Impact Objectives

- Develop a high speed, high linearity, low noise CMOS system that tackles many of the demands facing new technology
- Create ultra-small electrical components as well as small size antennas that offer faster performance, while using less energy and generating less noise pollution

The new future of energy harvesting

***Dr Haruichi Kanaya** is carrying out investigations focused on developing energy harvesting technology. He reveals his thoughts on the value of collaboration and working closely with early-stage researchers*

Can you talk a little about the rapidly changing world of wireless and mobile communications systems? What are some of the challenges we are currently facing in this sector?

As you say, wireless and mobile communications technology is rapidly evolving and there are particular issues that are really critical to development in this arena. Communication speed is key, as demand drives the need for ever-faster performance in real-time operation. There is also a very real need to lower power consumption in all electronics, for environmental concerns, as well as to lower running costs and maximise battery life. Increasing the capacity of batteries while also reducing both size and weight of the devices is also a strategic target for developers of this type of technology.

Generating energy is a major concern. While technology is now being designed to be more power-efficient, the need for more energy sources remains and we are finally realising that these sources need to be renewable in order to be sustainable.

How do you hope your research efforts will help to overcome some of these challenges?

Our project seeks to realise renewable energy sources and I feel that there are many new possibilities to discover. We are working on a number of systems and devices that we hope will address the challenges. My laboratory is working on a high speed, high linearity, low noise CMOS system that tackles many of the demands facing new technology. Not only will the system offer faster performance, but it will do so using less energy while also generating less noise pollution. Similarly, our antennae designs offer better performance across a variety of specific tasks and we have been striving hard to reduce the size of the components we are creating.

How important is it to support early-stage researchers in this industry?

I see supporting early-stage researchers as quite important in terms of ensuring the future of our specialty. We also want to generate lots of ideas to spur on innovation, so we need to provide research funding and living expenses for overseas researchers to come and collaborate with us on various projects. We are keen to share both knowledge and resources, such as our experimental equipment, as a means to collaborate on and drive research now and in the future.

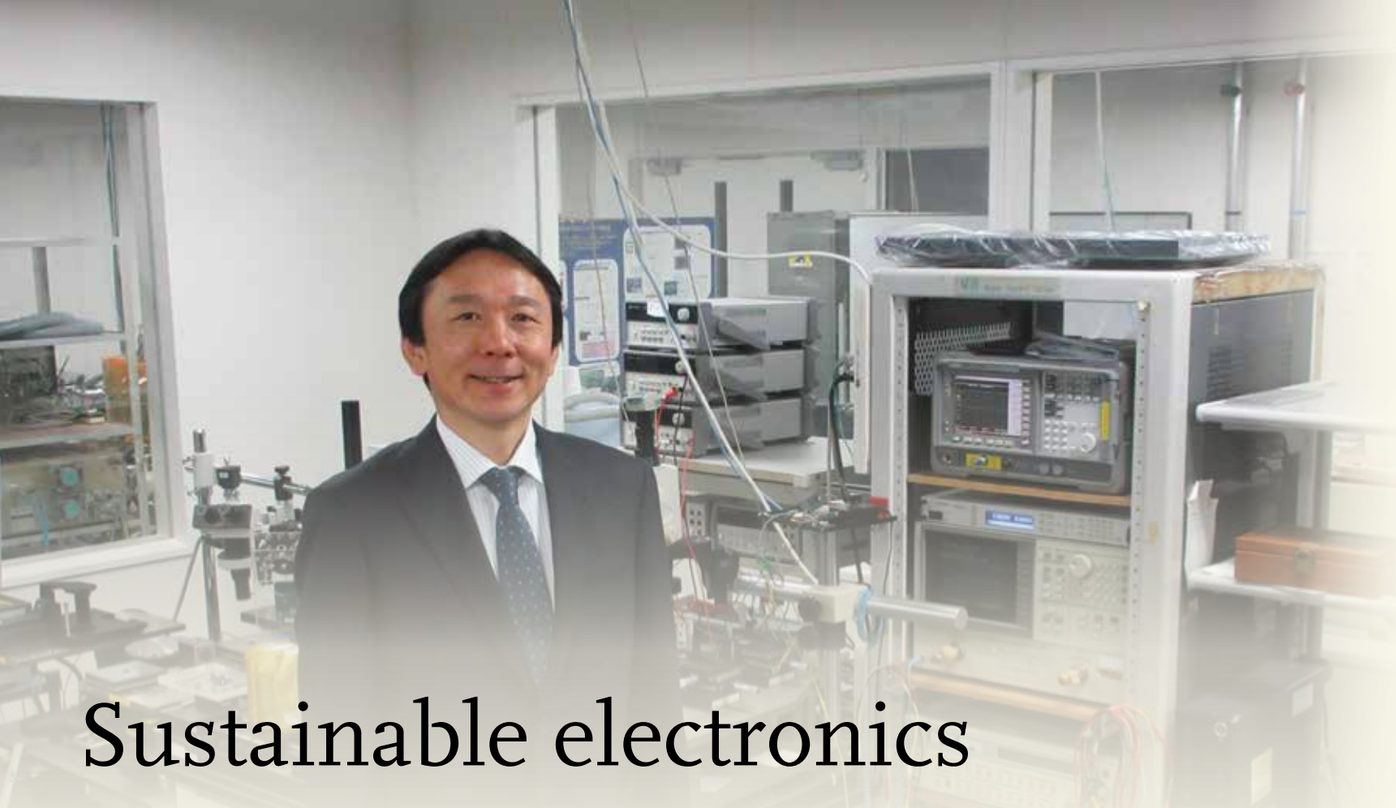
What is the importance of collaborative efforts to your research?

Collaboration is critical in modern research and we work with many partners, including healthcare and educational institutions, technology firms and research centres. Working with these collaborators has helped us in critical areas such as vital sensing, implant sensing, infrastructure sensing and wireless communication.

You offer laboratory tours to introduce people to the work underway at your laboratory. Can you talk about the value of such an initiative?

We host open campus lab tours for high school students every year to foster interest in science amongst youngsters. I think that this is a critical age for young people to decide on what they want to be when they grow up and how they're going to get to that stage. I consider it an important investment in the future of not only these children but also thinking in terms of future researcher development.

We also hold lab tours for company engineers working in industry. We are regularly approached by companies wishing to see what we do. I see this as an opportunity to discuss options for collaborative research as well as a means to share knowledge. ▶



Sustainable electronics

*A team from the **Kyushu University** in Japan seek to develop ultra-small electrical components that pack a punch, with high performance and small sizes fuelled by eco-friendly sustainable energy sources*

As fossil fuel levels are exhausted, building a more sustainable world is an issue that is coming to the fore as a crucial consideration in the development of new technology. The energy needs of the planet's population are immense, and an environmentally friendly source of energy is desperately needed. Energy harvesting from renewable sources is not a new concept - windmills have been around since the first century – but the desire to harness renewable energy has intensified. Energy harvesting technology is the term given to technology used for collecting unused energy from the surrounding environment and converting it into electrical power.

Solar, wind and hydroelectric power are perhaps the best-known of these technologies. However, there are many other forms of energy that are under developed and hold much potential for powering the future. These include vibration, pressure, heat and temperature difference. While large-scale power generation cannot be realised using these sources due to their low levels, devices with low power demands may be able to harness such energy sources, potentially eliminating the need for an external power source.

Dr Haruichi Kanaya, from the Radio-Frequency Integrated Circuits (RIFC) & Microwave Communication Device Laboratory at Kyushu University, leads a team investigating wireless technology. This team is particularly focused on ultra-small antennae and large-scale integrated circuits (LSIs) used in this type of technology. 'Wireless communication is naturally used in many electronic devices, so I thought that it would be possible to convert the electromagnetic wave energy that is taken for granted to natural power,' he explains.

The team is also working on other components for use within wireless communications systems. These feature high speed and high linearity functions and are also designed to operate at low noise levels. In addition, the researchers are working on components suitable for ultra-wideband (UWB) applications. These include Wideband RF front-end components, as well as electrically small antennae (also suitable for narrow band use). 'Other components we are creating operate for digital radio functionality, and include examples such as digitally controlled oscillators (DCO) and digitally controlled power amps that can be used in reconfigurable applications like software-defined radio,' Kanaya outlines.

'We are seeking to reduce parasitic components by developing interconnection and packaging technology of chips onto antennae.'

Kanaya's background in applied science covers work on the phase transition of muscle proteins, undertaken during his MSc and PhD studies. Subsequent to his doctorate, he entered the field of electrical engineering as an Assistant Professor at Yamaguchi University and engaged in research on planar bandpass filters for wireless communication using superconducting thin films based on electromagnetics theory and electrical circuits. 'I achieved this using the planar circuit designed by the transmission line theory and for this work I received the Younger Researcher Award in IUMRS-ICA-97,' he confirms. 'Using the sol-gel method, we developed a superconducting thin film able to operate at high temperatures.' It was this springboard that led to Kanaya's current work on wireless technologies, as well as the realisation of planar antennae on thin, flat or flexible substrates. Kanaya has also won design awards such as the LSI IP Design Award and IEEE ARFTG Conference awards.

'I want to harvest sustainable electricity from the world around us and harness this power for us in electrical devices without any need for power cables'

RESOURCING RESEARCH

The work this laboratory undertakes not only relies on support from the Japan Society for the Promotion of Science (JSPS) and the Japan Science and Technology Agency (JST), but they also have close partnerships with a number of academic and research institutions as well as private technology firms. Some of these collaborations opened up opportunities for the team to benefit from the expertise and resources of other groups.

The team uses a number of tools for their academic programme. These include HFSS, from ANSYS Co., ADS and EMpro from Keysight Technologies, and Virtuoso from CADENCE Corporation. Some of these are supported by the VLSI Design and Education Center (VDEC) as well as The University of Tokyo in collaboration with CADENCE and Keysight. Furthermore, certain technical equipment was used in Kanaya's work in order to analyse and generate signals. The vector network analysers used were from Keysight, Hewlett-Packard and Advantest, while the digital oscilloscopes originated from Tektronix, Agilent and Yokogawa. Other equipment included a signal source analyser (Rohde & Schwarz), a data generator from Tektronix and a noise figure analyser from Agilent. Cascade provided the probe stations while Keysight manufactured the Terahertz (THz) extender used by the group. A PCB prototyping machine by MITS Electronics was also used.

FACING THE CHALLENGES

'Wireless communication CMOS system LSIs are indispensable for communication in the Internet of Things (IoT) era,' Kanaya highlights. 'Without this, communication itself is not possible.' He believes that this reliance on LSIs will only increase over time. Happily, as his team has already proposed a design formula, an immediate response can be launched.

One of the key challenges facing Kanaya in his work lies within his educational role. The students working in his laboratory are present for a period of three years as part of their course. Thus, he experiences a changeover in his student body every three years, which poses the problem of teaching a new batch of students the necessary skills for work in a laboratory. His solution to this dilemma was to produce a manual, complete with photographs and videos, to guide his students in the techniques required in the lab. Furthermore, Kanaya instituted a mentorship system. 'We developed a guidance system in which senior students provided help and advice to junior students,' he notes. 'This helped them all establish critical skills that will be useful beyond their studies as they move into the real world and find jobs.'

THE NEXT STEP

Kanaya is keen to introduce the outcomes from his laboratory's research into real-world applications through collaborative research with companies, as well as other activities. He also attends exhibitions at trade fairs to showcase his developments to potential industrial partners. Through his training programme, he helps young researchers within companies learn and develop essential laboratory skills.

Looking forward, Kanaya seeks to leverage his existing accomplishments to investigate the possibility of communication on the THz band to deliver much higher communication frequencies than are currently available. He believes that this development could be achievable in the near future. 'We have already successfully developed an antenna,' he says. 'Development of amplifiers, mixers and transmitters is also necessary in order to produce devices that will work on the THz band, but we hope to do so in the near future.'

Wireless communications are an integral part of our world now and Kanaya believes that this technology is here to stay. 'Wireless communications will continue to evolve and will not disappear,' he notes. 'However, ensuring an adequate power supply is essential. I want to harvest sustainable electricity from the world around us and harness this power for us in electrical devices without any need for power cables.'

Kanaya's laboratory continues to strive towards achieving low-power, high-performance electronics components that look set to become essential parts of the technology we all rely on, and by harnessing sustainable, environmental sources of energy the team is also contributing towards a brighter tomorrow.

Project Insights

FUNDING

- Grant-in-Aid for Scientific Research, Japan Society for the Promotion of Science (JSPS)
- A-STEP, JSPS
- CREST, Japan Science and Technology Agency (JST)
- Grant-in-Aid for the Collaborative Research Program Based on Industrial Demand, Matching planner program, JST
- The Telecommunications Advancement Foundation
- The Cabinet Office (CAO), Cross-ministerial Strategic Innovation Promotion Program (SIP), 'An intelligent knowledge processing infrastructure, integrating physical and virtual domains' (funding agency: NEDO)

COLLABORATORS

Vital sensing project:
- ALSENS Inc.
- University Farm, Kyushu University
- Livestock Research Division, Oita Prefectural Agriculture, Forestry and Fisheries Research Center

Implant sensing project:
- Fukuoka Dental College Medical & Dental Hospital
- Kyushu University Hospital
- Section of Oral Rehabilitation, Kyushu University
- LOGICAL PRODUCT Co.

Infrastructure sensing project:
- Geodisaster Prevention Engineering Laboratory, Kyushu University
- Universiti Teknologi Malaysia, Malaysia
- Nahda University, Egypt

Wireless communication (in 2019)
- KYUSHU TEN LIMITED
- SEIKO ELECTRIC CO. LTD.
- Braveridge Co. Ltd.
- Logic Research Co. Ltd.
- Ericsson, France
- Pohang University of Science and Technology, Korea

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