Research Institute for Interdisciplinary Science (RIIS)

RIIS

· Established in April 2016 utilizing the strength of Okayama Univ.: Physics and Biological Science

· World-class research achievements in mathematics, physics, chemistry, and structural biology.

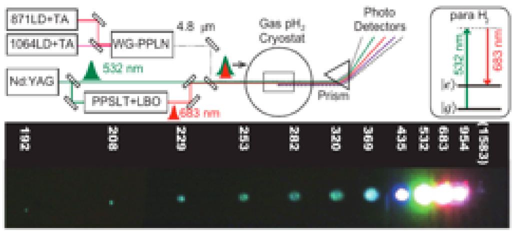
· Active Research (2010.1-2019.5) (Highly Cited Papers: 92
Impact factor >9.5 journals: 79 Nature·Science: 12 Patents: 16 (2017.5)

· Doctoral program (The division of Interdisciplinary Science)

Three Divisions (12 research sectors, 40 researchers, more than 100 students)

Quantum Universe

Neutrino physics by atomic spectroscopy

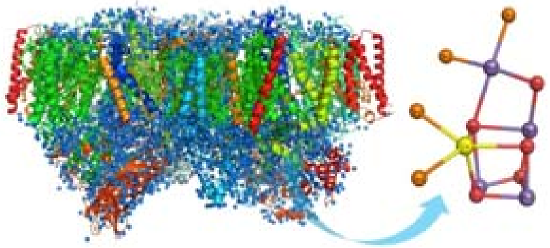


Research sectors

- Atomic Neutrino Spectroscopy ･･･ 2
- Advanced Quantum Beam ･･･3
- Mathematical Science ･･･4

Photosynthesis and Structural Biology

Mechanism of photosynthesis and development of artificial systems

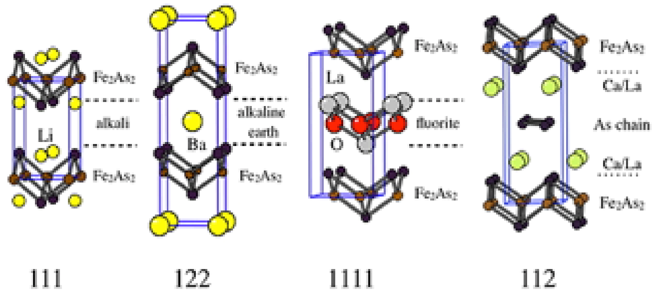


Research sectors

- Structural Biology for Photosynthesis ･･･5
- Functional Biology for Photosynthesis ･･･6
- Evolution and Structural Biology ･･･7
- Artificial Photosynthesis system ･･･8

Superconducting and Functional Materials

Design of new materials



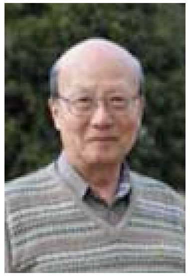
Research sectors

- Physics and Materials Design for High-T_c Superconductors ･･･ 9,10
- Quantum Physics for Superconductors ･･･11-13
- Light-Element Superconductors and Electronics ･･･ 14
- Synthetic Chemistry for Functional Materials Design ･･･15
- Theoretical Chemistry for Energy Storage Materials ･･･16,17

Yoshimura / Uetake Group

Research Sector of Neutrino Mass Spectroscopy

We are opening up the new field of "neutrino mass spectroscopy with atoms" using a "macro-coherent amplification mechanism", which is a newly invented and quantum coherent targets. The challenge will be to clarify various neutrino-related issues, such as the nature of neutrino mass (Dirac or Majorana), mass hierarchy, absolute neutrino mass, and the CP violating phase, all of which give essential clues to the origin of the matter-antimatter imbalance in our universe.

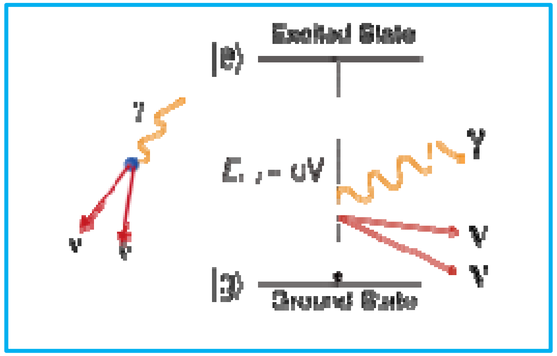


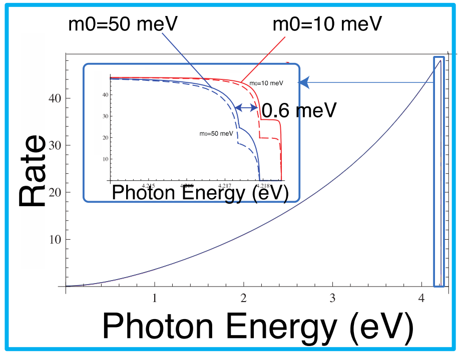
Prof. Yoshimura

Prof. Uetake

Neutrino mass spectroscopy with Atom

Observing a radiative emission of neutrino pair (RENP), we could determine absolute neutrino mass, mass hierarchy and so on, taking advantage of eV-order atomic excited energy and precision determination of laser energy.

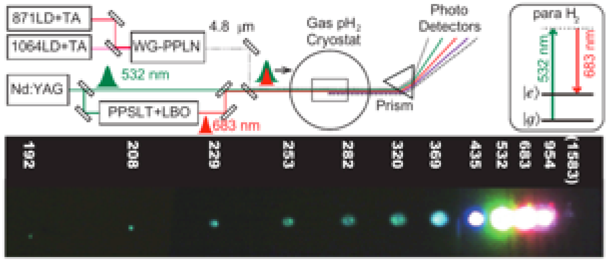




(left) Radiative emission of neutrino pair (RENP) (right) Neutrino mass measurement

Macro-coherent amplification mechanism

We are studying a new amplification mechanism, which is essential to research neutrino mass spectroscopy. We have observed coherent pair emission from para hydrogen target, suggesting "macro-coherent amplification".



(Left) Raman side band from coherently excited para Hydrogen.
(Right) High performance pulse laser system.

HP: http://www.riis.okayama-u.ac.jp/en/divisions/core1/ Email: uetake@okayama-u.ac.jp

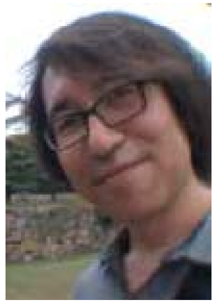
Yoshimura/Sasao/Yoshimi Group

Research Sector of Advanced Quantum Beam

We are creating new research fields, e.g. innovative quantum optics using the nucleus, and a coherent quantum beam based on a novel principle and so on, aiming at future development of both fundamental and applied science.

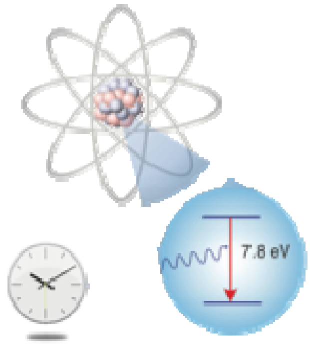

Prof. Yoshimura


Prof. Sasao


Prof. Yoshimi

Nuclear Photonics using Coherent Laser Light

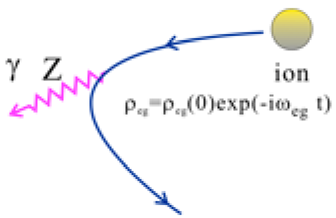
Among more than 3000 nuclei, only **Thorium 229** has an excited energy of order eV, which means it could be excited by coherent **laser** light source and utilized as a nuclear clock with ultimate precision.
We are developing a new method to search for Th-229 isomer level using **SPring-8 X-ray** source.

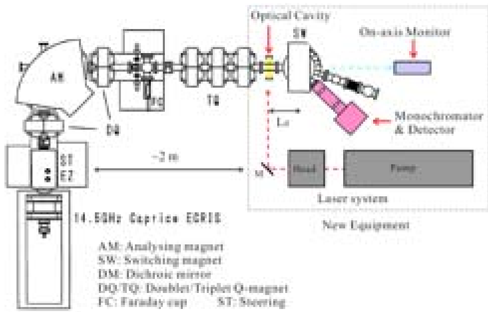


(left) Thorium-229 ; (right) SPring-8 BL09XU Experiment

Quantum Ion Beam

We are developing a new quantum ion beam (**QIB**) based on a novel principle, by which a intense gamma-ray beam would be produced from **coherently excited ion beam**. A pilot experiment is being built to prove its principle at RIKEN.





(Left) Basic principle of QIB. (Right) Proof-of-principle experiment at RIKEN.

HP: http://www.riis.okayama-u.ac.jp/en/divisions/core1/
Email: yosimura@okayama-u.ac.jp

Taniguchi / Kusuoka / Monobe Group

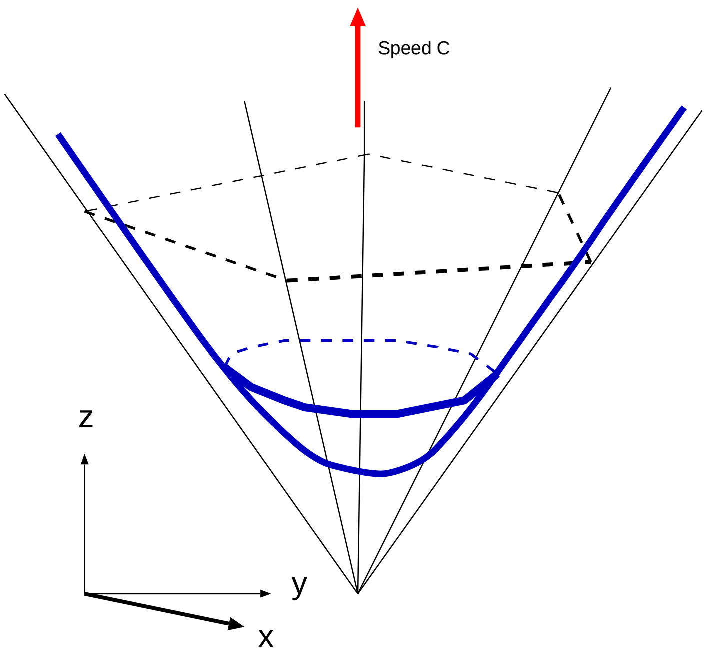
Research Sector of Mathematical Analysis

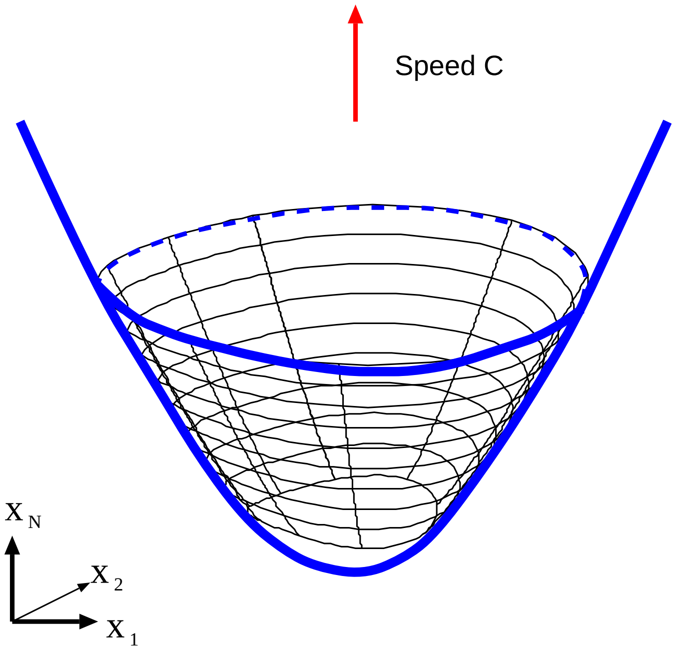

Prof. Taniguchi


Prof. Kusuoka


Prof. Monobe

- Nonlinear Partial Differential Equations (Prof. Taniguchi)
- Stochastic Differential Equations (Prof. Kusuoka)
- Free Boundary Problems (Prof. Monobe)





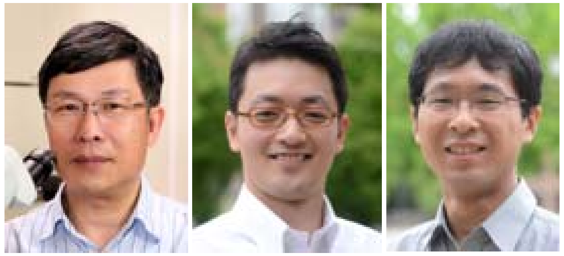
Pyramidal traveling fronts and axially non-symmetric traveling fronts to the Allen—Cahn Equations (Taniguchi, SIAM J. Math. Anal. 2007, 2015)

Email: taniguchi-m@okayama-u.ac.jp

Shen / Suga / Akita Group

Research sector of Structural Biology for Photosynthesis

We are studying the mechanism of photosynthetic water-splitting performed by photosystem II (PSII), a huge membrane-protein complex, by X-ray crystallography and cryo-electron microscopy in combination with other functional approaches. We also study the structures and functions of other photosynthetic membrane proteins as well as other plant-related membrane proteins.



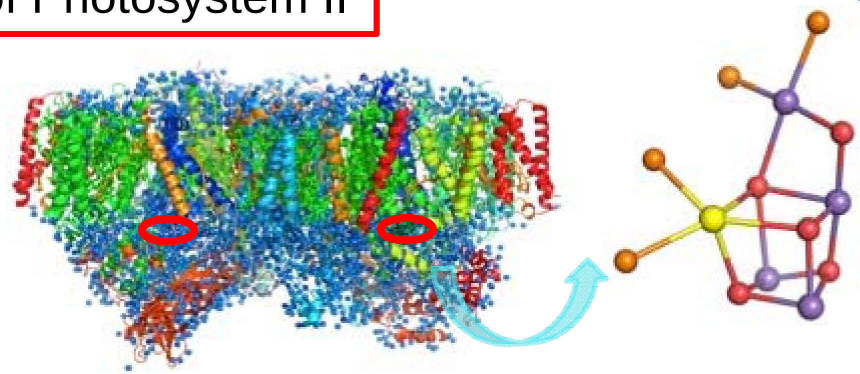
Prof. Shen | Asso. Prof. Suga | Asso. Prof. Akita

Structure and function of Photosystem II

We have solved the high-resolution structure of PSII and some of its reaction intermediates using X-ray crystallography and X-ray free electron laster (XFEL).

Ref:

1. Umena et al. **Nature**, 473, 55-60 (2011).
2. Suga et al. **Nature,** 517, 99-103 (2015).
3. Suga et al. **Nature,** 543, 131-135 (2017).



(left) Crystal structure of PSII; (right) The catalytic center of PSII for water-splitting (Mn_4CaO_5-cluster).

Structures and functions of other photosynthetic membrane proteins

We have solved the structure of plant photosystem I (PSI)-light harvesting I (LHCI) supercomplex and other photosynthetic membrane proteins and their complexes.

Ref:

1. Qin et al. **Science**, 348, 989-995 (2015).
2. Yu et al. **Nature,** 556, 209-213 (2018).
3. Wang et al. **Science**, 363, eaav0365 (2019).

Structure of plant PSI-LHCI (light-harvesting complex I) supercomplex. (Left) View along the membrane plane. (Right) View from the stromal side.

HP: http://www.riis.okayama-u.ac.jp/en/divisions/core2/ Email: shen@cc.okayama-u.ac.jp

Takahashi Group

Research Sector of Functional Biology for Photosynthesis

The objective of our group is to analyze structure/function relationship and functional dynamics of photosynthetic reaction center complex by molecular biology, biochemistry, and biophysics mainly using the green alga *Chlamydomonas reinhardtii* as a model organism.

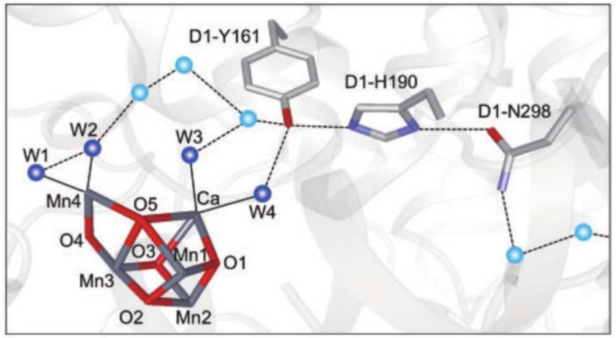
Prof. Takahashi

Engineering of reaction center protein by transformation

to clarify how light is converted into redox energy and how protons are translocated in reaction center complexes

Experimental methods

1. Chloroplast DNA is transformed to engineer amino acid residues on chloroplast-encoded proteins
2. Measurements of photosynthetic activities of transformants by various biophysical methods, such as PAM fluorometer, fluorescence spectrometer, thermoluminescence, Jolio-type spectrometer, etc.



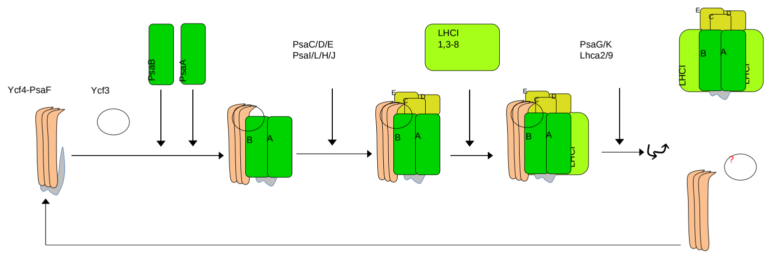
Hydrogen-bond network in photosystem II complex involved in proton translocation

Analyses of assembly apparatus of photosynthetic protein complexes

to clarify how multi-protein complexes of reaction center complexes are synthesized

Experimental methods

Auxiliary factors involved in the synthesis are genetically fused with tag and are purified by affinity chromatography and identify interacting proteins by LC-mass spectrometry



A schematic model of synthesis of photosynthetic reaction center complex

HP: http://www.riis.okayama-u.ac.jp/en/divisions/core2/ Email: taka@cc.okayama-u.ac.jp

Robinson Group

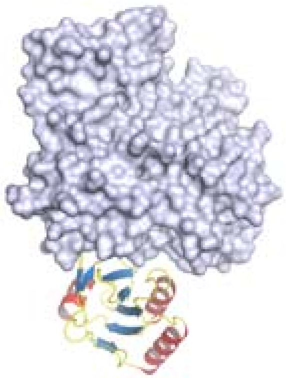
Laboratory of Evolution and Structural Biology

The Gods of the Actin Cytoskeleton

The origin of the eukaryotic cell is controversial. Metagenomics sequencing has revealed that Asgard archaea genomes contain potential homologs to eukaryotic genes. The Asgard superphylum of organisms includes Heimdahl, Loki, Odin, Thor archaeota named after the Gods from Norse mythology. Several of these gene products are involved in forming the cytoskeleton, a hallmark of eukaryotic cells. We structurally characterize the Asgard eukaryotic-like protein homologs, using X-ray crystallography and cryo-electron microscopy. We use biochemical and biophysical assays and mass spectrometry to compare the activities, and cross-activities, of Asgard, eukaryotic and bacterial proteins. Together, these data reveal the relationships between the archaea, bacteria and eukaryotic protein machineries, and determine whether the core interactions of these systems have been maintained during evolution.

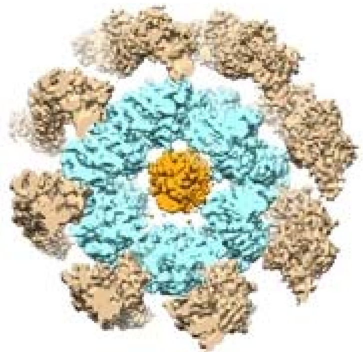
Prof. Bob Robinson
Email: br.okayama.u@gmail.com

Loki Profilin rabbit actin complex



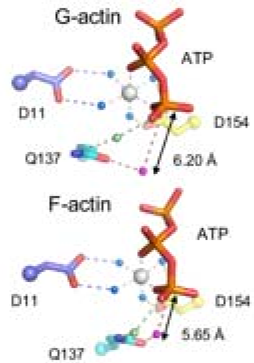
Akıl & Robinson (2018)
Nature, 562, 439–443

C. Botulinum actin-like filament



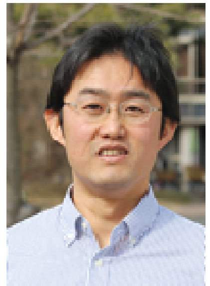
Koh et al. (2019)
Nat. Comm. In press

ATP hydrolysis in eukaryotic actin



Scipion et al. (2018)
PNAS 115, 10345-10350

Research Sector of Artificial Photosynthesis System
(*Coordination Chemistry Laboratory*)

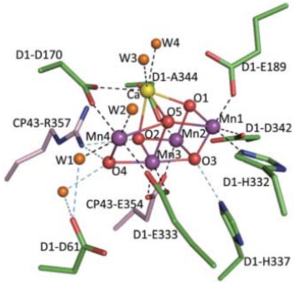



Prof. Suzuki **Prof. Isobe**

Our group aims to ...

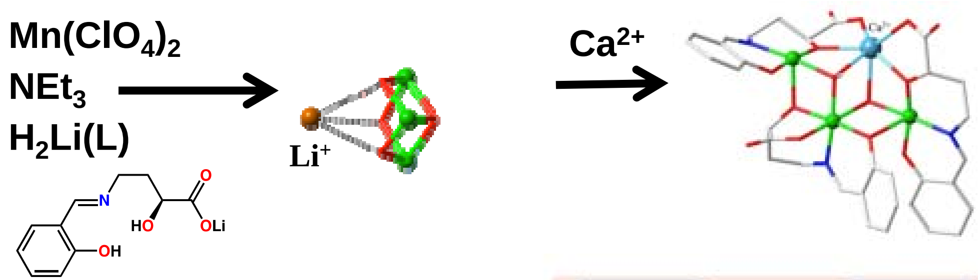
(1) create an artificial photosynthesis system by **mimicking the structure** of the oxygen-evolving complex (OCE) of photosynthetic organisms.

Mn_4Ca Cluster in OEC (a target compound)



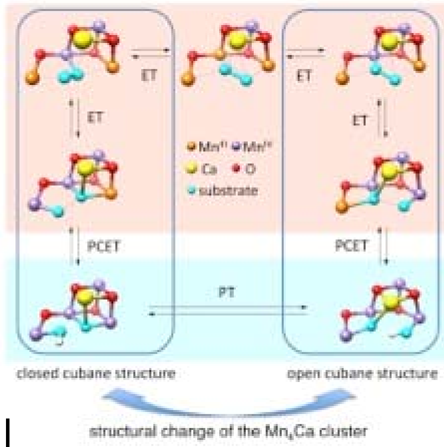
Our approach
with characteristic multi-dentate ligands which may stabilize cluster structure and multi-oxidation states.

$Mn_3Li(L)_3(OCH_3)$ **Mn_3Ca Cluster**



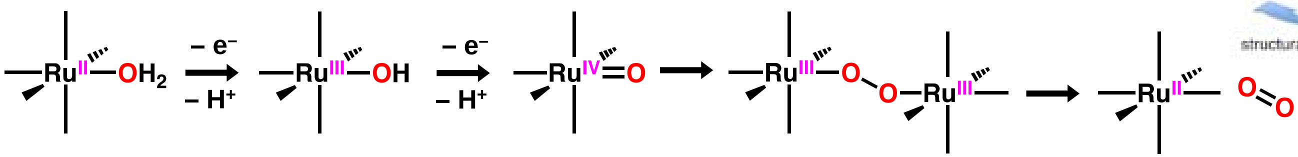
(2) investigate **the mechanism** of water-splitting and oxygen-evolving reaction on the Mn_4CaO_5 cluster.

Our approach with theoretical (DFT) calculation based on the structural and spectroscopic data for the Mn_4Ca cluster in OCE.



(3) develop new **transition metal complexes** that efficiently **split a water** into protons and an oxygen using light energy.

Strategy



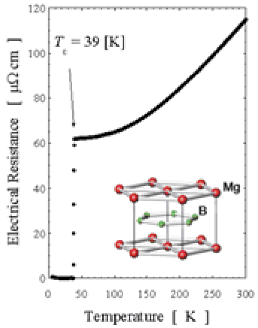
(4) synthesize novel mono-, di-, and multi-nuclear transition-metal complexes having **external stimuli-responsive** properties or peculiar crystallization behavior related to **chiral creation**.

HP: http://www.riis.okayama-u.ac.jp/en/divisions/core2/ Email: suzuki@okayama-u.ac.jp

Akimitsu Group

Research Sector of Physics and Materials Design for High-T_c Superconductors

Prof. Akimitsu



MgB_2 T_c= 39 K
Akimitsu 2001

We study superconductors and the main field lies in the synthesis of (various) novel superconductors.

Focus:

1. High Tc….synthesizing good quality crystals to study the superconducting properties.
2. Characterization & study on superconducting properties….investigating the detailed properties using high energy facilities (SPring 8 *etc*.). We have a strong collaboration with neutron facilities.
3. Study on the SC mechanism….Collaboration with international researchers to undercover the superconducting mechanism of our synthesis.

Supervisor:

Prof. Kobayashi

E-mail: kayakobayashi77@okayama-u.ac.jp

HP: http://www.okayama-u.ac.jp/user/akimitsu/top_eng.html

Nohara and Kudo Research Group

Prof. Nohara Prof. Kudo

Research Sector of Physics and Materials Design for High-T_c Superconductors

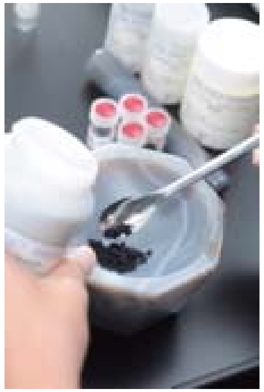
http://www.physics.okayama-u.ac.jp/nohara_homepage/index_e.html

Context

In recent years, quantum criticality has been considered as a universal guiding principle for developing unconventional superconductors, such as heavy fermion, iron-based, and high-T_c cupper-oxide superconductors, in which the superconducting transition temperature T_c can usually be enhanced by suppressing a competing antiferromagnetic order via chemical doping or the application of hydrostatic pressure. The study of the competitive nature of superconductivity and other orders can clarify the key factors governing T_c, and hence provide an opportunity to develop novel superconducting materials. We have applied this approach to reveal a competitive nature of superconductivity with structural phase transitions in a number of compounds, such as $IrTe_2$, $AuTe_2$, and $BaNi_2As_2$. For instance, we have demonstrated that the substitution of Pt for Ir can suppress the structural transition of $IrTe_2$, and induce superconductivity at the structural quantum critical point.

Aim of the study and work to be performed

One of the Ph. D study we propose aims at investigating chemical doping of Mo_3Sb_7 and demonstrates the competitive nature of superconductivity and the structural phase transition. Synthesis of Mo_3Sb_7 with various chemical doping will be performed: for instance a series of niobium-doped $Mo_{3-x}Nb_xSb_7$ will be synthesized. The products will be evaluated by power X-ray diffractions. The structural phase transition and superconducting transition will be examined by electrical resistivity, magnetization, and specific-heat measurements. Finally, electronic phase diagram that visualizes the competitive nature of superconductivity and the structural phase transition will be produced.



References

K. Kudo, M. Takasuga, Y. Okamoto, Z. Hiroi, and M. Nohara, Phys. Rev. Lett. **109**, 097002 (2012).

K. Kudo, H. Ishii, and M. Nohara, Phys. Rev. B **93**, 140505(R) (2016).

M. Nohara and K. Kudo, Advances in Physics: X **2**, 450 (2017).

Supervisors

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Prof. Kazutaka Kudo (kudo@science.okayama-u.ac.jp; Tel: +81-86-251-7805)

Yokoya / Muraoka Group

Research Sector of Quantum Physics for Superconductors

The objective of our group is to develop new materials that exhibit useful physical properties (functionalities) and to clarify the origin/mechanism of functionalities. Graduates from our group will have interdisciplinary field of view covering physics, chemistry, and engineering.

Prof. Yokoya

Prof. Muraoka

Electronic structure and local structure study

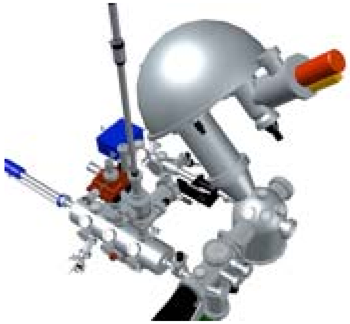
to clarify the origin/mechanism of functionalities using spectroscopic techniques

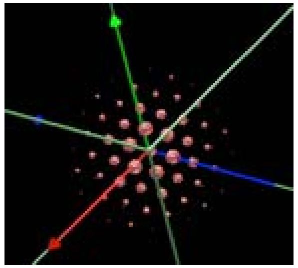
Materials for spectroscopic studies

New/Interesting superconductors, thermoelectric materials, half metals etc.

Experimental methods

Spin-resolved photoemission spectroscopy
Synchrotron spectroscopies
Photoelectron Holography(PEH)
EXAFS (in collaboration with Prof. Saini (Sapienza Univ. Rome)) etc.





(left) Photoemission spectrometer in our lab., (middle)SPring-8, and (right) local structure of diamond reconstructed from PEH.

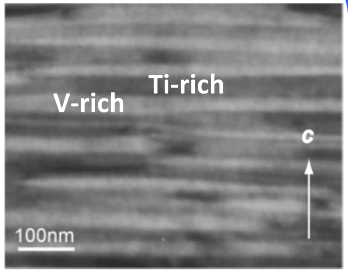
Preparation of functional material films

Target

Self-assembled multilayer films in oxides
ex) rutile-type TiO_2-VO_2 system
Born-doped diamond superconductor

Methods

Pulsed laser deposition
Hot-filament chemical vapor deposition



(Left) Excimer laser and growth chamber for film preparation.
(Middle) During film deposition.
(Right) Spontaneous formation of TiO_2-VO_2 multilayer films.

HP: http://film.rlss.okayama-u.ac.jp/index_eng.html E-mail: yokoya@cc.okayama-u.ac.jp, ymuraoka@cc.okayama-u.ac.jp

Ichioka / Adachi Group

Research Sector of Quantum Physics for Superconductors

Students of Ichioka/Adachi group will obtain research abilities of microscopic theories and computational calculations to clarify/predict new phenomena of condensed matter physics.

Prof. Ichioka Prof. Adachi

Theory of vortex/surface states of superconductivity

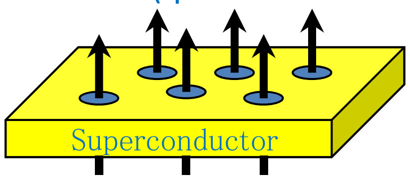
to clarify/predict new mechanism of unconventional superconductivity through the local electronic states and order parameter structures of non-uniform superconductivity.

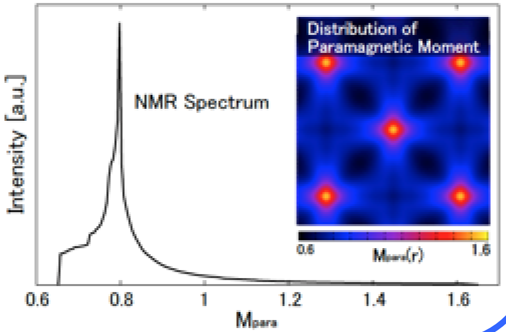
Physical properties under magnetic fields

Magnetic field dependence of specific heat, magnetization, STM image of local density of states, and NMR spectrum.

Topological superconductivity

Exotic vortex-core/surface states such as Majorana states. Multi-component superconductivity (spin-triplet pairing, multi-band).





Theory of novel spin transport phenomena

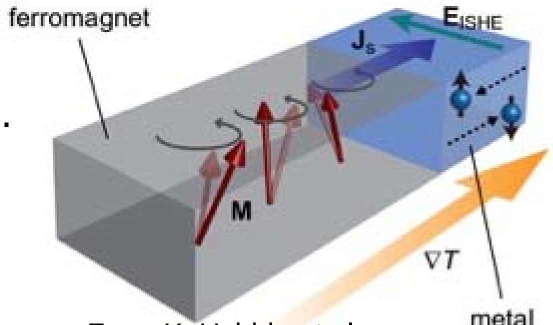
to clarify/predict new functionalities of spintronic devices using many-body theory

Spin Seebeck effect

Spin current generation by a temperature bias (spin Seebeck effect) attracts much attention as a versatile spin injection method.

Spin pumping

New spin injection method using microwaves (spin pumping) enables charge—free spin injection and thus has been applied to a number of exotic materials such as graphene, topological insulators, Rashba systems.



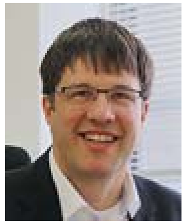
From K. Uchida et al., J. Appl. Phys. 111, 103903 (2012)

HP: http://www.physics.okayama-u.ac.jp/mp/index.eng.html E-mail: ichioka@okayama-u.ac.jp, hiroto.adachi@okayama-u.ac.jp

Jeschke/Otsuki Group

Research Sector of Quantum Physics for Superconductors

The group's activities are focused on connecting microscopic structure and measurable properties of solids by theoretical and computational methods. The objective is to understand complex properties like magnetism and superconductivity and to design new materials.



Prof. Jeschke

Prof. Otsuki

Analysis of lattice and electronic structure

Target:

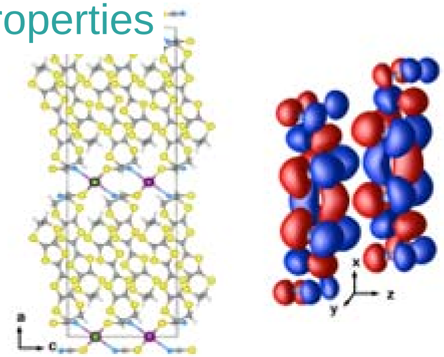
Microscopic understanding of properties

Materials:

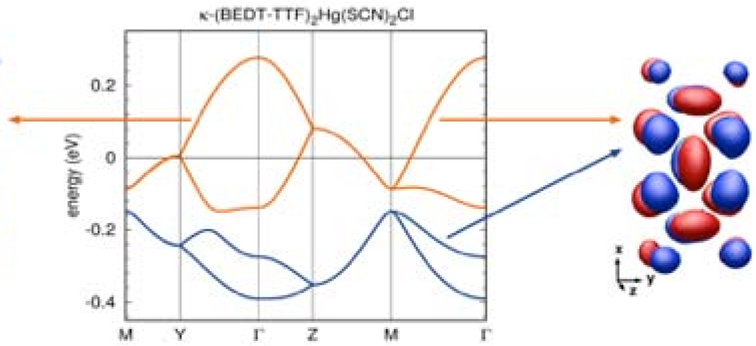
Superconductors, oxides, complex magnets, organics

Methods:

Density functional theory
Dynamical mean field theory
Model Hamiltonian approaches



organic charge transfer salt



electronic structure represented by Wannier functions

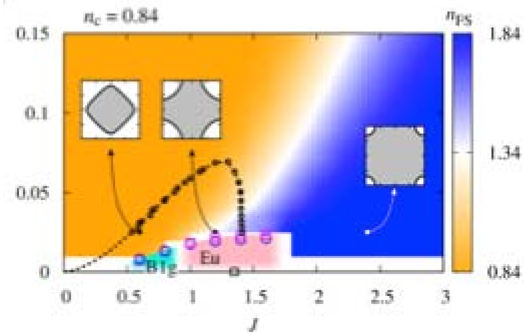
Theory for Strongly Correlated Electron Systems

Computer-physics approach:

New methods are developed for elucidating magnetic and superconducting properties in materials. Ex) beyond dynamical mean-field theory, quantum Monte Carlo method, etc

Data-science approach:

Long-standing problems in physics might be solved by new techniques such as data science, machine learning, etc



calculated superconducting phase diagram of a model heavy-fermion system

HP: http://www.physics.okayama-u.ac.jp/jeschke_homepage/ E-mail: Jeschke@okayama-u.ac.jp, j.otsuki@okayama-u.ac.jp

Kubozono / Goto Group

Research Sector of Light-Element Superconductors and Electronics

The objective of our group is to study and develop new functional materials and devices. Graduates from our group will have an interdisciplinary field covering physics, chemistry, and engineering.

Prof. Kubozono

Prof. Goto

Preparation and characterization of new functional materials

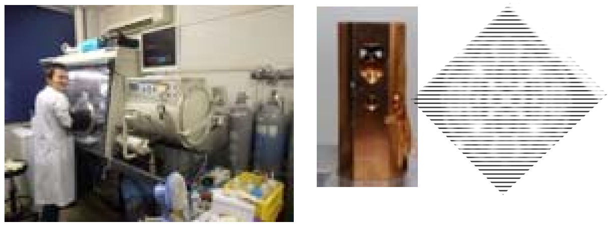
To prepare new materials with novel physical properties like superconductivity

Toward superconducting materials with high superconducting transition temperature (T_c) and novel physical properties

- New chemical and physical approach for preparation of new superconducting materials
- High pressure and magnetic field application

Experimental methods

- High-temperature synthesis, synthesis with liquid solvent, and electrochemical / electrostatic reaction
- Measurements of electrical and magnetic properties under pressure
- Structure determination by diffraction and holography



(left) Preparation of materials using glove box, (middle) photo of diamond anvil cell for electric transport measurement under pressure, (right) photoemission holography image

Preparation of functional electronic devices

To fabricate new electronic devices with two-dimensional (2D) materials

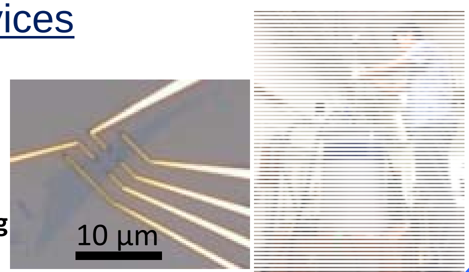
Achievement of new physics based on 2D materials and future practical devices

- Physics of Majorana and Weyl fermions
- Physics of Dirac fermions (graphene)
- Physics of carbon-based transistor and future application

Experimental methods

- transport properties at low temperature and high magnetic field

(left) Optical microscope image of graphene device, (right) measurement using superconducting magnet system



HP: http://interfa.rlss.okayama-u.ac.jp/index.html/ Email: kubozono@cc.okayama-u.ac.jp, hgoto@okayama-u.ac.jp

Nishihara / Iwasaki / Mori Group

Research Sector of Synthetic Organic Chemistry for Functional Materials

We are seeking for new catalytic reactions that can afford 100% of atom-efficiency, based on organometallic chemistry and synthetic organic chemistry. We are also interested in creation of the novel functional materials from our synthesized organic compounds.

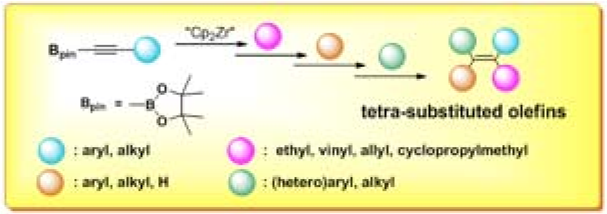

Prof. Nishihara

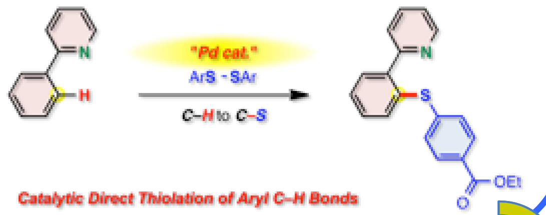

Dr. Iwasaki


Dr. Mori

Development of Synthetic Organic Reactions Catalyzed by Organometallic Complexes

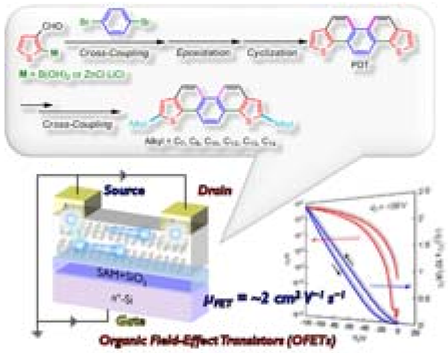
- Palladium-Catalyzed Cyanoesterification of Unsaturated Organic Compounds
- Highly Regio- and Stereoselective Synthesis of Multi-Substituted Olefins
- Development of an Efficient Synthetic Method for Unsymmetrical Diarylethynes by a Direct Activation of Carbon-Silicon Bonds
- Development of Direct Thiolation of C-H Bonds Catalyzed by Transition Metal Complexes

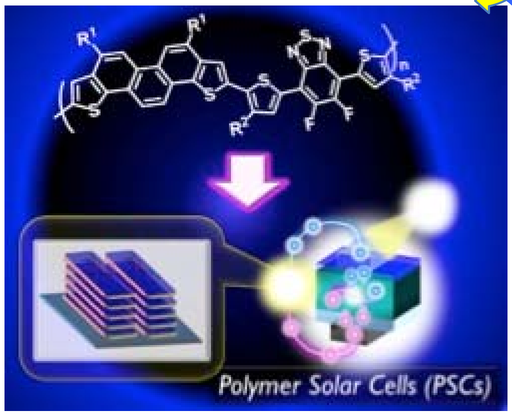




Application to Functional Materials

- Development of Sulfur-Containing Polycyclic Aromatic Hydrocarbons (PAHs) and Their Application to Organic Field-Effect Transistors
- Development of Phenacene-Based Semiconducting Polymers and Their Application to High-Performance Organic Solar Cells





HP: http://chem.okayama-u.ac.jp/~funcchem/top/ Email: ynishiha@okayama-u.ac.jp

Koga-Sumi Group

Research Sector of Theoretical Chemistry for Energy Storage Materials

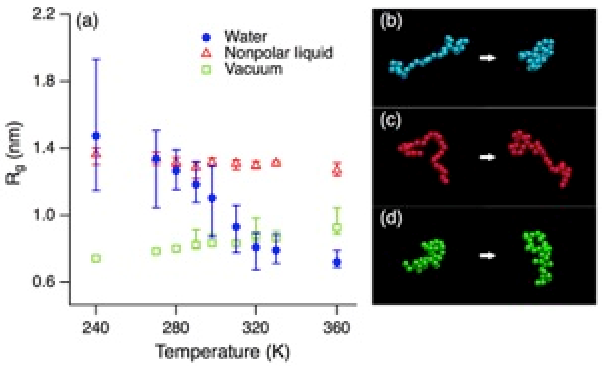
Theory and Computer Simulation of Liquids, Fluid Interfaces, and Biological Syste

http://phys.chem.okayama-u.ac.jp/english/index.html

Prof. Kenichiro Koga
koga@okayama-u.ac.jp

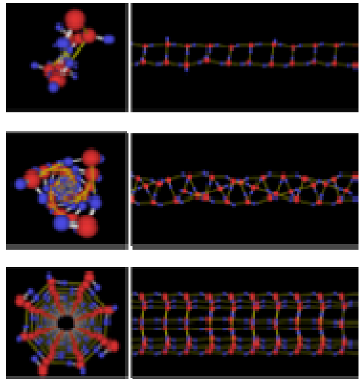
Assoc. Prof. Tomonari Sumi
sumi@okayama-u.ac.jp

- Hydrophobic effect and solvent-induced Interactions
  We understand the hydrophobicity and its role in biological systems.
- Phase transitions in bulk liquids, fluid interfaces, and confined systems
  We explore new kinds of phase transition in liquids and fluid interfaces.



Hydrophobic effect

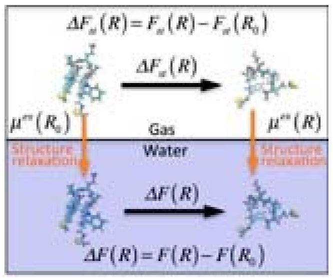
A hydrophobic polymer in water shrinks as the temperature is raised (blue) but the same polymer in a simple liquid or in vacuum does not (red).



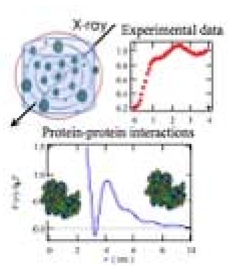
Phase transition

One-dimensional ice in carbon nanotube predicted by simulation

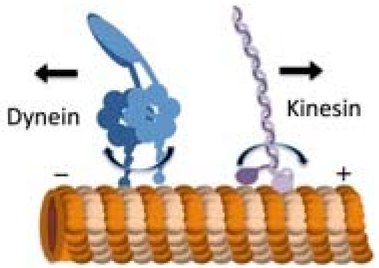
- Thermodynamic stability of proteins (Left)
  Liquid state theory and molecular simulations
- Colloid (protein) interactions (Middle)
  Small-angle scattering and an integral equation
- Chemomechanical coupling of molecular motors (Right)
  Stochastic modeling and single-molecule experimental data



Stability of proteins



Colloid interactions

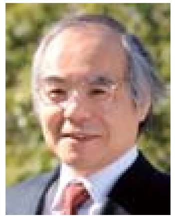


Molecular motors

Tanaka / Matsumoto Group

Research Sector of Theoretical Chemistry for Energy Storage Materials

The objective of our group is to understand structure, stability and dynamics of water, aqueous solutions, ices, and clathrate hydrates by developing theoretical methods and large-scale simulations. Graduates from our group will have interdisciplinary field of view covering physics, chemistry, and engineering.



Prof. Tananka

Prof. Matsumoto

Phase transition mechanism on water& aqueous phases in bulk & confined states
Prediction of novel ice polymorphs

Target

- Melting and formation mechanism of ices
- Liquid-liquid transition
- Novel ice structures (plastic ice, aeroice)

Methods

- Long-time molecular dynamics simulations

(Left) Melting mechanism of ice.
(Middle) Liquid-liquid coexistence of water.
(Right) New ice structure under very high pressures.

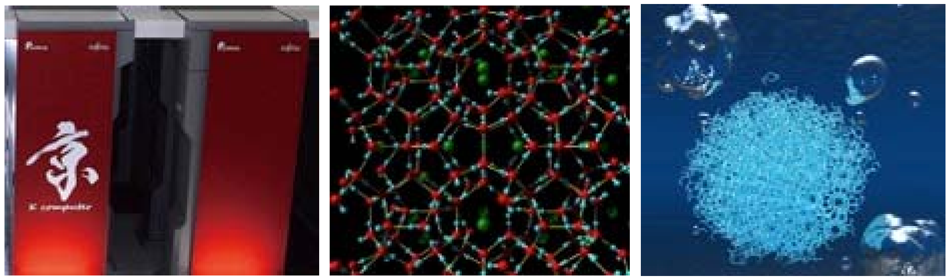
Theoretical study on stability and dissociation kinetics of clathrate hydrate

Target

- Clathrate hydrates
  - ex) Methane and CO_2 hydrates

Methods

- Statistical Mechanics
- Large scale molecular dynamics simulation



(Left) K-computer for large scale MD simulation.
(Middle) Structure of crystalline methane hydrate.
(Right) Dissociation of methane hydrate into water and methane bubble.

HP: http://theochem.chem.okayama-u.ac.jp/english/index.html Email: htanakaa@okayama-u.ac.jp, matsu-m3@cc.okayama-u.ac.jp

Financial support of international graduate students in RIIS

A three-year doctoral program is newly launched in the Division of Interdisciplinary Science, the Graduate School of Naturel Science and Technology at Okayama University. Research Institute for Interdisciplinary Science (RIIS) employs international graduate students of the doctoral program as a research assistant (RA). RAs normally earn about 120,000 yen a month. The amount is enough to complete the doctoral program.

Reference

· Tuition / Entrance / Application Fees

Tuition Fee	Entrance Fee	Application Fee
267,900 (yen/half year)	282,000 (yen)	30,000 (yen)

· Tuition / Entrance Fee Exemption

Full-time degree-seeking graduate students who have excellent academic records and yet have difficulties in continuing their academic study because of financial destitution might be exempted from paying half or the total of the tuition and entrance fees upon application.

· Cost of living in Okayama

Including rent and other costs, international students choosing to live in Okayama, the home of Okayama University, should budget about 80,000-100,000 yen a month for living expenses.

For life at Okayama, see “https://www.okayama-u.ac.jp/eng/about_okayama_university/About_Okayama.html”
For living in Okayama University, see “http://www.okayama-u.ac.jp/user/ouic/english/interstudents/livinginou.html”