The University of Electro-Communications

Leading Research in Optics, Photonics, Wireless Communications, and Fuel Cells

The University of Electro-Communications (UEC) in Tokyo is a small, luminous university at the forefront of applied sciences, engineering, and technology research. Its roots go back to the Technical Institute for Wireless Communications, which was established in 1918 by the Wireless Association to train so-called wireless engineers in maritime communications in response to the Titanic disaster in 1912. In 1949, the UEC was established as a national university by the Japanese Ministry of Education, and moved in 1957 from Meguro to its current Chofu campus in Tokyo.


Wataru Mitsuhashi

"Until a few years ago we taught courses on Morse code and radio navigation," explains **Wataru Mitsuhashi**, member of the board of directors responsible for research strategy at UEC. "The equipment we used for these courses is now on display in our Museum of Communications!" With approximately 4,000 students and 350 faculty, UEC is a regarded as a small university, but with particular expertise in wireless communications, laser science, robotics, informatics, and material science, to name just a few.

The UEC was selected for the Ministry of Education, Culture, Sports, Science and Technology (MEXT) Program for Promoting the Enhancement of Research Universities as a result of its strengths in three main areas: "optics and photonics research, where we are number one for the number of joint publications with foreign researchers; wireless communications, which reflects our roots; and materials-based research, particularly on fuel cells," explains Mitsuhashi.

UEC's main research reforms include the introduction of a new personnel salary system enabling the appointment of staff with a diverse range of experience; enhancement of its international standing by introducing an improved system to hire top-class researchers from all over the world; creation of an international photonics hub for laser and optics research; and training of university research administrators (URAs).

The University of Electro-Communications: www.uec.ac.jp/eng

Institute for Laser Science

The Institute for Laser Science (ILS) is one of the most active research groups based in optics and photonics in Japan, with 50 UEC faculty members conducting research at the institute. "Our international approach to research has enabled us to make tremendous advances since the institute was established in 1978," says **Hitoki Yoneda**, director of ILS. "We have published the largest number of multi-institute international joint papers in Japan, which underscores the international nature of this institute. What is remarkable is that ILS has only eight full-time core research staff."

Major milestones since 1978 can be divided into six areas: development of a laser driver for inertial confinement fusion; atom optics, Bose-Einstein condensates, and cold atoms; ultrashort pulsed lasers and high-energy density science; highly charged ions; high-frequency stabilized lasers and gravitational wave antennas; and quantum solids.


Hitoki Yoneda

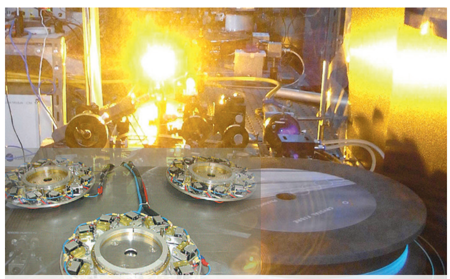
Findings from research conducted at ILS have often found further scientific application. One example is the high-quality optics and ultrahigh stability lasers that are being used for the construction of Japan's Kamioka Gravitational Wave Detector (KAGRA) to detect the gravitational waves predicted by Einstein's theory of general relativity. The project involves building two 3 km long laser interferometric gravitational wave detectors in a coal mine in Kamioka, Japan. Other "big-science" applications are highly stable lasers for precise frequency references for the X-ray free-electron laser, SCALA at the SPring-8 synchrotron in Japan, and the Atacama Large Millimeter/submillimeter Array (ALMA) telescope in Chile.

In 2000, ILS researchers reported the development of ceramic solid-state lasers, constructed from composite materials based on Cr^{4+}-doped crystals (Yb:YAG/Cr^{4+}:YAG) and capable of increased power output up to four orders of magnitude greater than current systems.

Progress has also been made in the application of highly charged ions (HCI) to fundamental science. In particular, ILS developed a greatly improved version of the electron beam ion trap for astrophysics, nuclear fusion, and ultrashort wavelength lithography. Notably, ILS researchers have demonstrated the use of HCI for forming a "hollow atom" in silicon and titanium oxide surfaces.

The research at ILS forms the basis for training and educating the next generation of scientists and engineers in this field. "We demonstrate unique experiments to students," says Yoneda. "For example, the management of sudden explosions and equipment failure are two daring experiments in our educational program. We also collaborate with partners overseas to organize regular courses on topics such as high-power lasers and their applications, and warm dense matter."

The outlook of postdoctoral fellows at ILS is truly global, with collaborations formed between ILS and the University of Southampton and the University of Edinburgh in the United Kingdom, Nanyang Technical


High Power Fiber Lasers

University in Singapore, the University of Toronto in Canada, and Stanford University in the United States. "We also have strong historical links with scientists in Russia, in particular, the Russian Academy of Sciences," explains Yoneda. "We plan to increase our international outreach by using the funding from the program to hire experts in optics and photonics on a global scale."

Institute for Laser Science:
www.ils.uec.ac.jp

Advanced Wireless Communication Research Center

The Advanced Wireless Communication Research Center (AWCC) was established in April 2005 as a global research center for wireless communications and advanced wireless technology education based on both theory and practice. Although UEC was founded to lead Japan's wireless technology efforts following the Titanic accident, much has changed since then. "Our research reflects our commitment to an innovative and integrated approach for developing wireless technologies for the future," says **Yasushi Yamao,** director of AWCC.

AWCC also aims to transfer the fruits of its laboratory research to society via industry-focused technology transfer. "Currently, 36 of the 350 faculty members at the university are conducting research at AWCC," explains Yamao. "These include three full-time faculty, four concurrent professors, 20 research collaborators, and nine visiting professors. All have extensive links to industry in order to facilitate technology transfer."

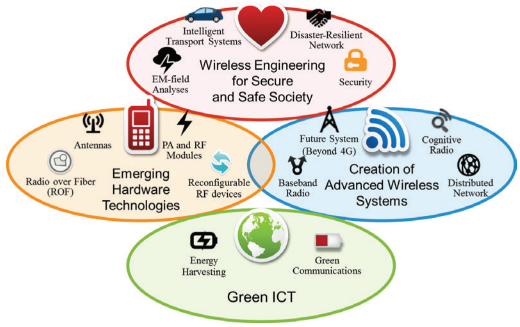
With the mission of realizing ubiquitous and "cognitive" wireless communications, AWCC is pursuing the following projects:

- Wireless engineering for a secure and safe society
- Emerging hardware technologies
- Green information communications technology
- Creation of advanced wireless systems.

Recent research findings include the development of a massive, wireless rewritable commercial price tag system incorporating 30,000 terminals. "This is an example of an industrial collaboration on ubiquitous wireless communications technology," says Yamao. "Our innovative protocol enables the connection of many devices as part of a low-power consumption, long-life, battery-operated system for use in large shops and supermarkets."

In response to demands for methods to monitor radiation levels in the wake of the Fukushima accident, AWCC has constructed an ad hoc wireless network of sensors to measure radiation levels. The system enables the measurement of temporal changes in radiation, including seasonal changes.

Yasushi Yamao



Areas of Research at AWCC

Advanced Wireless Communication Research Center:
www.awcc.uec.ac.jp/awcceng/index.htm

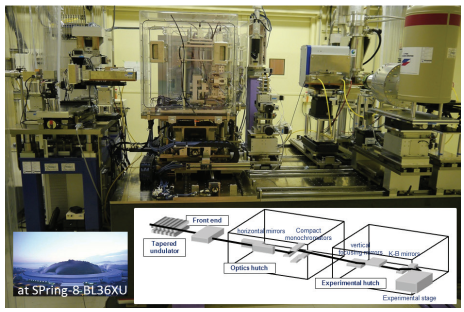
Innovation Research Center for Fuel Cells

Recent reports of cars powered by hydrogen fuel cells have captured the world's imagination with the hope of a clean energy source to mitigate environmental issues. The advent of commercial fuel cell automobiles is the result of intense basic research at many academic institutions. **Yasuhiro Iwasawa,** director of the Innovation Research Center for Fuel Cells, is one of the center's leading scientists and has made major contributions to unraveling the mysteries of the fundamental mechanisms underlying the generation of electricity from fuel cells. Iwasawa is the head of an approximately US$26 million project to use X-ray absorption fine structure (XAFS) spectroscopy to probe the atomic structure of catalysts in fuel cells, in situ and in real time. "Fuel cell catalysts are a black box right now," explains Iwasawa. "The atomic structure, reaction mechanisms, and degradation mechanism are still unclear. So we have built an 80 m beamline at the SPring-8 synchrotron facility in order to use XAFS to clarify these issues. This is the only XAFS beamline in the world capable of performing high-level in situ XAFS, real-time XAFS, and spatially resolved XAFS."

Yasuhiro Iwasawa

Specifically, Iwasawa and his colleagues are focusing on the XAFS analysis of the cathode catalyst inside the membrane electrode assembly during power generation. Fuel cell reactions are such swift, dynamic processes that high-spatial–resolution analysis is critical. "Our approach has several unique features," explains Iwasawa. "Being in situ and temporal, we can monitor chemical and structural changes down to a time scale of 100 μs at 100 nm spatial resolution, and at 1 μn 3-D resolution under the operating conditions used in our experiments."

Results from these unprecedented analyses at SPring-8 have yielded intriguing insights into how catalysts behave. Notable findings include elucidation of the structural changes in the Au(core)-Pt(shell)/C catalyst during the on-off process of fuel cells, and the discovery that the reaction rate of the Pt_3Co/C catalyst is faster than Pt/C, and in particular, that the reformation of the Pt-Pt bonds and the dissociation of the Pt-O bonds are fast reactions. These results are expected to enable the design of highly efficient and robust fuel cells for the automobile industry.



Time-Resolved and Spatially-Resolved XAFS Equipment at SPring-8 BL36XU Beamline

Innovation Research Center for Fuel Cells:
www.icfc.uec.ac.jp