



Waseda University

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

Akifumi YAMAJI,

Director, CMNE

Waseda University

Last updated: 2020/2/20





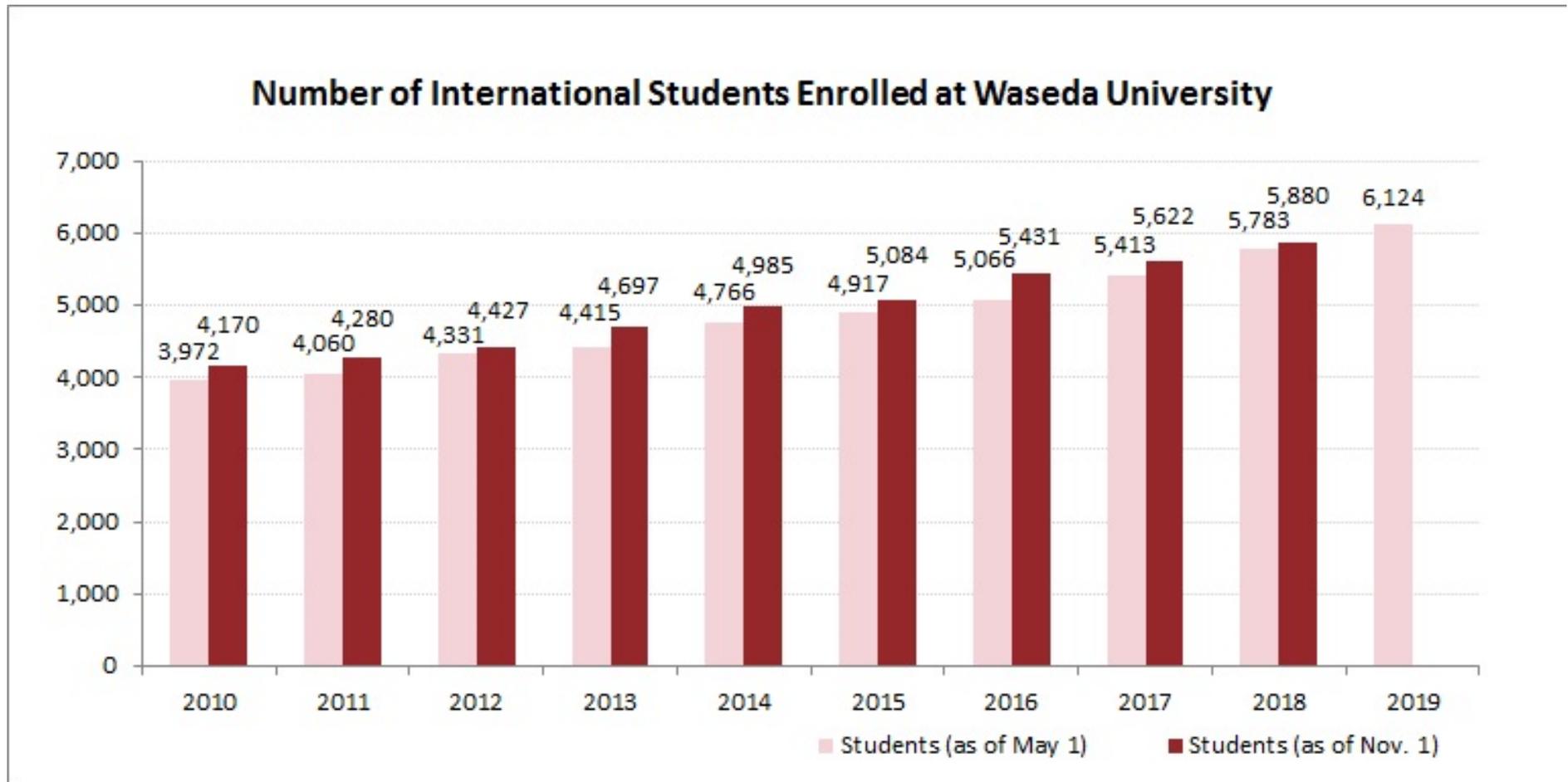
# Waseda University

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

	Students	Percentage	Name of Country / Region	
1	3,419	55.83	China	中国
2	810	13.23	Republic of Korea	韓国
3	436	7.12	Taiwan	台湾
4	332	5.42	United States	アメリカ
5	104	1.70	Indonesia	インドネシア

<https://www.waseda.jp/inst/cie/center/data>



 <b>Faculty of Political Science and Economics</b> 政	 <b>Faculty of Law</b>
 <b>Faculty of Letters, Arts and Sciences</b>	 <b>Faculty of Education and Integrated Arts and Sciences</b>
 <b>Faculty of Commerce</b>	 <b>Faculty of Science and Engineering</b> 工
 <b>Faculty of Social Sciences</b>	 <b>Faculty of Human Sciences</b> 人
 <b>Faculty of Sport Sciences</b> 体	 <b>Faculty of International Research and Education</b> 国

# Where We Are





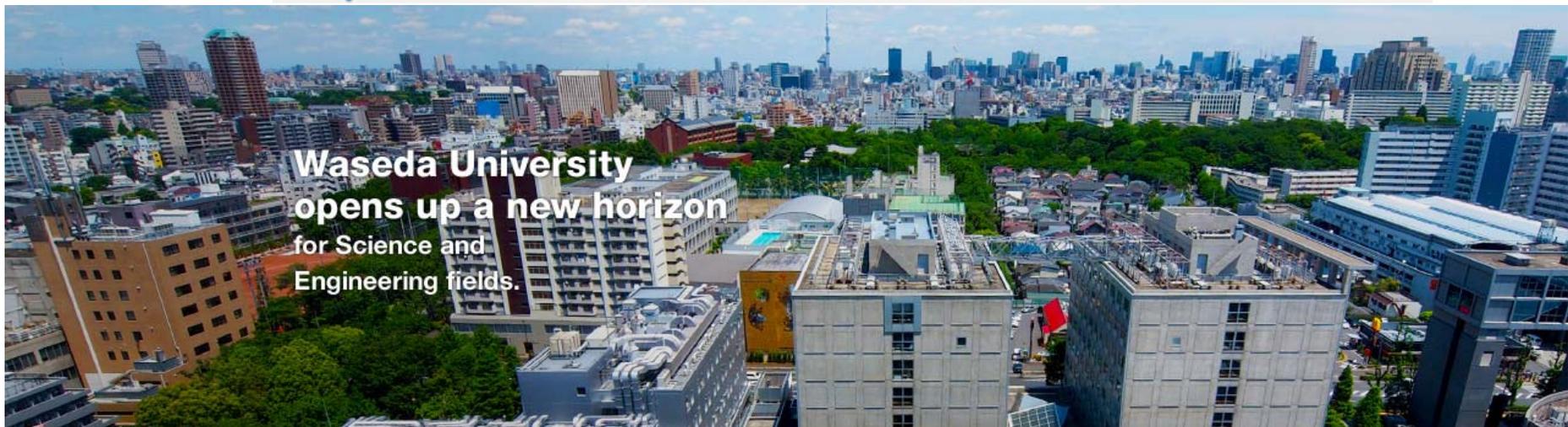
# Faculty of Science and Engineering

(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**



Waseda University  
School of **Advanced Science and Engineering**



Waseda University  
opens up a new horizon  
for Science and  
Engineering fields.

# Comprehensive collaboration agreement signed between JAEA, Waseda University and Tokyo City University

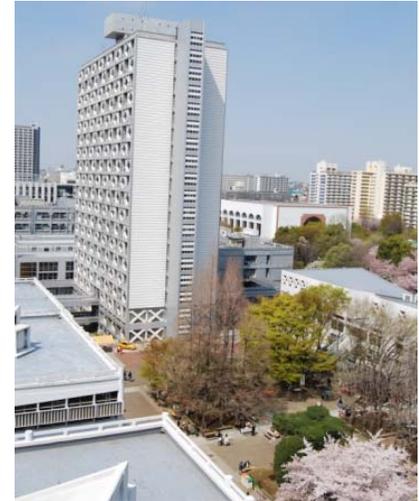


Reactor and fuel cycle experiments are held at JAEA (Japan Atomic Energy Agency) facilities



# 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

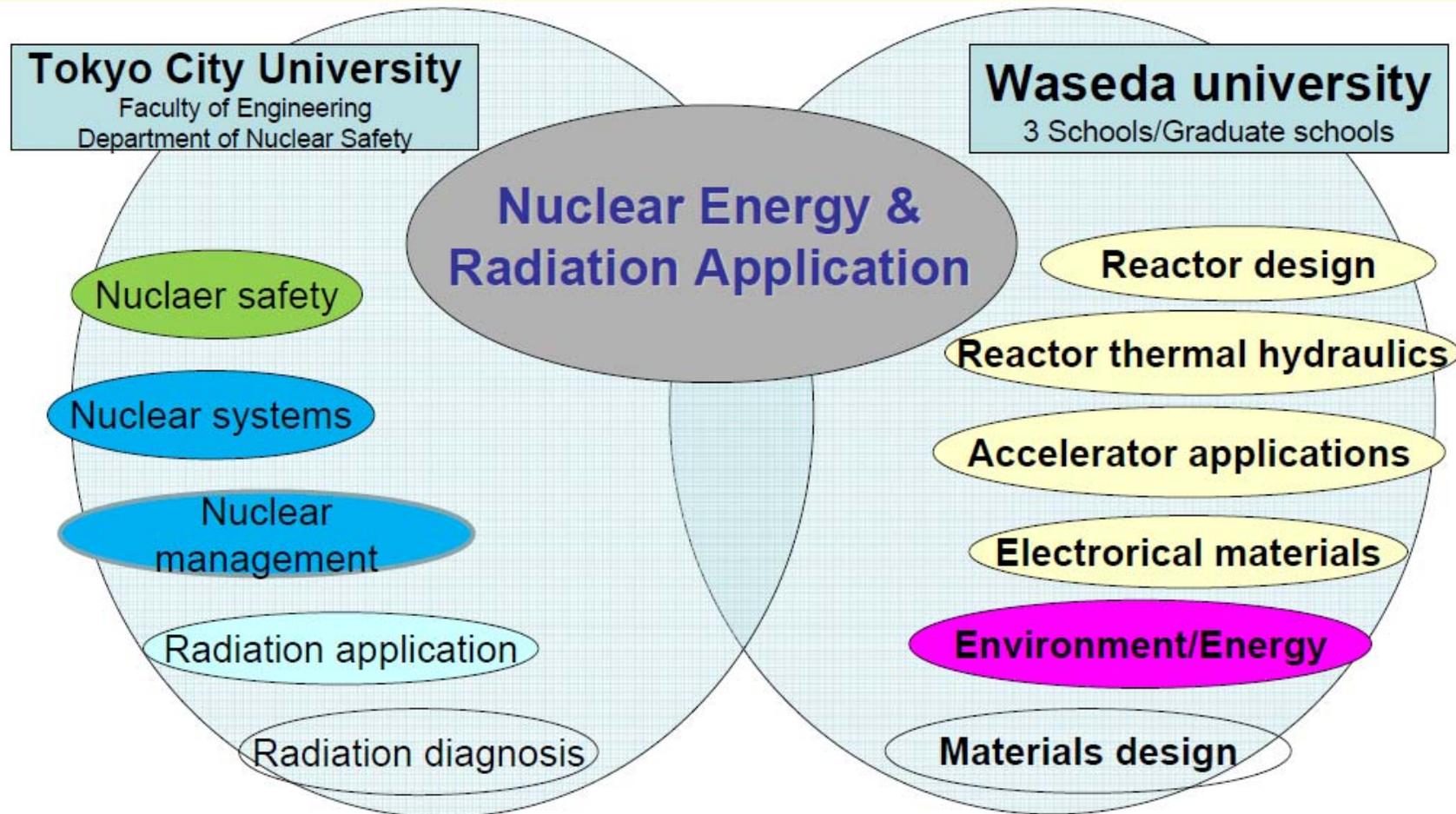


Annual symposium with the industry

# Research Fields

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

Waseda University

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@f.waseda.jp](mailto:akifumi.yamaji@f.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



Waseda University

# 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
  - [http://www.waseda.jp/fsci/en/admissions\\_gs/](http://www.waseda.jp/fsci/en/admissions_gs/)
- Inquiries regarding entrance examinations (E-mail)
  - [admission@\[list.waseda.jp\]](mailto:admission@[list.waseda.jp)
- Faculty of Science and Engineering
  - <http://www.waseda.jp/fsci/en/>
- Cooperative Major in Nuclear Energy (CMNE, Waseda University)
  - [http://www.nuclear.sci.waseda.ac.jp/index\\_en.html](http://www.nuclear.sci.waseda.ac.jp/index_en.html)
- 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@\[waseda.jp\]](mailto:akifumi.yamaji@[waseda.jp)

# Yamaji Laboratory

[http://www.f.waseda.jp/akifumi.yamaji/home\\_e.html](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)



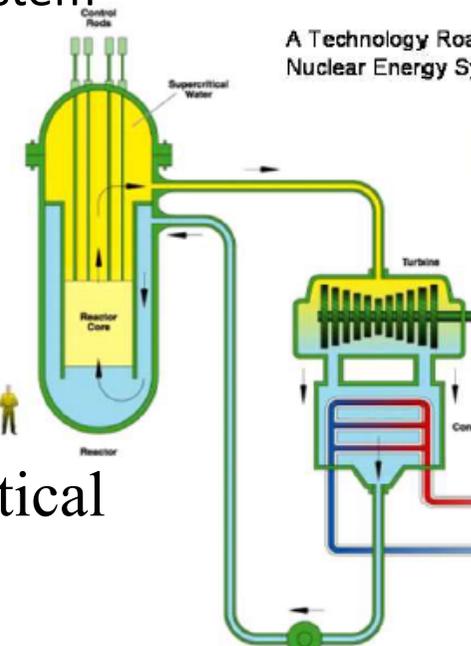


# Core Design and Safety Analysis of SCWR

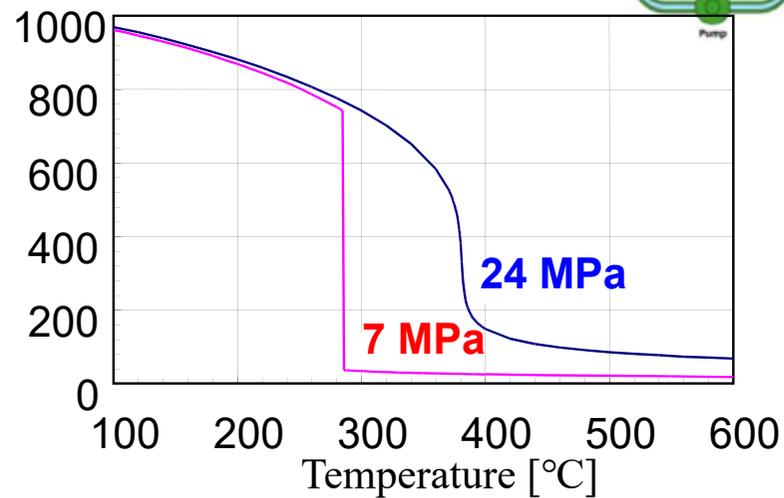
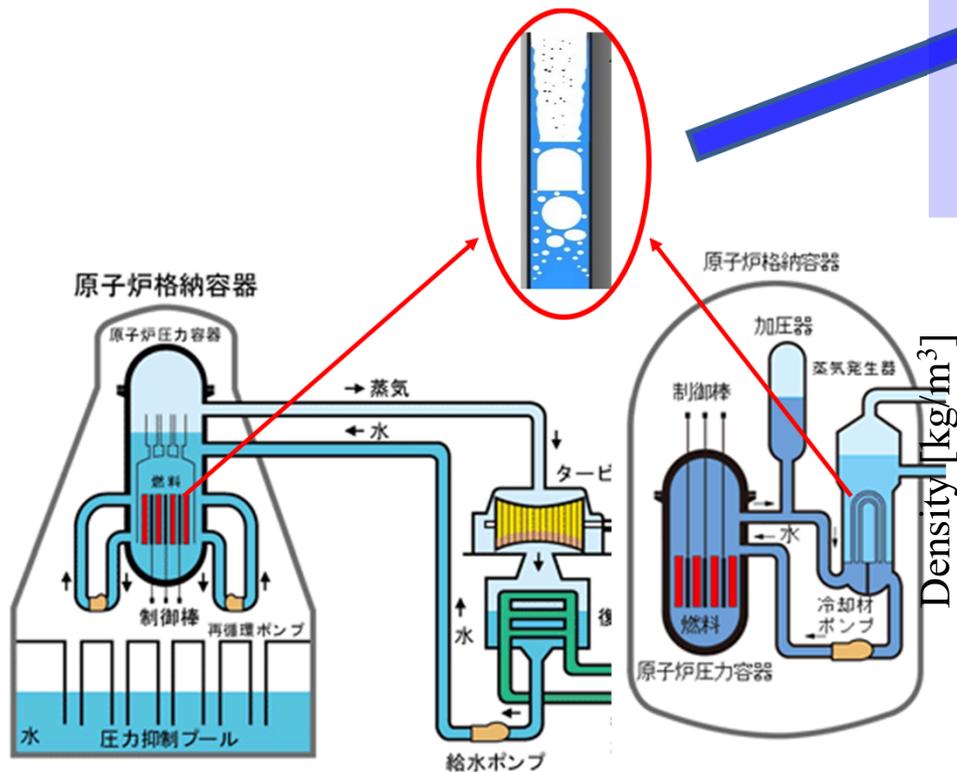
SCWR

- 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

A Technology Roadmap for Nuclear Energy Systems



Supercritical

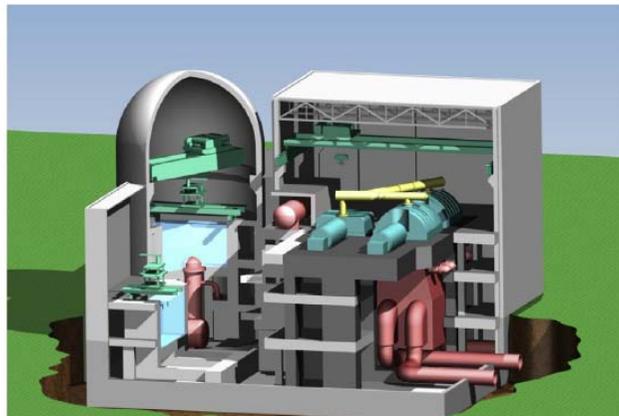


# Core Design and Safety Analysis of SCWR<sup>17</sup>

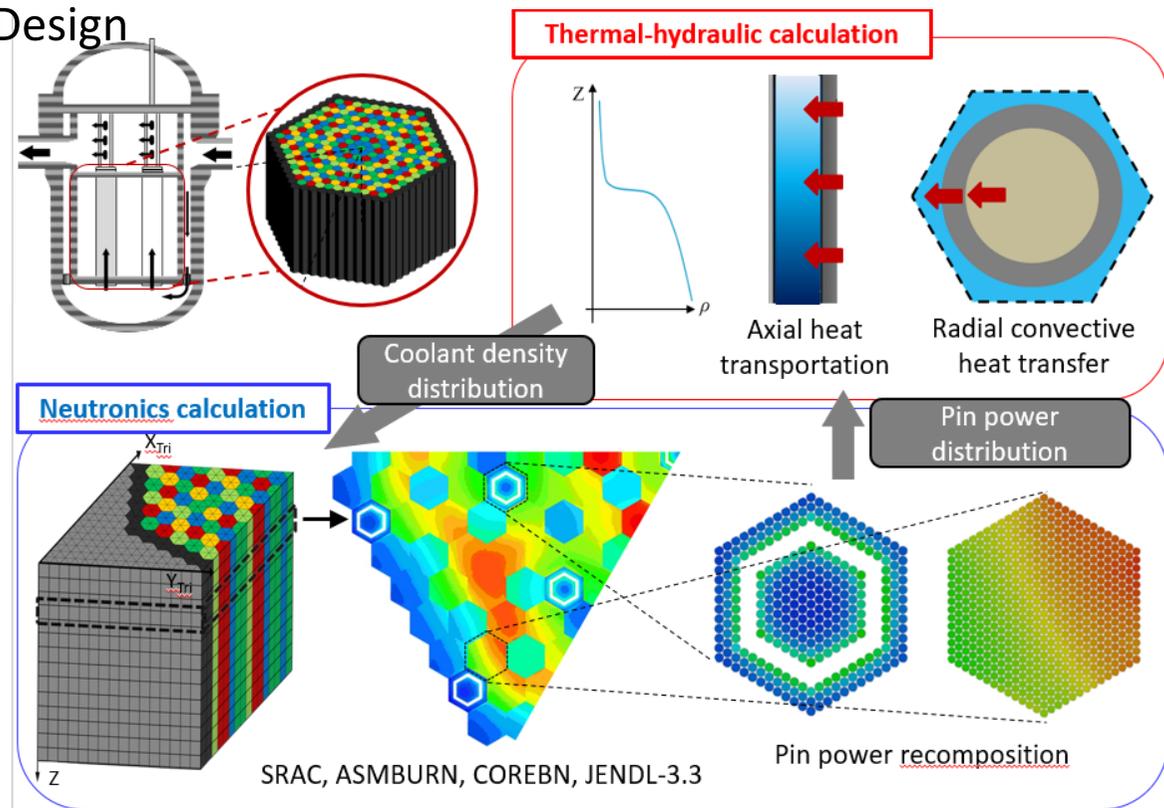
- Current works
  - Fast reactor core design studies
  - MA burning (+ LLFP transmutation)
  - Small Modular Reactor Design
  - Safety analyses

SCWR

GEN IV International Forum™



Y. Oka, H. Mori, "Supercritical-Pressure Light Water Cooled Reactors", ISBN 978-4-431-55024-2, Springer Tokyo Heidelberg New York Dordrecht London, 2014.

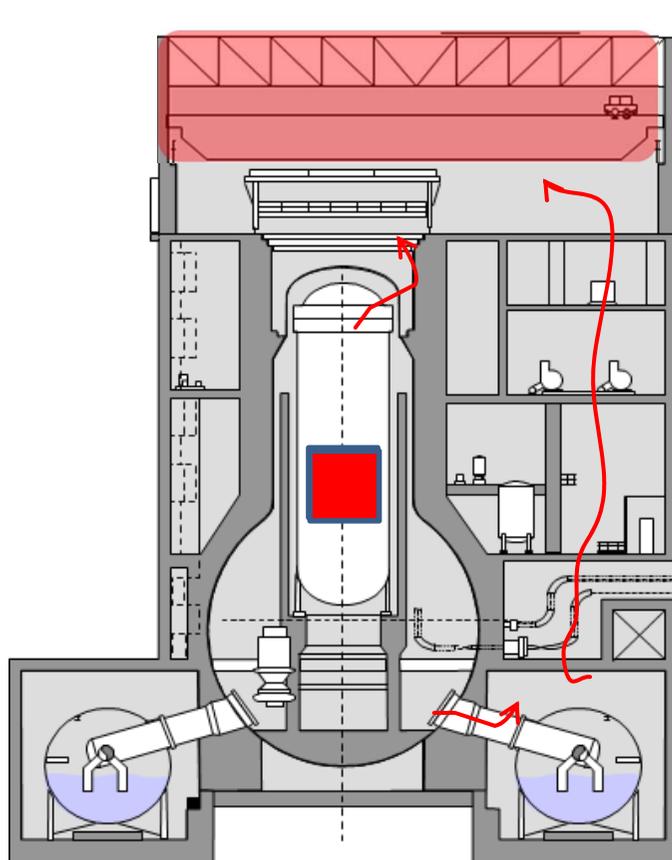
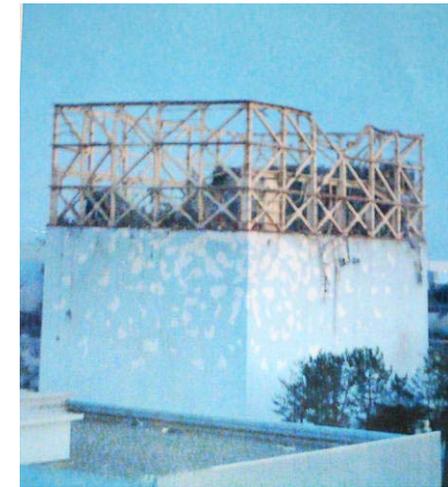


## Recent publications

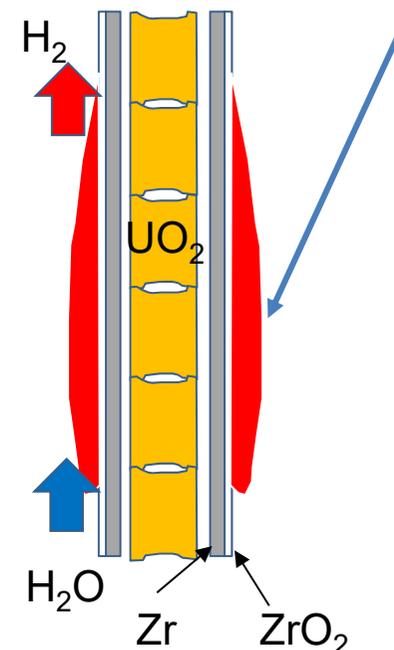
- (1) Sukarman, S. Noda, T. Fukuda, A. Yamaji, "Improving breeding performance of Super FR with fuel shuffling in multi-axial layers", Journal of Nuclear Engineering and Design Vol.355 (2019) 110323
- (2) Sukarman, A. Yamaji, T. Someya, "Improved Core Design of a High Breeding Fast Reactor Cooled by Supercritical Pressure Light Water", Journal of Nuclear Engineering and Radiation Science Vol.4(2018)
- (3) Shogo Noda, Takayuki Someya and Akifumi Yamaji "Flexible Core Design of Super FBR with Multi-Axial Fuel Shuffling", Nuclear Engineering and Design 324C (2017) pp. 45-53

# 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.**

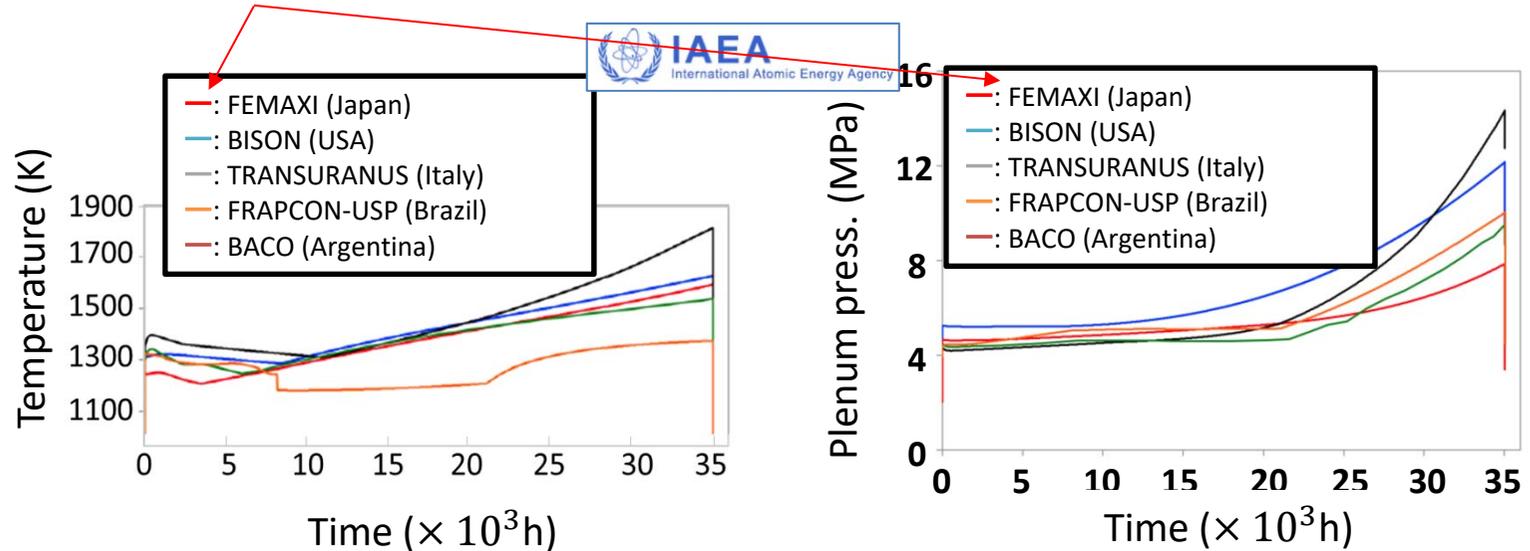


Hydrogen generation

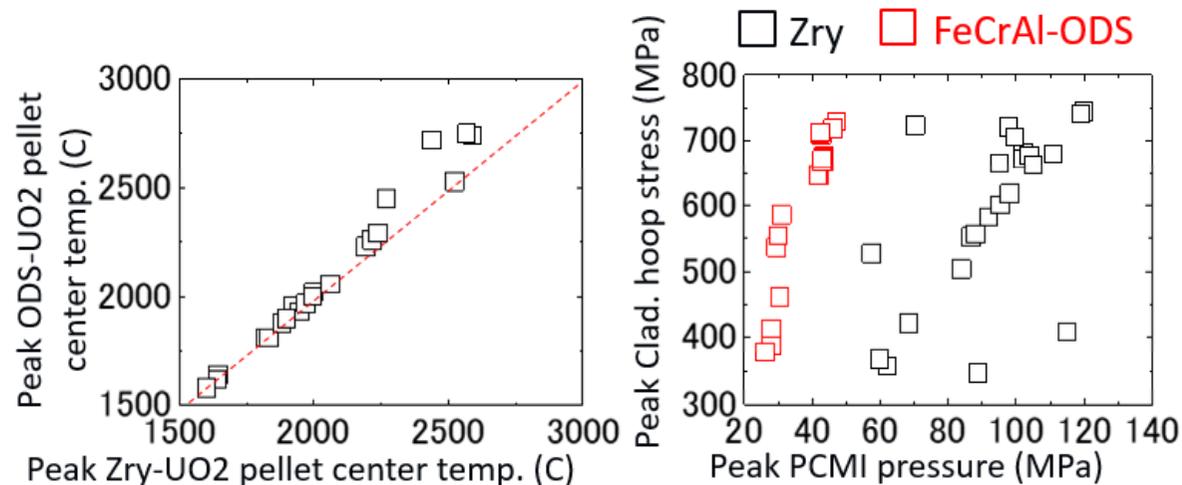


# Fuel Performance Modeling for ATF Development

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



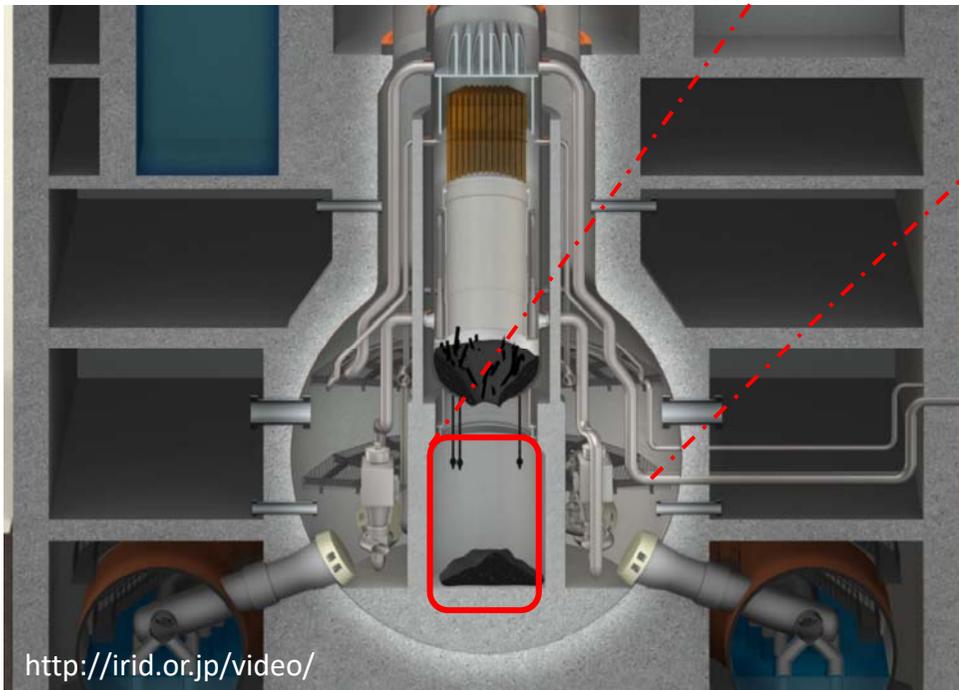
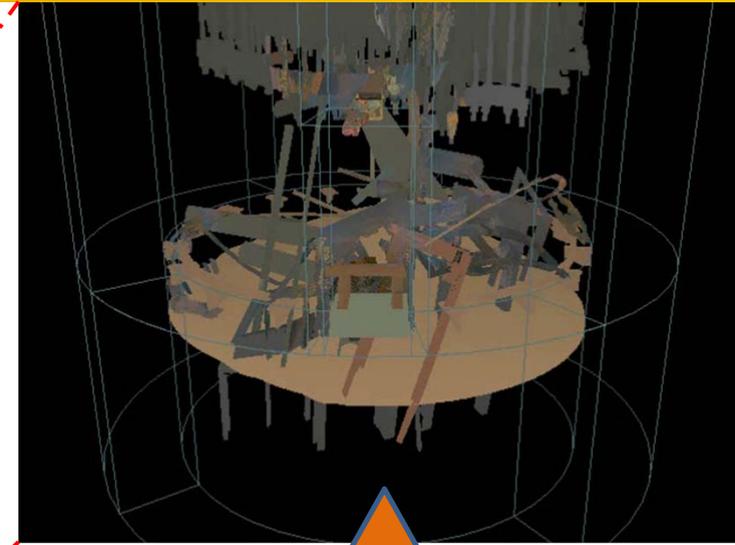
- Performance of FeCrAl-ODS-UO<sub>2</sub> during power ramps (FEMAXI-7)  
 Y. Fujiwara, A. Yamaji, S. Ukai, K. Sakamoto, S. Yamashita, "Analysis of FeCrAl-ODS Cladded Fuel Performance during BWR Power Ramp with FEMAXI-7", Proceedings of TopFuel2019, September 23-26, 2019, Seattle, USA



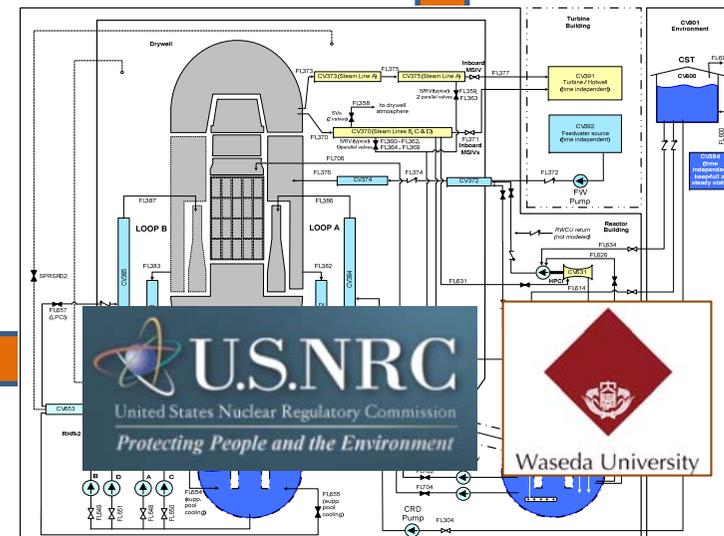
# Fukushima Analysis with MELCOR Code

Fukushima

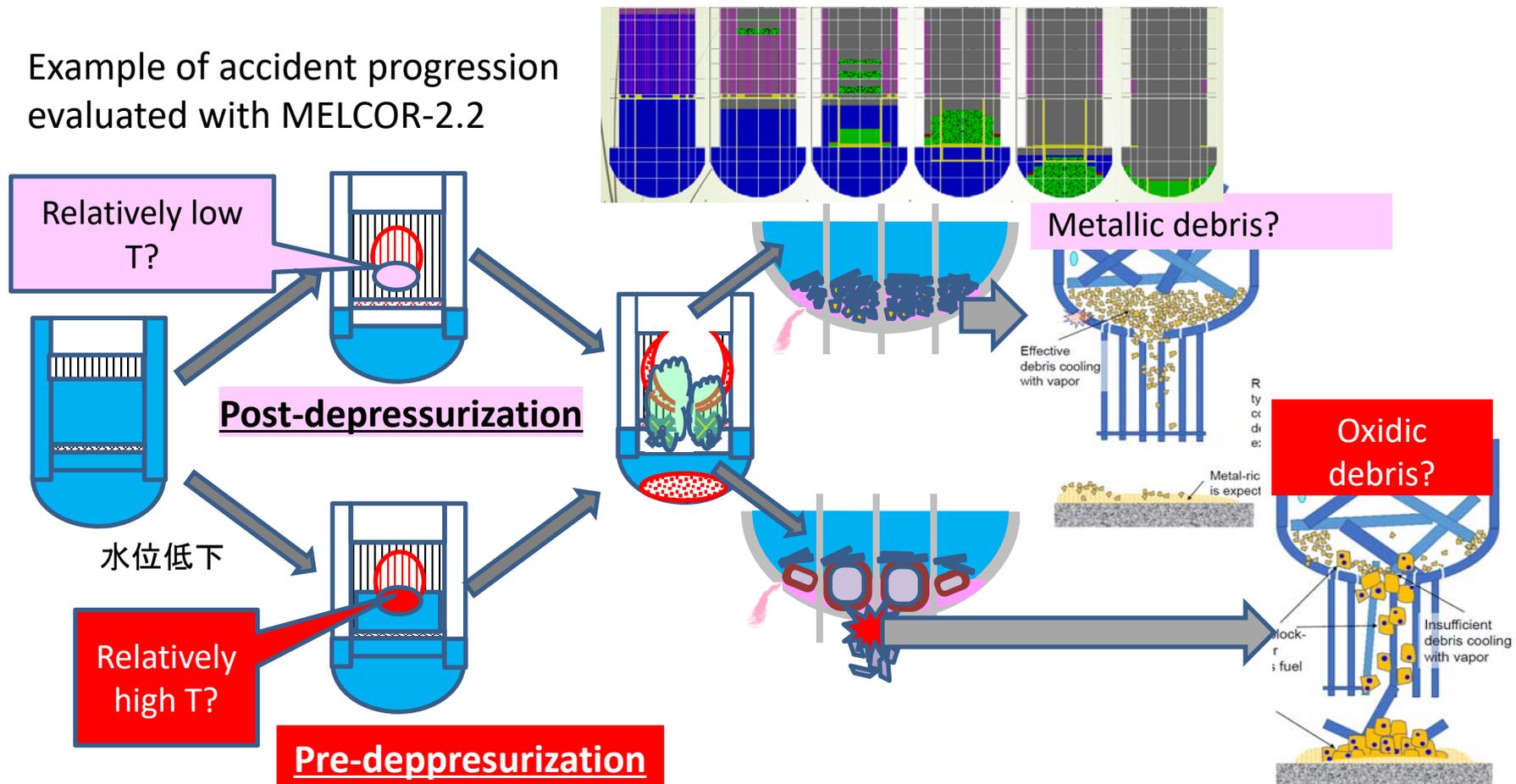
- Severe accident analysis with MELCOR code
  - For understanding severe accident
  - Contributions to Fukushima decommission
  - Implementing Agreement Relating to Participation in the Cooperative Severe Accident Research Program Between The United States Nuclear Regulatory Commission and Waseda University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



<http://irid.or.jp/video/>

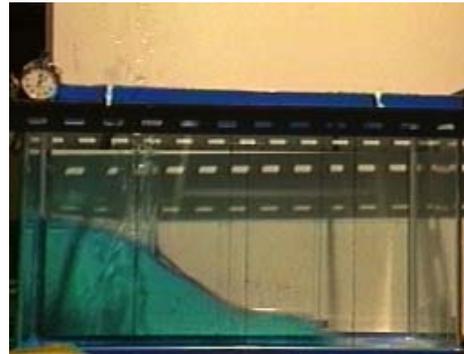
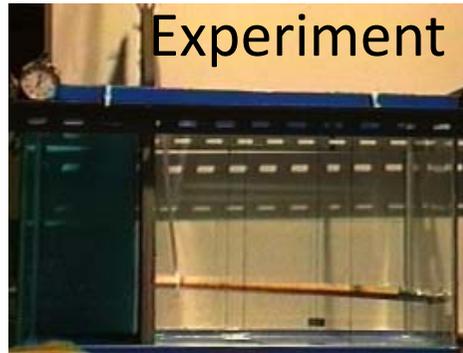


Example of accident progression evaluated with MELCOR-2.2



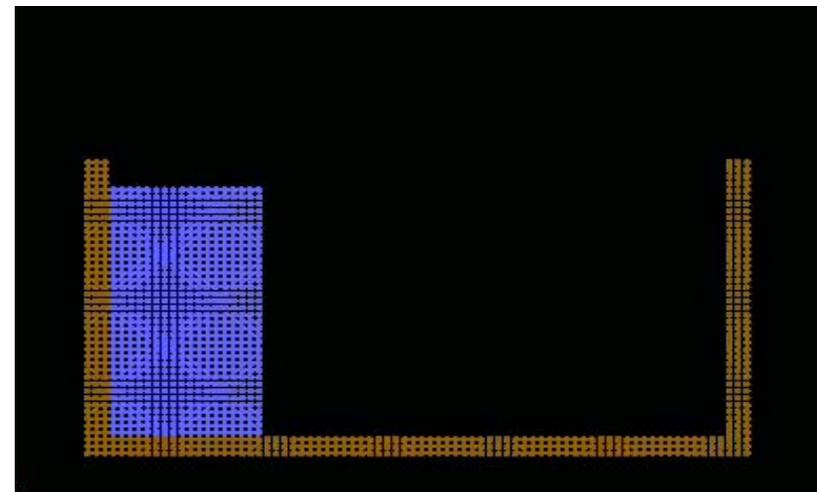
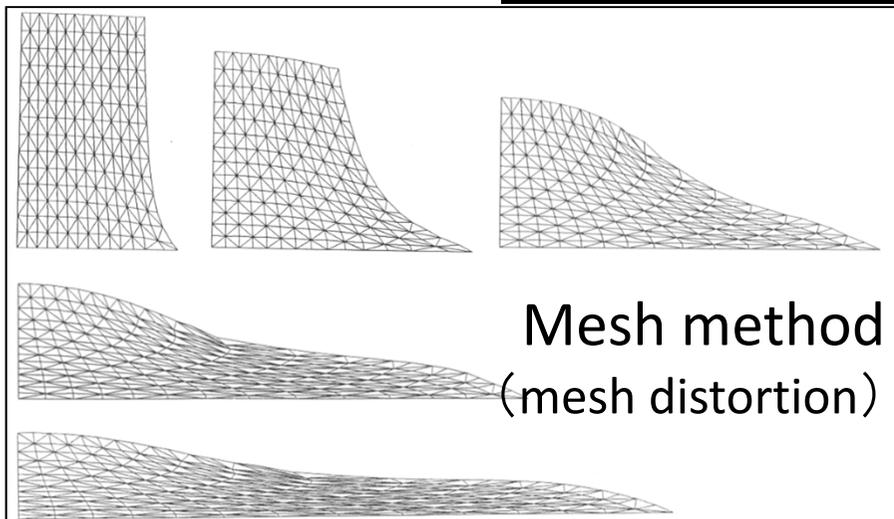
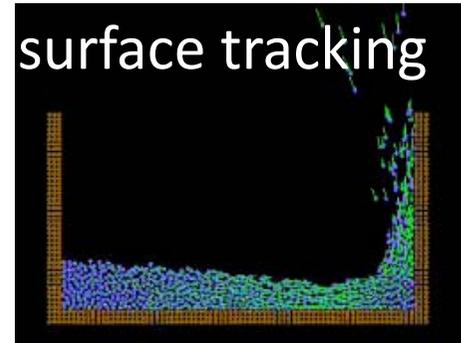
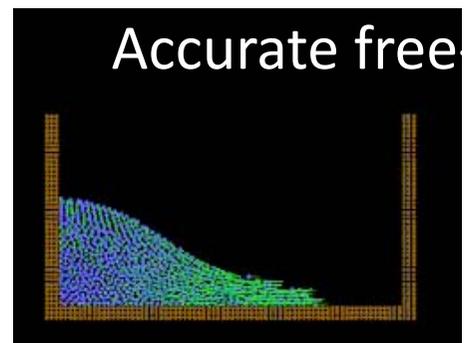
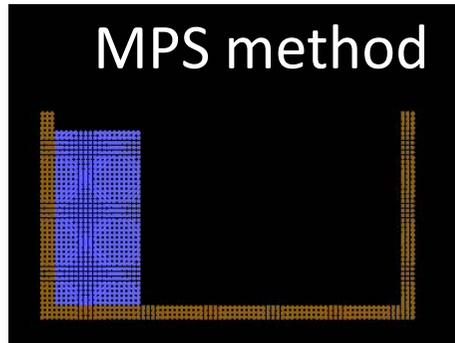
1. X. Li, I. Sato, A. Yamaji, "Sensitivity analysis of in-vessel accident progression behavior in Fukushima Daiichi Nuclear Power Plant Unit 3", *Annals of Nuclear Energy* Vol.133 (2019) 21-34
2. X. Li, I. Sato, A. Yamaji, "Insights on in-vessel core degradation behavior from sensitivity analysis of Fukushima Daiichi nuclear power plant unit3 by MELCOR", *Proceedings of FDR2019*, May 24-26, 2019, Fukushima, Japan
3. M. Regalado, A. Yamaji, "Preliminary sensitivity analysis for estimating core thermal energy at the time of core slumping of Fukushima Daiichi unit3 with MELCOR-2.2", *Proceedings of FDR2019*, May 24-26, 2019, Fukushima, Japan
4. K. Wadayama, A. Yamaji, "Estimation of thermal status of the fuel debris at the time of core slumping of 1F2 with MELCOR-2.2", *Proceedings of FDR2019*, May 24-26, 2019, Fukushima, Japan

# Particle Method



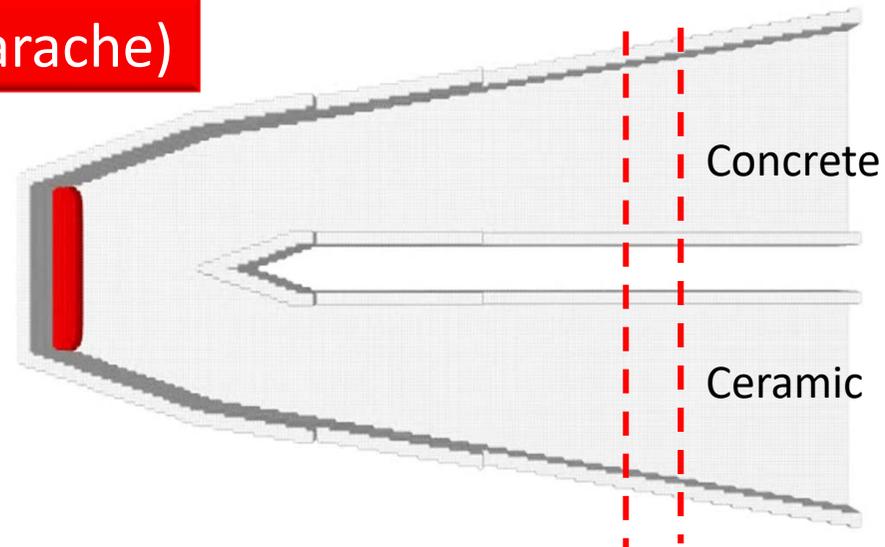
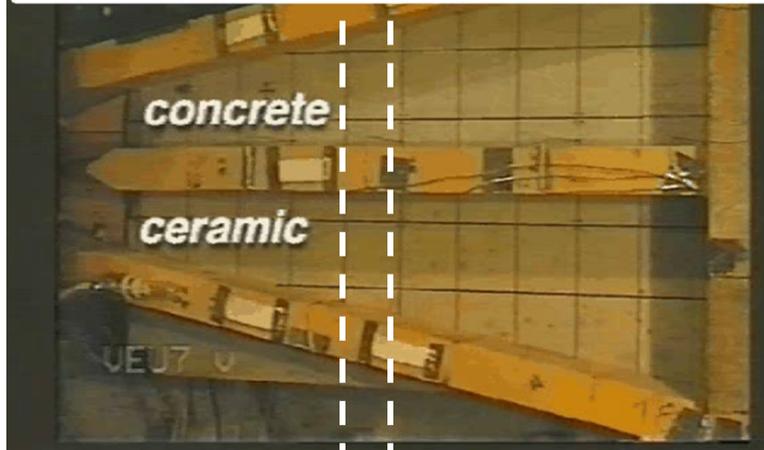
Originally proposed by  
Koshizuka et al.,

S. Koshizuka, Y. Oka,  
"Moving -particle semi-  
implicit method for  
fragmentation of  
incompressible fluid,"  
Nuclear Science and  
Engineering., 123, 421-  
434 (1996).

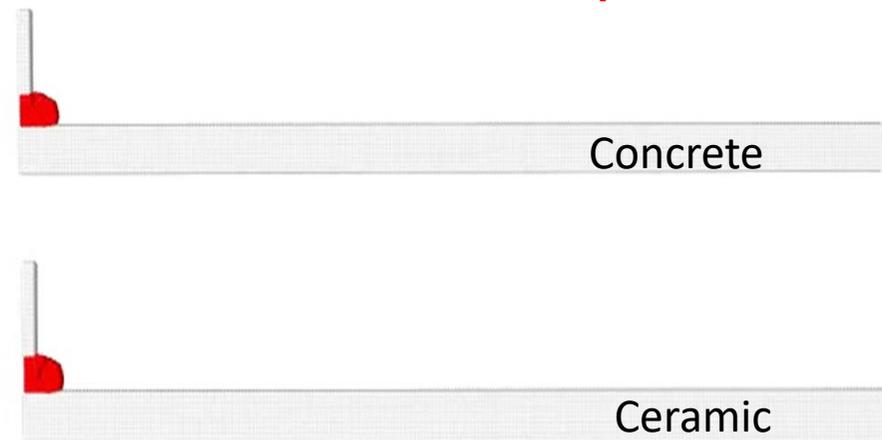
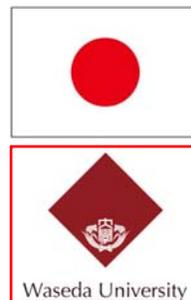


# Simulating Molten Fuel Behavior

## French experiment (CEA/Cadarache)



2018-2019



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





# Furuya Laboratory

<http://www.aoni.waseda.jp/furuya/>

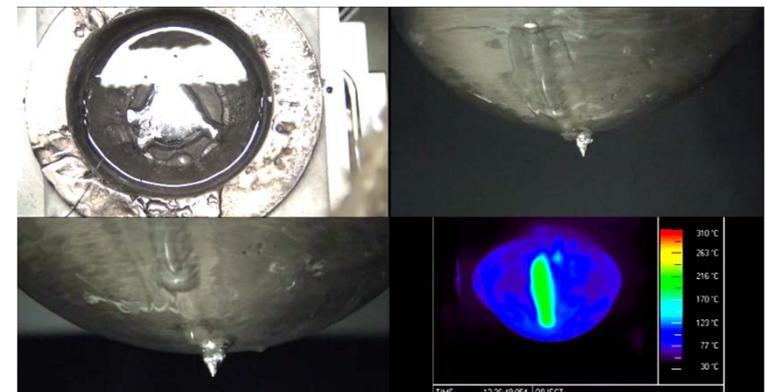
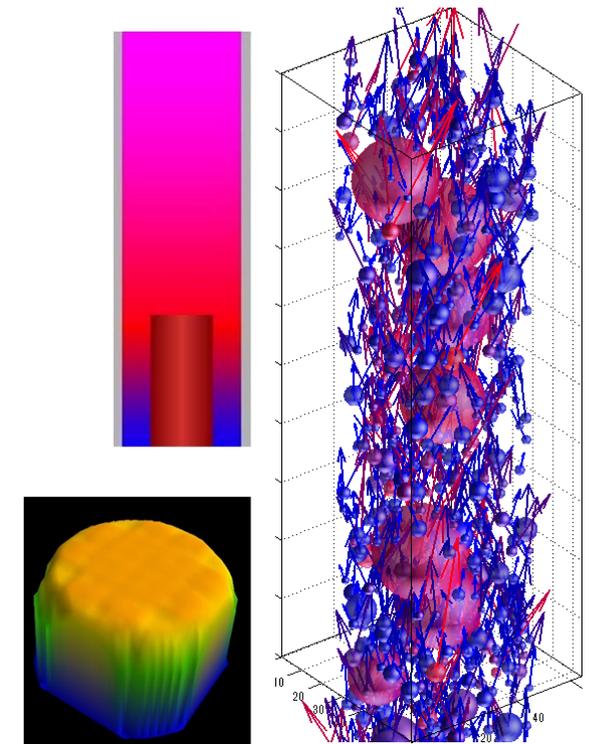
# Masahiro Furuya



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

# Thermal-Hydraulics Experiments and Simulations

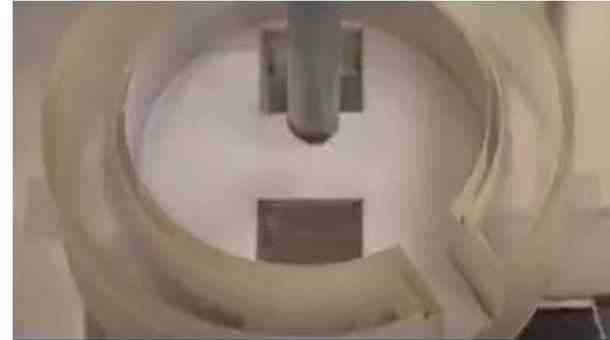
- Multi-dimensional
  - Three-dimensional, two-phase flow measurement and modeling
- Transient
  - Fast transients ( $\tau = 0.1 \text{ ms} \sim 0.1 \text{ s}$ )
  - Stability ( $\tau = 2 \text{ s} \sim 300 \text{ s}$ )
- Coupling with other phenomena
  - Void-reactivity feedback
  - Chemical reactions
  - Iodine & Aerosol Chemistry
  - (Photo-)catalytic reactions
  - Melting, solidification, eutectic



# CFD to System Analysis Codes

## ◆ CFD / CMFD

- StarCCM+
- AdvaceFlow/MP
- Open FOAM
- In-house LES



Experiment

## ◆ Subchannel Analysis

- COBRA-TF (CTF)

## ◆ Plant Transients

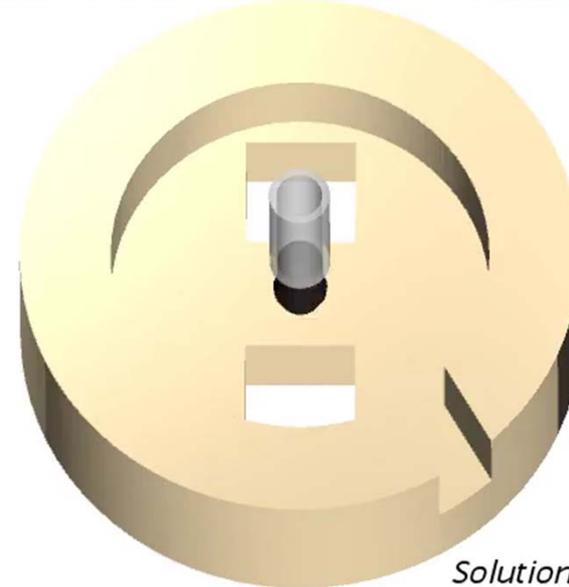
- TRACE
- RELAP
- RAMONA/MONA

## ◆ Severe accidents

- MAAP
- MELCOR
- SAMPSON

## ◆ Linearized analysis

- BWR linear stability analysis
- Vapor film stability analysis

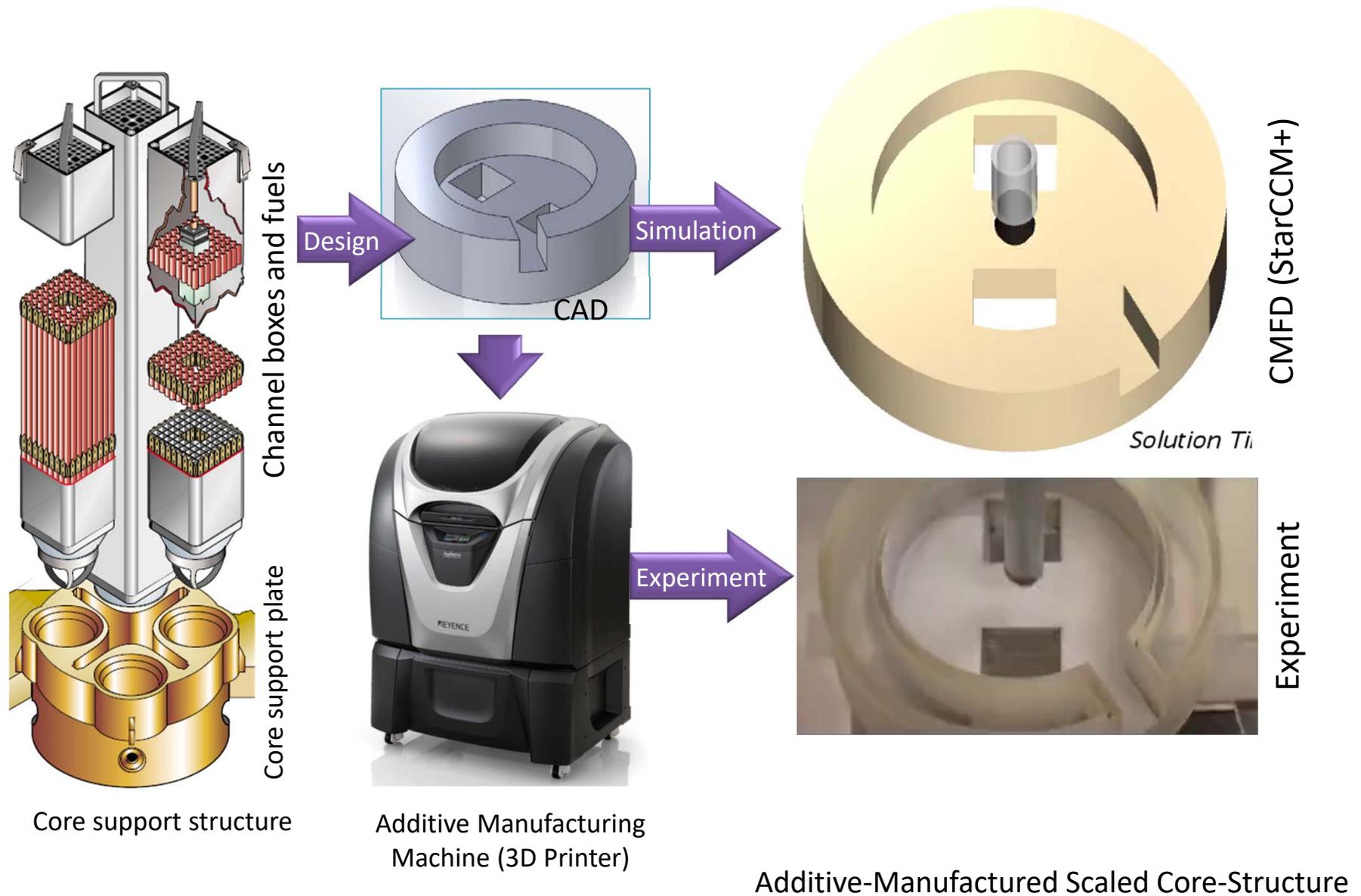


CMFD (StarCCM+)

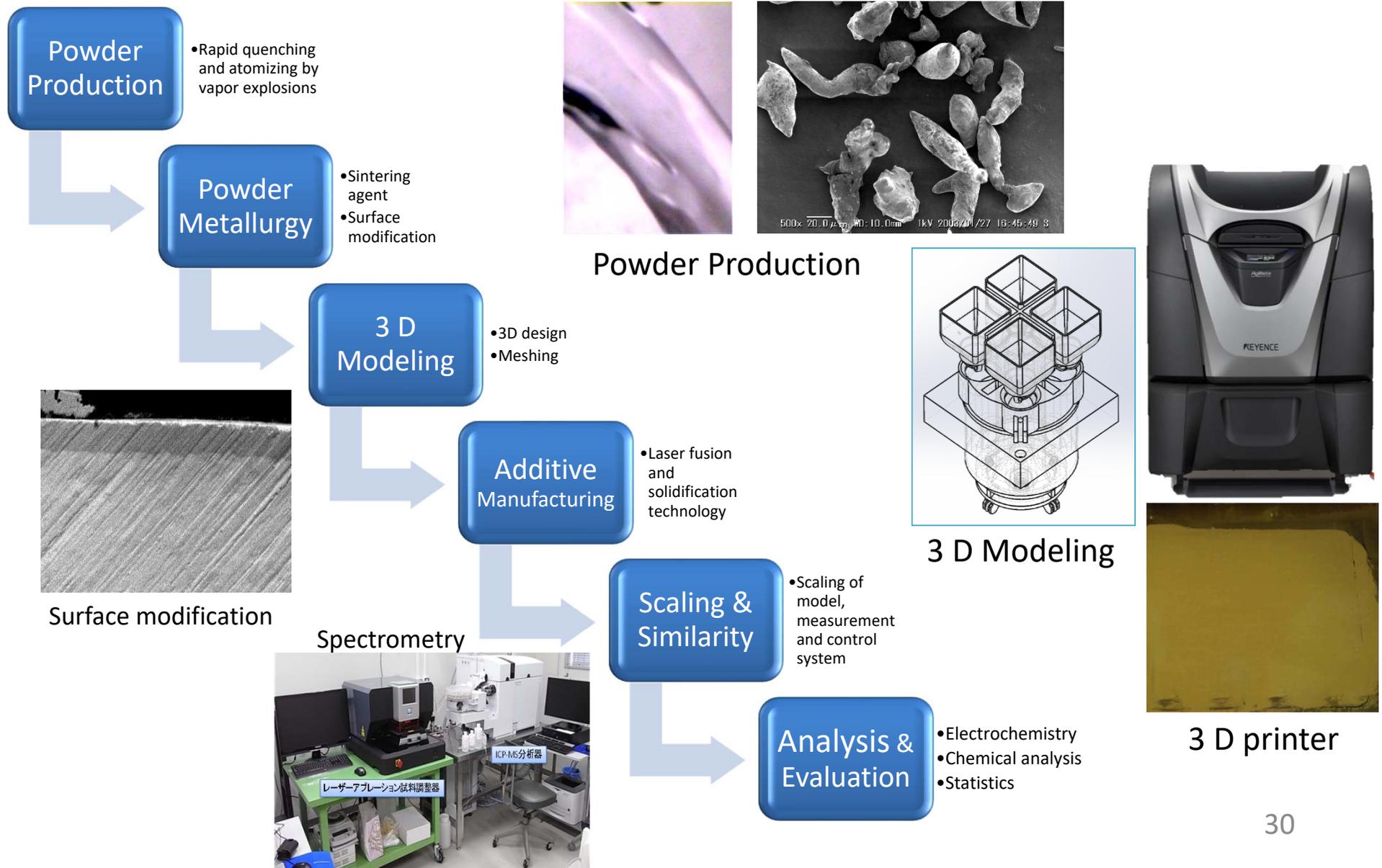
*Solution Ti*

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<sup>29</sup>



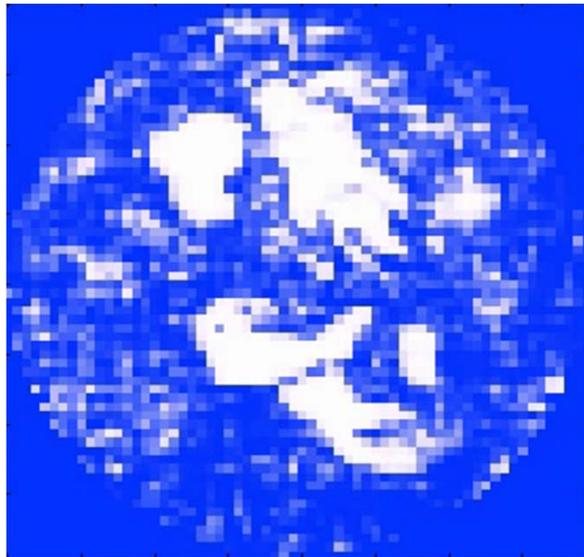
# Steps for Scalable Experiments toward Digital Twin



# Identify Individual Bubble Motion

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

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



air  water

Measured void Fraction

Reconstruction



Three dimensional reconstruction

Bubble Identification



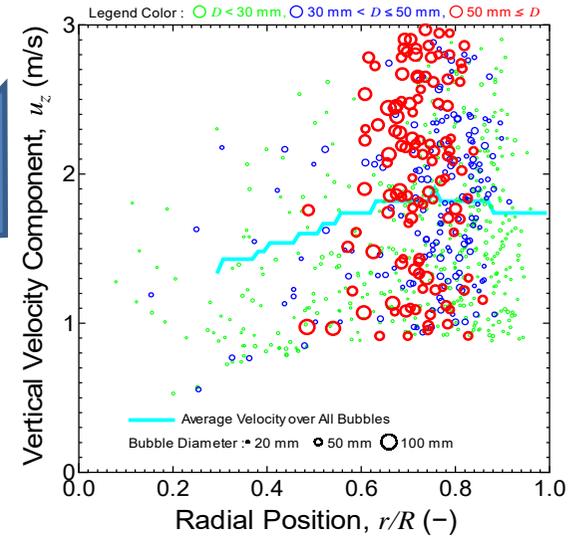
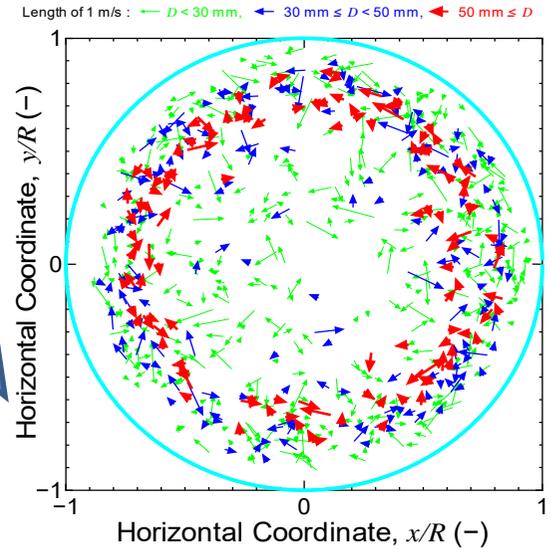
1000 bubbles  
 $j_G=0.64\text{m/s}$ ,  $j_L=0.64\text{m/s}$

○  $D < 30\text{mm}$   
○  $30\text{ mm} \leq D < 50\text{ mm}$   
○  $50\text{ mm} \leq D$

Velocity Vector Determination

Velocity Vector

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>

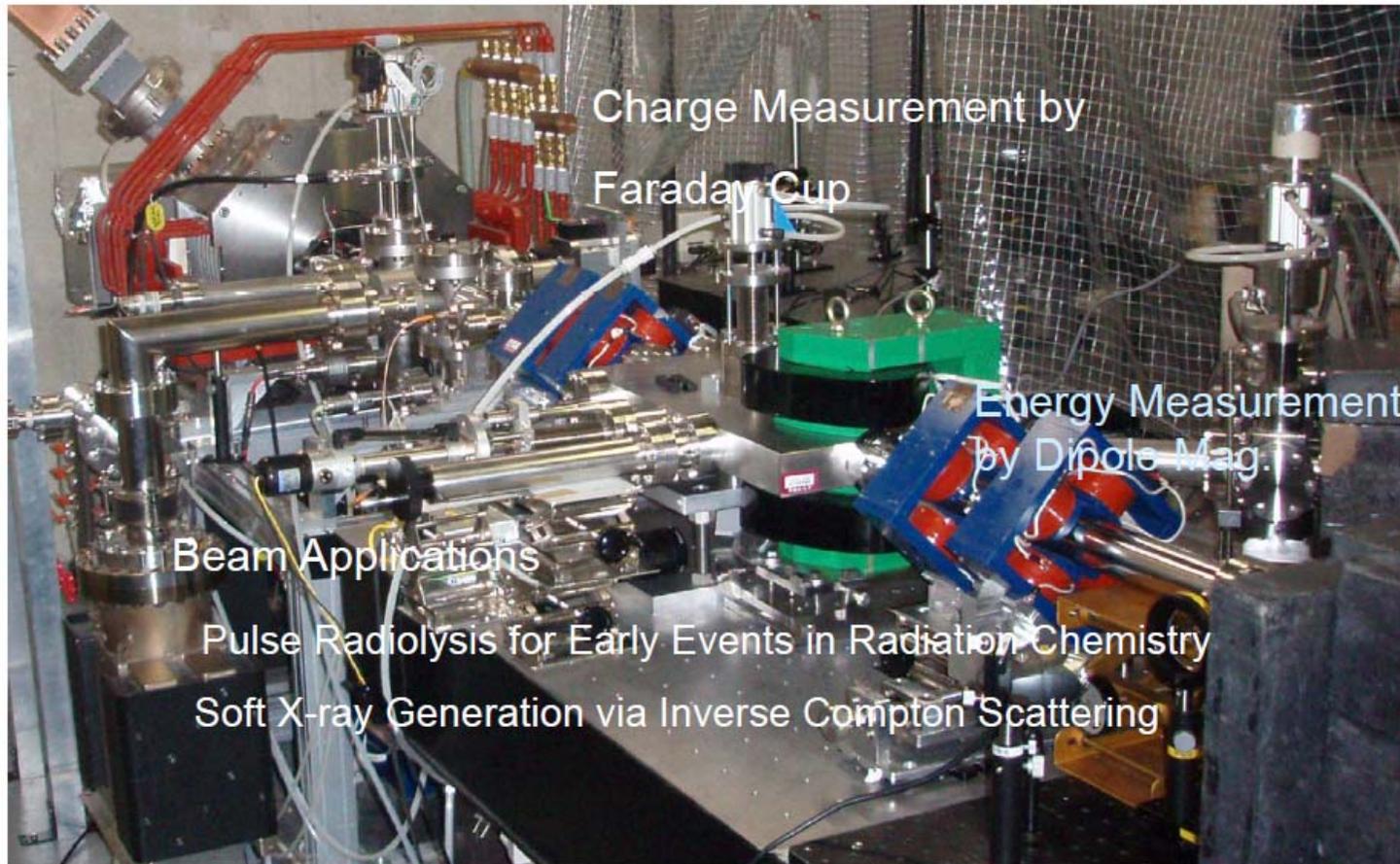
# Masakazu Washio



- 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*





## Washio Laboratory for High Quality Beam Sciences



### Advanced Accelerator Sciences

New Accelerator System

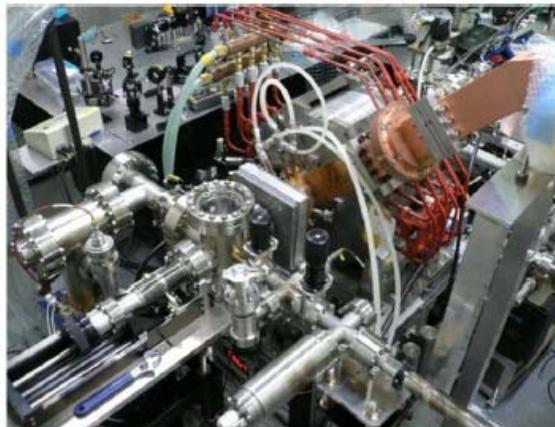
New Beam Generation such as

*Monochromatic, Tunable Energy X-ray*

High Quality Electron Beam

*ILC, Ultra-short Pulse, FEL,*

etc.



Laser Photo-cathode RF-gun

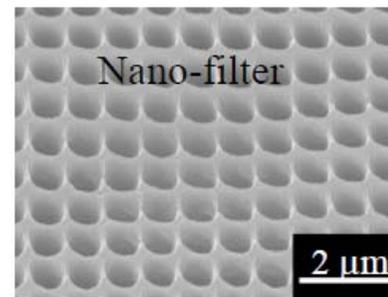
### Applications of Ionizing Radiation

Development of

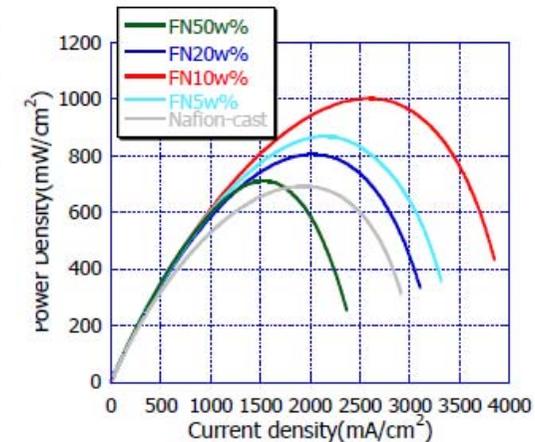
*Polymer Electrolyte Fuel Cell*

*Nano-scale Fabrications*

*Advanced Electron Beam Processing*



200keV Curetron



Fuel Cell Power Generation



## Washio Laboratory for High Quality Beam Sciences



Outlook of Kikui-cho Building

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-

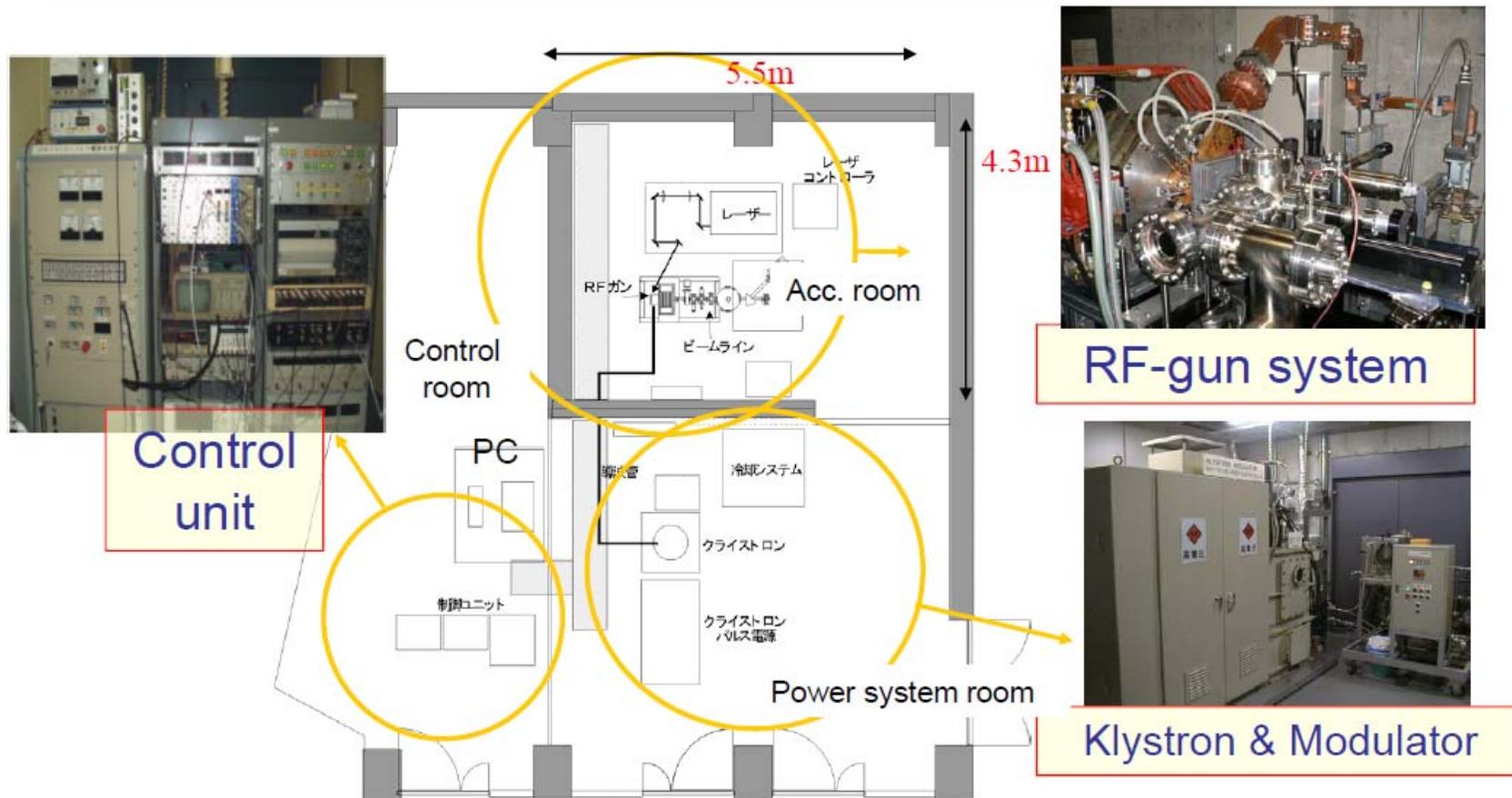
Applied for Accelerator Training of Students



## Washio Laboratory for High Quality Beam Sciences

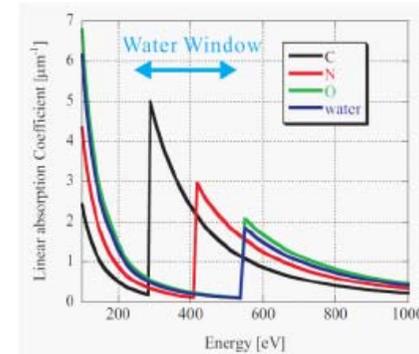
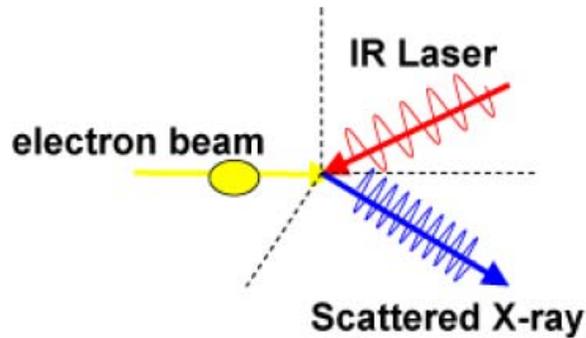


### Facility Layout at Kikui-cho campus in Waseda University

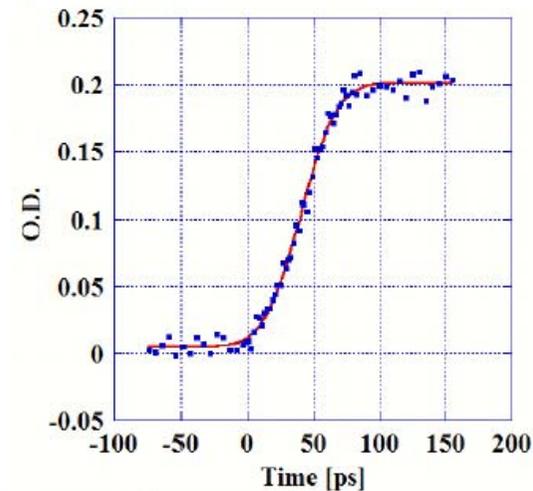
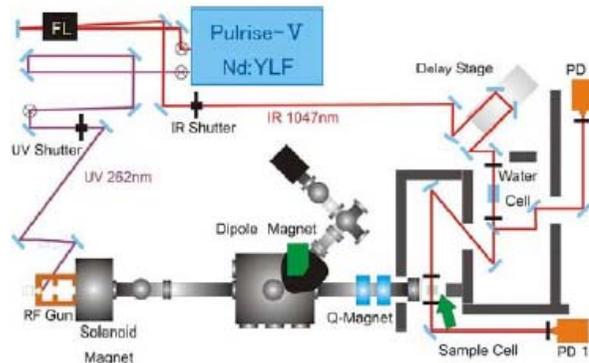




Washio Laboratory for *High Quality Beam Sciences*  
Advanced Accelerator Applications



X-ray Generation by Inverse Compton Scattering



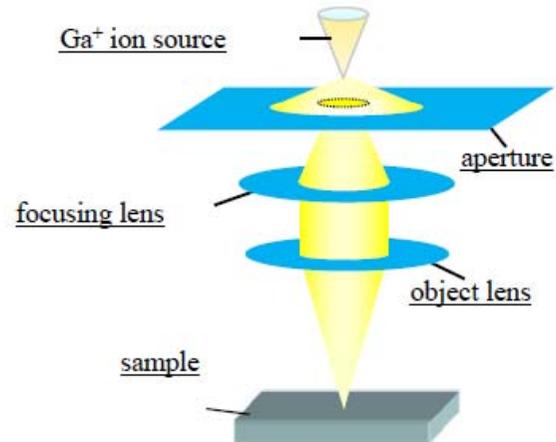
Pico-second Pulse Radiolysis for ultra fast phenomena



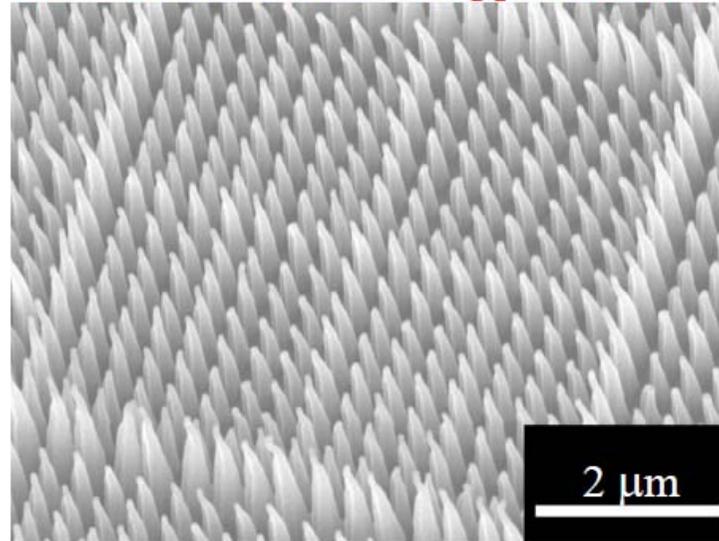
Washio Laboratory for High Quality Beam Sciences



Advanced Accelerator Applications



Focused **I**on **B**eam



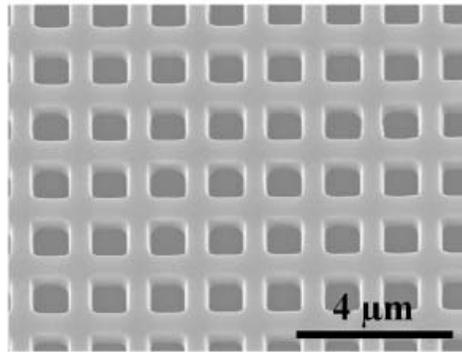
FE-SEM image of fiber pattern of Crosslinked PTFE (RX-PTFE) obtained by FIB process



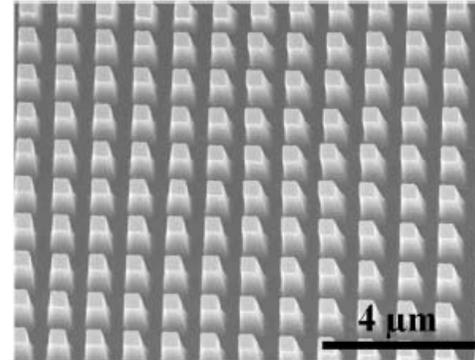
Washio Laboratory for High Quality Beam Sciences



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

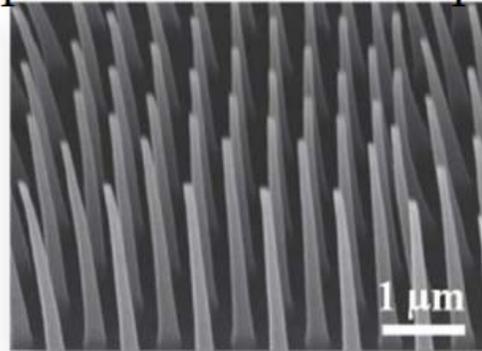


Mold(RX-PTFE)



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](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

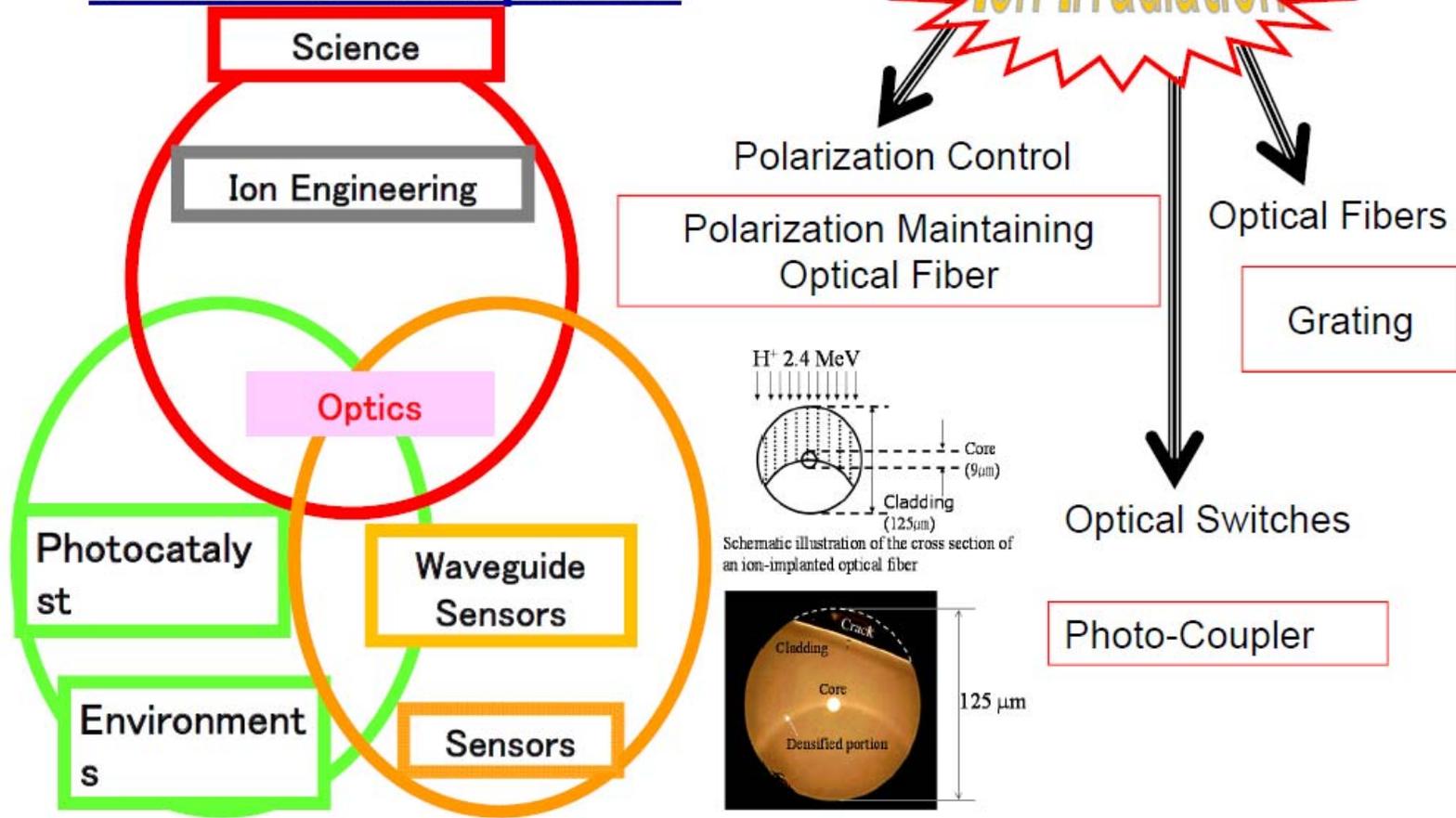
- has published a tremendous numbers of refereed papers in reputed journals (333 in journals, 219 at international conferences, and over 584 at domestic conferences)
- ➡ has been awarded many prizes. Many of his students have also been awarded, which significantly helps them to raise their careers.
- 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 Processing and Device Development



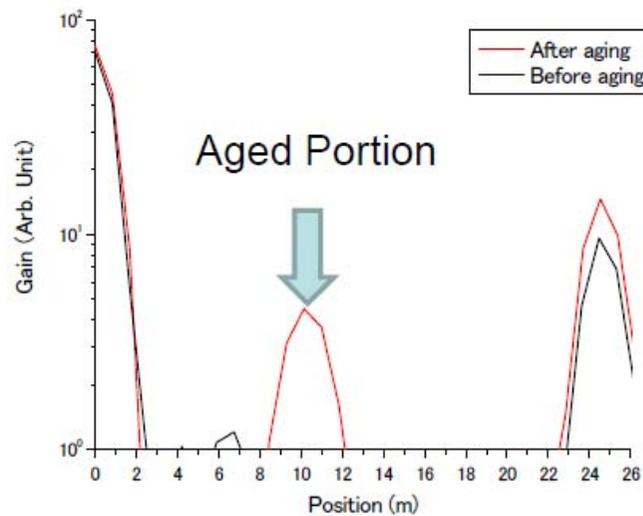
# Ohki Laboratory

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



Cables Tested and Irradiation Facility



Thank you for your attention.

akifumi.yamaji [at] waseda.jp

