

### **III. RESEARCH DIVISIONS AND LABORATORIES**

### III. RESEARCH DIVISIONS AND LABORATORIES (2010.6.1)

#### III-1. DEPARTMENT OF NUCLEAR SCIENCE AND ENGINEERING

By the reorganization of the Institute in 2003, this department, which consists of Division of Nuclear Engineering Science and Research Center for Safe Nuclear System, was formed. This department covers a wide research field such as the reactor safety, the management of radioactive materials, the development and effective use of nuclear energy, the studies on the recycling of nuclear fuels, and research reactor utilization.

##### III-1-1. Division of Nuclear Engineering Science

###### Professors

- YOSHIE, Toshimasa, D. Eng. (Osaka Univ.),  
Radiation Effects in Solids
- SHIBATA, Seiichi, D. Sc. (Kyushu Univ.), Nuclear  
Chemistry and Radiochemistry
- YAMANA, Hajimu, D. Eng. (Tohoku Univ.),  
Radiochemistry
- MAHARA, Yasunori, D. Eng. (Kyoto Univ.),  
Environmental Nuclear Science
- MORI, Yoshiharu, D. Eng. (Kyushu Univ.), Accelerator  
Physics
- KOYAMA, Akio, D. Eng. (Kyoto Univ.), Sanitary  
Engineering
- NAKAJIMA, Ken, D. Eng. (Hokkaido Univ.), Nuclear  
Engineering
- TAKAHASHI, Sentaro, Ph.D. (Kyoto Univ.),  
Radiation Health Sciences
- UNESAKI, Hironobu, D. Energy Sc. (Kyoto Univ.),  
Reactor Physics and Engineering
- MORIYAMA, Hirotake, D. Eng. (Kyoto Univ.),  
Nuclear Material

###### Associate Professors

- MISAWA, Tsuyoshi, D. Eng. (Kyoto Univ.), Reactor  
Physics and Engineering
- FUJIKAWA, Yoko, D. Eng. (Kyoto Univ.),  
Environmental Science
- OKI, Yuichi, D. Sc. (Univ. of Tsukuba), Nuclear  
Chemistry, Health Physics
- XU, Qiu, D. Eng. (Kyushu Univ.), Radiation Damage  
in Metals
- FUJII, Toshiyuki, D. Eng. (Osaka Univ.), Physical  
Chemistry
- TAKAHASHI, Tomoyuki, D. Eng. (Kyoto Univ.),  
Environmental Health Physics
- SAITO, Yasushi, D. Eng. (Kyoto Univ.), Thermal and  
Fluid Engineering
- TAKAMIYA, Koichi, D. Sc. (Osaka Univ.), Nuclear  
Chemistry

ISHI, Yoshihiro, PhD (Niigata Univ.), Accelerator  
Physics

TAKAHASHI, Toshiharu, D. Sc. (Tohoku Univ.),  
Solid State Physics

KINASHI, Yuko, M.D., D. Med. Sc. (Kyoto Univ.),  
Radiation Oncology

YAMAMOTO, Toshihiro, D. Eng. (Osaka Univ.),  
Reactor Physics

###### Assistant Professors

- YAMASAKI, Keizo, Health Physics
- KOIDE, Hiroaki, Nuclear Engineering
- IMANAKA, Tetsuji, Nuclear Engineering
- FUKUTANI, Satoshi, D. Eng. (Kyoto Univ.),  
Environmental and Sanitary Engineering
- KUBOTA, Takumi, D. Eng. (Tohoku Univ.),  
Radiochemistry
- KAWABE, Hidenori, D. Eng. (Kobe Univ.),  
Earthquake Engineering
- PYEON, Cheol Ho, D. Energy Sc. (Kyoto Univ.),  
Nuclear Reactor Physics
- SHEN, Xiu-Zhong, D. Eng. (Shanghai Jiao-Tong  
Univ.), Nuclear Reactor Safety Engineering
- HORI, Jun-ichi, D. Eng. (Tokyo Inst. of Tech.),  
Nuclear Engineering
- SATO, Koichi, D. Eng. (Kyoto Univ.), Radiation  
Effects in Solids
- YASHIMA, Hiroshi, D. Eng. (Tohoku Univ.),  
Radiation Control
- UEHARA, Akihiro, D. Eng. (Kyoto Inst. of Tech.)  
Analytical Chemistry
- UESUGI, Tomonori, D. Sc. (Univ. of Tokyo),  
Accelerator Science and Engineering
- OHTA, Tomoko, D. Eng. (Meiji Univ.),  
Radiochemistry
- OKUMURA, Kiyoshi, Reactor Engineering
- SEKIMOTO, Shun, D. Eng. (Kyoto Univ.),  
Radiochemistry and Geochemistry
- SANO, Tadafumi, D. Eng. (Osaka Univ.), Reactor  
Physics
- KURIYAMA, Yasutoshi, D. Sci. (Osaka Univ.),  
Accelerator Physics
- TAKAHASHI, Yoshiyuki, D. Eng. (Kyoto Univ.),  
Reactor Physics and Engineering

###### Program-Specific Assistant Professor

###### (Industry - Government - Academia Collaboration)

LIM, Jae-Yong, Ph.D. (Kyung Hee Univ.), Nuclear  
Engineering

###### Guest Researcher

###### Professors

OIGAWA, Hiroyuki, Nuclear Transmutation, Host  
laboratory: Research Reactor Safety

## Associate Professor

NISHIHARA, Kenji, Nuclear Transmutation, Host laboratory: Research Reactor Safety

This division, which consists of eleven research laboratories from the previous research divisions of Nuclear Safety Research, Nuclear Energy Science and Fuel Cycle and Environment, was formed in 2003. This division covers a wide research field as follows.

### III-1-1-(1) Research Reactor Safety

The Kyoto University Research Reactor (KUR) is a light water moderated, tank-type nuclear reactor, to utilize for general nuclear researches cooperated by all Japanese university researchers. It is used as a strong neutron source, which is applicable for a broad range of research fields. Besides the KUR, a 46 MeV electron linear accelerator (LINAC) is also used as a neutron source. Also, a new type of Fixed Field Alternating Gradient (FFAG) proton accelerator is under construction for the study of accelerator driven sub-critical nuclear reactor.

Using these three facilities, we are conducting the following research works:

- i) Experimental Research on Advanced Utilization of Neutron Sources, Neutron Behavior and Nuclear Reactions

The experimental researches on nuclear reaction data (cross sections) are conducted for the utilization of various neutron sources, such as research reactors, accelerators, and nuclear fusion reactors. The cross sections of minor actinides and long-lived fission products are being measured.

- ii) Research and development of future accelerators based on FFAG principle and their applications

The accelerator based on FFAG principle has a unique feature to utilize non-linear electric and magnetic fields efficiently, which is quite different from the ordinary accelerators. Non-linear beam dynamics, thus, is one of the most interesting subject in this type of accelerator. Various noble accelerator technologies based on FFAG principle such as ionization beam cooling, which could be useful for intense neutron source, are also under development.

- iii) Integral Tests for Nuclear Data Evaluation and Validation

The evaluation and validation of cross sections through the analysis of integral experiments such as critical experiments (Integral Tests) are conducted.

- iv) Research on safety of nuclear facilities

Researches on dynamic analysis and seismic safety evaluation of nuclear facilities are conducted.

Prediction of strong ground motion for large earthquake is being conducted as well as the development of analysis methods.

### III-1-1- (2) Nuclear Material Control

The activities of this laboratory are focused on optimum control and use of nuclear materials and development of innovative nuclear energy system to solve future energy issues. The current research subjects include:

- i) Study on innovative nuclear energy system with high potential on non-proliferation and nuclear material saving.
- ii) Study on energy policy issues, with special emphasis on the role of nuclear energy.
- iii) Study on nuclear material transportation, safeguards and physical protection methodology.

This laboratory is related to the Department of Socio-Environmental Energy Science (Energy Policy), Graduate School of Energy Science, Kyoto University.

Most of the studies conducted in this laboratory are made from the viewpoint of socio-technological interest, which is inevitable for discussing the role of nuclear materials as energy resource today and in the future.

### III-1-1- (3) Radioactive Waste Management

The research activities of this laboratory are focused on radioactive waste management experimentally and theoretically. Studies on nuclear safety are also important themes. The current subjects are as follows:

- i) Fundamental research on treatment and disposal of radioactive waste.
- ii) Technical aspects of radioactive waste treatment facilities.
- iii) Study of decommissioning of nuclear facilities.
- iv) Distribution and migration of radionuclides in the ground.
- v) Measurement of environmental radioactivity.
- vi) Studies on radiation protection from environmental radioactive pollution.

### III-1-1- (4) Radiation Safety and Control

In the laboratory of Radiation Safety and Control, a wide variety of researches are carried out, with relation to the safe and reliable control of radiation use in the nuclear industries and several radiation facilities. At present, following subjects are carried out with collaboration of multi-disciplinary researchers, including engineering, technology, biology, medicine and environmental science:

- i) Radiation safety in and surrounding the nuclear plants, in order to develop an advanced radiation safety management system and control procedures, with using experiences with KUR and KUCA.

- ii) The level and movement of radioactive gas and aerosols generated by the accelerators, from the view point of radiation safety assessment.
- iii) Behavior and kinetic of radio-nuclides originating from nuclear waste in soil and plants, especially the modeling of transfer of radio-carbon and radio-caesium.
- iv) Measurement and control of radioactivity induced by neutron and charged particles in nuclear plants and accelerators.
- v) Health effects and risks of radiation and radioactive materials, with relation to the nuclear industries and boron neutron capture therapy, as well as biological effects of radiation on human and non-human biota.

#### **III-1-1- (5) Isotope Production and Application**

This laboratory is focusing on studies concerning the production of isotopes using KUR and their various applications. The current research subjects are as follows:

- i) Multitracer preparation and its application
- ii) Trace element analysis by neutron activation method
- iii) Study on nuclear decay of actinide elements
- iv) Study on neutron energy spectrum induced by the Hiroshima atomic bomb using fast neutron product of  $^{63}\text{Ni}$
- v) Environmental science study using long-lived nuclides
- vi) Production mechanism of radioactive aerosol and its characteristics

#### **III-1-1- (6) Nuclear System**

To realize an emergent nuclear system with enhanced safety and high efficiency, this laboratory is performing basic studies on the nuclear characteristics of nuclear systems, which are subject to neutron transport and nuclear reactions, mainly based on reactor physics experiments using the Kyoto University Critical Assembly (KUCA). The current research subjects of this laboratory are as follows:

- i) Development of accelerator driven subcritical reactors.
- ii) Nuclear characteristics of next generation reactors including (a) thorium fueled reactors, (b) reactors for incinerating long-lived radioactive elements, (c) high performance research reactors, and so on.
- iii) Research on reactor physics experimental technique based on reactor noise analysis or higher mode analysis.
- iv) Development of neutron detectors and innovative experimental techniques for various reactor physics experiments.

- v) Development of detection system for landmine or illicit materials by radiation detecting techniques.

#### **III-1-1- (7) Heat Transport**

Research activity of this laboratory covers (a) thermal-hydraulics of nuclear energy, (b) fundamental aspects of multiphase flows, (c) boiling heat transfer, and (d) flow visualization and measurement using neutron radiography. Current research subjects include:

- i) Application of multi-sensor probes to measurement of characteristics of gas-liquid two-phase flow in a large diameter pipe.
- ii) Direct contact phase change of water droplets in a molten metal pool.
- iii) Heat transfer enhancement due to radiation induced surface activation (RISA).
- iv) Thermal-hydraulic characteristics of two-phase flow in mini-channels.
- v) Application of neutron radiography to flow visualization and measurement.

#### **III-1-1- (8) Materials Irradiation Effects**

The purpose of this research laboratory is to understand the fundamental aspects of irradiation effects in solids by high energy particles. It crosslinks with nuclear energy technology as well as solid state physics. The current research subjects are as follows:

- i) Irradiation damage in metals, ceramics and semiconductors from low to high temperatures.
- ii) Development of materials for advanced nuclear energy system.
- iii) Computer simulation of irradiation effects in solids.
- iv) Safety assessment of materials for nuclear power plants.

#### **III-1-1- (9) Environmental Radionuclide Science & Engineering**

Current studies in this laboratory have been focusing on transport and redistribution of trace elements released in the environment through anthropogenic activities and natural phenomena. We have developed the environmental tracer technique using these elements to clarify the mechanism of global mass transport. The developed tracer technique will be applied to the site characterization and the safety assessment for high-level radioactive waste disposal, and to exploitation of new water-resources for overcoming the global water shortage in the 21 century.

The ongoing research topics are as follows:

- i) Development of environmental tracer technique for the groundwater survey. The focusing tracer materials are dissolved noble gases and cosmogenic and geogenic  $^{36}\text{Cl}$  to estimate the

groundwater residence time over million years. Verification of the  $^{36}\text{Cl}$  method combined with  $^4\text{He}$  accumulation was success in the Great Artesian Basin, Australia. Groundwater flows with very low rate of less than 0.433 m/y.

- ii) Separation technique that only 1ccSTP of Kr is able to extract from 10 m<sup>3</sup> groundwater using the equipment with a hollow fiber membrane of the external pressure type was demonstrated to be an effective tool for young groundwater dating by Kr-85. The Kr-85 dating method is available for exploitation of new water resources.
- iii) Verification of the technique for estimation of the long-term erosion and/or uplift rate of the ground surface by measurement of  $^{10}\text{Be}$ ,  $^{26}\text{Al}$ , and  $^{36}\text{Cl}$  produced by cosmic ray spallation in quartz.
- iv) The distribution of iodine ratio of  $^{129}\text{I}/^{127}\text{I}$  and iodine concentration were survived in the Kanto plain for estimation of the origin of deep fluid and its circulation rate.

### III-1-1- (10) Nuclear Recycle Chemistry

This laboratory investigates the basic chemical characteristics of lanthanide and actinide in various liquids, which is essential for developing advanced chemical processing techniques for the recycle of radioactive substances. Specially focused technological targets of this chemical research are reprocessing of spent nuclear fuels, partitioning and transmutation, and radioactive waste management.

Current research subjects are:

- i) Coordination properties and separation characteristics of f-elements in high temperature melts and highly concentrated electrolyte solutions
- ii) Chemistry for the advancement of the processing of nuclear fuels and radioactive wastes
- iii) Mass-independent isotope effects in chemical exchange reactions
- iv) Radiochemical and analytical chemistry of elements related to nuclear fuel cycle.

### III-1-1- (11) Quantum Beam System (Visiting Research Laboratory)

In order to promote research systematically and synthetically by inviting active researchers who cover the field of quantum beam source development or nuclear safety, this laboratory has been prepared.

### III-1-2. Research Center for Safe Nuclear System

#### Director

FUKUNAGA, Toshiharu, D. Eng. (Tohoku Univ.),  
Neutron Scattering

#### Professors

KAMAE, Katsuhiro, D. Eng. (Nagoya Inst. of Tech.)  
Earthquake Engineering  
MORI, Yoshiharu, D. Eng. (Kyusyu Univ.)  
(Concurrently) Accelerator Physics

#### Associate Professor

ISHI, Yoshihiro, PhD (Niigata Univ.), (Concurrently)  
Accelerator Physics  
UEBAYASHI, Hiroto, D. Eng. (Osaka Inst. of  
Tech.), Earthquake Engineering

#### Assistant Professors

KAWABE, Hidenori, D. Eng. (Kobe Univ.)  
(Concurrently) Earthquake Engineering  
UESUGI, Tomonori, D. Sci. (Univ. of Tokyo)  
(Concurrently) Accelerator Physics

The Research Center for Nuclear Safety System was established originally to promote social understanding of safety of nuclear facilities and research activities at the Research Reactor Institute. It has two research laboratories which are Nuclear Disaster Prevention System and Hybrid Nuclear System.

### III-1-2-(1) Nuclear Disaster Prevention System

Social consensus regarding energy problems is essential to the sustaining development of humankind. In this laboratory, the strategy of disaster prevention in electricity sources is studied to construct safe and stable energy system focusing upon human disaster as well as natural disaster, especially by earthquake.

The current main research subjects are as follows:

- i) Study on the formation of public consensus on matters of energy in society.
- ii) Study on the systematization of disaster prevention system focusing upon human disaster as well as natural disaster, especially by earthquake.
- iii) Study on the strong ground motion prediction to mitigate earthquake disaster.
- iv) Study on the strategy of earthquake disaster reduction in collaboration with local government.

### III-1-2-(2) Hybrid Nuclear System

Novel nuclear power system such as ADS(Accelerator Driven System), intense neutron source and their applications using FFAG accelerators are studied. The FFAG(Fixed Field Alternating Gradient) accelerator has a unique feature compared with accelerators, which can utilize nonlinear beam optics effectively to realize a zero chromaticity in beam behavior providing the large dynamic apertures, and is conceived as one of the most suitable accelerators for intense hadron and muon accelerations and also for an intense secondary particle source using ERIT (Emittance Recovery Internal Target) with ionization cooling.

## III-2. DEPARTMENT OF MATERIAL SCIENCE

In the department our attention is focused on material science with devices and facilities developed uniquely and on the creation of highly-qualified quantum beams such as neutrons, nuclei and high-energy photons.

### III-2-1. Division of Quantum Beam Material Science

#### Professors

- FUKUNAGA, Toshiharu, D. Eng. (Tohoku Univ.),  
Neutron Scattering  
KAWABATA, Yuji, D. Eng. (Kyoto Univ.), Neutron  
Physics and Engineering  
OHKUBO, Yoshitaka, Ph. D. (Purdue Univ.), Applied  
Nuclear Physics  
MORIMOTO, Yukio, D. Sc. (Osaka Univ.),  
Macromolecular Science  
SETO, Makoto, D. Sc. (Kyoto Univ.), Solid State  
Physics

#### Associate Professors

- TANIGUCHI, Akihiro, D. Eng. (Nagoya Univ.),  
Nuclear Physics  
HINO, Masahiro, D. Sc. (Kyushu Univ.), Neutron  
Optics  
SUGIYAMA, Masaaki, D. Sc. (Kyoto Univ.),  
Radiation Physics  
CHATAKE, Toshiyuki, D. Sc. (Tokyo Inst. of Tech.),  
Neutron Structural Biology

#### Assistant Professors

- KAWAGUCHI, Akio, D. Sc. (Kyoto Univ.), Polymer  
Physics  
KOBAYASHI, Yasuhiro, D. Eng. (Osaka Univ.), Solid  
State Physics  
SATO, Nobuhiro, D. Eng. (Kyoto Univ.), Polymer  
Chemistry  
TANIGAKI, Minoru, D. Sc. (Osaka Univ.), Nuclear  
Physics  
KITAO, Shinji, D. Sc. (Kyoto Univ.), Solid State  
Physics  
ITO, Keiji, D. Sc. (Niigata Univ.), Neutron  
Scattering  
MORI, Kazuhiro, D. Sc. (Grad. Univ. Advanced  
Studies), Materials Structure Science  
KITA, Akiko, D. Sc. (Tokyo Inst. of Tech.), Structural  
Biology  
KITAGUCHI, Masaaki, D. Sc. (Kyoto Univ.), Neutron  
Coherence Optics

#### Program-Specific Assistant Professor

##### (Industry - Government - Academia Collaboration)

- NISHIO, Kazuya, Ph. D. (Osaka Univ.), Structural  
Biology  
NUMOTO, Nobutaka, Ph. D. (Kyoto Univ.), Structural  
Biology

This Division has six laboratories collaborating each other. In this division, the research projects are promoted especially on material science with particle beams of neutron, RI, electron and  $\gamma$ -ray. In the projects, the division also directs its effort to creating and characterizing highly qualified particle beams and to development of new facilities and devices for the advanced uses of them. The current research projects in the laboratories are described below.

#### III-2-1- (1) Neutron Scattering Science

Neutron, the best partner of the X-ray, scattering and diffraction method are the most powerful technique to investigate and clarify the relationship between structure and function of widely distributed materials. Our laboratory concentrates on quantum beam studies of:

- i) Structural biology of the macromolecule from the term of proton or protonation in a biological pathway. It is a very popular mechanism as a catalytic material. Three-dimensional structures at the atomic resolution and quaternary structures of proteins will deeply give us an information for understanding the physiological biophysics by use of the neutron and synchrotron radiation sources.
- ii) The structure of various kinds of amorphous materials by the method of X-ray or neutron scattering.

Also we have actively collaborated with other high-flux facilities: KENS, JRR-3M, J-PARC and synchrotron radiation facilities PF and Spring-8.

#### III-2-1- (2) Neutron Material Science

In this laboratory, static and dynamical structures of disordered (amorphous, glass and gel), non-equilibrium and crystalline materials are investigated by complementary use of neutron and x-ray scatterings. The obtained results are returned for production of intelligent and functional materials. Therefore, several subjects in the laboratory are focused to get structural information of functional, energy storage and high temperature materials.

#### III-2-1- (3) Neutron Optics

The main research filed of this laboratory is the development of neutron optical devices and its utilization. The current subjects are as follows:

- i) Development of VIN-ROSE which is a set of neutron resonance spin echo (NRSE) and MIEZE spectrometers for a pulse neutron source
- ii) Development of multilayer neutron mirrors, such as supermirrors, monochromators, and polarizers/analysers.
- iii) High contrast neutron imaging using low energy neutrons for engineering, agriculture, archeology and so on.

The development of VIN-ROSE is mainly performed in JRR-3M and J-PARC, JAEA. MIEZE was successfully operated with a white neutron beam in a pulsed neutron source at BL-10 and BL-05.

#### **III-2-1- (4) Nuclear Beam Material Science**

This laboratory is mainly concerned with the development of production methods of radioactive nuclear beams and their applications. The current research subjects are as follows:

- i) Development of on-line isotope separation system for fission products.
- ii) Research and development of nuclear radiation techniques.
- iii) Solid state physics and chemistry using gamma-ray perturbed angular correlation technique.
- iv) Nuclear structure studies of neutron-rich nuclei around mass  $A = 150$ .

#### **III-2-1- (5) Nuclear Radiation Physics**

Research subjects of this laboratory are focused on the followings:

- i) Condensed matter physics with nuclear methods, such as the study on the electronic states of synthetic metals and nano-structured materials using Mössbauer spectroscopy.
- ii) Fundamental studies of nuclear resonant excitation using synchrotron radiation and its application for materials and biological sciences.
- iii) Fundamental studies of X-ray radiation with charged particle beams.

#### **III-2-1- (6) Radiation Material Science**

Advanced utilization of radiation for material research is the key concept of this group's research activities. Recent studies are concerned with the fabrication of functional polymer materials through  $\gamma$ -ray-induced chemical processes. The current research topics are as follows:

- i) Application of  $\gamma$ -ray-induced reaction for developing nanomaterials, such as chemical modification of nanoparticles and simultaneous cross-linking and decomposing of multi-component polymer systems.
- ii) Exploration of the environmentally-friendly material synthesis process with  $\gamma$ -ray irradiation by taking advantage of their reaction free from chemical initiators or catalysts.

### **III-3. DEPARTMENT OF RADIATION LIFE SCIENCE AND RADIATION MEDICAL SCIENCE**

This department consists of one division and one center, that is, division of radiation life science and particle radiation oncology research center. In particle

radiation oncology research center, advanced neutron therapy session, which is financially maintained by private donations, was established since 2008.

Five research groups are collaborating for the research on physics, biology, chemistry and medicine using photon radiations and neutrons.

#### **III-3-1. Division of Radiation Life Science**

##### **Professors**

FUJII, Noriko, D. Med. Sc. (Tokyo Med. Den. Univ.),  
Radiation Biochemistry and Biological Function  
WATANABE, Masami, D. Pharm. (Univ. of Tokyo),  
Radiation Biology

##### **Associate Professors**

KOBAYASHI, Tooru, D. Eng. (Tokyo Inst. of Tech.),  
Biomedical Physics and Engineering  
SAKURAI, Yoshinori, D. Eng., (Kyoto Univ.)  
Biomedical Physics and Engineering  
TANO, Keizo, D. Med. Sc. (Nara Medical Univ.),  
Molecular Biology

##### **Senior Lecturer**

KINOUCHI, Tadatoshi, Ph. D. (Univ. of Tokyo),  
Biochemistry, Gerontology

##### **Assistant Professors**

TANAKA, Hiroki, D. Eng. (Kyushu Univ.),  
Biomedical Physics and Engineering  
KASHINO, Genro, D. Pharm. (Nagasaki Univ.),  
Radiation Biology  
SAITO, Takeshi, D. Sc. (Hiroshima Univ.), Radiation  
Physical Chemistry, Radiation Biology

This division is composed of three laboratories: Radiation Medical Physics, Radiation Biochemistry and Biological Function, and Radiation Biology.

The current research projects are as follows:

##### **III-3-1- (1) Radiation Medical Physics**

Medical physics is the general term for the physics and technology which are supporting medicine, especially radiation therapy and particle therapy. As it covers many different fields, the important subjects are "promotion for the advance of radiation therapy" and "quality assurance for radiation therapy". Our group is focusing on "boron neutron capture therapy (BNCT)", which is one kind of particle therapies. We are studying for the advance of BNCT as follows:

- i) Advance of the BNCT irradiation fields: We are studying about the improvement of the irradiation field at the Heavy Water Neutron Irradiation Facility of KUR. We are also performing the design studies for accelerator-based irradiation system.
- ii) Development of dose estimation methods: We are developing the separative estimation methods

for four components such as thermal (<0.5 eV), epi-thermal (0.5 eV to 10 keV) and fast neutrons (>10 keV), and gamma ray. Our final goal is the completion of the real-time estimation system for 3D dose distribution under BNCT.

- iii) Establishment of quality assurance (QA): We are studying about the QA program for BNCT, such as the standard dosimetry for the irradiation field, the dose estimations for pre- and post-treatment, the exposure estimation for patient, *etc.*.

### **III-3-1- (2) Radiation Biochemistry and Biological Function**

Our study is focused on various post-translational modifications, such as: deamidation, racemization, stereoinversion, isomerization, truncation, phosphorylation, oxidation and an increase in intramolecular disulfide bonding of inert proteins, such as lens, brain and skin. These post-translational modifications generate during aging process spontaneously and also are increased by UV (ultraviolet), gamma and neutron irradiation.

Our aim is to elucidate the post-translational modifications which can induce the partial unfolding of the protein, resulting in a reduction of the protein functions, followed by the related diseases. The current research includes the following projects:

- i) Study of post-translational modification of lens proteins induced by aging, UV, gamma and neutron irradiation.
- ii) Study of mechanism of D-amino acid formation in protein. The aggregation of protein induced by racemization of Asp residues in protein.
- iii) The identification of D-beta-Asp containing protein in UV-irradiated skin from elderly human donors.
- iv) Study of the radioresistant mechanisms in the radioresistant bacteria.
- v) Study of a specific enzyme that degrades D-Asp-containing protein.

### **III-3-1- (3) Radiation Biology**

After the life was born on the earth 3,600 million years ago, the life has not been separated from various environmental stresses, such as radiation, temperature and pressure. And the life built cell structure to distinguish it from the surrounded environment. Recently, it has been made clear that a cell is using basic mechanism of biological reaction for replying to various stresses. Therefore, basic biological reaction may be clarified by discovering stress response mechanism. Dysfunction of stress response in cell may be a cause of carcinogenesis and acceleration of aging. If so, it is also expected that a disease is cured by fixing a stress response function normally.

Along such a working hypothesis, we choose four environmental stress factors, such as radiation, hyperthermia, and pressure, and are doing the study focused on the following topics.

- i) Mechanism of carcinogenesis and aging
- ii) Mechanism of stress response
- iii) Development of new cancer therapy by hyperthermia and radiation
- iv) A search of cancer and aging prevention natural material

A last aim of our research activities is prevention and a treatment of cancer and aging.

As topics of our recent research in 2006, we found that nongenetic damage induced by long-lived radicals played an important role in an initial process of cellular malignant transformation. This new radical attacked centrosome, and destroyed its structure. In those cell culture, structural aberration of chromosome did not occur, but aneuploid was seen in high frequency. From these results, we speculated that a main target of radiation carcinogenesis is not DNA, but is centrosome, which are the proteins to constitute chromosomal homeostasis maintenance mechanism. If our experiment results are right, mutation theory of carcinogenesis is to be wrong. Therefore, we propose a new hypothesis of radiation carcinogenesis. This result was presented at International Congress of Radiation Research 2007 in San Francisco as an invited speaker.

### **III-3-2. Particle Radiation Oncology Research Center**

#### **Professor and Director**

ONO, Koji, M. D., D. Med. Sc. (Kyoto Univ.),  
Radiation Oncology

#### **Professor**

MARUHASHI, Akira, D. Eng. (Kyoto Univ.) Medical  
Physics, Radiation Basic Medicine, Radiation  
Oncology

#### **Associate Professor**

MASUNAGA, Shin-ichiro, M. D., D. Med. Sc. (Kyoto  
Univ.), Radiation Oncology

SUZUKI, Minoru, M. D., D. Med. Sc. (Kyoto Univ.),  
Radiation Oncology

#### **Assistant Professors**

KONDO, Natsuko, M. D., D. Med. Sc. (Nara Medical  
Univ.), Neuro-surgery

LIU, Yong, M.D., D. Med. Sc. (Hirosaki Univ.),  
Radiation Oncology

### **III-3-2-(1) Particle Radiation Oncology**

The research program of Boron Neutron Capture Therapy (BNCT) at KURRI has been re-organized since 1990. Over 270 cases of malignant tumors, that are refractory to standard treatment, have been treated by BNCT. They consist of many cases of malignant brain



tumors (mainly glioma), melanoma, H & N cancers, and two and four cases of lung and liver cancers, respectively. The 5-year survival rate of malignant melanoma of the skin is 55%. The first BPA-BNCT for malignant glioma in the world and first clinical trial using epithermal neutron beam without craniotomy in Asia were performed in KURRI at the beginning of 1994 and 2002, respectively. The 5-year survival rate of malignant glioma is 25%. According to the paper that reported the effectiveness of Temozolomide (TMZ) on newly diagnosed glioblastoma multiforme (GBM), X-ray therapy with or without TMZ achieved MSTs of 12.1 and 14.6 months, respectively. On the other hand, BNCT for this disease showed median survival time (MST) of 14.7 months. Only quite small number of patients received TMZ medication. So, BNCT can be considered to be equal to TMZ+X-ray therapy at least. For recurrent GBM, BNCT looks superior treatment than standard supportive therapy. From the previous report on TMZ+X-ray therapy trial, we can estimate MST of 7-8 months for recurrent GBM cases. BNCT for this disease elongated the MST to 11.8 months. Hazard ratio is around 1.5-1.7. In December of 2001, the first patient of recurrent H & N tumor in the world was treated by BNCT. An analysis was also performed on all recurrent H & N tumors. BNCT showed excellent effects on the cases of histopathology of adenocarcinoma. All patients of this pathology are surviving after BNCT. Malignant melanoma has also good clinical outcome, however, that of squamous cell carcinoma patients is not good. Although the reason is not clear, far advanced many cases might be included in this histopathological category.

The roles of this division are organization and operation of clinical trial of BNCT for cancers, and our division is the nucleus of BNCT and related researches in whole Japan.

The main research subjects are as follows:

- i) Radiation biology research for NCT.
- ii) Development of radio-medical techniques.
- iii) Development and test of boron-10 compounds for NCT.
- iv) Radiation dosimetry in living systems and microdosimetry.
- v) Clinical BNCT for cancer patients.

### III-3-2-(2) Advanced Neutron Therapy

As a result of  $^{10}\text{B}$ -thermal neutron reaction, energetic particles of  $^4\text{He}$  and  $^7\text{Li}$ , and gamma rays are emitted. Energies (ranges, LETs) of each particle,  $^4\text{He}$  and  $^7\text{Li}$ , are 1.47MeV (8.9 $\mu\text{m}$ , 165keV/ $\mu\text{m}$ ) and 0.84MeV, (4.8 $\mu\text{m}$ , 175keV/ $\mu\text{m}$ ) and 0.04% of those are 1.68MeV (9.8 $\mu\text{m}$ , 170keV/ $\mu\text{m}$ ) and 1.01MeV (5.3 $\mu\text{m}$ , 190keV/ $\mu\text{m}$ ) corresponding to the nuclear energy state of  $^7\text{Li}$  generated in  $^{10}\text{B}$  (n,  $^4\text{He}$ ) $^7\text{Li}$  reactions, respectively. All of these

particles possess most effective potential for giving damage to cells. If  $^{10}\text{B}$  compound accumulates selectively at higher concentration in all tumor cells than surrounding normal cells, we can completely destroy the tumor without damage to the normal tissues by BNCT. There exist the tumor cells in which  $^{10}\text{B}$  compound is low in concentration. Although the proportion of such cells is not so large, however, it is inevitable in the advanced malignant tumor. Another weak point of BNCT is that curable depth of tumor is limited to about 7cm by attenuation of epi-thermal neutron in a body. It is the object of our research program to overcome these problems of BNCT.

To advance the BNCT of the present situation, we decided to develop a new system of an accelerator and a moderator, and to achieve the neutron field the most suitable for BNCT. An accelerator-moderator system was installed in a medical research lab as one division of the innovation research laboratory on Apr. 2009. This accelerator is able to supply 30MeV proton beam of the constant intensity of 1mA over 1hour continuously. At present, characteristics of neutron field of an irradiation port achieved by this system were examined by means of physical (dosimetry of mixed radiation fields of neutron and gamma-ray) and biomedical (radiation effect and radiation safety) methods.

### III-4. HEAD OFFICE FOR SAFETY MANAGEMENT

Recently, safety management is becoming more and more important in view of public acceptance of nuclear facilities. Therefore, the Head Office for Safety Management was established in 2002 to supervise the safety management in the Institute, especially in the nuclear facilities. In FY 2009, to strengthen the quality control function, Division of Quality Control has newly established in this Head Office.

### III-5. HEAD OFFICE OF ACADEMIC INFORMATION

This office supports the institute in information-related aspects. It has mainly three duties interrelated with each other.

- i) Network operation: The office maintains the network system and operates servers for e-mail and homepage.
- ii) Support of research and education: The library is a constituent unit of the office. Meeting the multidisciplinary character of the institute, it possesses a wide variety of research journals, books, and other documents, especially, related to nuclear science and engineering. Through the network, electronic journals and databases subscribed by Kyoto University are also available. The office transmits lectures given in the institute to other campuses of Kyoto University and other universities via internet TV-systems.

iii) Public relations: The office introduces to the public activities of the institute through the homepage, by issuing brochures and progress reports, and by holding an open lecture meeting and open campus.

### III-6. TECHNICAL STAFF OFFICE

The technical staff office takes charge of the technical works for the operation of a reactor, maintenance of the experimental facilities, safety control of radiation and radioactive waste disposal. It consists of four groups and each group has two subgroups.

#### General Manager

IKEGAWA, Ryusho  
(Concurrent) Group Chief

#### Group Chiefs

MINAMI, Kaoru  
(Concurrent) Subgroup Chief

TSUCHIYAMA, Tatsuo

KOBORI, Hiroshige  
(Concurrent) Subgroup Chief

#### Subgroup Chiefs

YOSHIMOTO, Takaaki

YAMAMOTO, Hiroshi

YOSHINO, Hirofumi

KAKIHANA, Eiko

#### Senior Staff Members

OONO, Kazuomi

TAKESHITA, Tomoyoshi

HIRAI, Yasuhiro

OKUMURA, Ryou

YOSHINAGA, Hisao

#### Technical Staff Members

ABE, Naoya

ITAMI, Teppei

INO, Yuta

IMOTO, Haruka

KANAYAMA, Masaya

KURIHARA, Kouta

SAKAMOTO, Masaaki

TANAKA, Yoshiaki

ZHANG, Jian

NAKAMORI, Akira

HASEGAWA, Kiyoshi

FUJIHARA, Yasuyuki

FUJIWARA, Keiko

MARUYAMA, Naoya

MIYAKE, Tomohiro

YAMADA, Tatsuya

#### General Affairs Division:

Director : NISHIGAKI Masayo

Section Chief : IZUMORI Yoshihiro

#### General Affairs Section

Section Chief : NAKAYAMA Chiyoko

SUZUKI Michiyo

YAMAMOTO Yuka (nurse)

#### Joint Use Program Section:

Section Chief : HASHI Masahiro

#### Library Section :

Section Chief : NISHIGAKI Masayo

KOMORI Chihiro

#### Financial Affairs Division

Director : ASAI Masahiko

#### Accounting Section

Section Chief: IWASE Tomohiro

OKIGUCHI Kouji

#### Supplies Section :

Section Chief : INUI Hironori

ISETO Motoko

IWATA Masayo

#### Building Work Section :

Section Chief : FUJIWARA Youji

YASUI Kouji

#### Electricity Work Section :

Section Chief : MORI Tetsuya

TANIGUCHI Masaru

FUJIWARA Kenji

#### Other Utility Work Session :

Section Chief : KAWASE Syuji

MIYAHARA Masahiro

### III-7. ADMINISTRATION OFFICE

Director : NAGATA Toshiyuki