this process is to determine the optimal maintenance policies that aim to provide maximal system reliability or availability and safety performance at the lowest possible maintenance cost. **Consecutive-k systems** can be used to model systems with complex failure (operating) conditions, such as signal transduction systems, nuclear accelerator photography, and pixel-based display systems such as liquid crystal displays. In this research, we focus on the **optimization problems** for the consecutive-k systems. In addition, the results of the consecutive-k systems can be interpreted as the basic system of the network type systems, and it is expected to be used for the optimum design and maintenance measures of the network type systems.



Reactor sensor system. Three or more consecutive sensors need to respond to detect a fault of a certain size.

About Researcher

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