Introduction of Cooperative Major in Nuclear Energy (CMNE) of Waseda University and Research on Reactor Engineering and Other Studies at CMNE

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Waseda University
Last updated: 2020/2/20
Waseda University

- Most popular Univ. in Japan (est. 1882)
- Located in the central Tokyo
- Reputation for fostering CEOs of international companies
- Facts (as of 2017)
  - 41,965 undergraduates
  - 8,256 postgraduates
  - 5,622 international students
  - 1,870 faculties
Number of International Students

https://www.waseda.jp/inst/cie/center/data
# Countries and Regions  As of May 1, 2019

<table>
<thead>
<tr>
<th></th>
<th>Students</th>
<th>Percentage</th>
<th>Name of Country / Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3,419</td>
<td>55.83</td>
<td>China</td>
</tr>
<tr>
<td>2</td>
<td>810</td>
<td>13.23</td>
<td>Republic of Korea</td>
</tr>
<tr>
<td>3</td>
<td>436</td>
<td>7.12</td>
<td>Taiwan</td>
</tr>
<tr>
<td>4</td>
<td>332</td>
<td>5.42</td>
<td>United States</td>
</tr>
<tr>
<td>5</td>
<td>104</td>
<td>1.70</td>
<td>Indonesia</td>
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</tbody>
</table>

https://www.waseda.jp/inst/cie/center/data
<table>
<thead>
<tr>
<th>Faculty of Political Science and Economics</th>
<th>Faculty of Law</th>
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<tbody>
<tr>
<td>Faculty of Letters, Arts and Sciences</td>
<td>Faculty of Education and Integrated Arts and Sciences</td>
</tr>
<tr>
<td>Faculty of Commerce</td>
<td>Faculty of Science and Engineering</td>
</tr>
<tr>
<td>Faculty of Social Sciences</td>
<td>Faculty of Human Sciences</td>
</tr>
<tr>
<td>Faculty of Sport Sciences</td>
<td>Faculty of International Research and Education</td>
</tr>
</tbody>
</table>
Where We Are

Science & Eng.

WASEDA University

Imperial Palace

Shinjuku
Faculty of Science and Engineering

(as of May 2015)

- 7,983 undergraduates, 3,066 postgraduates
- 491 professors and assistants
- 3 Schools/graduate schools, in total of 17 departments
  - Fundamental Science and Engineering
  - Creative Science and Engineering
  - Advanced Science and Engineering
Comprehensive collaboration agreement signed between JAEA, Waseda University and Tokyo City University

Reactor and fuel cycle experiments are held at JAEA (Japan Atomic Energy Agency) facilities
Cooperative Major in Nuclear Energy

• Established in April 2010 in collaboration with Tokyo City University (TCU)
• Admissions to Waseda University
  – 15 master course students / year
  – 4 doctor course students / year
  – Admissions examinations conducted at each university
• Lectures (Master course)
  – Lectures given by professors from both Waseda and TCU
  – Proficiency in Japanese required
• Research (Master and Doctor courses)
  – Principal research activities and supervisions separately conducted under each university
  – Peer reviews jointly conducted

Joint review with TCU

Annual symposium with the industry
Waseda University; popular in fundamental science and engineering as well as accelerator/radiation applications
Tokyo city University; Nuclear safety engineering and research reactor applications
Professors of Waseda University CMNE

Akifumi Yamaji
(Director, 2019-)

http://www.f.waseda.jp/akifumi.yamaji/
Advanced reactor design, core physics, nuclear safety and severe accidents, computational physics, fuel modeling
E-mail: akifumi.yamaji[@]waseda.jp
Dept. of Applied Physics

Masahiro Furuya

http://www.aoni.waseda.jp/furuya/
Reactor thermal-hydraulics, reactor safety, heat transfer, sensor technology, computational fluid dynamics, electro-chemistry, machine learning, material informatics

Yoshimichi Ohki

http://www.f.waseda.jp/yohki/
Electrical insulating materials, dielectrics, ion engineering
Dept. of Electrical Engineering and Bioscience

Masakazu Washio

http://www.f.waseda.jp/washiom/
Accelerator science, radiation physics, radiation chemistry, radiation engineering,
Dept. of Applied Physics
Applications to Doctor Course

• General requirements
  – Master’s degree in science or engineering
  – English proficiency (all guidance, communications in English)

• Admission to Graduate Schools under Faculty of Science and Engineering

• Inquiries regarding entrance examinations (E-mail)
  – admission[@]list.waseda.jp

• Faculty of Science and Engineering

• Cooperative Major in Nuclear Energy (CMNE, Waseda University)

• Akifumi Yamaji
  HP: [www.f.waseda.jp/akifumi.yamaji/home_e.html](http://www.f.waseda.jp/akifumi.yamaji/home_e.html)
  E-mail: akifumi.yamaji[@]waseda.jp
Yamaji Laboratory

http://www.f.waseda.jp/akifumi.yamaji/home_e.html
Akifumi Yamaji

- 1997 – 2006: University of Tokyo, Dr. Engineering
- 2006 – 2011: Research Engineer, Japan Atomic Energy Agency (JAEA)
- 2011 – 2014: Nuclear Scientist, OECD Nuclear Energy Agency (NEA)
- 2014 –: Assistant Professor (tenure), Waseda University
- 2018 –: Associate Professor
- 2019 –: Director (Head of Department)
Research Scope (Akifumi Yamaji)

1. SCWR
2. Fuel Performance Modeling (ATF)
3. Severe Accident Analysis (MELCOR)
4. Particle method (MPS method)

Since 2014
Core Design and Safety Analysis of SCWR

- Features of SuperCritical Water-cooled Reactor (SCWR)
  - Simple and compact once-through direct cycle plant system
  - High thermal efficiency (43-48%)
  - Utilization of matured LWR and FFPP
  - Flexible fuel management with thermal / fast neutrons
Core Design and Safety Analysis of SCWR

- Current works
  - Fast reactor core design studies
  - MA burning (+ LLFP transmutation)
  - Small Modular Reactor Design
  - Safety analyses

Recent publications

Accident Tolerant Fuel Development Project

- FeCrAl-ODS(Oxide Dispersion-Strengthened alloy)
- SiC/SiC composite
- Development teams:
  - Research institutes: JAEA, QST
  - Industry: MNF, MHI, Toshiba, Hitachi-GENE, NFD, GNF-J
  - University: Hokkaido U., Kyoto U., Waseda U.

Hydrogen generation

\[ \text{Zr} + 2\text{H}_2\text{O} \rightarrow \text{ZrO}_2 + 2\text{H}_2 \]
Fuel Performance Modeling for ATF Development

- Japanese (FEMAXI-7) contributions to IAEA-CRP-ACTOF (2018)

- Performance of FeCrAl-ODS-UO₂ during power ramps (FEMAXI-7)
Fukushima Analysis with MELCOR Code

- Severe accident analysis with MELCOR code:
  - For understanding severe accident
  - Contributions to Fukushima decommission
  - Implementing Agreement Relating to Participation in the Cooperative Severe Accident Research Program Between The United States Nuclear Regulatory Commission and Waseda University of Japan (2019-)

http://irid.or.jp/video/
Analyses of Unit-2 and Unit-3

Example of accident progression evaluated with MELCOR-2.2

Relatively low T?

水位低下

Relatively high T?

Pre-depressurization

Post-depressurization

Metallic debris?

Oxidic debris?

2. X. Li, I. Sato, A. Yamaji, "Insights on in-vessel core degradation behavior from sensitivity analysis of Fukushima Daiichi nuclear power plant unit3 by MELCOR", Proceedings of FDR2019, May 24-26, 2019, Fukushima, Japan
Particle Method

Simulating Molten Fuel Behavior

French experiment (CEA/Cadarache)

2018-2019

SAKURA Project

Jubaidah, Guangtao Duan, Akifumi Yamaji, Christophe Journeau, Laurence Buffe, Jean-Francois Haquet, "Investigation on corium spreading over ceramic and concrete substrates in VULCANO VE-U7 experiment with moving particle semi-implicit method," Annals of Nuclear Energy 141 (2020) 107266
Student Internships, Foreign Students
Furuya Laboratory

http://www.aoni.waseda.jp/furuya/
Masahiro Furuya

- Reactor thermal-hydraulics
- Reactor safety
- Heat transfer
- Sensor technology
- Computational fluid dynamics (CFD)
- Electro-chemistry
- Machine learning
- Material informatics
Thermal-Hydraulics Experiments and Simulations

• Multi-dimensional
  – Three-dimensional, two-phase flow measurement and modeling

• Transient
  – Fast transients (τ = 0.1 ms ~ 0.1 s)
  – Stability (τ = 2 s ~ 300 s)

• Coupling with other phenomena
  – Void-reactivity feedback
  – Chemical reactions
  – Iodine & Aerosol Chemistry
  – (Photo-)catalytic reactions
  – Melting, solidification, eutectic
We propose the new digital twin concept: physical replica of a numerical simulation with a help of the additive manufacturing technology.
Tackling scaling issue with additive manufacturing

Additive Manufacturing Machine (3D Printer)

Additive-Manufactured Scaled Core-Structure
Steps for Scalable Experiments toward Digital Twin

- **Powder Production**
  - Rapid quenching and atomizing by vapor explosions

- **Powder Metallurgy**
  - Sintering agent
  - Surface modification

- **3D Modeling**
  - 3D design
  - Meshing

- **Additive Manufacturing**
  - Laser fusion and solidification technology

- **Scaling & Similarity**
  - Scaling of model, measurement and control system

- **Analysis & Evaluation**
  - Electrochemistry
  - Chemical analysis
  - Statistics

- **Spectrometry**

- **Surface modification**

- **3D printer**
Identify Individual Bubble Motion

New algorm to determine three-dimensional velocity vectors for modeling lift and drag forces

Horizontal cross section of vertical round tube (i.d. 224 mm)

Length of 1 m/s: $D < 30 \text{ mm}$, $30 \text{ mm} < D < 50 \text{ mm}$, $50 \text{ mm} < D$

1000 bubbles $j_c=0.64 \text{ m/s}$, $j_L=0.64 \text{ m/s}$

Average Velocity over All Bubbles

Legend Color:
- $D < 30 \text{ mm}$
- $30 \text{ mm} \leq D < 50 \text{ mm}$
- $50 \text{ mm} \leq D$

Legend Color:
- $20 \text{ mm}$
- $50 \text{ mm}$
- $100 \text{ mm}$

Radial Position, $r/R$ (-)

Horizontal Coordinate, $x/R$ (-)

Vertical Velocity Component, $u_z$ (m/s)

Three dimensional reconstruction

Measured void Fraction

Velocity Vector Determination

Velocity Vector
CFD to System Analysis Codes

◆ Severe accidents
  ➢ MAAP
  ➢ MELCOR
  ➢ SAMPSON

◆ Transients
  ➢ TRACE
  ➢ RELAP
  ➢ RAMONA/MONA

◆ Subchannel Analysis
  ➢ COBRA-TF (CTF)

◆ CFD / CMFD
  ➢ StarCCM+
  ➢ AdvaceFlow/MP
  ➢ Open FOAM
  ➢ In-house LES

◆ Others
  ➢ BWR linear stability analysis
  ➢ Vapor film stability analysis
Washio-laboratory

http://www.f.waseda.jp/washiom/top-e.html
Masakazu Washio

- Radiation and accelerator applications
- Applied physics
- Capability of design and fabrication of advanced accelerators by himself, key of success in research and venture business
- Operating two advanced accelerators.
- Associate director of Science and engineering Institute of Waseda University
Washio Laboratory for High Quality Beam Sciences
Graduate School of Advanced Science and Engineering,
Joint Department of Nuclear Energy
Waseda University

Charge Measurement by Faraday Cup
Energy Measurement by Dipole Mag.

Beam Applications
Pulse Radiolysis for Early Events in Radiation Chemistry
Soft X-ray Generation via Inverse Compton Scattering
Washio Laboratory for **High Quality Beam Sciences**

Advanced Accelerator Sciences  
New Accelerator System  
New Beam Generation such as  
  *Monochromatic, Tunable Energy X-ray*  
High Quality Electron Beam  
  *ILC, Ultra-short Pulse, FEL,* etc.

Applications of Ionizing Radiation  
Development of  
  *Polymer Electrolyte Fuel Cell*  
  *Nano-scale Fabrications*  
  *Advanced Electron Beam Processing*

- Laser Photo-cathode RF-gun
- 200keV Curetron
- Nano-filter
- Fuel Cell Power Generation
Washio Laboratory for High Quality Beam Sciences

1999~
New Research Project was approved.
"High-Tech Research Center Project"
Purpose
High Quality Electron Beam Generation
and Application Experiments
(Pulse Radiolysis and Soft X-ray Generation)
2000/9 Construction of new building completed
Manufacturing of Accelerator
2001~ Main components installed
2002/4 An RF-gun facility was approval for operation
Beam Experiments started
2003/1 First Monochromatic Soft X-ray Generation
2003/10 Pico-second Pulse Radiolysis started
2004~ Low Emittance Electron Beam by Modified
Laser Beam Injection Technique
2004/4 Approval of Second Stage of the Project
2005- Improvement of Pulse Radiolysis System
and Soft X-ray Generation System
2006- RF-Gun Upgrading project started
2009- Multi-bunch Electron Pulses
2010- Applied for Accelerator Training of Students

Outlook of Kikui-cho Building
Washio Laboratory for High Quality Beam Sciences

Facility Layout at Kikui-cho campus in Waseda University

Control unit

RF-gun system

Power system room

Klystron & Modulator
**Washio Laboratory for High Quality Beam Sciences**

**Advanced Accelerator Applications**

X-ray Generation by Inverse Compton Scattering

Pico-second Pulse Radiolysis for ultra fast phenomena
Focused Ion Beam

Advanced Accelerator Applications

FE-SEM image of fiber pattern of Crosslinked PTFE (RX-PTFE) obtained by FIB process

Gα⁺ ion source

focusing lens

aperture

object lens

sample

2 μm
Electron beam nano-imprint lithography (EB-NIL) with RX-PTFE mold

Mold (RX-PTFE) → Nano-imprint pattern

Example of fine structure pattern

Top: 100 nm
Bottom: 300 nm
Height: 3.8 μm
Aspect ratio >12
Ohki-laboratory

http://www.f.waseda.jp/yohki/top_en.html
Yoshimichi Ohki

• Electrical materials, insulators etc.
• Electrical engineer
• Operates an accelerator for irradiation effect research of electrical cables
• Received many awards such as Whitehead memorial award of IEEE.
• Wrote many papers and helped many graduate students to get prizes
• Honorary professor of Xian Jiao Tong University
Prof. Yoshimichi OHKI

- has published a tremendous numbers of refereed papers in reputed journals (333 in journals, 219 at international conferences, and over 584 at domestic conferences)
- has been awarded many prizes. Many of his students have also been awarded, which significantly helps them to raise their careers.
- has supervised a largest number of doctoral students in electrical engineering.
- has been active in many institutes such as international and domestic academia and governmental bodies.

2011 – Present  Honorary Professor, Xian Jiaotong University
2011 – Present  President of the Institute of Engineers on Electrical Discharges in Japan
2008     Vice President, IEE Japan
2006 – 2008  Senior Fellow, Japan Science and Technology Agency
2006 - Present  Director, IEE Japan
2006 – 2010  Committee Member, Nuclear Energy Agency, OECD
2004 – Present  Committee Member, Nuclear and Industrial Safety Agency, METI
2001 – 2006  Visiting Professor, RIKEN
1982 – 1984  Visiting Scientist of Electrical Engineering, MIT, USA
1981 – 1983  Visiting Scientist, Nagoya University
Ohki Laboratory Dielectric Materials
Research Applications of Ion Irradiation to Dielectrics
Processing and Device Development

Science
Ion Engineering

Optics

Photocatalyst
Environment

Waveguide Sensors
Sensors

Polarization Control
Polarization Maintaining Optical Fiber

Optical Fibers
Grating

Optical Switches
Photo-Coupler

Schematic illustration of the cross section of an ion-implanted optical fiber
Ohki Laboratory
Development of a Location System for Cable Aging, especially in NPPS

METI-NISA Project: Development of a Non-destructive Cable Aging Location System by Broadband Impedance Spectroscopy
Will be a standard test method

BIS ⇒ To detect changes in characteristic impedance of a cable

Test Result

Aged Portion

Cables Tested and Irradiation Facility
Thank you for your attention.

akifumi.yamaji [@] waseda.jp