RAP

RIKEN Center for Advanced Photonics

2022 - 2023

RIKEN Center for Advanced Photonics
2-1, Hirosawa, Wako, Saitama, 351-0198, Japan

https://rap.riken.jp/en/

RIKEN 2022-008

Opening up new horizons with photonics

RIKEN Center for Advanced Photonics (RAP) is helping to realize the dream of making the invisible visible.

As one example, stroboscopes, which allow us to see high-speed phenomena by pulsing light in a short duration, cannot catch the movements of molecules or atoms because they simply move too fast. However, thanks to research in photonics, lasers developed to generate pulses at even shorter duration such as 10^{-15} second (1 femtosecond) or 10^{-18} second (1 attosecond) now allow us to see the movements of electrons in atoms or molecules.

Electron microscopy makes it possible for us to observe objects at extremely high resolution. However it requires the specimen to be put in a vacuum, making it impossible to see living cells. Using an optical microscope opens up that possibility. It was generally thought that it was impossible to picture objects smaller than half of the wavelength of light in the visible spectrum, but the super-resolution microscopes break this barrier and allow us to access the nanoworld.

We sometimes need to inspect the inner structure of a device or look for contamination in foods without destroying a sample. Terahertz wave makes this possible. Terahertz wave, which has been called the "unexplored spectrum of light," is now moving into the application phase thanks to advances in light sources and detectors.

In addition, applications in the field of photonics are expanding in areas such as light wave manipulation with metamaterials, relativistic geodesy using ultraprecision optical lattice clocks, nondestructive inspection of concrete structures with a compact neutron source, all making visible what nobody has ever seen before. Being able to see objects helps us to understand and manipulate them.

The work of the Center for Advanced Photonics focuses not simply on making discoveries that will be recognized by the research community, but rather on contributing to society by developing practical applications of advanced photonics.

Just as our social infrastructure was transformed by the steam engine in the 19th century and by electronics in the 20th century, photonics technology will lead to another transformation of social infrastructure in the current century.

The possibilities opened by photonics are expanding. We are still in the very early stage of this new revolution.

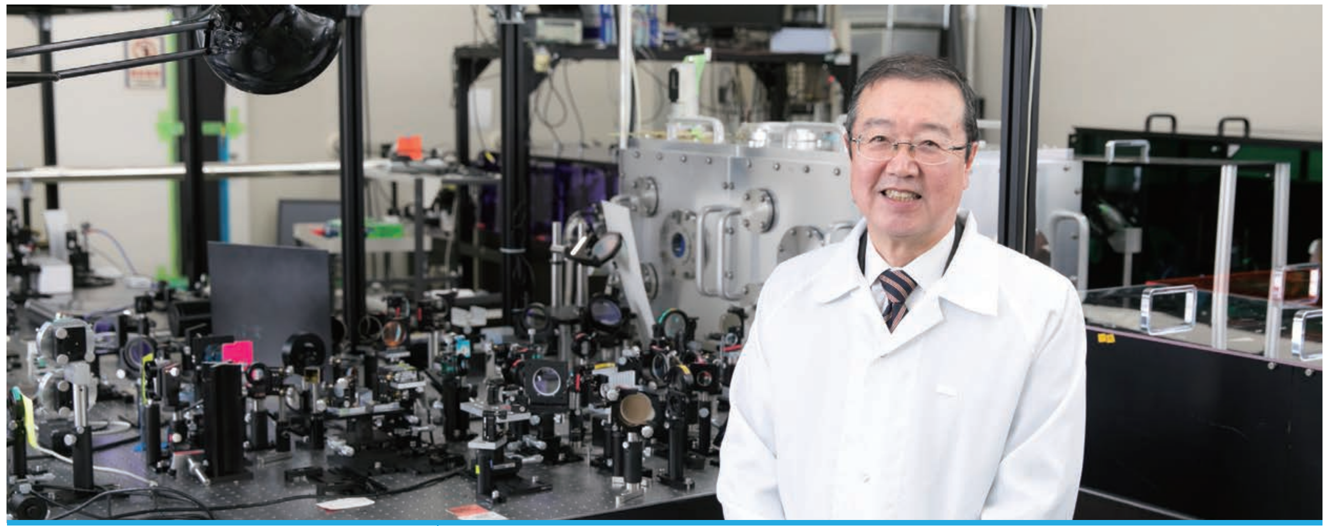
RIKEN Center for Advanced Photonics is committed to expanding the horizons of photon science.

Center Director
Katsumi Midorikawa

RIKEN Center for Advanced Photonics

Attosecond Science Research Team

Team Leader Katsumi Midorikawa Dr.Eng.



▶ Fields

Interdisciplinary Science and Engineering, Engineering, Physics, Chemistry

▶ Keywords

Attosecond Science, Ultrafast Lasers, Strong Field Physics, Nonlinear Optics, Multiphoton Microscopy

▶ Publications

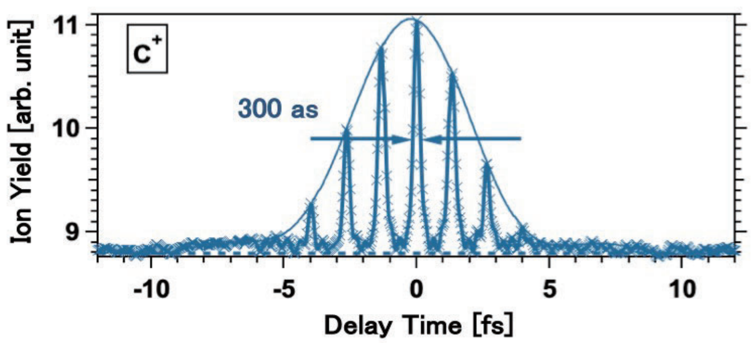
1. Midorikawa, K.: "Progress on table-top isolated attosecond light sources" , *Nature Photonics* 16, 267 (2022).
2. Matsubara, T., Fukahori, S., Lötstedt, E., Nabekawa, Y., Yamanouchi, K., and Midorikawa, K.: "300 attosecond response of acetylene in two-photon ionization/dissociation processes" , *Optica* 8, 1075 (2021).
3. Kanda, N., Imahoko, T., Yoshida, K., Tanabashi, A., Eilanlou, A. A., Nabekawa, Y., Sumiyoshi, T., Kuwata-Gonokami, M., and Midorikawa, K.: "Opening a new route to multiport coherent XUV sources via intracavity high-order harmonic generation" , *Light: Sci & Appl.* 9, 168 (2020).
4. Lin, Y-C., Nabekawa, Y., and Midorikawa, K.: "Optical parametric amplification of sub-cycle shortwave infrared pulses" , *Nat. Commun.* 11, 3413 (2020).
5. Xue, B., Tamaru, Y., Yuan, H., Lan, P., Mücke, O. D., Suda, A., Midorikawa, K., and Takahashi, E. J.: "Fully stabilized multi-TW optical waveform synthesizer: Toward gigawatt isolated attosecond pulses" , *Science Advances* 6, eaay2820 (2020).

▶ Member

Yasuo Nabekawa / Yutaka Nagata / Keisuke Isobe / Tomoya Okino / Takashige Fujiwara / Yu-Chieh Lin / Takayuki Michikawa / Kaoru Yamazaki / Bing Xue / Lu Xu / Giang Nahan Tran / Tohru Kobayashi / Takiko Wakabayashi

Expanding the horizon of optical science by attosecond photonics

Recent advances in femtosecond high-intensity laser technology have made it possible to generate intense ultrashort pulses of a few cycles and control their phases. As a result, research on the nonlinear interaction between light and atoms/molecules has progressed dramatically, and new research areas such as high-order harmonic generation, Coulomb explosion, and high-energy X-ray/particle generation have been born. High-order harmonic generation can provide intense attosecond pulses that cause nonlinear optical phenomena in the extreme ultraviolet to soft X-ray region. The generation of high-order harmonics is also a unique physical phenomenon that makes it possible to observe ultrafast phenomena occurring in atoms and molecules on an attosecond time scale. Our team is researching extreme nonlinear optics and attosecond atomic/molecular dynamics using a high-intensity attosecond pulse light source.



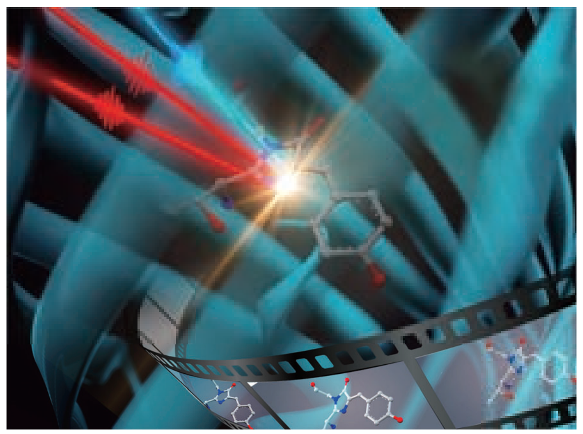
Autocorrelation waveform of attosecond pulse train measured with carbon ion yield from acetylene

Ultrafast Spectroscopy Research Team

Team Leader 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 nuclei 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 (quadrillionth), 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 chromophor of a protein in reaction

▶ Fields

Chemistry, Physics, Biology / Biochemistry

▶ Keywords

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

▶ Publications

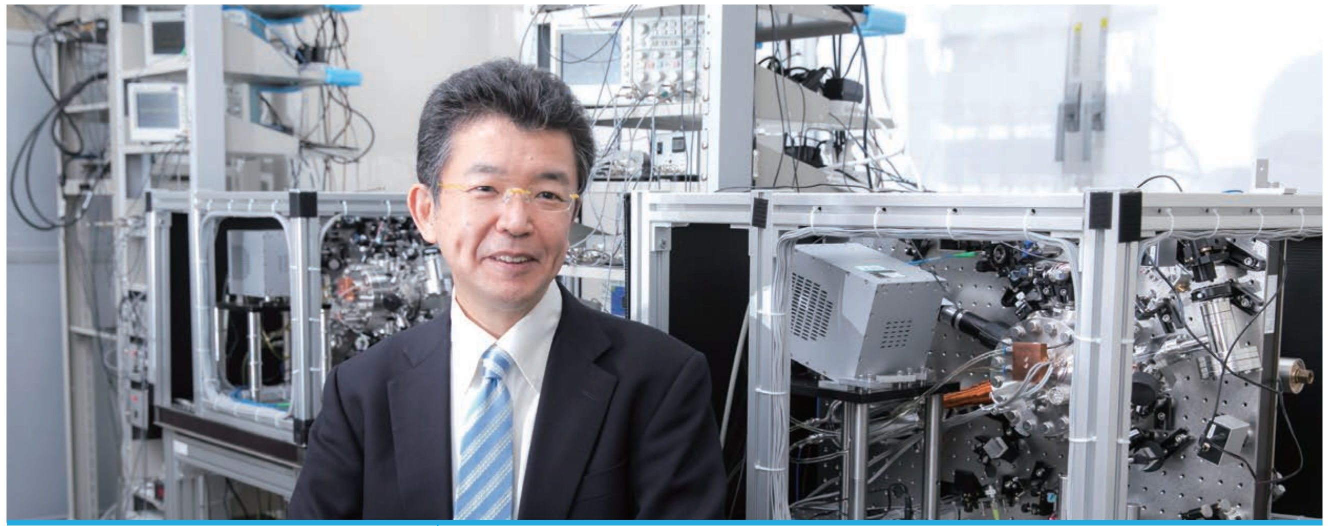
1. Chang, C., Kuramochi, M., Singh, M., Abe-Yoshizumi, R., Tsukuda, T., Kandori, H., and Tahara, T.: "A unified view on varied ultrafast dynamics of the primary process in microbial rhodopsins" , *Angew. Chem. Int. Ed.* 61, e202111930 (2022).
2. Kuramochi, H., and Tahara, T.: "Tracking ultrafast structural dynamics by time-domain Raman spectroscopy" , *J. Am. Chem. Soc.* 143, 9699 (2021). Perspective
3. Kusaka, R., Nihonyanagi, S., and Tahara, T.: "The photochemical reaction of phenol becomes ultrafast at the air–water interface" , *Nat. Chem.* 13, 306 (2021).
4. Inoue, K., Ahmed, M., Nihonyanagi, S., and Tahara, T.: "Reorientation-induced relaxation of free OH at the air/water interface revealed by ultrafast heterodyne-detected nonlinear spectroscopy" , *Nat. Commun.* 11, 5344 (2020).
5. Ahmed, M., Inoue, K., Nihonyanagi, S., and Tahara, T.: "Hidden isolated OH at the charged hydrophobic interface revealed by two-dimensional heterodyne-detected VSFG spectroscopy" , *Angew. Chem. Int. Ed.* 59, 9498 (2020).

▶ Member

Kunihiko Ishii / Satoshi Nihonyanagi / Korenobu Matsuzaki / Ahmed Mohammed

Space-Time Engineering Research Team

Team Leader Hidetoshi Katori D.Eng.

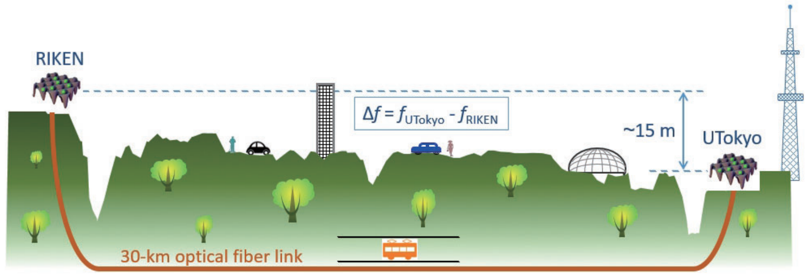


Relativistic Space-Time Engineering with Ultra Precise Atomic Clocks

Clocks have served as a tool to share time, based on universal periodic phenomena; humankind relied upon the rotation of the earth from antiquity. The radiation from an atom provides us with far more accurate periodicity. The state-of-the-art atomic clocks sense the relativistic space-time curved by gravity, which reveal the difficulty of sharing time with others. Moreover, such clocks may be used to investigate the constancy of fundamental constants, where the foundation of the atomic clocks is anchored.

Optical lattice clocks raised the possibility of ultra-stable and accurate timekeeping by applying the "magic wavelength" protocol on optical lattices. Since the proposal of the scheme in 2001, the optical lattice clocks are being developed by more than 20 groups in the world, and the clocks are surpassing the uncertainty of the current SI second, becoming one of the most promising candidates for the future redefinition of the second.

Our team develops highly precise and transportable optical lattice clocks capable of long time operation by introducing advanced techniques in the field of atomic physics and quantum optics; we thus explore applications of "space-time engineering" that fully utilize the novel time resource provided by such clocks. For example, a transportable ultraprecise atomic clock, which may be taken out into the field, will function as a gravitational potential meter. We experimentally investigate the impact of such relativistic geodesy and new roles for clocks 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).
2. Ushijima, I., Takamoto, M., and Katori, H.: "Operational magic intensity for Sr optical lattice clocks" , ***Phys. Rev. Lett.*** 121, 263202 (2018).
3. Takano, T., Takamoto, M., Ushijima, I., Ohmae, N., Akatsuka, T., Yamaguchi, A., Kuroishi, Y., Munekane, H., Miyahara, B., and Katori, H.: "Geopotential measurements with synchronously linked optical lattice clocks" , ***Nat. Photonics*** 10, 662-666 (2016).
4. Yamanaka, K., Ohmae, N., Ushijima, I., Takamoto, M., and Katori, H.: "Frequency ratio of ^{199}Hg and ^{87}Sr optical lattice clocks beyond the SI limit" , ***Phys. Rev. Lett.*** 114, 230801 (2015).
5. Ushijima, I., Takamoto, M., Das, M., Ohkubo, T., and Katori, H.: "Cryogenic optical lattice clocks" , ***Nat. Photonics*** 9, 185-189 (2015).

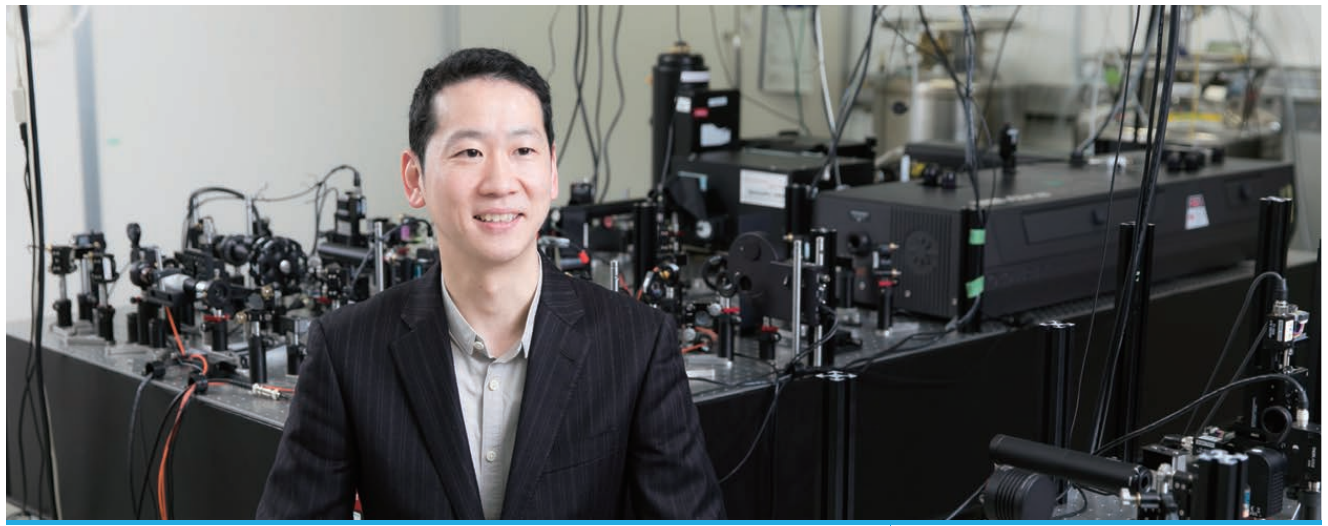
▶ Member

Masao Takamoto / Atsushi Yamaguchi

Extreme Photonics Research Group

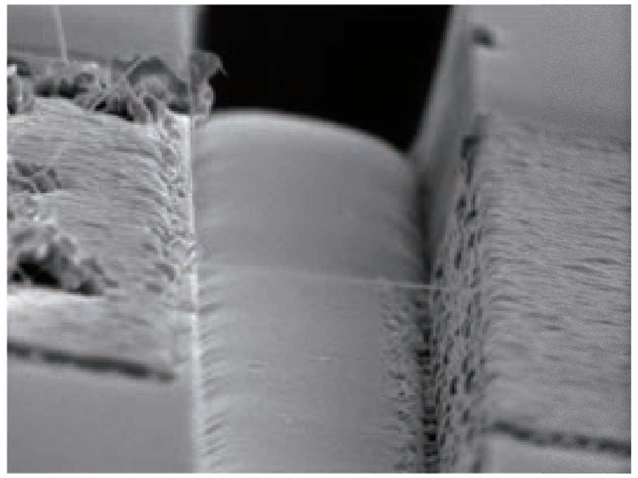
Quantum Optoelectronics Research Team

Team Leader Yuichiro Kato Ph.D.



Towards optoelectronic devices that utilize the quantum nature of electrons and photons

Advances in device fabrication techniques have enabled integration of individual nanomaterials, where single electrons and single photons could be addressed. We exploit state-of-the-art nanofabrication technologies to develop and engineer optoelectronic devices with novel functionalities that can only be achieved by utilizing the quantum nature of electrons and photons at the nanoscale. We investigate devices that would allow for control over the interactions between electrons and photons at the quantum mechanical level, which would lead to quantum photon sources and optical-to-electrical quantum interfaces.



Scanning electron micrograph of a suspended carbon nanotube field effect transistor

▶ Fields

Interdisciplinary Science and Engineering, Engineering, Mathematical and physical sciences, Chemistry

▶ Keywords

Optoelectronics, Quantum devices, Nanoscale devices, Carbon nanotubes, Photonic crystals

▶ Publications

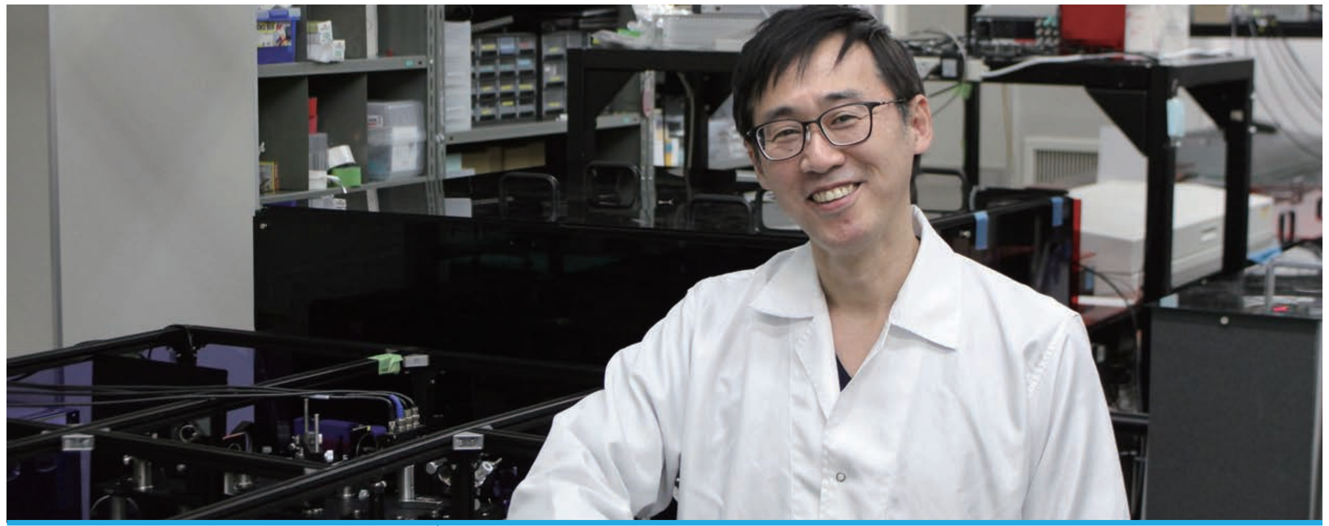
1. Li, Z., Otsuka, K., Yamashita, D., Kozawa, D., and Kato, Y. K.: "Quantum emission assisted by energy landscape modification in pentacene-decorated carbon nanotubes" , ***ACS Photonics*** 8, 2367 (2021).
2. Otsuka, K., Fang, N., Yamashita, D., Taniguchi, T., Watanabe, K., and Kato, Y. K.: "Deterministic transfer of optical-quality carbon nanotubes for atomically defined technology" , ***Nature Commun.*** 12, 3138 (2021).
3. Ishii, A., Machiya, H., Kato, Y. K.: "High efficiency dark-to-bright exciton conversion in carbon nanotubes" , ***Phys. Rev. X*** 9, 041048 (2019).
4. Ishii, A., Uda, T., Kato, Y. K.: "Room-temperature single-photon emission from micrometer-long air-suspended carbon nanotubes" , ***Phys. Rev. Applied*** 8, 054039 (2017).
5. Jiang, M., Kumamoto, Y., Ishii, A., Yoshida, M., Shimada, T., Kato, Y. K.: "Gate-controlled generation of optical pulse trains using individual carbon nanotubes" , ***Nature Commun.*** 6, 6335 (2015).

▶ Member

Daichi Kozawa / Shun Fujii / Daiki Yamashita

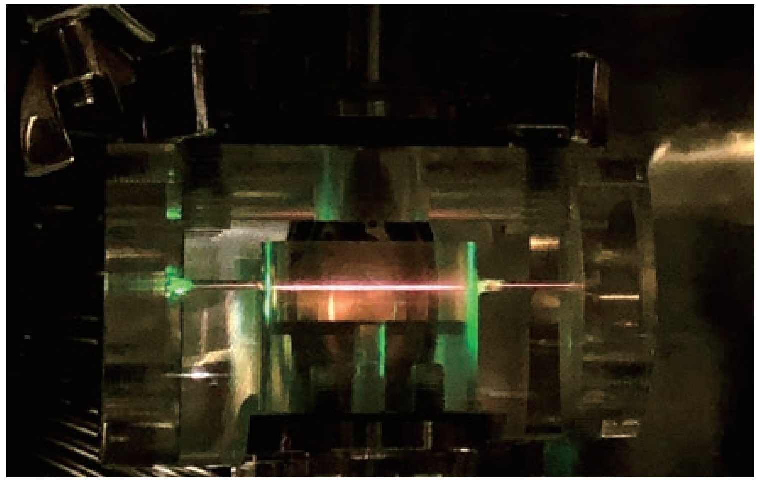
Ultrafast Coherent Soft X-ray Photonics Research Team

Team Leader Eiji J. Takahashi D.Eng.



Creating novel ultrafast soft x-ray sources using the extreme nature of laser

Laser is the ultimate light source created by mankind, and it has become an indispensable tool for our social life. In this laboratory, our main goal is to create an unexplored ultrafast laser by using the extreme nature of laser such as ultrashort pulse, super broadband, high power, and so on. Specifically, we are developing a high-power a few-cycle laser source, and using it to develop novel laser source with full coherence in the soft x-ray region and a pulse width of attosecond region. We extend the frontier of laser science through the development of novel laser sources.



Emission from the generating medium of coherent soft x-ray

▶ Fields

Interdisciplinary Science and Engineering,
Engineering, Complex systems

▶ Keywords

High-power a few-cycle laser, Coherent soft x-ray,
Quantum beam, Strong-field physics,
Ultrafast soft x-ray photonics

▶ Publications

1. Bing, X., Tamaru, Y., Fu, Y., Yuan, H., Lan, P., Mücke, O.D., Suda, A., Midorikawa, K., and Takahashi, E.J.: “A Custom-Tailored Multi-TW Optical Electric Field for Gigawatt Soft-X-Ray Isolated Attosecond Pulses” , ***Ultrafast Science*** 2021: 9828026 (2021).
2. Nishimura, K., Yuxi, F., Suda, A., Midorikawa, K., and Takahashi, E.J.: “Apparatus for generation of nanojoule-class water-window high-order harmonics” , ***Rev. Sci. Instrum.*** 92: 063001 (2021).
3. Bing, X., Tamaru, Y., Fu, Y., Yuan, H., Lan, P., Mücke, O.D., Suda, A., Midorikawa, K., and Takahashi, E.J.: “Fully stabilized multi-TW optical waveform synthesizer: Toward gigawatt isolated attosecond pulses” , ***Science Advances*** 6: eaay2802 (2020).
4. Yuxi, F., Nishimura, K., Shao, R., Suda, A., Midorikawa, K., Lan, P., and Takahashi, E.J: “High efficiency ultrafast water-window harmonic generation for single-shot soft X-ray spectroscopy” , ***Communications Physics*** 3: 92 (2020).
5. Lu, X., Nishimura, K., Suda, A., Midorikawa, K., Fu, Y., and Takahashi, E.J.: “Optimization of a multi-TW few-cycle 17-μm source based on Type-I BBO dual-chirped optical parametric amplification” , ***Optics Express*** 28: 15138-47 (2020).

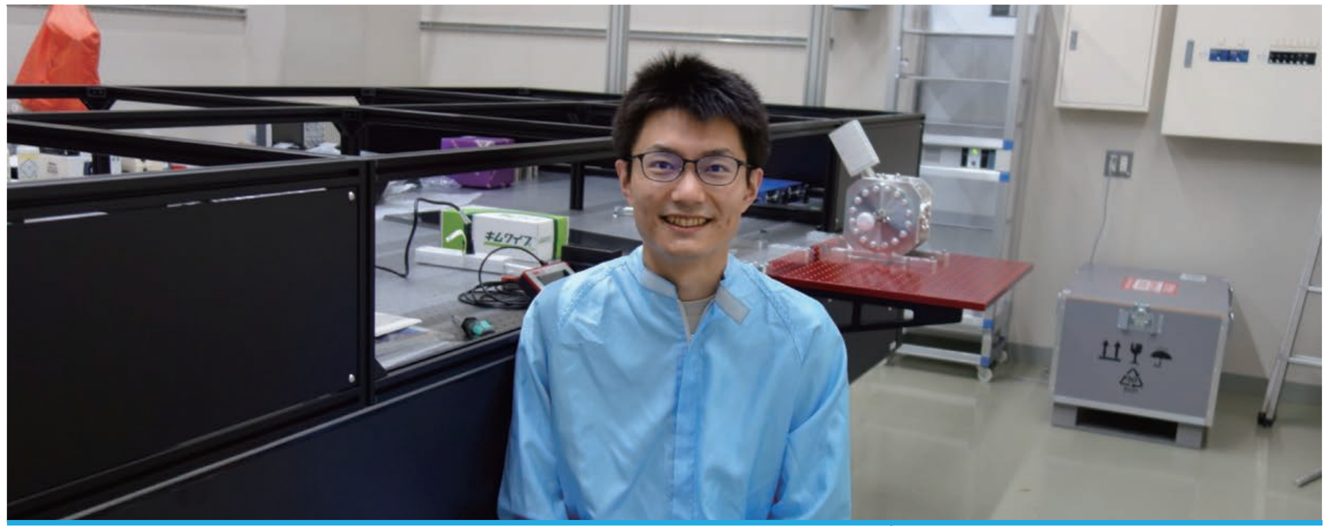
▶ Member

Yasuo Nabekawa / Lu Xu / Giang Nahan Tran

Extreme Photonics Research Group

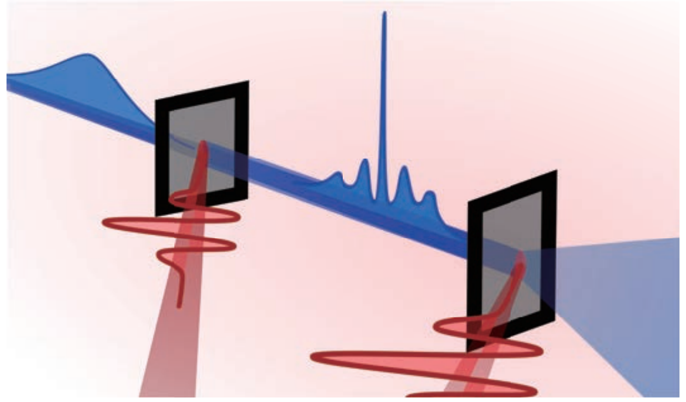
Ultrashort Electron Beam Science RIKEN Hakubi Research Team

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

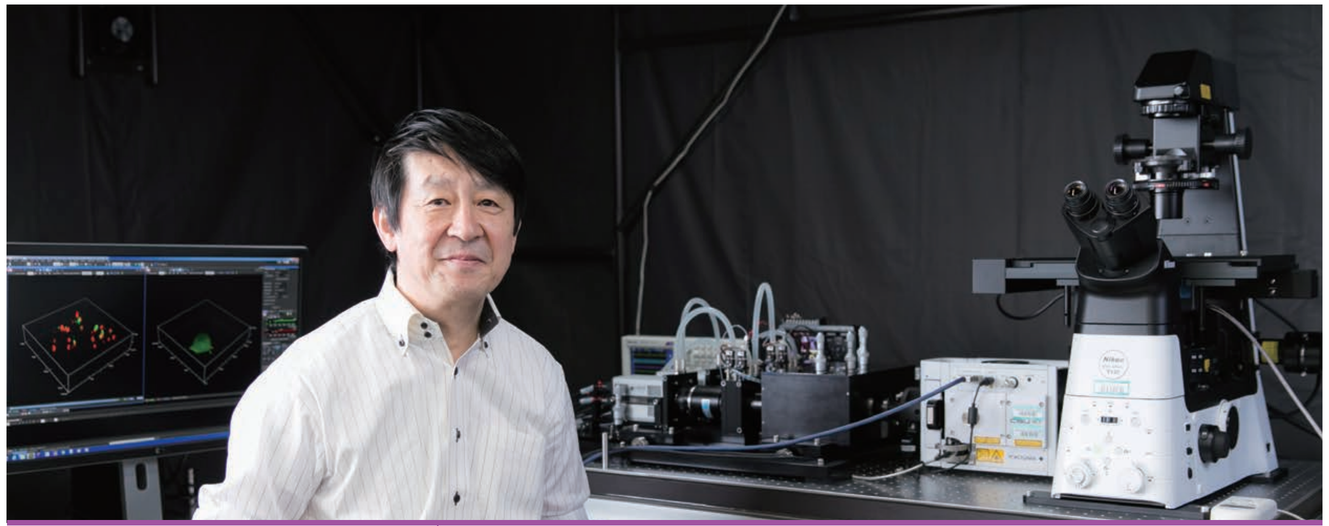
1. Morimoto, Y., Shinohara, Y., Ishikawa, K.L., and Hommelhoff, P.: “Atomic real-space perspective of light-field-driven currents in graphene” , ***New J. Phys.*** 24, 033051 (2022).
2. Morimoto, Y., Shinohara, Y., Tani, M., Chen, B.H., Ishikawa, K.L., and Baum, P.: “Asymmetric single-cycle control of valence electron motion in polar chemical bonds” , ***Optica*** 8, 382 (2021).
3. Morimoto, Y., Hommelhoff, P., and Madsen, L.B.: “Coherent scattering of an optically-modulated electron beam by atoms” , ***Phys. Rev. A*** 103, 043110 (2021).
4. Morimoto, Y., and Baum, P.: “Single-Cycle Optical Control of Beam Electrons” , ***Phys. Rev. Lett.*** 125, 193202 (2020).
5. Morimoto, Y., and Baum, P.: “Diffraction and microscopy with attosecond electron pulse trains” , ***Nat. Phys.*** 14, 252 (2018).

▶ Member

Yuichi Tachibana

Live Cell Super-Resolution Imaging Research Team

Team Leader Akihiko Nakano D.Sci.



▶ Fields

Biological Sciences, Complex systems, Interdisciplinary science and engineering, Biology / Biochemistry

▶ Keywords

Membrane traffic, Vesicular transport, Super-resolution live imaging, Confocal microscopy, Organelles

▶ Publications

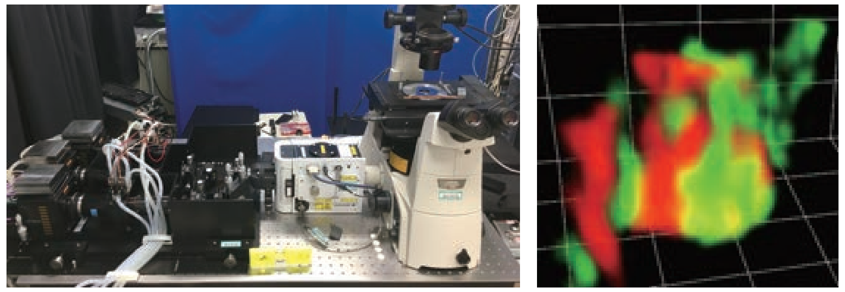
1. Nakano, A.: "The Golgi apparatus and its next-door neighbors" , ***Frontiers Cell Dev. Biol.*** in press (2022).
2. Shimizu, Y., Takagi, J., Ito, E., Ito, Y., Ebine, K., Komatsu, Y., Goto, Y., Sato M., Toyooka, K., Ueda, T., Kurokawa, K., Uemura, T., and Nakano, A.: "Cargo sorting zones in the *trans*-Golgi network visualized by super-resolution confocal live imaging microscopy in plants" , ***Nat. Commun.*** 12:1901 (2021).
3. Rodriguez-Gallardo, S., Kurokawa, K., Sabido-Bozo, S., Cortes-Gomez, A., Ikeda, A., Zoni, V., Aguilera-Romero, A., Perez-Linero, A.M., Lopez, S., Waga, M., Araki, M., Nakano, M., Riezman, H., Funato, K., Vanni, S., Nakano, A., and Muñiz, M.: "Ceramide chain length-dependent protein sorting into selective endoplasmic reticulum exit sites" , ***Sci. Adv.*** 6:eaba8237 (2020).
4. Tojima, T., Suda, Y., Ishii, M., Kurokawa, K., and Nakano, A.: "Spatiotemporal dissection of the *trans*-Golgi network in budding yeast" , ***J. Cell Sci.*** 132:jcs231159 (2019).
5. Kurokawa, K., Osakada, H., Kojidani, T., Suda, Y., Asakawa, H., Haraguchi, T., and Nakano, A.: "Visualization of secretory cargo transport within the Golgi apparatus in living yeast cells" , ***J. Cell Biol.*** 218:1602-1618 (2019).

▶ Member

Kazuo Kurokawa / Takuro Tojima / Natsuko Jin / Daisuke Miyashiro / Tomohiro Uemura / Yasuyuki Suda / Yoko Ito / Emi Ito / Kumiko Ishii / Miho Waga / Hideo Hirukawa

Observe nano-scale activities within a living cell by sub-wavelength high-speed imaging

Light is a cutting-edge tool for life science research. Development of useful fluorescent probes and the advancement of light microscope technologies have brought us a new world of "live" imaging within a cell. We are developing super-resolution confocal live imaging microscopy (SCLIM) by the combination of a high-speed confocal scanner and a high-sensitivity camera system. With this method we will observe membrane trafficking and organellar dynamics in living cells at high-speed and sub-wavelength space resolution (4D) and elucidate underlining molecular mechanisms. We will also try to extend this technology to medical and pharmacological applications.



(Left) SCLIM2 microscope.
(Right) Yeast *trans*-Golgi network (red) and clathrin-coated vesicles (green) assembling and leaving there. Captured from a high-speed 3D movie taken by SCLIM2.

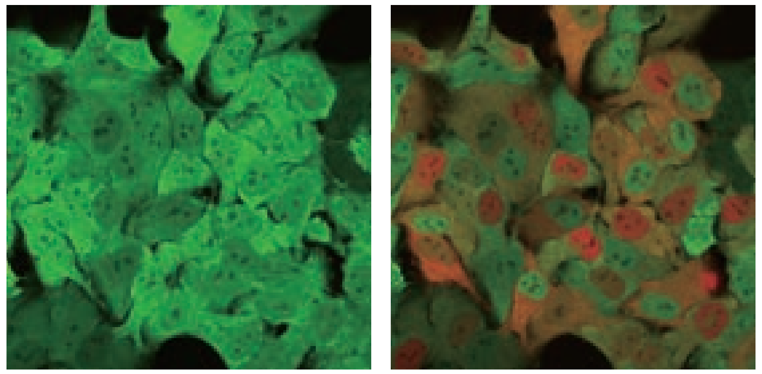
Subwavelength Photonics Research Group

Biotechnological Optics Research Team

Team Leader 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.



Cultured HeLa cells expressing the photoconvertible fluorescent protein, Keade. Before (left) and after (right) multiple, local irradiation of violet laser light, green-to-red color conversion occurred in the cytosol or nucleus of targeted cells.

▶ Fields

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

▶ Keywords

Bio-imaging, Fluorescence protein, Chromophore group

▶ Publications

1. 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).
2. Katayama, H., Hama, H., Nagasawa, K., Kurokawa, K., Sugiyama, M., Ando, R., Funata, M., Yoshida, N., Homma, M., Nishimura, T., Takahashi, M., Ishida, Y., Hioki, H., Tsujihata, Y., and Miyawak,i A.: "Visualizing and Modulating Mitophagy for Therapeutic Studies of Neurodegeneration" , ***Cell*** 181(5), 1176-1187 (2020).
3. Iwano, S., Sugiyama, M., Hama, H., Watakabe, A., Hasegawa, N., Kuchimaru, T., Tanaka, KZ., Takahashi, M., Ishida, Y., Hata, J., Shimozono, S., Namiki, K., Fukano, T., Kiyama, M., Okano, H., Kizaka-Kondoh, S., McHugh, TJ., Yamamori, T., Hioki, H., Maki, S., and Miyawaki, A.: "Single-cell bioluminescence imaging of deep tissue in freely moving animals" , ***Science***, 359 (6378): 935-939. (2018).
4. Sakaue-Sawano, A., Yo, M., Komatsu, N., Hiratsuka, T., Kogure, T., Hoshida, T., Goshima, N., Matsuda, M., and Miyawaki, A.: "Genetically encoded tools for optical dissection of the mammalian cell cycle" , ***Mol. Cell***, 68: 626-640. (2017).
5. Hama, H., Hioki, H., Namiki, K., Hoshida, T., Kurokawa, H., Ishidate, F., Kaneko, T., Akagi, T., Saito, T., Saido, T., and Miyawaki, A.: "ScaleS: an optical clearing palette for biological imaging" , ***Nat. Neurosci.*** 18 (10), 1518-1529 (2015).

▶ Member

Masahiko Hirano / Asako Tosaki

Image Processing Research Team

Team Leader Hideo Yokota D.Eng.

Image processing research for scientific information

Our goal is to develop original RIKEN data processing technology and multidimensional measurement technology in order to contribute to understanding biological phenomena. We are especially contributing to the fields of mathematical biology, bio-medical simulations as well as medical diagnostic and treatment technology by researching and developing new data and image processing technologies and establishing new tools for quantification of biological phenomena, intended for researchers both inside and outside RIKEN.

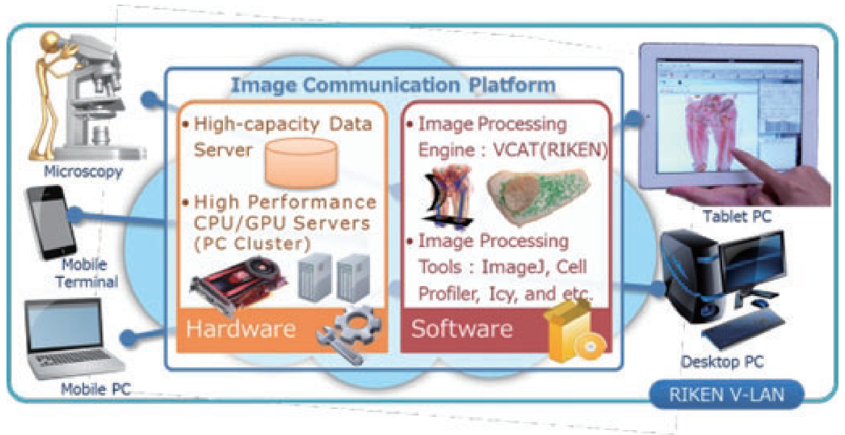


Image Processing Cloud

▶ Fields

Engineering, Informatics, Computer Science

▶ Keywords

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

▶ Publications

1. Tamura, N., Goto, S., Yokota, H., and Goto, S.: "Contributing Role of Mitochondrial Energy Metabolism on Platelet Adhesion, Activation and Thrombus Formation under Blood Flow Conditions", *Platelets* 1-7 (2022).
2. Yamashita, N., Matsuno, T., Maeda, D., Kikuzuki, M., and Yokota, H.: "Efficient 3D observation of steel microstructure using serial sectioning with precision cutting and on-site etching" , ***Precision Engineering*** 75, pp.37-45 (2022).
3. Takematsu, M., Umezawa, M., Sera, T., Kitagawa, Y., Kurahashi, H., Yamada, S., Okubo, K., Kamimura, M., and Yokota, H., Soga, K.: "Influence of the difference in refractive index on the interface of an object and the surrounding in near-infrared fluorescence tomography" , ***Applied Optics*** (2021).
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 Reports*** 37,6, 109966 (2021).
5. Hori, K., Ikematsu, H., Yamamoto, Y., Matsuzaki, H., Takeshita, N., Shinmura, K., Yoda, Y., Kiuchi, T., Takemoto, S., Yokota, H., and Yano, T.: "Detecting colon polyps in endoscopic images using artificial intelligence constructed with automated collection of annotated images from an endoscopy reporting system" , ***Digestive Endoscopy*** (2021).

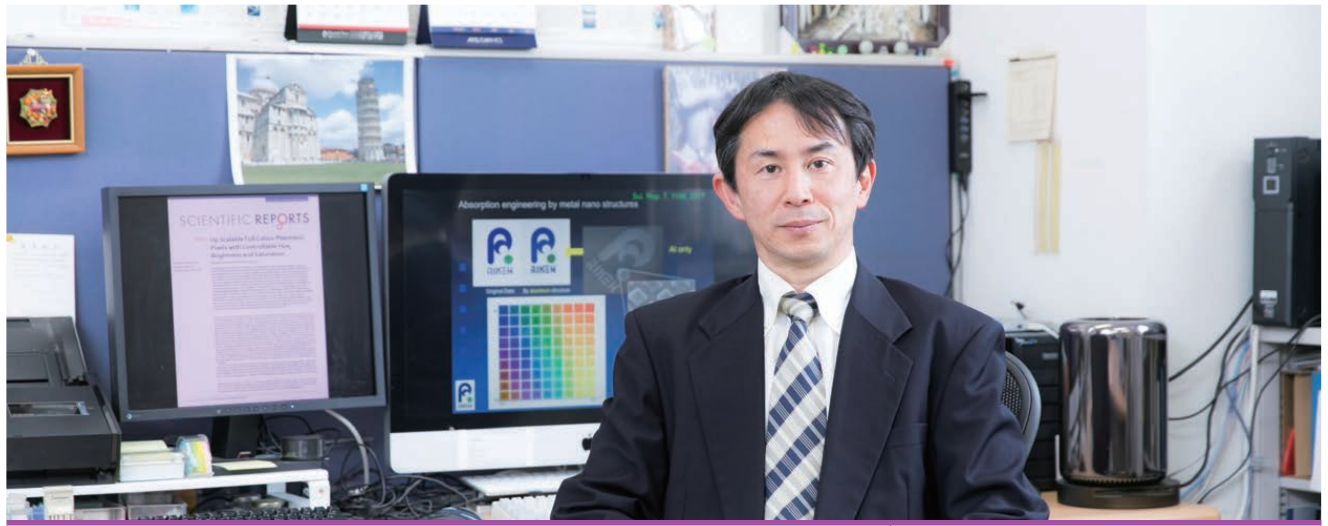
▶ Member

Shin Yoshizawa / Satoshi Oota / Shigeho Noda / Takashi Michikawa / Satoko Takemoto / Masahiko Morita / Norio Yamashita / Zhe Sun / Sakiko Nakamura / Yuki Tsujimura / Xianping Zhang / Hiroaki Iwase / Takashi Uematsu

Subwavelength Photonics Research Group

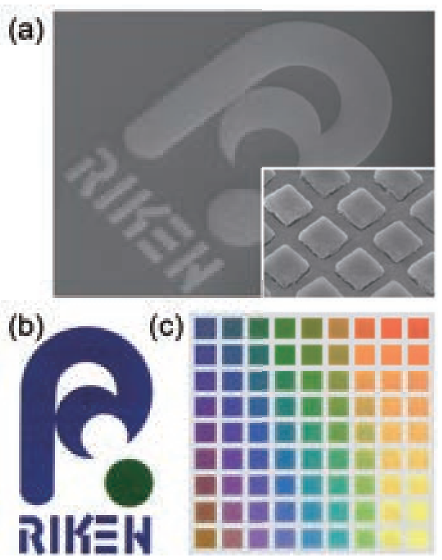
Innovative Photon Manipulation Research Team

Team Leader Takuo Tanaka D.Eng.



Lightwave manipulation by subwavelength structures

Our team intensively studies novel photon manipulation technologies using knowledge and experiences obtained from the researches on light wave interaction with sub-wavelength fine structures. These photon manipulation technologies will be applied for three-dimensional nanofabrication systems, ultra-high sensitive molecular sensing devices, and so on. Figure (a) shows a scanning electron microscope image of RIKEN' s logo consists of a sub-wavelength aluminum structure, which absorbs light of certain wavelength determined by its size and shape. Figure (b) shows an observed image of the RIKEN' s logo under white light illumination. Figure (c) shows a demonstrated color palette covering a broad 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

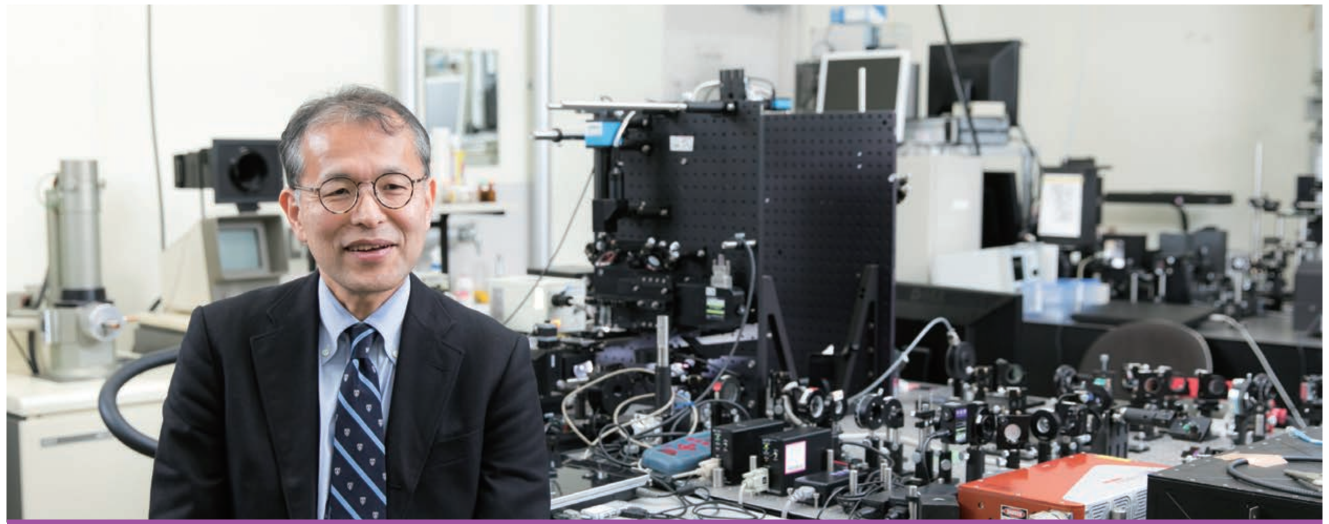
1. Jung, W., Jung, Y., Pikhitsa, P., Feng, J., Yang, Y., Kim, M., Tsai, H., Tanaka, T., Shin, J., Kim, K., Choi, H., Rho, J., and Choi, M.: "Three-dimensional nanoprinting via charged aerosol jets", ***nature*** 592, 54 (2021).
2. Luo, T., Chu, C., Vyas, S., Kuo, H., Chia, Y., Chen, M., Shi, X., Tanaka, T., Misawa, H., Huang, Y., and Tsai, D.: "Varifocal Metalens for Optical Sectioning Fluorescence Microscopy", ***Nano Letters*** 21, 5133-5142 (2021).
3. Olaya, C. M., Hayazawa, N., Hermosa, N., and Tanaka, T.: "Angular Goos-H nchen shift sensor using gold film enhanced by surface plasmon resonance", ***J. Phys. Chem. A*** 125, 451-458 (2021).
4. Balois, M. V., Hayazawa, N., Yasuda, S., Ikeda, K., Yang, B., Kazuma, E., Yakota, Y., Kim, Y., and Tanaka, T.: "Visualization of subnanometric local phonon modes in a plasmonic nanocavity via tip-enhanced Raman spectroscopy in ambient" , ***NPJ 2D Mater. Appl.*** 3, 38 (2019).
5. Le, H.-H.-T., Morita, A., Mawatari, K., Kitamori, T., and Tanaka, T.: "Metamaterials-Enhanced Infrared Spectroscopic Study of Nanoconfined Molecules by Plasmonics-Nanofluidics Hydrid Device", ***ACS Photonics*** 5, 3179-3188 (2018).

▶ Member

Norihiko Hayazawa / Maria Vanessa Balois Oguchi / Maria Herminia Marallag Balgos / Cherrie May Mogueis Olaya / Takashi Yamaguchi

Advanced Laser Processing Research Team

Team Leader Koji Sugioka D.Eng.



▶ Fields

Engineering, Materials Sciences, Interdisciplinary science and engineering, Multidisciplinary

▶ Keywords

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

▶ Publications

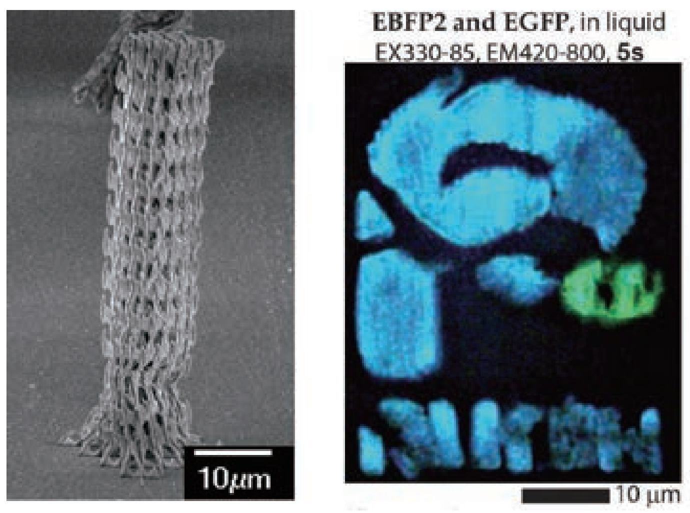
1. Zhang, D., Li, X., Fu, Y., Yao, Q., Li, Z., and Sugioka, K.: "Liquid vortexes and flows induced by femtosecond laser ablation in liquid governing formation of circular and crisscross LIPSS" , ***Opto-Electron. Adv.*** 5, 210066 (2022).
2. Bai, S., Serien, D., Ma, Y., Obata, K., and Sugioka, K.: "Attomolar sensing based on liquid-interface assisted surface enhanced Raman scattering in microfluidic chip by femtosecond laser processing" , ***ACS Appl. Mater. Interfaces*** 12, 42328–4233 (2020).
3. 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).
4. 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).
5. Sugioka, K., and Cheng, Y.: "Femtosecond laser three-dimensional micro- and nanofabrication" , ***Appl. Phys. Rev.*** 1, 041303 (2014).

▶ Member

Kotaro Obata / Jiawei Zhang / Shi Bai / Kazunari Ozasa / Felix Sima / Daniela Serien

Femtosecond Laser 3D Micro/Nanofabrication: Creation of 3D Structures Made of Pure Protein

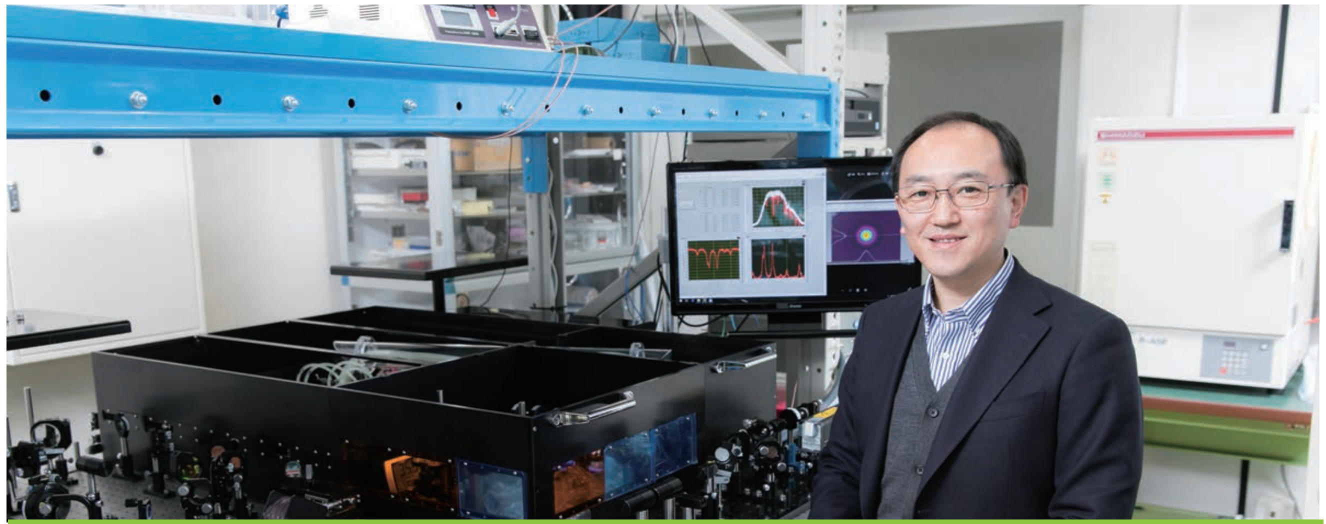
Our research team is developing advanced laser processing techniques which realize low environmental load, high quality, high efficiency fabrication of materials. In particular, by using femtosecond lasers, novel material processing techniques including 3D fabrication, surface nanostructuring, novel nanomaterial synthesis, and tailored beam processing are developed, which are applied for fabrication of functional micro/nanodevices. As one of examples of the 3D fabrication, our team successfully created a 3D complex shape of pure protein such as bovine serum albumin (BSA). Furthermore, enhanced green fluorescent protein and enhanced blue fluorescent protein were formed on a single substrate to realize a two-color fluorescence image exhibiting a RIKEN logo. The 3D proteinaceous micro and nanostructures fabricated by this technique will offer many applications including cell culture, tissue engineering, biochips, micromachines, etc.



(Left) Complex 3D microstructure of Bovine serum albumin (BSA) fabricated by femtosecond laser 3D printing
(Right) RIKEN logo fabricated by femtosecond laser 3D printing of EBFP and EGFP.

Tera-Photonics Research Team

Team Leader Hiroaki Minamide D.Eng.



Leading Terahertz science & applications with innovative Tera-photonics technology

Our team develops state-of-the-art frequency-tunable THz-wave sources which exploit new THz-wave application fields. A nonlinear optical process is utilized for realizing the THz-wave source which lights up the THz-wave gray zone, and our original design and method will be demonstrated. We develop THz sources with high output, wide tunability, high stability and narrow linewidth.

Active collaboration with both internal and external research groups is carried out for exploring new applications by development of instrument combined with new THz-wave sources. Advanced THz-wave technologies are also being developed in cooperation with industry to establish practical THz-wave sources and technologies in the world.

Backward terahertz parametric oscillator (left) and organic nonlinear crystals (right)

▶ Fields

Engineering, Interdisciplinary science and engineering

▶ Keywords

Development of kilo-watt-power Terahertz-wave source, Sensitive Terahertz-wave detection, Terahertz-wave applications, Nondestructive measurements, Nonlinear optics

▶ Publications

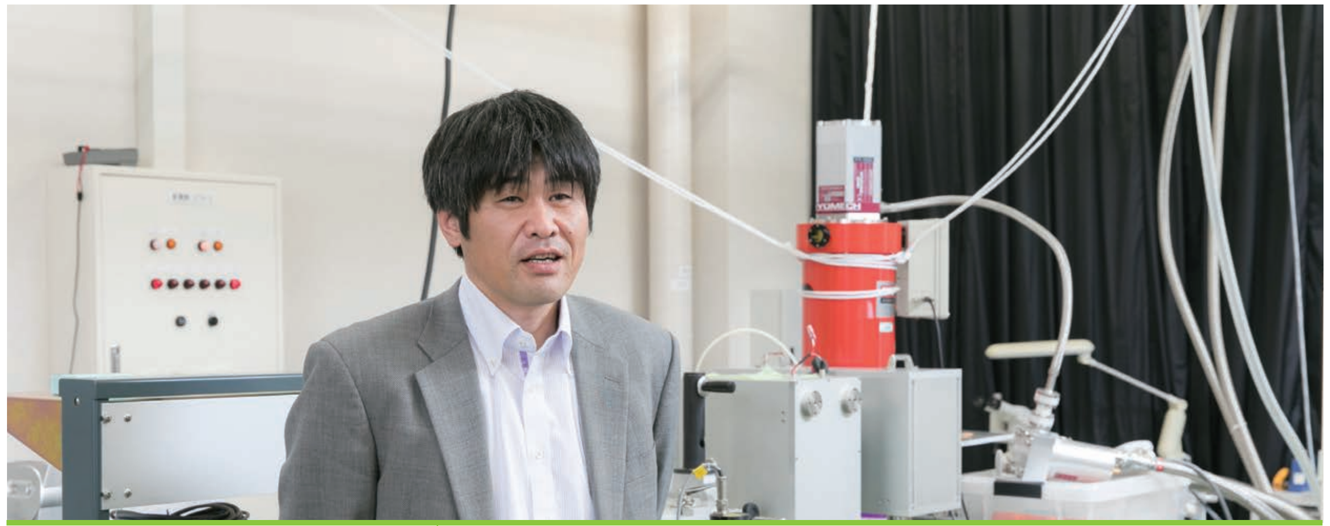
1. Takida, Y., Nawata, K., Notake, T., Otsuji, T., and Minamide, H.: "Optical up-conversion-based cross-correlation for characterization of sub-nanosecond terahertz-wave pulses" , ***Optics Express*** 30, 7, 11217−11227 (2022).
2. 南出泰亜, "後進テラヘルツ波パラメトリック光源", CSJ 42 Current Review42 赤外線の化学利用-近赤外からテラヘルツまで-, 32-36 (2021).
3. Minamide, H., Nawata, K., Moriguchi, Y., Takida, Y., and Notake T.: "Injection-seeded terahertz-wave parametric generator with timing stabilized excitation for nondestructive testing applications", ***Review of Scientific Instruments*** 92, 9, 093002, 1-8 (2021).
4. Shibuya, K., Nawata, K., Nakajima, Y., Fu, Y., Takahashi, E., Midorikawa, K., Yasui, T., and Minamide, H.: "Characteristics of nonlinear terahertz-wave radiation generated by mid-infrared femtosecond pulse laser excitation", ***Appl. Phys. Express*** 14, 9, 092004 (2021).
5. Han, Z., Ohno, S., and Minamide, H.: "Electromagnetic Wave Tunneling from Metamaterial Antiparallel Dipole Resonance" , ***Adv. Photonics Res.*** 2, 2000186, 1-7 (2021).

▶ Member

Yuma Takida / Takashi Notake / Kouji Nawata / Seigo Ohno / Yoshikiyo Moriguchi

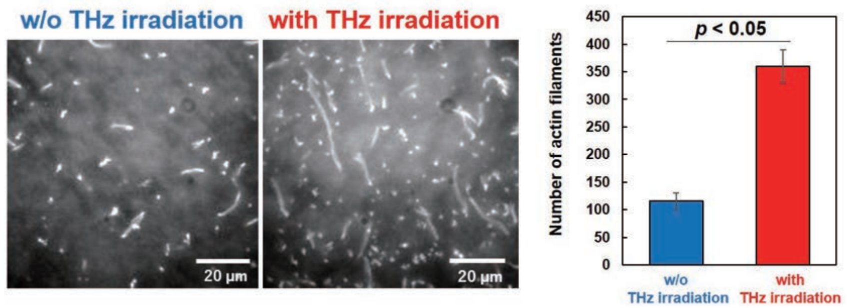
Terahertz Sensing and Imaging Research Team

Team Leader 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 technology, science and applications in THz sensing and imaging. Especially, we have promoted the research of THz spectroscopy of macromolecules, the challenge to the control of molecular structures and functions by the strong THz fields, the research of THz spectroscopy of macromolecules, and the development of high-sensitivity imaging detectors and their applications to the observational research as well as the collaborative research and development for its practical applications.



(Left) Fluorescent microscope images of biopolymer (actin filaments).
(Right) The number of actin filaments with or without THz irradiation.

Fields

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

Keywords

Terahertz science, Terahertz spectroscopy, Terahertz imaging, Terahertz control, Superconducting detector

Publications

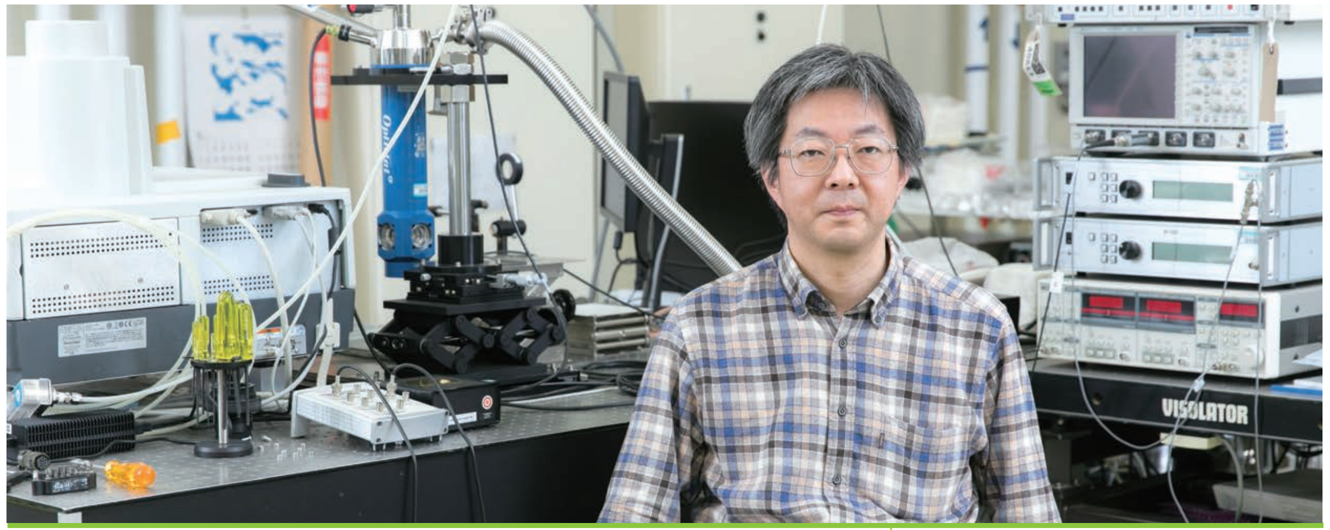
1. Feng, C. H., Otani, C., and Ogawa, Y.: "Innovatively identifying naringin and hesperidin by using terahertz spectroscopy and evaluating flavonoids extracts from waste orange peels by coupling with multivariate analysis" , *Food Control* vol.137, 108897 (2022).
2. Yamazaki, S., Ueno, Y., Hosoki, R., 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).
3. Momiyama, H., Sasaki, Y., Yoshimine, I., Nagano, S., Yuasa, T., and Otani, C.: "Depth super-resolved imaging of infrastructures defects using a terahertz-wave interferometer" , *NDT&E Int'* l. vol. 120, 102431 (2021).
4. Yamashita, M., and Otani, C.: "Intrinsic and extrinsic effects on intraband optical conductivity of hot carriers in photoexcited graphene" , *Physical Review Research* 3, 013150 (2021).
5. Ikeda, S., Yamashita, M., and Otani, C.: "Hot carrier dynamics and electron-phonon coupling in photoexcited graphene via time-resolved ultrabroadband terahertz spectroscopy" , *Physical Review Research* 3, 043143 (2021).

Member

Hiromichi Hoshina / Yoshiaki Sasaki / Javier Miguel Hernandez / Mingxi Chen / Yuya Ueno

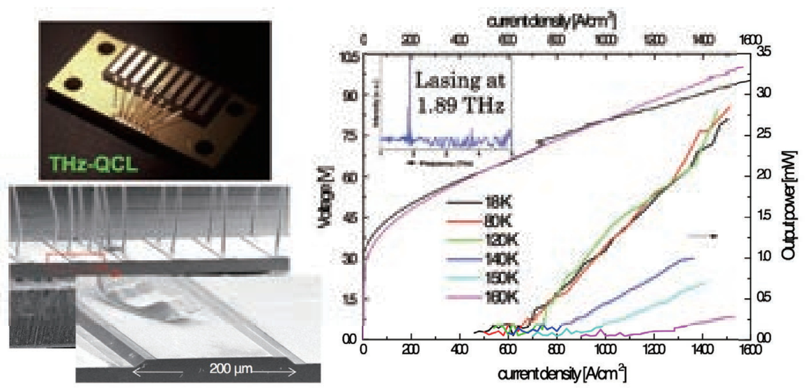
Terahertz Quantum Device Research Team

Team Leader Hideki Hirayama D.Eng.



Development of compact and potable terahertz laser source

Terahertz light having both the transparency of radio wave and the high resolution of light is expected to be used in a wide range of application fields as a light source for various perspective and nondestructive inspections. We are developing THz-QCL (terahertz quantum-cascade laser), which is expected to be a very compact, portable, high power terahertz light source. Through the introduction of a new quantum subband structure and/or nitride semiconductors, THz-QCL aiming for implementation in society is being developed by performing room temperature oscillation and enlarging the operating frequency region which have been impossible so far. By developing the next generation compact terahertz imaging devices, we would like to contribute to the realization of a prosperous society in the near future.



Schematic structure and operating properties of terahertz quantum-cascade laser (THz-QCL)

Fields

Optical Devise Engineering, Quantum Electronics, Semiconductor Physics

Keywords

Terahertz, Quantum cascade lasers, Inter-subband transition, Nitride semiconductors lasers, Molecular-beam epitaxy

Publications

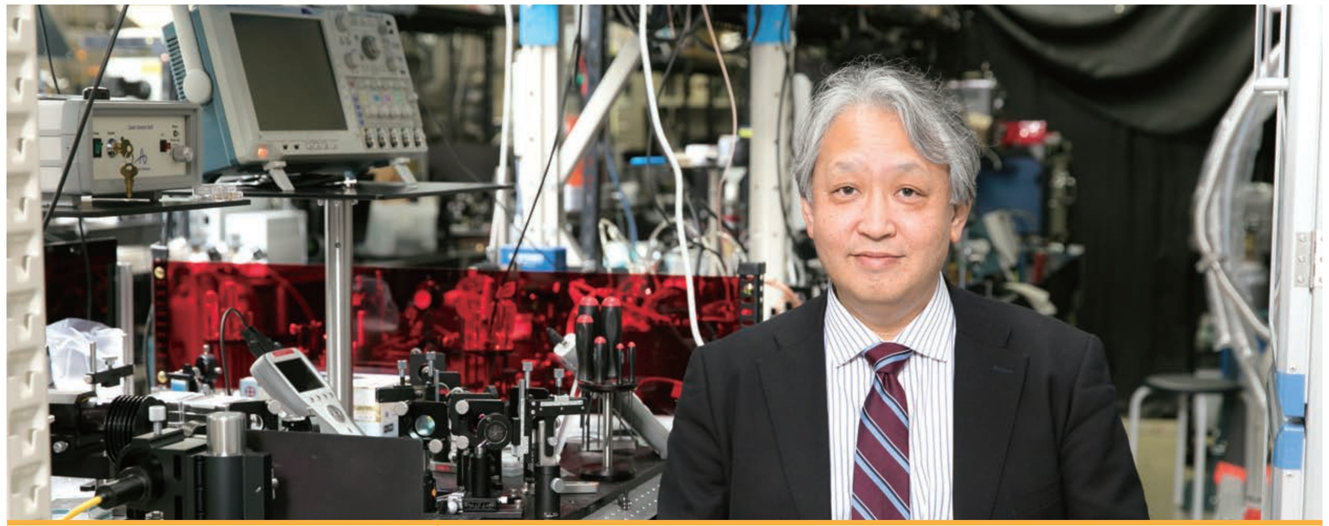
1. Wang, L., Lin, T., Wang, K., Grange, T., and Hirayama, H.: "Leakages suppression by isolating the desired quantum levels for high temperature terahertz quantum cascade lasers" , *Scientific reports* 11, 23634 (2021).
2. Wang, L., Lin, T., Wang, K., Grange, T., and Hirayama, H.: "Engineering of electron–longitudinal optical phonon coupling strength in m-plane GaN terahertz quantum cascade lasers" , *Applied physics Express* 14, 11, 112003 (2021).
3. Wang, L., Lin, T., Wang, K., Grange, T., Birner, S. and Hirayama, H.: "Short-period scattering-assisted terahertz quantum cascade lasers operating at high temperatures" , *Scientific Reports* 9, 9446 (2019).
4. Wang, L., Lin, T., Wang, K., and Hirayama, H.: "Parasitic transport paths in two-well scattering-assisted terahertz quantum cascade lasers" , *Applied Physics Express* 12, 8, 082003-1-5 (2019).
5. Lin, T., Wang, L., Wang, K., Grange T. and Hirayama, H.: "Optimization of terahertz quantum cascade lasers by suppressing carrier leakage channel via high-energy state" , *Appl. Phys. Express* 11, 11, 112702 1-5 (2018).

Member

TsungTse Lin / Li Wang / Masafumi Jo / Ke Wang

Photonics Control Technology Team

Team Leader Satoshi Wada Ph.D.



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

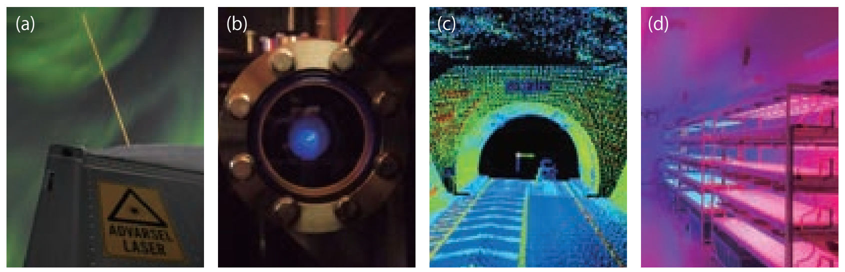
1. Miyata, K., Kato, K., Wada, S., and Petrov, P.: "Thermo-optic dispersion properties of CdSe for parametric nonlinear interactions", ***Opt. Mater. Express*** 12, 963-969 (2022).
2. Fujii, K., Goto, T., Koike, K., Sugiyama, M., Nakamura, S., and Wada, S.: "Carrier Pathway for Photoelectrochemical Water Oxidation with Intermediate State in n-type GaN Compared with Route of Anodic Corrosion" , ***The Journal of Physical Chemistry C*** 125 (16), 8562-8569 (2021).
3. Matsuura, R., Lo, CW., Wada, S., Somei, J., Ochiai, H., Murakami, T., Saito, N., Ogawa, T., Shinjo, A., Benno, Y., Nakagawa, M., Takei, M., and Aida.,Y.: "SARS-CoV-2 disinfection of air and surface contamination by TiO2 photocatalyst-mediated damage to viral morphology, RNA, and protein" , ***Viruses*** 13, 942 (2021).
4. Tsuyama, S., Taketani, A., Murakami, T., Sakashita, M., Miyajima, S., Ogawa, T., Wada, S., Maeda, H., and Hanada, Y.: "Quantitative prediction of a functional ingredient in apple using Raman spectroscopy and multivariate calibration analysis" , ***Appl. Phys. B*** 127, 92 (2021).
5. Yumoto, M., Kawata, Y., Abe, T. Matsuyama, T., and Wada, S.: " Non-destructive mid-IR spectroscopy with quantum cascade laser can detect ethylene gas dynamics of apple cultivar 'Fuji' in real time" , ***Sci. Rep.*** 11, 20695 (2021).

Member

Norihito Saito / Kiwamu Kase /
Tomoki Matsuyama / Takafumi Sassa /
Takayo Ogawa / Masaki Yumoto / Katsushi Fujii /
Kentaro Miyata / Masayuki Maruyama /
Takeharu Murakami / Masato Otagiri /
Yoshito Ishiki / Michio Sakashita /
Katsuhiko Tsuno / Kei Taneishi / Kei Morishita /
Yasushi Kawata / Toshihiro Okashita / Yoko Ono /
Takeshi Matsumoto

Development of photonics control technology for science and social issues

Our team investigates new optical technologies for solving world-wide environmental and energy problems. We are mainly developing remote-sensing system of poisonous gas, lidar as an atmospheric monitor for high energy cosmic ray observation, and solar-pumped laser for advanced energy source. We are also developing tunable laser-based biosensors for biomedical and agricultural applications. These researches will contribute to build and to maintain social environment that humans can live safely. Moreover, we are investigating fundamental research topics including particle control with high power Lyman α coherent source, and development of laser pumped neutron source. New applied researches were performed on the basis of basic research of laser materials, and nonlinear optics.

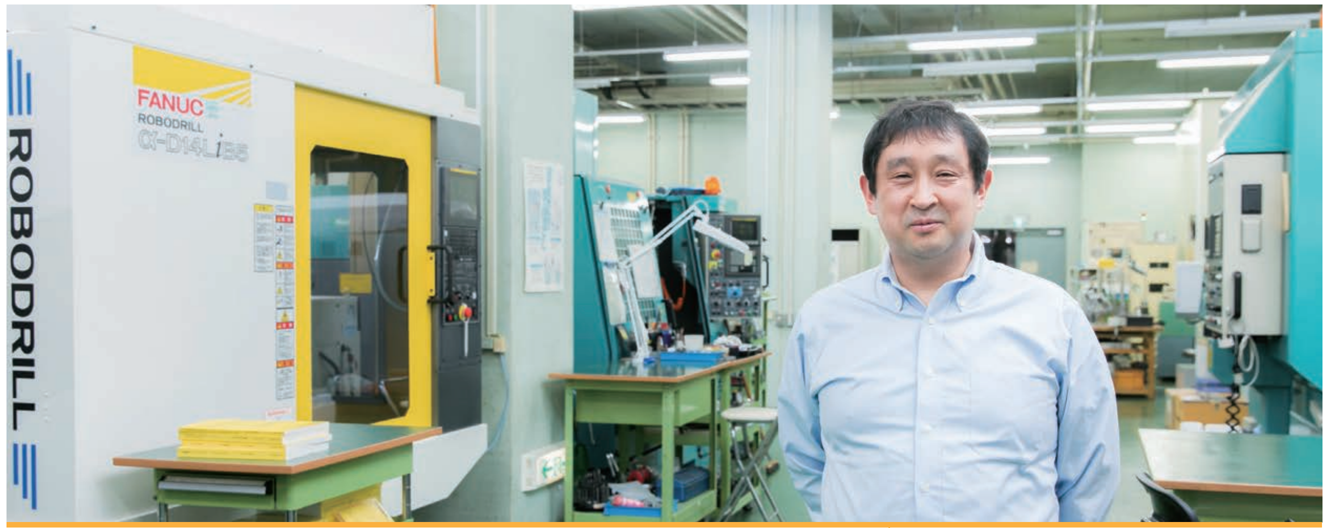


(a) Sodium LIDAR
(b) Coherent Lyman-α resonance radiation source for ultra-slow muon generation
(c) Laser inspection of infrastructure by courtesy of Shizuoka Pref. and Topcon Corp.
(d) Application of photonics control technology to plant cultivation

Advanced Photonics Technology Development Group

Ultrahigh Precision Optics Technology Team

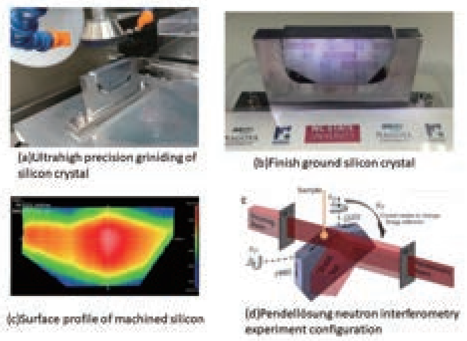
Team Leader Yutaka Yamagata D.Eng.



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 four 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.



Ultrahigh precision machining and metrology of silicon crystal for pendellösung interferometry

Fields

Engineering,
Interdisciplinary science and engineering

Keywords

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

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. Yamada, N., L., Hosobata, T., Nemoto, F., Hori, K., Hino, M., Izumi, J., Suzuki, K., Hirayama, M., Kanno, R., and Yamagata, Y.: "Application of precise neutron focusing mirrors for neutron reflectometry: latest results and future prospects" , ***J. Appl. Cryst.*** 53 (2020).
3. Saiki, T., Hosobata, T., Kono, Y., Takeda, M., Ishijima, A., Tamamitsu, M., Kitagawa, Y., Goda, K., Morita, S., Ozaki, S., Motohara, K., Yamagata, Y., Nakagawa, K., and Sakuma, I.:"Sequentially timed all-optical mapping photography boosted by a branched 4f system with a slicing mirror", ***Opt. Express*** 28, 31914-31922 (2020).
4. Hosobata, T., Yamada, N., L., Hino, M., Yoshinaga, H., Nemoto, F., Hori, K., et al.: "Elliptic neutron-focusing supermirror for illuminating small samples in neutron reflectometry" , ***Optics Express*** Vol. 27, Issue 19, pp. 26807-26820 (2019), https://doi.org/10.1364/OE.27.026807
5. Notake, T., Takeda, M., Okada, S., Hosobata, T., Yamagata, Y., and Minamide, H.: "Characterization of all second-order nonlinear-optical coefficients of organic N-benzyl-2-methyl-4-nitroaniline crystal" , ***Scientific Reports*** 9(1) (2019), DOI: 10.1038/s41598-019-50951-1

Member

Koichiro Shirota / Yusuke Tajima /
Yoshiyuki Takizawa / Tetsuya Aoyama /
Noboru Ebizuka / Hiroyoshi Aoki /
Takuya Hosobata / Satoru Egawa /
Masahiro Takeda

Neutron Beam Technology Team

Team Leader **Yoshie Otake** D.Sci.

Fields

Physics, Engineering,
Interdisciplinary science and engineering

Keywords

Accelerator-based compact neutron system, Characterization of microstructure and texture evaluation in steels, Research and development of non-destructive inspection for infrastructures, Visualization of water and air hole in concrete slabs, Detection of salt damage in the concrete by prompt-gamma neutron activation analysis

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 METH PHYS RES A*** Vol.994, 165091 pp1-6 (2021).
2. 藤田訓裕，岩本ちひろ，高梨宇宙，大竹淑恵，野田秀作.: "散乱中性子イメージング法を用いた道路橋床版の滞水・土砂化検知システム", 日本材料学会第21回コンクリート構造物の補修，補強，アップグレードシンポジウム論文集.Vol. 21, pp484-489 (2021).
3. Otake, Y.: "RIKEN Accelerator-driven compact Neutron systems, RANS project -RANS, RANS-II, III, RANS-μ-" ***J. Neutron Res.*** vol. 23, no. 2-3, pp119-125 (2021).
4. Wakabayashi, Y., Yan, M., Takamura, M., Ooishi, R., Watase, H., Ikeda, Y., and Otake, Y.: "Conceptual study of salt-meter with 252Cf neutron source for on-site inspection of bridge structure", ***J. Neutron Res.*** vol. 23, no. 2-3, pp207-213 (2021).
5. Xu, P.G., Ikeda, Y., Hakoyama, T., Takamura, M., Otake, Y., and Suzuki, H.: "In-house texture measurement using a compact neutron source", ***J Appl Crystallogr*** Vol.53, pp444-454 (2020).

Member

Atsushi Taketani / Masato Takamura / Tomohiro Kobayashi / Yasuo Wakabayashi / Maki Mizuta / Takaoki Takanashi / Kunihiro Fujita / Chihiro Iwamoto / Mingfei Yan / Shota Ikeda / Makoto Goto

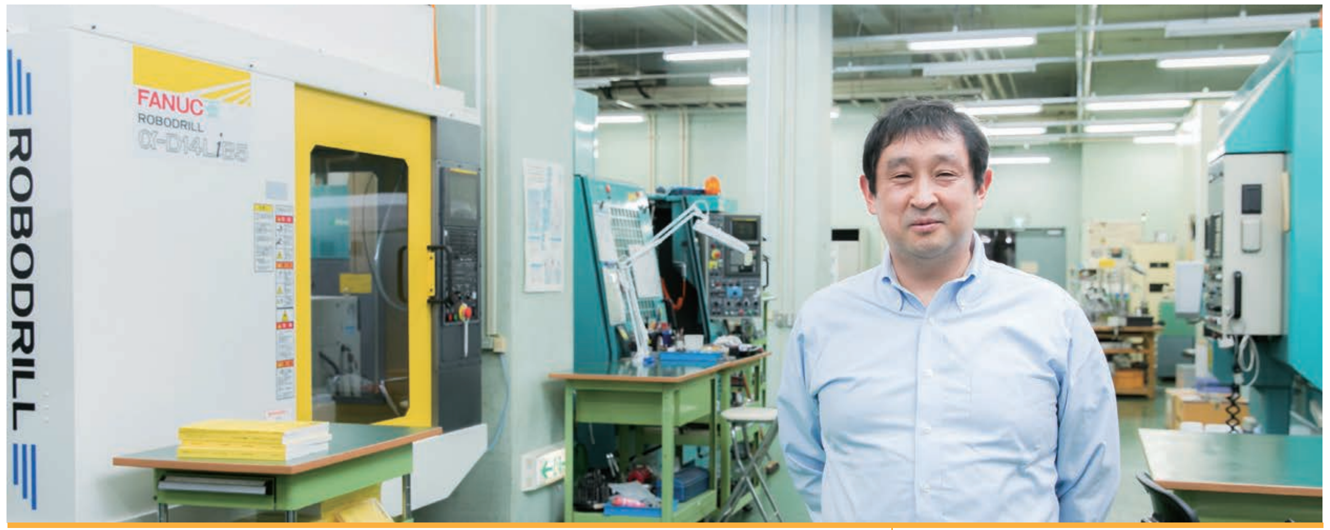
Research and development of compact neutron system for practical use at anytime, anywhere

RIKEN has developed accelerator-driven compact pulse neutron systems for practical use in industrial applications and non-destructive infrastructure inspection. They are called RIKEN accelerator-driven compact neutron source RANS and RANS-II. RANS has succeeded to develop non-destructive inspection methods with slow and fast neutrons. One is the visualization method of the corrosion and its related water movement of painted steels and the analytical method of the quantitative estimation of the water movement in the painted steels, the other is the neutron engineering diffractometer for the texture evaluation and the austenite volume fraction estimation of iron and steel. The others are the fast neutron imaging applications. Novel scattered neutron imaging method to see through the fracture in the concrete slab has been successfully developed. The compact neutron systems are expected to be widely used on-site.

The future imaging of compact neutron non-destructive test system on-site

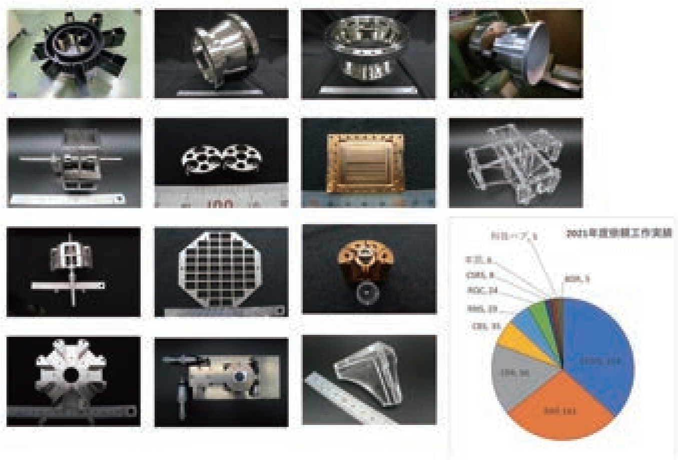
Advanced Manufacturing Support Team

Team Leader **Yutaka Yamagata** D.Eng.



Example of manufactured parts for scientific apparatus and number of requests

It is inevitably required to devise and/or maintain variety of advanced research instruments and equipments 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 equipments. 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 FY2021

Fields

Engineering,
Interdisciplinary science and engineering

Keywords

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

Publications

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Member

Kenji Yamazawa / Shigeru Ikeda / Takeshi Fujimoto / Masahiro Takeda / Masaharu Watanuki / Ichiro Takahashi / Susumu Shimoda