# Contributing to Research in Superconductivity and Spintronics Using High-resolution Photoemission Spectroscopy

Superconductors have zero electric resistivity, and transfer energy without loss. In the past, superconductivity was realized by cooling down to -269 ℃ with expensive liquid helium. Recently, however, discovery of high-temperature superconductors can achieve the superconductivity with comparatively economical liquid nitrogen. Clarification of the mechanism of superconductivity is an important research subject for both basic science and practical application.

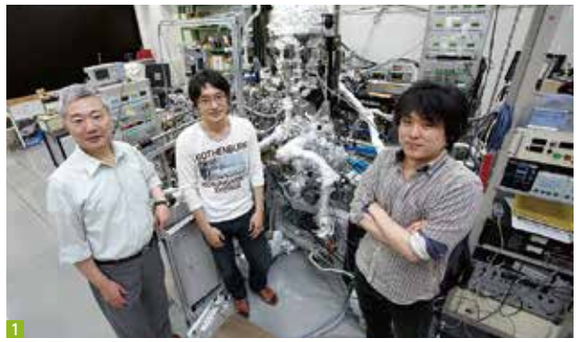
"The driving mechanism of novel properties in materials such as superconductivity is understood with the electronic structure. The most direct experimental method to measure the electron structure is photoemission spectroscopy based on the Einstein's light quanta (photon) hypothesis." states Professor Takashi Takahashi.

In photoemission spectroscopy, we inject photons onto the sample, so that electrons are emitted from the surface due to the external photoelectric effect. By measuring the energy and speed of emitted photoelectrons, we can experimentally determine the electronic structure of material. The photoemission spectrometer developed by Professor. Takahashi's group achieves a world-top-level resolution to survey the electronic state of materials with a very high precision. In fact, the spectrometer has been successfully used in the research of semiconductors and high-temperature superconductors.

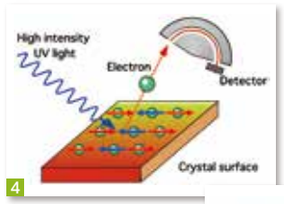
"Another important physical property of electrons is the spin. Recently we have constructed a spin-resolved photoemission spectrometer with the world-best resolution (8meV) at Tohoku University. This new machine would greatly contribute to the research of spintronics."

Currently, Professor Takahashi and his coworkers are carrying out active researches with this new machine on several novel functional materials such as topological insulators, graphene, iron-based high-temperature superconductors, and surface Rashba effect.

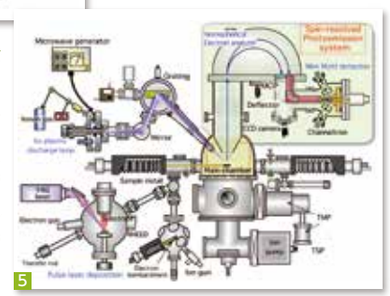
"Tohoku University is a center of materials science in the world. There are many active researchers and various interesting materials nearby. By taking this advantage, we would like to contribute to the research of new advanced materials."



[Photo 1 2 3 ] In Professor Takahashi's laboratory, the ultrahigh-resolution spin-resolved photoemission spectrometer was constructed to study the spin state of materials. The machine achieves the world-best resolution of 8meV.




[Photo 4] Schematic diagram of photoemission spectroscopy. We measure the energy, momentum, and spin of photoelectrons emitted by incident photons. Arrows show the direction of spin in the antiferromagnetic state.



[Photo 5] Schematic view of the spin-resolved ultrahigh-resolution photoemission spectrometer constructed at Tohoku University. The energy and momentum of photoelectrons are analyzed by the hemispherical electron energy analyzer and then the spin is determined by the mini-Mott detector.

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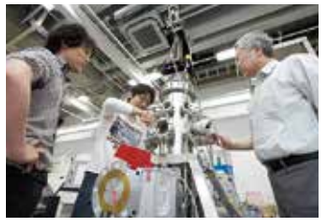
Professor **Takashi Takahashi**

Born in Niigata Prefecture in 1951. He graduated from Tokyo University School of Science, specializing in physics. After serving as an assistant professor of Tohoku University, School of Science, Department of Physics, Dr. Takahashi has served at his current post since 2007.

http://arpes.phys.tohoku.ac.jp/index-e.html



# A gene-manipulated rat which sense light at its skin - Innovative informational transmission to the brain

How do we sense light and feel things? The answer is not as easy as it seems. Professor Hiromu Yawo and others at the Graduate School of Life Sciences, Tohoku University successfully developed the world's first rat with "Supersense", light-sensing skin. To develop this transgenic rat, the researchers focused on "Channelrhodopsin (ChR)", light-sensitive proteins obtained from single-celled green algae "Chlamydomonas".

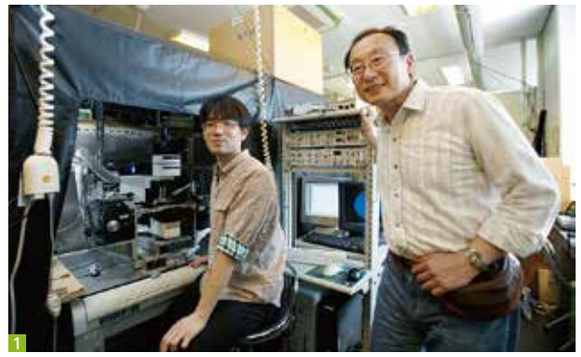
Professor Yawo says, "When light hits the rat's leg from under the cage, the rat moves as if physically touched."
In this experiment, if ChR can be expressed in living brain cells, neural manipulation by light is possible.

In the human brain, external stimuli are recognized through the links between neurons. However, methodologically explaining their function in detail is difficult, since those links are made up of multiple cells. Using light, it is possible to stimulate the targeted cells one by one, and as a result the relationship between these cells can be studied.

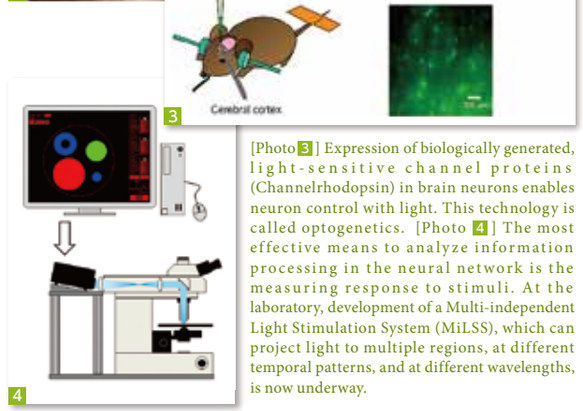
"How our brains recognize shape, size, movement, texture and other kinds of information provided through the sense of touch is still not well understood. We believe that the development of this rat will enhance studies in this area."

This technology allow us to directly send information to the brain by transmitting signals with specific meaning to the brain, through the irradiation of patterned light.
Professor Yawo says, "By connecting the brain to external devices such as a computer, brain-to-brain, and brain-to-machine communication using light may become a reality in the future."

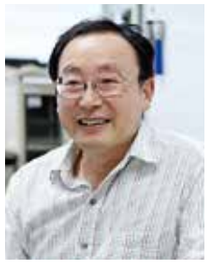
Professor Yawo's research group is now conducting research on a Brain-Machine Interface (BMI), a direct communication pathway to the brain through light, by applying technology obtained in this basic research .



[Photo 1 2 ] Methods to stimulate neurons with light, and to visualize the function of synapses, junctions where neurons are connected each other, using genetic engineering techniques, are now currently employed in the laboratory.




[Photo 3] Expression of biologically generated, light-sensitive channel proteins (Channelrhodopsin) in brain neurons enables neuron control with light. This technology is called optogenetics. [Photo 4] The most effective means to analyze information processing in the neural network is the measuring response to stimuli. At the laboratory, development of a Multi-independent Light Stimulation System (MiLSS), which can project light to multiple regions, at different temporal patterns, and at different wavelengths, is now underway.



Laboratory of Molecular and Cellular Neurosciences,
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Professor **Hiromu Yawo**

Born in Fukuoka Prefecture in 1952. He graduated from the Faculty of Medicine and the Graduate School of Medicine, Kyoto University, specializing in brain function analysis. Dr. Yawo has worked as Research Fellow for Japan Society for the Promotion of Science, and Assistant and Lecturer at Kyoto University. He has worked as Professor at Faculty of Medicine, Tohoku University since 1995, and has served in his current post since 2001.

http://neuro.med.tohoku.ac.jp/english/ENGLISH.htm