RAP

RIKEN Center for Advanced Photonics

2026 - 2027

RIKEN Center for Advanced Photonics

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Walking the scientific path with light.

— Drawing out the full potential of light

The Old Testament passage "God said, 'Let there be light,' and there was light." and the story of the existence of "light," which is thought to have been inseparable from matter at the beginning of the Big Bang universe, have been going around and around in my head and heart. I have come to the thrilling conclusion that the root of nature always involves an as yet unknown essence of light. This is a completely unscientific statement, but I have a feeling that the allure of "light" felt by all people originates from such a thought.

Light has undoubtedly been our most familiar means of observation and exploration in the development of science. Observations of the distant universe through telescopes and explorations of bacteria through microscopes have contributed to the development of astronomy and medicine. The light-quantum hypothesis proposed by Einstein in 1905 led to the understanding of light as a quantum "photon." This has led to the current development of quantum physics and has laid the foundations of modern society. The laser, invented around 1960, advanced the technology to measure frequency and time with ultra-precision, defining time by the technology of light. The development of lasers capable of emitting pulses with very short intervals of femtoseconds (10^{-15} s) and attoseconds (10^{-18} s) has also contributed significantly to the development of physics. These pulses allow for precise prediction of the dynamic movement of electrons in atoms and molecules. Photonics research will continue to maximize the various potentials of light, making it an indispensable research area for the development of science as a whole.

The RIKEN Center for Advanced Photonics (RAP) is on the cutting-edge of scientific discovery, pioneering new frontiers in various fields with its groundbreaking research in photonics. We're thrilled to announce our new motto, "Edge Photonics," which beautifully captures the essence of our pioneering spirit. The word "edge" symbolizes our innovative approach, with its triple meaning: cutting-edge photonics, photonics at the edge (boundary area), and photonics at the network edge. In the cutting-edge photonics, we are at the forefront of ultra-precise optical lattice clocks and developing materials science research using attosecond lasers. The development of quantum electronics in the terahertz range is also a promising area of research in the future. Photonics in the boundary research area provides new means of observation and analysis necessary for solving fundamental problems in the life sciences and the universe. In the field of photonics at the network edge, we are exploring the potential of artificial intelligence (AI)-based photonics, which is a highly advanced area that connects the digital and physical worlds.

Center Director
Koichiro Tanaka

田中耕一郎

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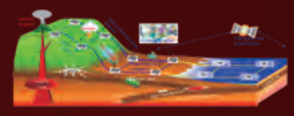
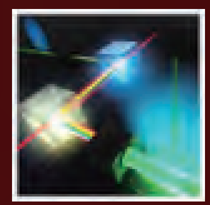
Quantum Metrology Research Group

The Quantum Metrology Research Group investigates technologies for precisely controlling quantum systems composed of light and atoms, and develops for measuring time, frequency, and gravitational potential with extreme precision. At the core of the group's research are optical lattice clocks, which achieve ultra-stable and accurate timekeeping beyond conventional atomic clocks. They are expected to contribute not only to next-generation time standards but also to relativistic geodesy, in which differences in gravitational potential are measured through time and frequency. Our group is advancing optical lattice clocks by improving their accuracy, compactness, portability, and long-term operability, while also exploring new spectroscopic methods and developing key technologies toward nuclear clocks. Building on ultrahigh-precision time measurement, our group aims to open new frontiers in science and technology enabled by quantum metrology, from investigations of fundamental physics to future societal implementation.



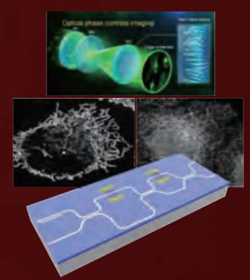
Ultrafast Photonics Research Group

The Ultrafast Photonics Research Group pursues the direct observation and mechanistic understanding of electron and nuclear dynamics that govern the functions of materials and molecules, employing ultrashort optical and electron pulses in the femtosecond and attosecond regimes. Advances in laser technology and electron beam control have made it increasingly possible to investigate ultrafast phenomena in a time-resolved manner that was previously unattainable. Our research integrates the development of innovative laser sources for post-attosecond science, ultrashort electron beam technologies, and state-of-the-art molecular spectroscopy. Through these efforts, we seek to elucidate the dynamical processes underlying material responses, chemical reactions, and molecular functions, while establishing new scientific principles and experimental foundations that will pave the way toward controlling these processes.



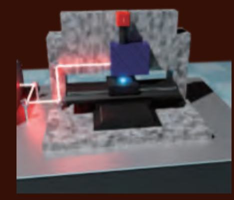
Interdisciplinary Research Group

The Interdisciplinary Research Group actively explores new research frontiers that connect diverse academic fields, including life sciences, materials science, nanophotonics, and quantum technology, through light as a unifying foundation. Our group spans a wide range of research topics, including the visualization of biological phenomena using fluorescent proteins and super-resolution imaging, the creation of novel optical devices through quantum optoelectronics, and the development of light manipulation technologies based on metamaterials. By advancing technologies that use light to observe, control, and generate new functionalities across disciplinary boundaries, we seek to foster innovation at the intersections of these fields. Going beyond the limits of conventional disciplines and uncovering new connections among living systems, materials, nanostructures, and quantum phenomena, we aim to expand the scope of optical science and open new avenues of research.



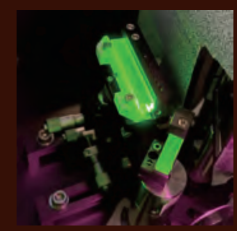
Artificial Intelligence Photonics Research Group

The Artificial Intelligence Photonics Research Group develops innovative approaches in advanced laser processing, image information processing, and multidimensional measurement technologies. By integrating optical technologies with AI and deep learning, the group promotes the development of "digital twins" that reproduce real-space phenomena and functions in cyberspace. In advanced optical technologies such as optical measurement and laser processing, numerous parameters are intricately involved, making it challenging to understand phenomena and optimize processes. Our group analyzes complex data obtained from laser microfabrication, imaging, and observations of photoexcited processes, and uses originally developed optimization methods and AI technologies to establish improved processes. Through these efforts, we extend advanced optical technologies to complex systems involving biological functions, chemical reactions, medical applications, and engineering, and develop new techniques for measurement, analysis, and control.



Terahertz Science Research Group

The Terahertz Photonics Research Group advances quantum electronics and photonics in the terahertz and infrared regions, with a view toward applications in next-generation IoT, information and communications technology, precision measurement, materials science, and life science. Terahertz waves occupy the frequency region between radio waves and light, and provide a powerful means of for investigating low-frequency dynamics in matter, molecular vibrations, and the responses of semiconductors and other quantum materials. Our group is enhancing its original terahertz-wave sources and detection technologies, while also advancing research on quantum light sources, quantum sensing, ultra-precision spectroscopy, high-sensitivity imaging, and devices integrating photonics and electronics. We also seek to open up new directions in terahertz science and technology through high-precision light-source technologies, precision spectroscopy of molecular rotational states, and spectroscopy using quantum entanglement.

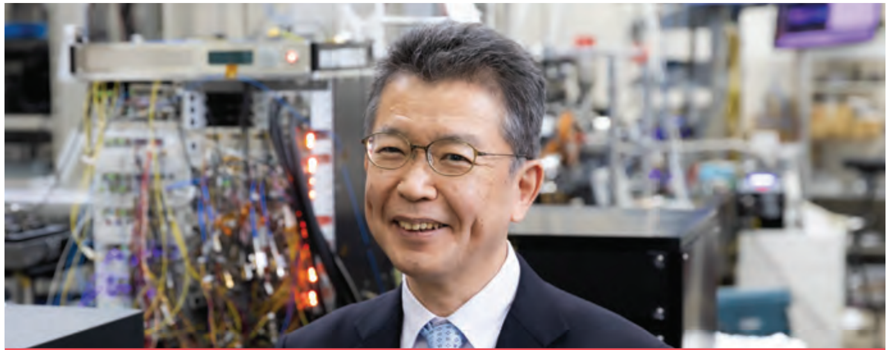


Advanced Photonics Technology Development Group

The Advanced Photonics Technology Development Group develops and integrates core technologies that support frontier research in photonics and quantum science while fostering new research fields. Bringing together expertise in advanced lasers and light sources, optical materials and devices, neutron-based technologies, and research infrastructure, the Group creates new technological foundations for photonics and quantum science. Its activities include advanced instrumentation, precision measurement and processing, and material characterization, with applications in quantum technologies, advanced materials, energy and environmental solutions, space utilization, and industrial infrastructure. Through the development of scientific instruments and research platforms, and collaboration with industry, the Group promotes the social implementation of emerging technologies and contributes to new value creation through photonics and quantum science.

Spacetime Engineering Research Team

Team Director Hidetoshi Katori D. Eng.

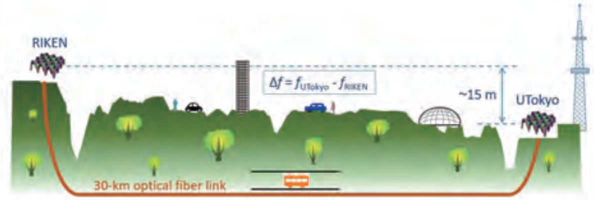


Relativistic Spacetime Engineering with Ultra-Precise Atomic Clocks

Clocks have been tools for sharing time based on universal periodic phenomena; humankind has relied on the Earth's rotation since antiquity. The radiation from an atom provides us with far more accurate periodicity. State-of-the-art atomic clocks sense the relativistic spacetime curved by gravity, revealing the difficulty of sharing time with others. Moreover, such clocks may be used to investigate the constancy of fundamental constants upon which their operation is based.

Optical lattice clocks proposed in 2001 made ultra-stable and accurate clocks possible by applying the "magic wavelength" protocol. Their precision now surpasses the current definition of the SI second, positioning them as strong candidates for its future redefinition.

Our team leverages advanced techniques in atomic physics and quantum optics to develop highly precise, compact, and long-term-operable optical lattice clocks. This enables us to explore novel applications of "spacetime engineering" that fully use these new time resources. For instance, a transportable optical lattice clock deployed in the field can function as a gravitational potential sensor. Through such experiments, we are investigating the scientific and practical impact of relativistic geodesy—and the new roles that clocks may play in the future.



Remote frequency comparison of optical lattice clocks between RIKEN and the University of Tokyo (UTokyo) reveals their different tick rates as predicted by general relativity.

▶ Fields

Interdisciplinary Science and Engineering, Engineering

▶ Keywords

Quantum electronics, Atomic clock, Quantum metrology, Optical lattice clock, Relativistic geodesy

▶ Publications

1. Takamoto, M., Ushijima, I., Ohmae, N., Yahagi, T., Kokado, K., Shinkai, H., and Katori, H.: "Test of general relativity by a pair of transportable optical lattice clocks", ***Nat. Photonics.*** 14, 411-415 (2020).
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5. Ushijima, I., Takamoto, M., Das, M., Ohkubo, T., and Katori, H.: "Cryogenic optical lattice clocks", ***Nat. Photonics.*** 9, 185-189 (2015).

▶ Members

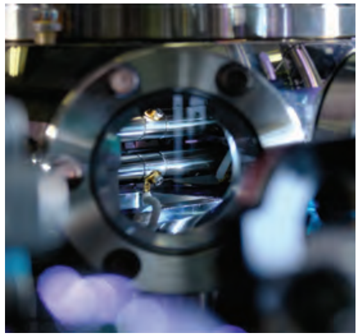
Masao Takamoto / Shoichi Okaba / Quentin d' Armagnac de Castanet / Shota Yo / Shinji Ito

Nuclear Laser Spectroscopy Research Unit

Unit Leader Atsushi Yamaguchi D. Sci.

Building an accurate clock via laser spectroscopy of atomic nuclei

Our daily lives, from smartphones to car navigation, rely heavily on accurate clocks. Currently, the most accurate are atomic clocks, which utilize the energy levels of electrons. Aiming for even higher accuracy, we are developing a nuclear clock that utilizes the energy levels of the atomic nucleus instead. Since the nucleus is highly immune to external noise, this clock is expected to surpass existing atomic clocks. Recently, we successfully trapped thorium ions—to be used in the nuclear clock—and developed laser spectroscopy techniques to precisely control their motion and internal states. We aim to apply nuclear clocks not only for frequency standards but also to unlock mysteries of the universe, such as searching for dark matter.



An ion trap apparatus for thorium ions used in nuclear clocks

▶ Fields

Interdisciplinary science and engineering, Physics, Engineering

▶ Keywords

Quantum electronics, Quantum metrology, Nuclear clock, Thorium-229, Ion trap

▶ Publications

1. Shigekawa, Y., Yamaguchi, A., Tokoi, K., Sato, N., Kikunaga, H., Shirasaki, K., Kasamatsu, Y., Wada, M., and Haba, H.: "Lifetime of the singly charged ^{229}Th nuclear isomer", ***Nat. Phys.*** 22, 832-837 (2026).
2. Hiraki, T., Okai, K., Bartokos, M., Beeks, K., Fujimoto, H., Fukunaga, Y., Haba, H., Kasamatsu, Y., Kitao, S., Leitner, A., Masuda, T., Guan, M., Nagasawa, N., Ogake, R., Pimon, M., Pressler, M., Sasao, N., Schaden, F., Schumm, T., Seto, M., Shigekawa, Y., Shimizu, K., Sikorsky, T., Tamasaku, K., Takatori, S., Watanabe, T., Yamaguchi, A., Yoda, Y., Yoshimi, A., and Yoshimura, K.: "Controlling ^{229}Th isomeric state population in a VUV transparent crystal", ***Nat. Commun.*** 15, 5536 (2024).
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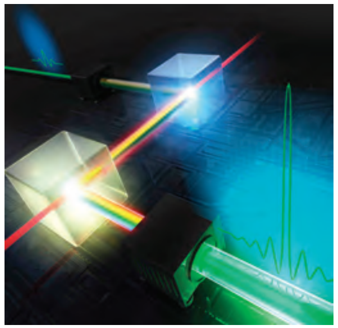
▶ Members

Extreme Photonics Research Team

Team Director Eiji J. Takahashi D. Eng.

Creating innovative optical pulses by exploiting the extreme nature of laser

Laser is highly controllable light, and by using various laser technologies, we can create optical pulses with arbitrary electric field shape, pulse duration, and beam shape. The main research goal of our laboratory is to extend the wavelength range of coherent light sources up to hard x-ray by using the extreme nature of laser light, such as ultra-short pulse duration, ultra-broadband wavelength, and ultra-high intensity. Through the development of novel laser technologies, we demonstrate extreme laser sources useful for strong field physics and push the frontiers of laser science.



Amplification of single-cycle laser pulses

▶ Fields

Interdisciplinary Science and Engineering, Engineering, Physics

▶ Keywords

High-power single-cycle laser, Attosecond laser, Thin-disk laser, Fiber laser, Strong-field physics

▶ Publications

1. Dong, D., Wang, H., Xue, B., Imasaka, K., Kanda, N., Fu, Y., Nabekawa, Y. and Takahashi, E. J.: "Perturbed three-channel waveform synthesizer for efficient isolated attosecond pulse generation and characterization", *Opt. Lett.* 50, 1461 (2025).
2. Nishimiya, K., and Takahashi E. J.: "Advances in dual-chirped optical parametric amplification", *Adv. Phys: X.* 10, 1 (2025).
3. Rajpoot, R., and Takahashi E. J.: "Systematic analysis of an attosecond pulse generation by a subcycle laser field", *Phys. Rev. Res.* 7, 013047 (2025).
4. Nishimiya, K., and Takahashi E. J.: "Octave-spanning supercontinuum coherent soft x-ray for producing a single-cycle soft x-ray pulse", *Opt. Lett.* 49, 5779 (2024).
5. Lu, X., and Takahashi, E.J.: "Dual-chirped optical parametric amplification of high-energy single-cycle laser pulses", *Nat. Photonics* 18, 99-106 (2024).

▶ Members

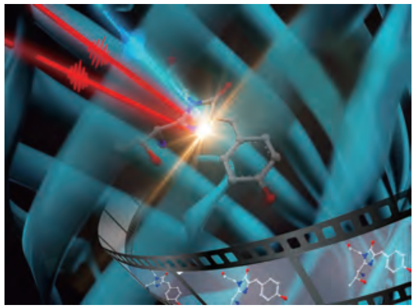
Yasuo Nabekawa / Natsuki Kanda / Lin Yu-Chieh / Dai Ikeda / Kaito Nishimiya / Kotaro Imasaka / Hiroki Kawase / Rambabu Rajpoot / Ahmed Ramadan Ibrahim / Dianhong Dong / Minshuang Xia / Yunpeng Liu

Ultrafast Spectroscopy Research Team

Team Director Tahei Tahara D.Sci.

Elucidating complex molecular dynamics with femtosecond light

Most of the phenomena in nature are realized by the dynamic behavior of molecules. Among them, chemical reactions are critically important, which dynamically cause the cleavage and formation of chemical bonds and alter the nuclear arrangement within the molecules. Even non-reactive molecules are vibrating, which provides rich information about the molecular properties. Because the timescale of such molecular motion is femtosecond (one quadrillionth of a second), femtosecond spectroscopy is essential for elucidating chemical phenomena. Our team investigates the dynamics of molecules from fundamental to complex systems, as well as the molecules in special environments such as interfaces. We extend the frontier of molecular science through the development and use of advanced spectroscopic methods.



Coherent nuclear motion of the chromophore of a protein in reaction

▶ Fields

Chemistry, Physics

▶ Keywords

Ultrafast spectroscopy, Nonlinear spectroscopy, Single molecule spectroscopy, Dynamics, Interface

▶ Publications

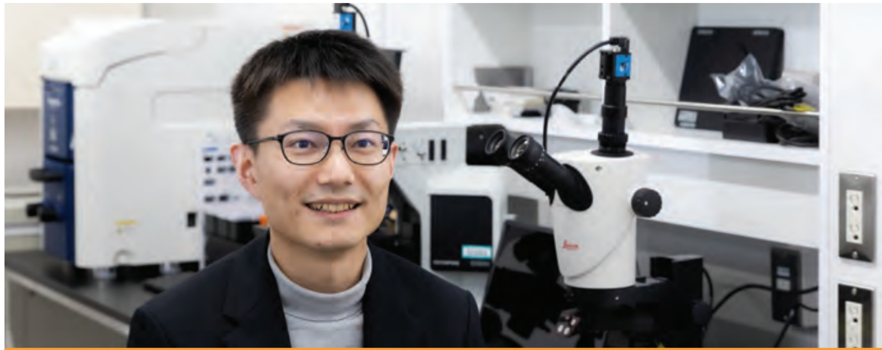
1. Liu, L., Kuramochi, H., Iwamura, M., Nozaki, K., and Tahara, T.: "Localization of the Au–Au bond strength in the triplet excited state of the $[Au(CN)_2^-]$ oligomers revealed by ultrafast time-domain Raman spectroscopy", *Chem. Sci.* 17, 2676 (2026).
2. Kuramochi, H., Tsutsumi, T., Saita, K., Wei, Z., Osawa, M., Kumar, P., Liu, L., Takeuchi, S., Taketsugu, T., and Tahara, T.: "Ultrafast Raman observation of the perpendicular intermediate phantom state of stilbene photoisomerization", *Nat. Chem.* 16, 22 (2024).
3. Sung, W., Inoue, K., Nihonyanagi, S., and Tahara, T.: "Unified picture of vibrational relaxation of OH stretch at the air/water interface", *Nat. Commun.* 15, 1258 (2024).
4. Chang, C., Kuramochi, M., Singh, M., Abe-Yoshizumi, R., Tsukuda, T., Kandori, H., and Tahara, T.: "A unified view on varied ultrafast dynamics of the primary process in microbial rhodopsins", *Angew. Chem. Int.* Ed. 61, e202111930 (2022).
5. Kusaka, R., Nihonyanagi, S., and Tahara, T.: "The photochemical reaction of phenol becomes ultrafast at the air–water interface", *Nat. Chem.* 13, 306 (2021).

▶ Members

Kunihiko Ishii / Korenobu Matsuzaki / Subhadip Roy

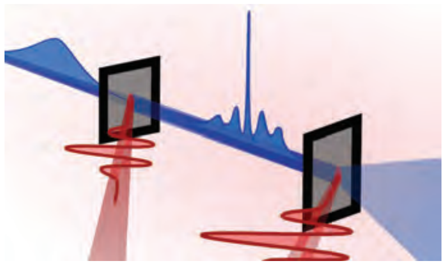
Ultrashort Electron Beam Science RIKEN Hakubi Research Team

RIKEN Hakubi Team Leader Yuya Morimoto Ph.D.



Space-time imaging of the initial steps of chemical reactions with ultrashort electron beams

Electron beams are used for examples in electron microscopy and electron-beam lithography, where high spatial resolution is required. By using state-of-the-art laser and electron-beam technologies, we control the temporal structure of an electron beam with ultimate attosecond resolution and apply the controlled electron beams for imaging and controlling ultrafast chemical reactions. We explore the atomic-scale dynamics of electrons in a material which is the initial step of most photochemical reactions.



Light-wave modulation of an electron beam

▶ Fields

Chemistry, Physics, Interdisciplinary Science and Engineering, Engineering

▶ Keywords

Ultrashort electron beam, Electron beam imaging, Nonlinear optics, Attosecond science, Atomic collisions

▶ Publications

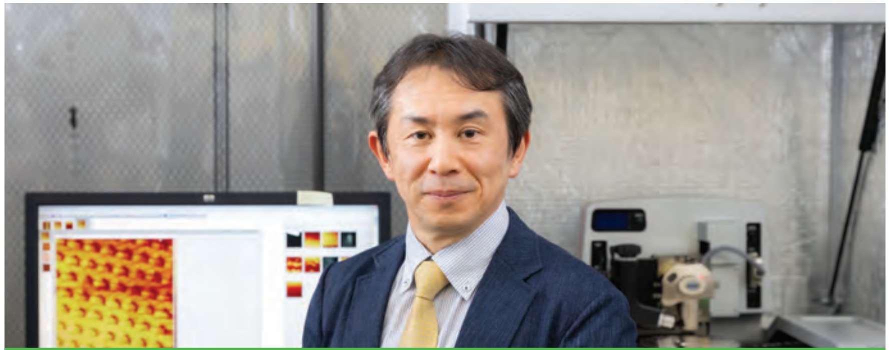
1. Morimoto, Y., Hommelhoff, P., and Madsen, L. B.: "Scattering-asymmetry control with ultrafast electron wave packet shaping", *New J. Phys.* 27 103201 (2025).
2. Morimoto, Y., and Baum, P.: "Field-induced rocking curve effects in attosecond electron diffraction", *Phys. Rev. Lett.* 132, 216902 (2024).
3. Morimoto, Y., and Madsen, L. B.: "Scattering of ultrashort electron wave packets: optical theorem, differential phase contrast and angular asymmetries", *New J. Phys.* 26, 053012 (2024).
4. Morimoto, Y.: "Attosecond electron-beam technology: a review of recent progress", *Microscopy* 72, 2-17 (2023).
5. Morimoto, Y., Shinohara, Y., Tani, M., Chen, B. H., Ishikawa, K. L., and Baum, P.: "Asymmetric single-cycle control of valence electron motion in polar chemical bonds", *Optica* 8, 382 (2021).

▶ Members

Yui Yamashita

Metaphotonics Research Team

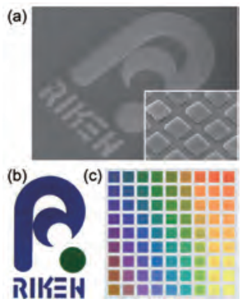
Team Director Takuo Tanaka D.Eng.



Lightwave manipulation by subwavelength structures

Our team conducts intensive research on novel photon manipulation technologies, building upon knowledge and experience gained from studies of light-wave interactions with nanometer scale fine structures. These photon manipulation technologies are intended for applications such as three-dimensional nanofabrication systems and ultra-sensitive molecular sensing devices.

Figure (a) shows a scanning electron microscope image of the RIKEN logo, composed of a nanometer scale aluminum structure that absorbs light at specific wavelengths determined by its size and shape. Figure (b) presents an optical image of the RIKEN logo under white light illumination. Figure (c) demonstrates a color palette exhibiting a wide gamut of colors.



Colors created by metamaterial absorber that consists of subwavelength aluminum structure.

▶ Fields

Engineering, Complex systems, Interdisciplinary Science and Engineering

▶ Keywords

Metamaterials, Plasmonics, Nanophotonics, Near-field Optics, Applied Optics

▶ Publications

1. Olaya, C. M., Hayazawa, N., Balgos, M. H., and Tanaka, T.: "Enhancing angular photonic spin Hall effect at surface plasmon resonance", Nanophotonics 14, 3115 (2025).
2. Balgos, M. H., Hayazawa, N., Tani, M., and Tanaka, T.: "Single pulse shaping for higher harmonic demodulation in terahertz time-domain spectroscopy", Appl. Phys. Lett. 125, 171104 (2024).
3. Liu, X., Zhao, Z., Xu, S., Zhang, J., Zhou, Y., He, Y., Yamaguchi, T., Ouyang, H., Tanaka, T., Chen, M. K., Shi, S., Qi, F., and Tsai, D. P.: "Meta-Lens Particle Image Velocimetry", Adv. Mater. 36, 2310134 (2023).
4. Tanaka, T., Yano, T., and Kato, R.: "Nanostructure-enhanced infrared spectroscopy", *Nanophotonics* 11, 2541-2561 (2022).
5. Jung, W., Jung, Y., Pikhitsa, P., Feng, J., Yang, Y., Kim, M., Tsai, H., Tanaka, T., Shin, J., Kim, K., Choi, H., Rho, J., and Choi, M.: "Three-dimensional nanoprinting via charged aerosol jets", *Nature* 592, 54 (2021).

▶ Members

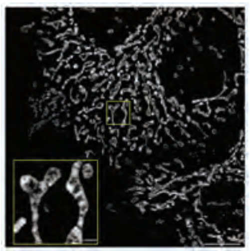
Norihiko Hayazawa / Daiki Kawasaki / Cherrie May Mogueis Olaya / Daigo Oue / Takeshi Yamaguchi

Biotechnological Optics Research Team

Team Director Atsushi Miyawaki M.D., Ph.D

Bioimaging Technologies by use of glowing proteins

We label a fluorescent probe on a specific region of a biological molecule and bring it back into a cell. We can then visualize how the biological molecule behaves in response to external stimulation. Since fluorescence is a physical phenomenon, we can extract various kinds of information by making full use of its characteristics. For example, the excited energy of a fluorescent molecule donor transfers to an acceptor relative to the distance and orientation between the two fluorophores. This phenomenon can be used to identify interaction between biological molecules or structural change in biological molecules. Besides, we can apply all other characteristics of fluorescence, such as polarization, quenching, photobleaching, photoconversion, and photochromism, in experimentation. Cruising inside cells in a super-micro corps, gliding down in a microtubule like a roller coaster, pushing our ways through a jungle of chromatin while hoisting a flag of nuclear localization signal --- we are reminded to retain a playful and adventurous perspective at all times. What matters is mobilizing all capabilities of science and giving full play to our imagination.



Visualization of mStayGold-harboring inner mitochondrial membranes by super-resolution microscopy (lattice structured illumination microscopy). Cells were scanned with a *z* step of 0.11μm over an axial range of 2.08μm. Scale bars, 10μm, 1μm (inset).

▶ Fields

Medicine, dentistry, and pharmacy, Engineering, Biological Sciences, Biology / Biochemistry

▶ Keywords

Bioimaging, Fluorescence protein, Chromophore

▶ Publications

1. Hirano, M., Yonemaru, Y., Shimozono, S., Sugiyama, M., Ando, R., Okada, Y., Fujiwara, T., and Miyawaki, A.: "StayGold photostability under different illumination modes", ***Sci. Rep.*** 14, 5541 (2024).
2. Ando, R., Shimozono, S., Ago, H., Takagi, M., Sugiyama, M., Kurokawa, H., Hirano, M., Niino, Y., Ueno, G., Ishidate, F., Fujiwara, T., Okada, Y., Yamamoto, M., and Miyawaki, A.: "StayGold variants for molecular fusion and membrane-targeting applications", ***Nat. Methods*** (2024).
3. Hirano, M., Ando, R., Shimozono, S., Sugiyama, M., Takeda, N., Kurokawa, H., Deguchi, R., Endo, K., Haga, K., Takai-Todaka, R., Inaura, S., Matsumura, Y., Hama, H., Okada, Y., Fujiwara, T., Morimoto, T., Katayama,K., and Miyawaki, A.: "A highly photostable and bright green fluorescent protein", ***Nat Biotechnol.*** 40, 1132-1142 (2022).
4. Michikawa, T., Yoshida, T., Kuroki, S., Ishikawa, T., Kakei, S., Kimizuka, R., Saito, A., Yokota, H., Shimizu, A., Itohara, S., and Miyawaki, A.: "Distributed sensory coding by cerebellar complex spikes in units of cortical segments", ***Cell Rep.***37 (6), 109966 (2021).
5. Katayama, H., Hama, H., Nagasawa, K., Kurokawa, H., Sugiyama, M., Ando, R., Funata, M., Yoshida, N., Homma, M., Nishimura, T., Takahashi, M., Ishida, Y., Hioki, H., Tsujihata, Y., and Miyawaki, A.: "Visualizing and Modulating Mitophagy for Therapeutic Studies of Neurodegeneration", ***Cell*** 181(5), 1176-1187 (2020).

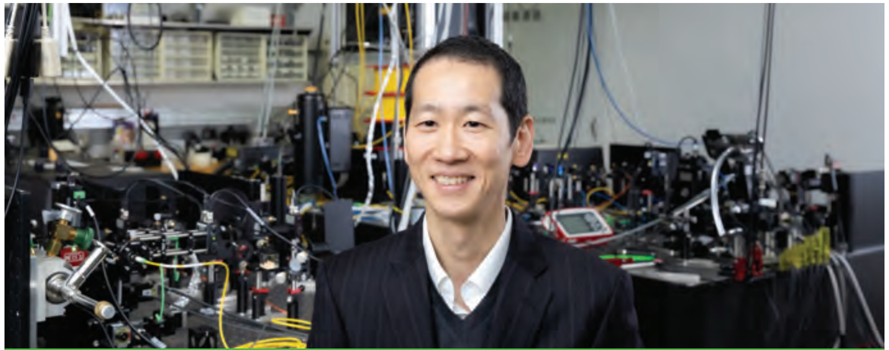
▶ Members

Asako Sakaue-Sawano / Masahiko Hirano / Asako Tosaki

Interdisciplinary Research Group

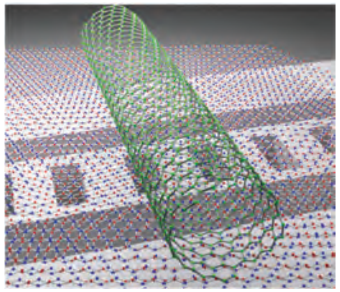
Quantum Optoelectronics Research Team

Team Director Yuichiro Kato Ph.D



Shaping light at the nanoscale edge for the quantum era

Optoelectronic devices harness the interactions between electrons and photons and are widely used in everyday applications, for example solar cells and light-emitting diodes. Continued advances in device fabrication techniques have enabled the integration of individual nanomaterials into device structures, providing opportunities to utilize the quantum nature of photons. Our research focuses on pioneering and engineering next-generation nanodevices that exploit the quantum properties of nanomaterials and enable control of light at the quantum level. By combining state-of-the-art nanofabrication and nanosynthesis techniques, we investigate devices capable of manipulating single photons in the telecommunication band as well as integrated photonics for quantum applications at room temperature.



carbon nanotube and two-dimensional material on photonic crystal nanobeam cavity

▶ Fields

Interdisciplinary Science and Engineering, Engineering, Physics, Chemistry

▶ Keywords

Carbon nanotubes, Two-dimensional materials, Photonic crystals, Nanoscale devices, Integrated photonics

▶ Publications

1. Fang, N., Chang, Y. R., Fujii, S., Yamashita, D., Maruyama, M., Gao, Y., Fong, C. F., Kozawa, D., Otsuka, K., Nagashio, K., Okada, S., and Kato, Y. K.: "Room-temperature quantum emission from interface excitons in mixed-dimensional heterostructures", ***Nat. Commun.*** 15, 2871 (2024).
2. Fang, N., Chang, Y. R., Yamashita, D., Fujii, S., Maruyama, M., Gao, Y., Fong, C. F., Otsuka, K., Nagashio, K., Okada, S., and Kato, Y. K.: "Resonant exciton transfer in mixed-dimensional heterostructures for overcoming dimensional restrictions in optical processes", ***Nat. Commun.*** 14, 8152 (2023).
3. Kozawa, D., Wu, X., Ishii, A., Fortner, J., Otsuka, K., Xiang, R., Inoue, T., Maruyama, S., Wang, Y., and Kato, Y. K.: "Formation of organic color centers in air-suspended carbon nanotubes using vapor-phase reaction", ***Nat. Commun.*** 13, 2814 (2022).
4. Otsuka, K., Fang, N., Yamashita, D., Taniguchi, T., Watanabe, K., and Kato, Y. K.: "Deterministic transfer of optical-quality carbon nanotubes for atomically defined technology", ***Nat. Commun.*** 12, 3138 (2021).
5. Ishii, A., Machiya, H., and Kato, Y. K.: "High efficiency dark-to-bright exciton conversion in carbon nanotubes", ***Phys. Rev. X*** 9, 041048 (2019).

▶ Members

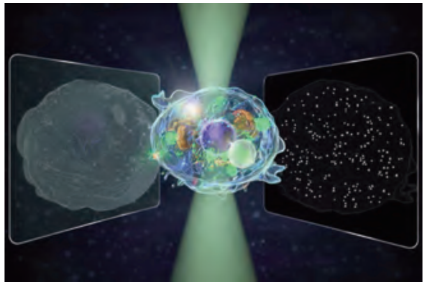
Clement Deleau / Natthajuks Pholsen / Christian Simo / Ufuk Erkilic / Hiroyuki Nishidome /

Optical Life Metrology Research Team

Team Director Takuro Ideguchi Dr. rer. nat.

Optical Life Metrology
Enabled by Advanced Laser Technologies

Microscopic observation of biological specimens such as cells and tissues is a fundamental technique in life sciences. We develop advanced laser-based, label-free quantitative imaging methods that enable visualization of molecular and structural information without staining. Our research includes vibrational microscopy for quantitative chemical analysis and high-sensitivity scattering microscopy for spatiotemporal characterization of microstructures and nanoparticles. Using these original technologies, we also investigate biophysical phenomena such as intracellular thermal dynamics. Through these efforts, we aim to pioneer Optical Life Metrology—an interdisciplinary field bridging photonics and the life sciences.



Conceptual illustration of bidirectional scattering microscope

▶ Fields

Interdisciplinary science and engineering, Physics, Biology / Biochemistry, Engineering

▶ Keywords

Laser, Spectroscopy, Microscopy, Biophotonics, Bioimaging

▶ Publications

1. Horie, K., Toda, K., Nakamura, T., and Ideguchi, T.: "Bidirectional quantitative scattering microscopy" , ***Nat. Commun.*** 16, 9712 (2025).
2. Toda, K., and Ideguchi, T.: "Ludwig-Soret microscopy with the vibrational photothermal effect" , ***PNAS.*** 122, e2510703122 (2025).
3. Tamamitsu, M., Toda, K., Fukushima, M., Badarla, V. R., Shimada, H., Ota, S., Konishi, K., and Ideguchi, T.: "Mid-infrared wide-field nanoscopy" , ***Nat. Photonics.*** 18, 738-743 (2024).
4. Hashimoto, K., Nakamura, T., Kageyama, T., Badarla, V. R., Shimada, H., Horisaki, R., and Ideguchi, T.: "Upconversion time-stretch infrared spectroscopy" , ***Light. Sci. Appl.*** 12, 48 (2023).
5. Hashimoto, K., Badarla, V. R., Kawai, A., and Ideguchi, T.: "Complementary Vibrational Spectroscopy" , ***Nat. Commun.*** 10, 4411 (2019).

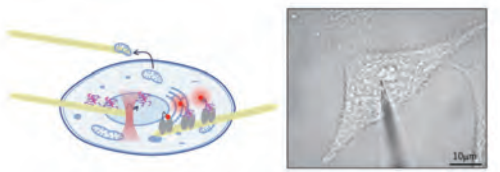
▶ Members

Nano-Photochemistry Research Unit

Unit Leader Tomoko Inose Ph.D.

Single live-cell manipulation
using photoresponsive nanomaterials

In our unit, we aim to establish novel nano-optical technologies that realize molecular-level manipulation of functions of single live cell, based on the nanowire-based single live-cell endoscopy technique. In particular, by integrating photoresponsive nanomaterials such as plasmonic nanowires with a wide range of photoresponsive organic and inorganic molecules, we try to achieve precise control of localized photochemical reactions at the nanometer scale. By applying this approach to a single live cell, we aim to selectively induce various photochemical reactions at an arbitrary intracellular location. This will provide precise control over biological phenomena that have remained inaccessible so far, ultimately leading to a deeper understanding of cellular functions at the molecular level.



Localized photochemical reactions within a single live cell using nanowire technology.

▶ Fields

Interdisciplinary science and engineering, Chemistry, Materials Sciences, Molecular Biology / Genetics

▶ Keywords

Plasmonics, Photochemistry, Nanoprobe, Nanophotonics, Single-cell manipulation

▶ Publications

1. Yoshimura, M., Sasayama, R., Kajiwara, T., Mori, C., Nakasone, Y., Inose, T.: "Remote Silyl Groups Enhance Hydrolytic Stability and Photocleavage Efficiency in Carbamates for Protein Release" , ***Angew. Chem. Int. Ed.***, e202502376 (2025).
2. Yoshimura, M., and Inose, T.: "Photocleavable Systems for Cell Biology: Conceptual Design across Molecular Modalities" ***ChemBioChem,*** e202500564 (2025).
3. Inose, T., Toyouchi, S., Hara, S., Sugioka, S., Walke, P., Oyabu, R., Fortuni, B., Peeters, W., Usami, Y., Hirai, K., De Feyter, S., Uji-i, H., Fujita, Y., Tanaka, H.: "Visualizing Ribbon-to-Ribbon Heterogeneity of Chemically Unzipped Wide Graphene Nanoribbons by Silver Nanowire-Based Tip-Enhanced Raman Scattering Microscopy" , ***Small,*** 2301841 (2023).
4. Fortuni, B., Ricci, M., Vitale, R., Inose, T., Zhang, Q., Hutchison, J., Hirai, K., Fujita, Y., Toyouchi, S., Krzyzowska, S., Van Zundert, I., Rocha, S., Uji-i, H.: "SERS Endoscopy for Monitoring Intracellular Drug Dynamics" , ***ACS Sens.***, 8, 2340-2347 (2023).
5. Zhang, Q., Inose, T., Ricci, M., Li, J., Tian, Y., Wen, H., Toyouchi, S., Fron, E., Thi Ngoc Dao, A., Kasai, H., Rocha, S., Hirai, K., Fortuni, B., Uji-i, H.: "Gold-Photodeposited Silver Nanowire Endoscopy for Cytosolic and Nuclear pH Sensing" , ***ACS Appl. Nano Mater.***, 4, 9886-9894 (2021).

▶ Members

Image Processing Research Team

Team Director Hideo Yokota D.Eng.

Image processing research for scientific information

Our goal is to develop RIKEN's unique data processing and multidimensional imaging technologies for the advancement of science and technology. We focus on contributing to the fields of precision engineering, mathematical biology, biomedical simulation, quantification of biological phenomena, and computer-aided diagnosis by developing new image processing tools and new imaging devices for researchers both inside and outside RIKEN.

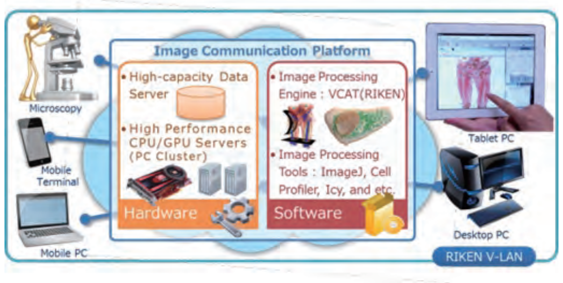


Image Processing Cloud

▶ Fields

Engineering, Informatics, Computer Science

▶ Keywords

Multi dimensional image processing, Multi dimensional imaging, Bioengineering, Image analysis, Medical engineering

▶ Publications

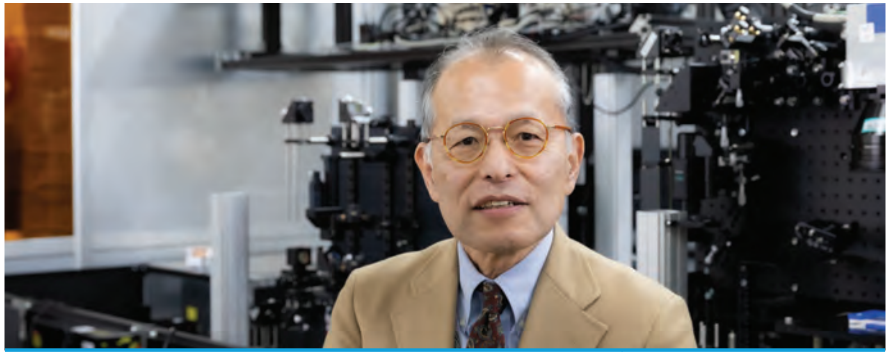
1. Yoshizawa, S., and Yokota, H.: "Fast and high-quality scale-aware filtering for 3D images", ***The. Visual. Comput.*** 42, 82:1-82:18 (2025); "Correction", 42: 144 (2026).
2. Yamashita, N., Koyanagi, Y., Takemura, H., Kasuya, T., Inoue, J., and Yokota, H.: "Large-scale 3D observation of microstructure around heat-affected zone using 3D internal structure microscopy", ***Precis. Eng.*** 97, 609-623 (2026).
3. Uehara, T., Takiguchi, A., Tojima, T., Nakano, A., Kagawa, S., Nehira, T., Satoh, T., and Satoh, A. K.: "Biotin methyl ester enhances cargo release in RUSH system and enables rapid biotinylation with TurboID", ***Commun. Biol.*** 8, 1767 (2025).
4. Yamashita, N., Morita, M., Yokota, H., and Mimori-Kiyosue, Y.: "Spatial Statistics of Three-Dimensional Growth Dynamics of Spindle Microtubules", ***The Mitotic Spindle. Methods. Mol. Biol.*** 2872, 51-72 (2025).
5. Han, S., Sun, Z., Michikawa, T., Caiafa, C., Sole-Casals, J., and Yokota, H.: "Enhanced Scene-Specific Saliency Prediction Incorporating Scene Information", ***Cognit. Comput.*** 17, 155-174 (2025).

▶ Members

Shin Yoshizawa / Satoshi Oota / Kenji Yamazawa / Shigeho Noda / Takashi Michikawa / Takuro Tojima / Satoko Takemoto / Shinichi Goto / Hidekazu Takahashi / Sakiko Nakamura / Yuki Tsujimura / Masaomi Nishimura / Ryo Nonogaki / Hideo Hirukawa / Daisuke Miyashiro

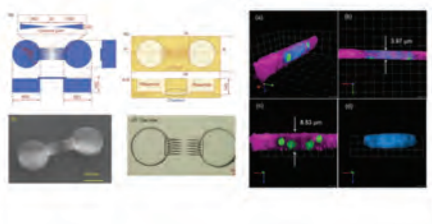
Advanced Laser Processing Research Team

Team Director Koji Sugioka D.Eng.



Femtosecond Laser 3D Processing: Fabrication of Highly Functional Micro/Nanosystems

Our research team is developing advanced laser processing techniques which realize low environmental load, high quality, high efficiency fabrication of materials. In particular, by using femtosecond lasers, novel material processing techniques including 3D fabrication, surface nanostructuring, novel nanomaterial synthesis, and tailored beam processing are developed, which are applied to fabricate highly functional micro/nanodevices. As one of examples, our team has developed a technique that can fabricate 3D micro/nanofluidic chips using CYTOP as substrates by combining two-photon polymerization and molding process. CYTOP is an amorphous fluoropolymer with excellent transmittance over a wide range of wavelengths and the almost same refractive index as water. By taking advantage of these properties, we successfully demonstrated super-resolution live imaging of the behavior of cancer cells migrating in microchannels. The CYTOP biochips produced by the developed technique can be used for various biological studies and are expected to provide new knowledge.



(Left) Structural drawing and optical micrograph of a 3D CYTOP microfluidic chip.
(Right) Multicolor 3D super-resolution imaging of cancer cells migrating in a CYTOP microfluidic channel.

▶ Fields

Engineering, Materials Sciences, Interdisciplinary science and engineering, Multidisciplinary

▶ Keywords

Femtosecond laser, Laser processing, Micro/nanofabrication, 3D fabrication, Biochip

▶ Publications

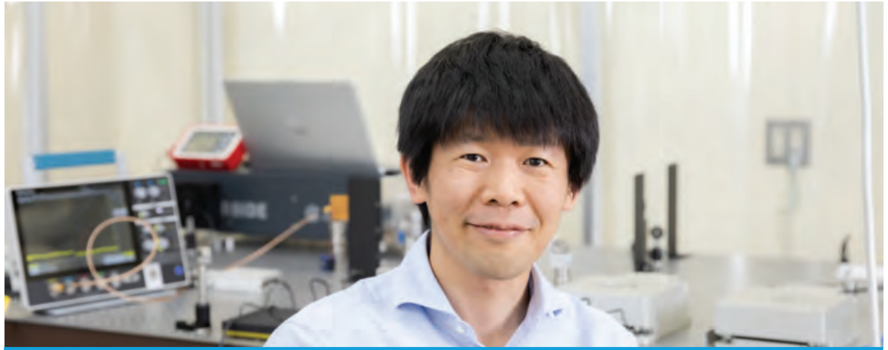
1. Sugioka, K., Hanzawa, M., Obata, K., Matsumoto, S., Takagi. M., Sakaue-Sawano, A., Tosaki, A., Shimozono, S., Sima, F., Kawano, H., Tojima, T., Miyashiro, D., Ozasa, K., Hanada, Y., Miyaji, G., Nakano, A., and Miyawaki, A.: "Femtosecond-laser-fabricated 3D CYTOP microfluidic chips enabling super-resolution live imaging of cell behavior in confined microspaces", ***Adv. Mater. Technol.*** 11, e01883 (2026).
2. Zhang, J., Obata, K., Ozasa, K., Uzawa, T., Ito, Y., and Sugioka, K.: "Rapid manufacturing of glass-based digital nucleic acid amplification chips by ultrafast Bessel pulses", ***Small Sci.*** 4, 2300166 (2024).
3. Kawabata, S., Bai, S., Obata, K., Miyaji, G., and Sugioka, K.: "Two-dimensional laser-induced periodic surface structures formed on crystalline silicon by GHz burst mode femtosecond laser pulses", ***Int. J. Extreme Manuf.*** 5, 015004 (2023).
4. Bai, S., Serien, D., Hu, A., and Sugioka, K.: "Three-dimensional microfluidic SERS chips fabricated by all-femtosecond-laser-processing for real-time sensing of toxic substances", ***Adv. Funct. Mater.*** 28, 1706262 (2018).
5. Wu, D., Xu, J., Niu, L., Wu, S., Midorikawa, K., and Sugioka, K.: "In-channel integration of designable microoptical devices using flat scaffold-supported femtosecond-laser microfabrication for coupling-free optofluidic cell counting", ***Light Sci. Appl.*** 4, e228 (2014).

▶ Members

Ashkan MomeniBidzard / Kun Fang / Ryohei Nagata / Wilder Rodrigues / Shota Kawabata

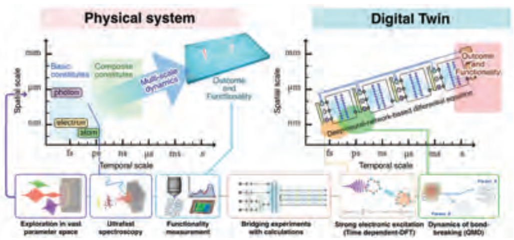
Digital Twin for Light-Matter Interaction RIKEN ECL Research Team

RIKEN ECL Team Leader Shuntaro Tani Ph.D.



Constructing Digital Twin for Multi-Scale Phenomena Driven by Photo-Excitation

With the advancement of laser technology, we can now apply laser fields onto materials, the strength of which is comparable to the interatomic bonds of the materials themselves. These strong and controllable light electric fields are expected to be utilized in precise laser processing and various forms of material state control. However, the physics underlying irreversible processes, such as the fragmentation of a continuous solid into discrete atoms, remains not fully understood. At present, extensive trial and error is necessary to control these processes. In this research project, we aim to develop a method to extract the 'context' of phenomena by extensively observing microscopic processes beginning with photoexcitation, through the complete automation of experiments. Utilizing this technique, we intend to elucidate the governing equations of materials' irreversible transformation and construct a digital twin for optimizing these processes.



Digital twin of laser processing

▶ Fields

Interdisciplinary science and engineering, Physics, Engineering

▶ Keywords

Precision laser processing, Ultrafast spectroscopy, Deep learning, Digital Twin, Autonomous experiment

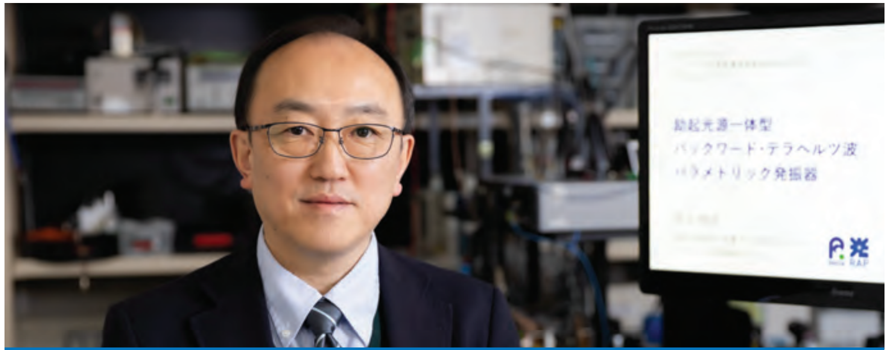
▶ Publications

1. Ozaki, F., Tani, S., Tanaka, S., Choi, YH., Mukai, K., Osada, W., Horio, M., Koitaya, T., Yamamoto, S., Matsuda, I., Ozaki, T., Kawamura, M., Fukuda, M., Kobayashi, Y., and Yoshinobu, J.: "Selective Observation of Edge-specific Electronic States and Chemical Reactivity of Laser-cut MoS_2 Surfaces", *J. Phys. Chem.* C 129, 19380 (2025).
2. Tani, S., and Kobayashi, Y.: "Pulse-by-pulse evolution of surface morphology driven by femtosecond laser pulses", *J. Appl. Phys.* 133, 143104 (2023).
3. Shimahara, K., Tani, S., Sakurai, H., and Kobayashi, Y.: "A deep learning-based predictive simulator for the optimization of ultrashort pulse laser drilling", *Commun. Eng.* 2, 1 (2023).
4. Tani, S., Sugiyama, K., Sukegawa, T., Sato, T., Ishizuka, Y., Taya, S., Feng, F., Komeda, O., Suto, H., Saitoh, H., and Kobayashi, Y.: "Real-time high-spectral-resolution mid-infrared spectroscopy with a signal-to-noise ratio of ten thousand", *Opt. Express* 30, 36813 (2022).
5. Tani, S., and Kobayashi, Y.: "Ultrafast laser ablation simulator using deep neural networks", *Sci. Rep.* 12, 5837 (2022).

▶ Members

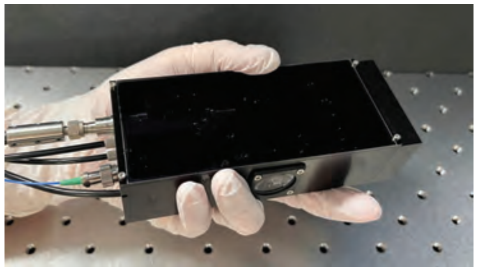
Tera-Photonics Research Team

Team Director Hiroaki Minamide D.Eng.



Shaping the future with advanced terahertz-wave nonlinear photonics

Our team is advancing innovative research in terahertz (THz)-wave nonlinear photonics. We have achieved world-leading results, including kilowatt-level THz-wave generation, attojoule-level THz-wave detection, and backward THz-wave parametric oscillation. Moving forward, we aim to develop Terahertz-System on a Chip (T-SoC) technology. We are focusing on next-generation sensing technologies such as coherent detection and quantum interference with non-classical light to drive future innovations. By strengthening collaborations with universities and industries worldwide, we are expanding our international network and fostering young researchers, with a goal to promote THz-wave technologies and technological advancements globally.



Palm-sized backward THz-wave parametric oscillator

▶ Fields

Engineering,
Interdisciplinary science and engineering

▶ Keywords

Advanced Nonlinear Photonics,
Backward THz-wave parametric oscillation,
THz-System on a Chip (T-SoC),
Next-Generation Sensing Technologies,
THz quantum research

▶ Publications

1. Muldera, J., Takida, Y., De Los Reyes, A., Nawata, K., and Minamide, H.: "Backward terahertz-wave parametric oscillation in periodically poled stoichiometric lithium tantalate", *Opt. Lett.* 50(23), 7324 (2025).
2. Notake, T., Nawata, K., Takida, Y., Yadav, D., and Minamide, H.: "Room-temperature ultrasensitive photon-level detection in the subterahertz frequency regime", *Sci. Rep.* 15(1), 37106 (2025).
3. De Los Reyes, A., Muldera, J., Takida, Y., Kajikawa, K., Yadav, D., Xu, Y., Sato, M., Otani, C., and Minamide, H.: "Swept-source optical coherence tomography based on a backward terahertz-wave parametric oscillator achieving depth super-resolution", *Opt. Express* 33(19), 40739 (2025).
4. 瀧田佑馬, 南出泰亜.: "はじめてのテラヘルツ波非破壊計測", 精密工学会誌 91(9), 895-898, (2025).
5. Muldera, J., Nawata, K., Takida, Y., De Los Reyes, A., Yadav, D., and Minamide, H.: "Octave-Spanning Continuously Tunable Injection-Seeded Backward Terahertz-Wave Parametric Oscillator", Opt. Express 33(10), 22049-22061, (2025). is featured in the August 2025 issue of "Spotlight on Optics", highlighting articles from the Optica Publishing Group journals. (2025).

▶ Members

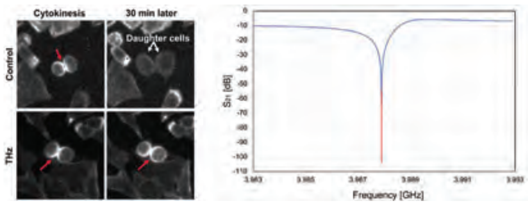
Yuma Takida / Alexander De Los Reyes / Yuto Yoneda

Terahertz Sensing and Imaging Research Team

Team Director Chiko Otani D.Sci.

Terahertz Sensing, Imaging and Applications

Terahertz (THz) wave has the unique characteristics such as the transparency to many soft materials and their spectral absorption features. These characteristics can be utilized for many applications in various scientific and industrial fields. In this team, we are developing novel technologies, science and applications in THz sensing, imaging, and detection. In particular, we are conducting research and development on the control of molecular structure and function by THz-wave irradiation, high-sensitivity imaging and observations using superconducting detectors as well as the collaborative research and development with companies.



(Left) Inhibition of cell division by actin protein fibrillation in cells by terahertz-wave irradiation (microscopic image).
(Right) VNA spectrum of a thin-film superconducting microwave resonator with a high quality factor (Q_i~10^5).

▶ Fields

Engineering, Space Science, Molecular Biology / Genetics, Physics, Agricultural Sciences, Chemistry, Interdisciplinary science and engineering

▶ Keywords

Terahertz wave, Spectroscopy and Imaging, Sensing, Structural and Functional control of biological tissues, Superconducting detector

▶ Publications

1. Hernández-Cabrera, J. F., De Miguel, J., Hernández-Suárez, E., Joven, E., Otani, C., Rubiño-Martín, J. A., and Zioutas, K.: "Echo-free quality factor of a multilayer axion haloscope", *Phys. Rev. D.* 110(7), 072013 (2024).
2. Kamei, Y., Ishidoshiro, K., Ito, R., Kobayashi, T., Mima, S., Nakajo, Y., Otani, C., and Taino, T.: "Development of Kinetic Inductance Detector on ZrO_2 Substrate for Double-Beta Decay Search", *J. Low Temp. Phys.* 217, 481-490 (2024).
3. Sueno, Y., Baselmans, J. J. A., Coppens, A. H. M., Génova-Santos, R. T., Hattori, M., Honda, S., Karatsu, K., Kutsuma, H., Lee, K., Nagasaki, T., Oguri, S., Otani, C., Peel, M., Suzuki, J., Tajima, O., Tanaka, T., Tsujii, M., Thoen, D. J., and Won, E.: "Pointing Calibration of GroundBIRD Telescope Using Moon Observation Data", *Prog. Theor. Exp. Phys.* 2024, 023F01 (2024).
4. Ikari, T., Sasaki, Y., and Otani, C.: "275-305 GHz FM-CW radar 3D imaging for walk-through security body scanner", *Photonics*. 10(3), 343 (2023).
5. Yamazaki, S., Ueno, Y., Hosoki, R., Saito, T., Idehara, T., Yamaguchi, Y., Otani, C., Ogawa, Y., Harata, M., and Hoshina, H.: "THz irradiation inhibits cell division by affecting actin dynamics", *PLOS One*. 16, e0248381 (2021).

▶ Members

Hiromichi Hoshina / Yoshiaki Sasaki / Shusaku Nakajima / Yuto Kamei / Shinsuke Uno

Terahertz and Infrared Quantum Photonics Research Team

Team Director Koichiro Tanaka D.Sci.

Pioneering Quantum Material Science with Terahertz and Infrared Quantum Light Sources

We explore the mysteries of the microscopic realm where matter and light intersect by developing next-generation quantum light sources that redefine the boundaries of terahertz and infrared spectroscopy.

At the heart of our research is the convergence of proprietary light source technologies and innovative measurement methodologies. In particular, we pursue the "optical manipulation of matter" by utilizing ultra-precisely controlled terahertz waves to govern the quantum states of matter on nano- and picosecond timescales. Simultaneously, by employing "non-classical light"—characterized by its quantum mechanical correlations—as a novel diagnostic "eye," we establish transformative nonlinear spectroscopy and imaging techniques that unveil the hidden depths of matter beyond the reach of conventional methods.

The light we generate serves as a cornerstone for the future of science and technology, ranging from fundamental inquiries into the origins of the universe and the essence of matter to practical applications such as frequency standards surpassing GPS for telecommunications and advanced bio-imaging to visualize the phenomena of life.

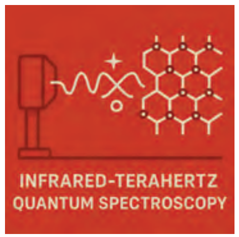


Illustration of THz and Infrared Quantum Photonics

▶ Fields

Physics, Engineering, Interdisciplinary science and engineering

▶ Keywords

Solid state spectroscopy, Ultrafast Phenomena, Terahertz Science and technology, Quantum Spectroscopy, Bioimaging

▶ Publications

1. Eguchi, K., Arikawa, T., Ito, H., and Tanaka, K.: "Lamb-dip spectroscopy of rotational levels with photomixing terahertz emitter", *Opt. Express* 33, 29442-29455 (2025).
2. Nakano, A., Uchida, K., Tomioka, Y., Takaya, M., Okimoto, Y., and Tanaka, K.: "Dominant role of charge ordering on high harmonic generation in $Pr_{0.6}Ca_{0.4}MnO_3$", *Phys. Rev. Res.* 6, L042032(2024).
3. Uchida, K., and Tanaka, K.: "High harmonic Mach–Zehnder interferometer for probing sub-laser-cycle electron dynamics in solids", *Optica* 11, 1130-1137 (2024).
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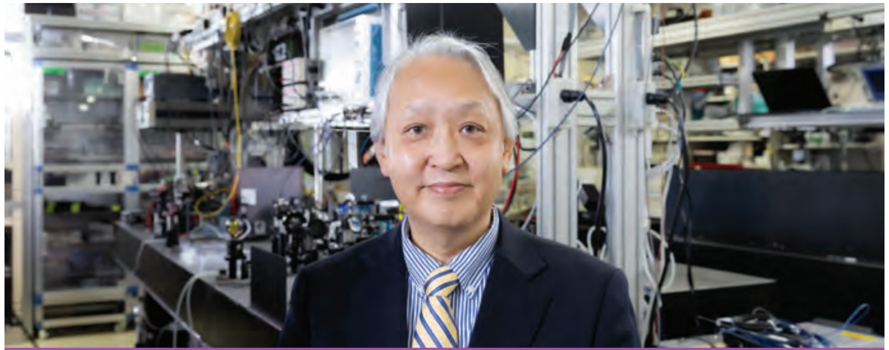
▶ Members

Keisuke Isobe / Tomoki Hiraoka / Henrik Boedker Lassen

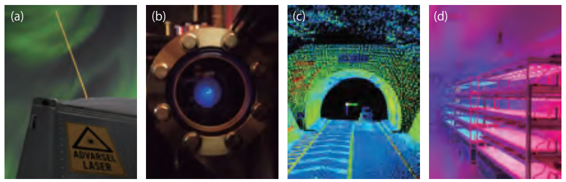
Photonics Control Technology Team

Team Director Satoshi Wada Ph.D.



Development of photonics control technology for science and social issues

Our team leverages advanced photonic technologies to tackle global challenges such as agriculture, aging societies, energy resource management, and environmental change, while also contributing to breakthroughs in fundamental science. We develop optical remote sensing systems for detecting gases in daily life and industry, atmospheric monitoring tools for analyzing cosmic ray and solar activity indicators, breath analysis techniques for health diagnostics, short-range LiDAR for tunnel degradation detection, and hydrogen-based renewable energy systems. In fundamental science, we are advancing high-power coherent Lyman-alpha light sources for ultra-slow muon generation in particle physics, as well as laser-based solutions for space debris removal and spaceborne sensing. These efforts are rooted in core research on photonic materials and optical control. We focus especially on tunable infrared light sources based on nonlinear wavelength conversion for quantum sensing.



(a) Sodium LiDAR
(b) Coherent Lyman-α resonance radiation source for ultra-slow muon generation
(c) Laser inspection of infrastructure by courtesy of Shizuoka Pref. and Topcon Corp.
(d) Application of photonics control technology to plant cultivation

▶ Fields

Engineering, Physics, Biology / Biochemistry, Agricultural Sciences, Medicine, dentistry, and pharmacy

▶ Keywords

Particle control and measurement, Medical and agricultural measurement, Trace gas measurement, Natural energy, Space applications

▶ Publications

1. Lim, T., Ooka, H., Yu, Y., Murakami, T., Wada, S., and Nakamura, R.: "Hydration entropy of cations regulates chloride ion diffusion during electrochemical chlorine evolution", ***Nat. Chem*** 18,552-560 (2026).
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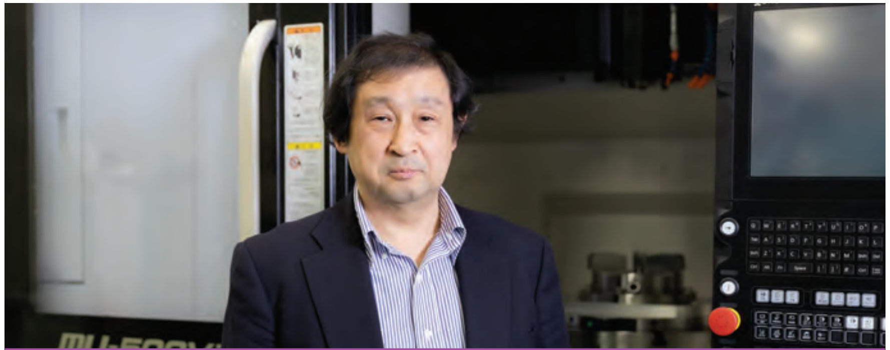
3. Nakamura, Y., Kikuchi, K., Sekine, G., Isomura, A., Sasoh, A., Wada, S., Tsuno, K., Ogawa, T., and Fukushima, T.: "Thrust performance of pulsed-laser ablation impulses for wavelengths of 1064 nm and 532 nm", ***Acta Astronaut.*** 232, 557-563 (2025).
4. Kurose, N., Obata, K., Nomura, S., Ogawa, T., Wada, S., Sugioka, K., and Aoyagi, Y.: "Formation of two-dimensional multichannel vertical optical waveguides in a nitrogen-vacancy center diamond using a femtosecond Bessel beam laser for local quantum sensing", ***Appl. Phys. Lett.*** 126, 161102 (2025).
5. Nara, M., Fujii, K., Matsui, D., Ogura, A., Murakami, T., Ogawa, T., Ito, S., Cheng, C. D., Scholes, C. A., Wada, S.: "Evaluating Cation-Exchange Membrane Properties Affecting Polymer Electrolyte Membrane Water Electrolysis", ***ACS Omega,*** 10, 10425-10431 (2025).

▶ Members

Norihito Saito / Kiwamu Kase / Tomoki Matsuyama / Takafumi Sassa / Shigeharu Moriya / Yutaka Nagata / Takayo Ogawa / Katsushi Fujii / Kentaro Miyata / Masato Otagiri /Takeharu Murakami / Tatsuya Shinozaki / Kentaro Nishigori / Hiroshi Kasuga / Yasuhiro Maeda / Akihiro Tanabashi / Tomohiro Tsukihana / Kei Morishita / Yoko Ono / Takeshi Matsumoto / Miyuki Nara

Ultrahigh Precision Optics Technology Team

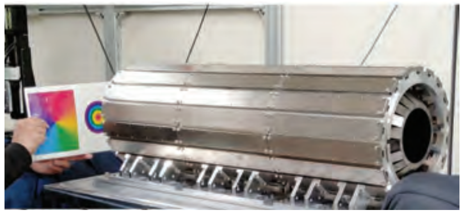
Team Director Yutaka Yamagata D.Eng.



Developing advanced optical components by ultrahigh precision technology

Our team develops advanced ultrahigh-precision/micro fabrication technologies and their application to scientific apparatuses and devices to support advanced scientific research at RIKEN. Research and development plans of our team include the following three topics; (1) Development of ultrahigh-precision optics including design, fabrication, metrology and computational simulation; (2) Development of ultrahigh-precision/micro fabrication technologies; (3) Development of materials and devices for biology or biochemistry such as microfluidic immunoassay devices.

In all R&D topics, our team collaborates with laboratories inside and outside of RIKEN and helps them to construct the most advanced experimental apparatuses, which will lead to innovative scientific research results.



A fully revolutional metallic neutron focusing ellipsoid mirror

▶ Fields

Engineering, Interdisciplinary science and engineering

▶ Keywords

Ultrahigh Precision Machining, Ultrahigh Precision Metrology, Aspherical Optics, Production Technology, Neutron Optics

▶ Publications

1. Wei, Y., Takeda, M., Hosobata, T., Yamagata, Y., and Morita, S.: "Mid-spatial-frequency waviness in ultra-precision machining: Real-time trajectory analysis of three machine tools", ***Precis Eng.*** 99, 37 (2025).
2. Kawasaki, Y., Iwaguchi, S., Ishikawa, T., Nishizawa, A., Kitaguchi, M., Yamagata, Y., Chen, Y., Wu, B., Shimizu, R., Umemura, K., Tsuji, K., Shimizu, H., Michimura, Y., Kobayashi, K., Onishi, T., and Kawamura, S.: "Sagnac-type neutron displacement-noise-free interferometeric gravitational-wave detector", ***Class. Quantum Gravity*** 41(11), 115001 (2024).
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5. Iwaguchi, S., Nishizawa, A., Chen, Y., Kawasaki, Y., Ishikawa, T., Kitaguchi, M., Yamagata, Y., Wu, B., Shimizu, R., Umemura, K., Tsuji, K., Shimizu, H., Michimura, Y., and Kawamura, S.: "Displacement-noise-free interferometeric gravitational-wave detector using unidirectional neutrons with four speeds". ***Phys. Lett. A*** 458, 128581 (2023).

▶ Members

Koichiro Shirota / Yoshiyuki Takizawa / Tetsuya Aoyama / Noboru Ebizuka / Hiroyoshi Aoki / Takuya Hosobata / Hiromi Okada / Kai Sakurai / Masahiro Takeda

Neutron Frontier Research Team

Team Director Takehiko Saito Ph.D.

Frontiers of Fundamental and Applied Science with Neutron Beams

Building on RIKEN's prior efforts in advancing non-destructive inspection techniques for large-scale structures (e.g., infrastructure) using neutron beams, this program will promote research utilizing neutrons across a wide range of fields, including materials science (semiconductors, energy storage materials and structures), biology and medicine, space science, novel material creation, and fundamental physics. Furthermore, in addition to developing neutron sources and detectors that support these studies, we will also pursue the creation of new experimental methodologies and data analysis techniques.

RANS, a compact accelerator-driven neutron source
and one of the core research facilities of the Neutron Frontier Research Team.
Leveraging three compact accelerator-driven neutron sources—RANS, RANS-II,
and RANS-III—the team conducts frontier research in neutron science and its applications.

▶ Fields

Physics, Engineering, Space Science, Multidisciplinary

▶ Keywords

Neutron beam, Applied science, Fundamental science, Material science, Radiation hardness

▶ Publications

1. Okuno, Y., Kamikawa, Y., Imaizumi, M., Okamoto, T., Kobayashi, T., Makino, T., Ryuta, K., Jimba, Y., Usui, K., Gotoh, Y., Akiyoshi, M., Sato, N., Nakamura, T., and Otake, Y.: "Gamma ray ionizing dosimeter with a high radiation resistant CIGS solar cell", ***J. Appl. Phys.*** 65, 041003 (2026).
2. Koizumi, S., Noda, Y., Izunome, H., Otake, Y., Kobayashi, T., Fujita K., and Iwamoto, C.: "Time-of-flight small-angle neutron scattering instrument ib-SAS at the compact accelerator-based neutron source RANS", ***J. Appl. Cryst.*** 58, 2066-2077 (2025).
3. He, Y., Saito, R. T., Ekawa, H., Kasagi, A., Gao, Y., Liu, E., Nakazawa, K., Rappold, C., Taki, M., Tanaka, K. Y., Wang, H., Yanai, A., Yoshida, J., and Zhang, H.: "Artificial intelligence pioneers the double-strangeness factory", ***Nat. Commum.*** 16, 11084 (2025).
4. Muneem, A., Yoshida, J., Saito, R. T., Ekawa, H., Hino, M., Hirota, K., Ichikawa, G., Kasagi, A., Kitaguchi, M., Mishima, K., Nabi, J., and Nakagawa, M.: "Advancing neutron imaging techniques to highest resolution with fluorescent nuclear track detectors", ***Sci. Rep.*** 15, 2103-1-11 (2025).
5. Kusano, H., Nagaoka, H., Enoto, T., Yamashita, N., Karouji, Y., Hoshino, T., Ueno, M., and Hareyama, M.: "Sensitivity of leakage neutrons to the abundance and depth distribution of lunar subsurface water", **Planet. Space. Sci.** 251, 105968 (2024).

▶ Members

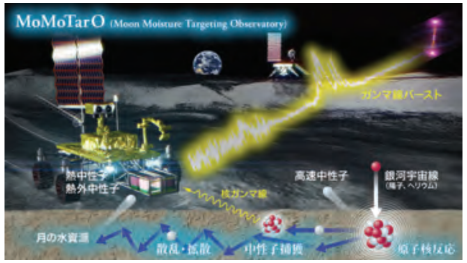
Yoshie Otake / Shigeho Noda /
Tomohiro Kobayashi / Sohei Imajo /
Yasuki Okuno / Hiroki Kusano / Tomonori Fukuchi /
Maki Mizuta / Yasuo Wakabayashi /
Abdul Muneem

Cosmic Neutron and Photon Frontier Research Unit

Unit Leader Teruaki Enoto Ph.D.

From Lunar Resource Exploration to the Creation of Cislunar Science

The Cosmic Neutron and Photon Frontier Science Research Unit aims to establish "Cislunar Science" using cosmic radiation detection, beginning with lunar resource exploration. A primary focus is the non-contact mapping of lunar water using galactic cosmic rays. Neutrons generated by cosmic ray impacts lose energy via scattering with subsurface hydrogen. Leveraging this process, our compact "MoMoTarO" monitor precisely measures lunar moisture and elemental composition. By expanding these space-based observations, we seek to solve the neutron lifetime puzzle and contribute to gravitational wave cosmology through gamma-ray burst observations, transforming cislunar space into a new frontier for scientific discovery.



Conceptual diagram of exploring lunar water resources
using neutrons generated by galactic cosmic ray impacts.

▶ Fields

Physics, Space Science, Multidisciplinary, Engineering, Geosciences

▶ Keywords

Cislunar Science, Lunar Resource Exploration, Space Neutrons, Space Photons, Radiation Science

▶ Publications

1. Tamagawa, T., Enoto, T., Kitaguchi, T., Iwakiri, W., Kato, Y., Numazawa, M., Mihara, T., Takeda, T., Ota, N., Watanabe, S., Aoyama, A., Iwata, S., Takahashi, T., Yamasaki, K., Hu, C. P., Takahashi, H., Yoshida, Y., Sato, H., Hayashi, S., Zhou, Y., Uchiyama, K., Jujo, A., Odaka, H., Tamba, T., and Taniguchi, K.: "NinjaSat: Astronomical X-ray CubeSat observatory", ***PASJ***, 77, 466 (2025).
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4. Enoto T., Terasawa T., Kisaka S., Hu, C. P., Guillot, S., Lewandowska, N., Malacaria, C., Ray, S. P., Ho, C. G. W., and Tanaka, J. S.: "Enhanced x-ray emission coinciding with giant radio pulses from the Crab Pulsar", ***Science***, 372, 187 (2021).
5. Enoto T., Wada Y., Furuta Y., Nakazawa, K., Yuasa, T., Okuda, K., Makishima, K., Sato, M., Sato, Y., Nakano, T., Umemoto, D., and Tsuchiya, H.: "Photonuclear reactions triggered by lightning discharge", ***Nature***, 551, 481 (2017)

▶ Members

Advanced Photonics Technical Support Division

Division Director Koichiro Tanaka D.Sci.

An Engineering Hub for Advanced Photonics

The Advanced Photonics Technical Support Division was established to provide research support for advanced photonics, as well as to manage, operate, and develop the necessary facilities. We provide experimental apparatus construction support not only for scientists within the RIKEN Center for Advanced Photonics but also for researchers across all of RIKEN, in addition to operating the RIKEN compact accelerator-driven neutron source system (RANS). Advanced Manufacturing Support Team gives design and manufacturing service of apparatuses and components based on request from RIKEN scientists. Also, it manages do-it-yourself machine shop with safety training of mechanical machining. Neutron Operation Unit provides neutron beams and support experiments using compact accelerators through management and operation of RANS (I/II/III). It also conducts technological developments to improve those facilities. Those specialized support teams will enhance creative research activities and contribute to fundamental science, industries and society.

Machine Tools of Advanced Manufacturing Support Team

RIKEN compact accelerator-driven neutron source system RANS-III

Fields

Engineering, Physics, Interdisciplinary science and engineering, Materials Sciences

Keywords

Manufacturing Engineering, Quantum Beam Science, Ultraprecision Machining, Neutron

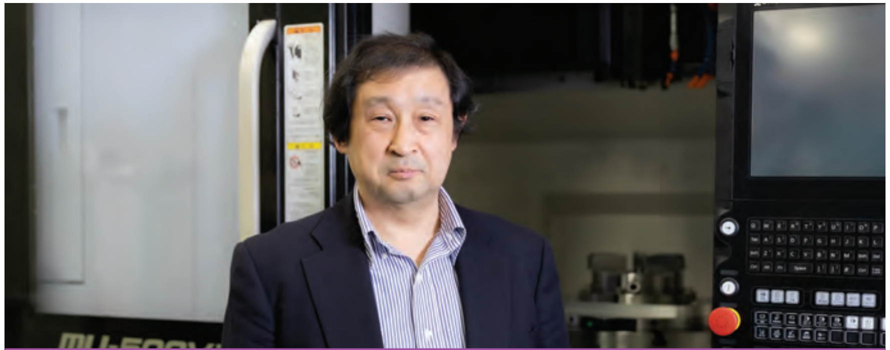
Laboratories

- Advanced Manufacturing Support Team
- Neutron Operation Unit

Advanced Photonics Technical Support Division

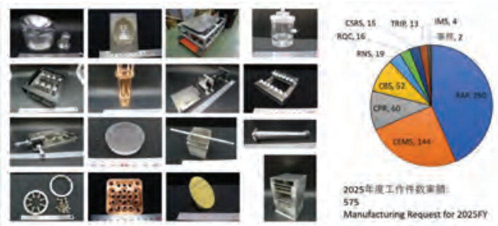
Advanced Manufacturing Support Team

Team Director Yutaka Yamagata D.Eng.



Manufacturing of apparatuses by requests from researchers and technological developments

It is inevitably required to devise and/or maintain variety of advanced research instruments and equipment to promote and support laboratories for wide ranges of research fields from fundamental to practical phases. The main duty of our team is to develop those instruments required by researchers, and also this duty should be conducted consequently from concept design to manufacture through detailed design and instrumentation. Our team also deals with improvement and maintenance of working scientific experimental equipment. For these purposes, we are constantly making efforts to improve our design, manufacturing and engineering capabilities for rapid services.



Examples of manufactured components for scientific apparatuses and number of requests in FY2025

Fields

Engineering, Interdisciplinary science and engineering

Keywords

Production technology, Mechanical machining, Laser machining, CAD/CAM/CAE, 3D printer

Publications

1. Heacock, B., Fujiie, T., Haun, W.R., Henins, A., Hirota, K., Hosobata, T., Huber, M.G., Kitaguchi, M., Pushin, D.A., Shimizu, H., Takeda, M., Valdillez, R., Yamagata, Y., and Young, A.R.: "Pendellosung interferometry probes the neutron charge radius, lattice dynamics, and fifth forces", ***Science*** 373, 1239-1243 (2021).
2. Teshima, Y., Hosoya, Y., Sakai, K., Nakano, T., Tanaka, A., Aomatsu, T., Yamazawa, K., Ikegami, Y., and Watanabe, Y.: "Development of Tactile Globe by Additive Manufacturing", ***Springer LNCS*** 12376, 419-426 (2020).
3. Yamazawa, K., Teshima, Y., Watanabe, Y., Ikegami, Y., Fujiyoshi, M., Oouchi, S., and Kaneko, T.: "Three-Dimensional Model Fabricated by Layered Manufacturing for Visually Handicapped Persons to Trace Heart Shape", ***Springer LNCS*** 7383, 505-508 (2012).
4. Oouchi, S., Yamazawa, K., and Secchi, L.: "Reproduction of Tactile Paintings for Visual Impairments Utilized Three-Dimensional Modeling System and the Effect of Difference in the Painting Size on Tactile Perception", ***Springer LNCS*** 6180, 527-533 (2010).
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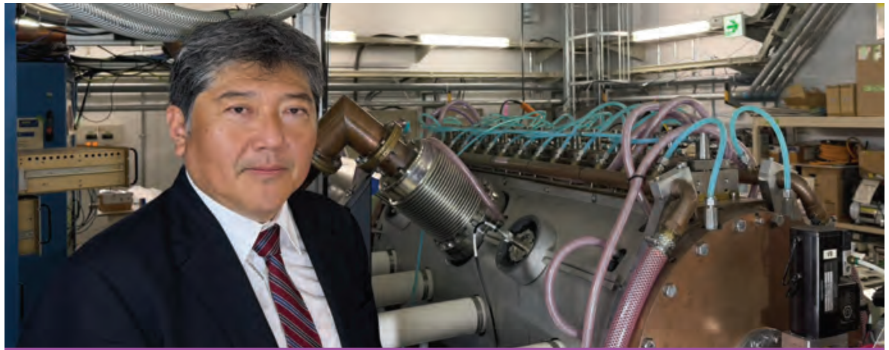
Members

Takuya Hosobata / Takashi Isoshima / Yoshiyuki Takizawa / Hiromi Okada / Akihiro Hattori /Takayo Ogawa / Takeshi Fujimoto / Masaharu Watanuki / Masahiro Takeda / Shigeru Ikeda

Advanced Photonics Technical Support Division

Neutron Operation Unit

Unit Leader Tomohiro Kobayashi D.Eng.



Operation and Performance Enhancement of Compact Accelerator Neutron Source Systems

Our unit operates three RANS (RIKEN Accelerator-driven compact Neutron Systems) systems, providing neutron irradiation facilities to experimental groups both within and outside the institute. RANS-I uses 7 MeV protons and a beryllium (Be) target, while RANS-II and III use 2.49 MeV protons and a lithium (Li) target. Users range from research institutions and universities to private companies. The RANS development program has focused on miniaturization with the goal of portability. RANS-III, which began operation in 2025, has been successfully mounted on a vehicle, and we are advancing its implementation in society. We are conducting comprehensive development of ion sources, accelerators, control systems, neutron-generating targets, radiation shielding, detectors, and measurement methods, with the aim of developing neutron sources that benefit society.

RIKEN Accelerator-driven compact Neutron System
(Top left: RANS-I; Bottom left: RANS-II; Right: RANS-III)

▶ Fields

Engineering, Physics, Materials Sciences, Interdisciplinary science and engineering

▶ Keywords

Neutron, Accelerator, Ion source, Radiography, Neutron-generating target

▶ Publications

1. Kobayashi, T., Ikeda, S., Otake, Y., Ikeda, Y., and Hayashizaki, N.:"Completion of a new accelerator-driven compact neutron source prototype RANS-II for on-site use", *Nucl Instrum Methods Phys Res, Sect A* 994, 165091 (2021).
2. Sugihara, K., Ikeda, Y., Kobayashi, T., Fujita, K., Ikeda, S., Shigyo, N., and Otake, Y.: "Radiation field characterization with emphasis on the collimator configuration at the compact neutron source RANS-II facility", *J Nucl Sci Technol* 60(2), 110-123 (2022).
3. Yan, M., Ma, B., Hashiguchi, T., Taketani, A., Iwamoto, C., Wakabayashi, Y., Fujita, K., Takanashi, T., Takamura, M., Kobayashi, T., Ikeda, S., Mizuta, M., Ikeda, Y., and Otake, Y.: "Investigation of Dose Rate Distribution in an Experimental Hall of a RIKEN Accelerator-Driven Compact Neutron Source Based on the 9Be(p, n) Reaction With 7 MeV Proton Injection", *IEEE Trans Nucl Sci* 69(2), 118-125 (2022).
4. Ikeda, S., Kobayashi, T., Otake, Y., Matsui, R., Okamura, M., and Hayashizaki, N.:"Fabrication and RF test of the 500 MHz-RFQ linear accelerator for a transportable neutron source RANS-III", *J. Neutron Res.* 24(3-4), 249-259 (2022).

▶ Members

Office of the Center Director

Office Director Akihiko Tanaka

Connecting RAP with society through collaboration and outreach

The Office of the Center Director works to provide an environment in which researchers can focus on their research and helps maximize the impact of their achievements on society. To support this mission, the office carries out a wide range of support, including planning and operation, collaboration coordination, external funding support, and outreach.

Through the planning and operation of symposiums and seminars, the office promotes exchange and collaboration among researchers within and outside RAP, as well as with companies, universities, and research institutions. These interactions help deepen new partnerships and joint research, leading to the creation of new innovations.

The office also provides up-to-date information on external funding opportunities and various programs, and supports the application process. By coordinating with relevant stakeholders, it helps create an environment in which research activities can develop sustainably.

Through effective communication using websites, promotional materials, and various media, the office presents RAP's research activities, technologies, and achievements in an accessible way. It also serves as a point of contact for researchers, students, companies, and external institutions interested in RAP, helping to create new opportunities for collaboration.

Through the planning and operation of symposiums, the Office of the Center Director supports the dissemination of research achievements and exchange among researchers within and outside RAP.

▶ Members

Takuo Ohata / Shigeto Nakai / Shigeho Noda / Kotaro Obata / Hidekazu Hatanaka