7. Personal Interchange Joint Research Program

NIFS provides many types of joint research programs that cover a variety of researches on nuclear fusion or plasma physics. On the other hand, many original ideas and the extensive studies are also carried out in university laboratories and other institutes. Sometimes, they are complementary to the specific projects of NIFS, and worth to be supported by NIFS. "Personal interchange joint research program" has been established for this purpose. Being different from other collaboration programs of NIFS, where the university researchers come and join the research activities performed at NIFS, this program supports financially that the staffs of NIFS go out to join the collaboration research in universities. Two categories are prepared for collaboration; one is "project type" where the collaboration is made between two facilities; one is at NIFS and the other is at the university. A systematic research on the common subjects is done at both facilities by the researchers of both organizations to obtain a comprehensive knowledge on the subjects. The other is "dispatch type" where the researchers of NIFS take part in the study using the facility or experimental device at the university with a new idea or with an expert knowledge to explore a new field.

In this fiscal year, five subjects were carried out as "project (P) Type" and ten for "dispatch (D) type". The results of all subjects are reported here, and brief summaries of each subject are listed below.

[P1]: *"Experiments on the Excitation of an Electron Bernstein Wave in the Internal Coil Device " by Ogawa Y., et al.*

This collaboration was carried out between University of Tokyo and NIFS on the excitation of electron Bernstein waves (EBW) on the internal coil torus device, Mini-RT. In order to examine mode conversion of waves from electromagnetic mode to electrostatic one, three kinds of probes are inserted, i.e. pole-antennas (for electric component), loop-antennas (for magnetic component) and triple probe (for density). Interferometry system is introduced to obtain the snapshot of electric or magnetic field. In radial electric field measurements, short wavelength mode is observed in higher density area than UHR region, i.e. this mode wave is able to propagate in the evanescent region and excited around the UHR region. In this area, electromagnetic mode waves are damped down, which suggests that the short wavelength mode waves are electrostatic mode ones and excited by conversion from electromagnetic mode ones. The phase information of this electrostatic wave shows that it is a backward wave.

[P2]: *"Plasma Simulation Experiments using Versatile Highly Charged Ion Sources" by Nakamura N., et al.*

This collaboration was carried out between NIFS and Univ. of Electro-Communications to obtain atomic data of highly charged ions such as the cross sections of resonant recombination and ionization processes. Those data are important as fundamental atomic data in non-equilibrium plasmas such as the peripheral plasma in fusion devices and the transition region in the solar atmosphere. For spectroscopic studies of iron ions relevant to the solar corona, a compact EBIT was used. Typical result for the electron density dependence of line intensity ratio of Fe XIII and Fe XIVshows good agreement between the experiment and the theory, where the electron density was determined by the electron current and the electron beam profile was obtained with a pinhole EUV camera. For actively simulating non-equilibrium plasmas with the EBIT, fast and remote control of electron beam energy and current by PC was conducted.

[P3]: *"Plasma Heating and Flow Control in a Fast-Flowing Plasma" by Ando A., et al.*

This subject was carried out between NIFS RF heating group and Tohoku University. The production and control of fast-flowing plasma are important to clarify various MHD phenomena observed in space and fusion plasmas, for developing advanced electric propulsion systems and for applying in various industrial researches. In order to elucidate the magnetic field deformation by the plasma flow, magnetic field and Mach numbers (ion Mach number M_i and Alfven Mach number M_A) were measured by the Alfven Mach probes, which is composed of a conventional Mach probe and a magnetic probe. A fast-flowing plasma with $M_i \sim 1$ is generated by using a Magneto-Plasma-Dynamic Arcjet (MPDA) attached at the HITOP device. The supersonic and super-Alfvenic flow was obtained with an additional small coil attached to the MPDA. The magnetic field deformation was occurred by the plasma flow, and it is related to the plasma detachment phenomena.

[P4]: *"Development of Neoclassical Diffusion Coefficients Database for Integrated-Transport-Code Analyses of LHD Plasmas" by Yokoyama M., et al.*

This subject was carried out between Kyoto University and NIFS group. The neoclassical(NC)-diffusion-coefficients database has been prepared and extended to perform accurate and fast analyses of NC diffusion for a variety of LHD plasmas. For this extension, the two NC transport codes, DCOM and GSRAKE, have been utilized to complement advantages/disadvantages. Combining these two NC transport codes, the diffusion coefficients database has been extended towards low-collisional regime. It has been incorporated into the NC module of the integrated-transport-code, TASK3D, so that accurate and fast evaluation of NC diffusion for a wide range of LHD plasmas has been made possible.

[P5]: *"Development of High Power Sub-Terahertz Pulse Gyrotron" by Saito T., et al.*

Development of a high power sub terahertz pulse gyrotron is under way with collaboration between FIR-FU and NIFS for application to a power source of the collective Thomson scattering from a high density plasma in LHD. As the first step, a second harmonic gyrotron of demountable type was fabricated. Experiments have proved single mode oscillation of second harmonic modes and oscillation power of 50 kW at 350 GHz and about 40 kW at 390 GHz A gyrotron of sealed-off type was manufactured as the second step. A group of second harmonic oscillation modes such as the $TE_{3,7}$, $TE_{1,8}$ and $TE_{17,2}$ modes has been adopted in the second step gyrotron because these modes are further isolated from the competing fundamental $TE_{4,3}$ mode than the $TE_{8,5}$ mode used in the first step gyrotron. In the experiment, $TE_{1,8}$ mode reached the highest power of 62 kW at the beam voltage of 65 kV and the beam current of 11A.

[D1]: *"Development of External Control Knob for Improved Confinement Mode in TU-Heliac" by Kitajima S., et al.*

Study of magnetic island effects on the transport is important, because it leads to the advanced control method for a plasma periphery in a fusion reactor. This research is to investigate island effects on confinement modes in Tohoku University Heliac (TU-Heliac). The island effects on the plasma periphery by the external perturbation fields in TU-Heliac were surveyed. The fixed m = 3 magnetic island were produced by the two pairs of external cusp field coil. The positions of local maxima in the plasma space potential profile agree well with the position of the n/m = 5/3 rational surface. In order to study the effects of magnetic islands on plasma poloidal flow, they externally controlled the flow velocity by changing the electrode current with the current control power supply. When the electrode current exceeded a critical value, the Mach probe current ratio (poloidal flow velocity) increased suddenly. It was also clearly shown that after this time the temperature fluctuation was significantly suppressed and, the electron density increased by a factor of 3, which suggests the improved mode transition. The magnetic island located at the plasma periphery affects the poloidal flow as the drag term.

[D2]: *"Development of Cesium-Free Deuterium/ Hydrogen Negative-Ion Source Based on Catalytic Ionization Method" by Oohara W., et al.*

This subject was carried out between Yamaguchi Univ. and NIFS NBI group. Development of deuterium/hydrogen negative-ion source without cesium admixture is performed. Hydrogen atomic pair ions are produced by plasma-assisted catalytic ionization using a porous nickel plate. When positive ions in a hydrogen plasma discharged are irradiated to the porous plate, the pair ions are produced from the back surface of the plate. The porous catalyst is negatively biased at dc voltage of V_{pc} with respect to grounded chamber wall, and the irradiation current of positive ions can be obtained. Plasma parameters are measured by Langmuir probes. The probe characteristics show the production quantity of positive ions from the catalyst surface is greater than that of negative ions. The positive- and negative-saturation currents of the probe are obtained and the dependences on the irradiation energy are inspected precisely.

[D3]: *"Investigation of Cu Addition MgB_2 Superconducting Long Wire Deformation and Strain Sensitivity Evaluation System of J_c Property " by Yamada S., et al.*

This collaboration was carried out between NIFS and National Institute for Materials Science. They have proposed that the simultaneous transport both superconducting power transmission and liquid hydrogen as the new energy sources, which is so-called " Hybrid Energy Transfer Line (HETL) " . They have developed Cu addition MgB_2 superconducting cable made in NIFS under liquid hydrogen temperature (20 K). Recently, they succeeded to develop the 100 A class MgB_2 superconducting wire above liquid hydrogen temperature (20 K). They tried to fabricate the 50 m long class Cu addition MgB_2/Ta/Cu multifilamentary wire and studied about the optimum wire deformation condition. In order to evaluate strain sensitivity on J_c , they investigated and fabricated a probe to measure the bending strain impressed J_c, which was inserted in an 18 T superconducting magnet of Tsukuba magnet laboratory of National Institute for Materials Science (TML-NIMS). They will investigate bending strain and flexural structure effects of MgB_2 wires using Walter spring system.

[D4]: *"RF Plasma Generation and Current Ramp-up Experiments on the TST-2 Spherical Tokamak " by Takase Y., et al.*

The purpose of this collaborative research is to perform plasma generation and plasma current ramp-up experiments using radiofrequency (RF) waves on the TST-2 spherical tokamak, with the eventual objective of developing an innovative method for realizing high-performance high-β plasmas. In FY 2010 the combline antenna was installed in TST-2. Plasma generation and plasma current ramp-up to over 10 kA were achieved using this antenna under collaboration with NIFS RF group. This is the first experimental demonstration of ST plasma start-up using waves in this frequency range. In addition, an asymmetry in the achievable level of plasma current with respect to the direction of the excited travelling wave (co vs. counter current drive direction) was observed, suggesting the importance of directly driven current relative to the pressure gradient driven current.

[D5]: *"Estimate of Confinement Properties in a Low-*

Aspect-Ratio RFP using Interferometer" Masamune S., et al..

The objectives of this research include estimating confinement properties of a low-aspect-ratio RFP plasma in RELAX (a low-A RFP machine operated at Kyoto Institute of Technology) from density measurement using an interferometer. It is important to measure electron density in high-density region ($n_e = 2 - 3 \times 10^{19}\mathrm{m}^{-3}$), for the detailed study on self-organization to helical RFP state and its confinement performance. Development of a 140GHz millimeter wave interferometer has been started as a NIFS collaboration program. In FY 2010, operation of a gun oscillator and frequency modulation using a saw-teeth signal generator has been tested. Measurements of attenuation characteristics of an over-sized waveguide (WR-12) have been also performed.

[D6]: *"Study on Accessibility of Electron Bernstein Wave to Core Region of Ultra High Beta Plasmas " by Ono Y., et al.*

This experimental proposal aims to investigate feasibility of electron heating in extreme high-beta plasma by electron Bernstein wave (EBW). EBW is a method to overcome a density limit by which accessibility of conventional electron cyclotron resonance heating is limited. To this end, electron Bernstein wave emission (EBE) measurement was employed for compact torus experiments TS-3, which is an inverse process of mode conversion of EBW heating. In FY2010, they have attempted measurement of EBE from spherical tokamak (ST) whose $< \beta >$ was about 0.1. The EBE system covers frequency range of 2.1-5.1 GHz with four channels. A time evolution of radiation temperature T_{rad} of the ST plasmas was measured by the EBE system. T_{rad} was in the range of 0.5-3.5 eV and depending on the receiver angle. This detected radiation was considered to originate from thermal electrons at the edge region of the ST. The frequency corresponds to 5-6 harmonics of the electron cyclotron frequency at the edge region,

[D7]: *"Investigation of Deuterium Retention in Dust and Redeposited Layers by using Divertor Plasma Simulator" by Ohno T., et al.*

Dust particles generated in fusion devices have a strong influence on safety and operational issues. Many kinds of metal and carbon dust particles including deposits have been collected in large fusion devices to investigate shape and size distribution of dust particles. Further, gas retention in collected dust particles were analyzed by using thermal desorption spectroscopy (TDS). Firstly, they have analyzed a divertor tile, which was used in the LHD. TDS spectra of a specimen shows a strong He peak, probably because He is trapped in defects, such as bubbles of metal layers. They also made deposition layer of W on Mo substrate under high density deuterium plasma in the NAGIS-II device to investigate characteristics of deuterium gas retention in tungsten dust particles and deposits.

[D8]: *"Study on the Interaction between Metal Vapor and Plasma using Stabilized High Current Arc " by Uesugi Y., et al.*

The properties of high heat flux arc plasmas are very useful to study the transient behaviour of the divertor materials during ELMs and disruptions in fusion reactor complementally with other ELM/disruption experiments. They used an arc plasma torch as a high heat flux source. The plasma heat flux onto the cathode surface is several hundreds $\mathrm{MW/m^2}$ in steady state and several $\mathrm{GW/m^2}$ in arc ignition and arc quenching phases. In the experiments disruptive ejection of the cathode molten materials (Hf), which may related to some fluid dynamic instabilities, is observed in the steady state arc in addition to the arc ignition phase with pulse $\sim \mathrm{GW/m^2}$ heat flux. They have a plan to test tungsten cathode with helium arc plasmas using this arc plasma torch.

[D9]: *"High-Sensitivity Tritium Gas Monitoring System Using Two-Parameters Pulse Height Analyzer" by Kawano T., et al.*

The tritium gas monitor developed in NIFS is employing ingenious techniques including a two-parameter-pulse height analyzer, where two parameters are a pulse height and a rise time of signal arose from radiation detection. It was composed of five parts: (1) Tritium detector, (2) Nuclear radiation analyzer for proportional counter, (3)Two-parameters pulse height analyzer, (4) Control data analyzer, (5) Two-channel oscilloscope. The developed high-sensitivity tritium gas monitoring system employs the two-parameter pulse height analyzer for strictly separating the signal caused by tritium beta ray from all other ones. The prototype system was constructed and detail examination will be performed next year.

[D10]: *"Development of SINET Online Data Acquisition and Share System" by Ono Y., et al.*

This collaboration was carried out between University of Tokyo and NIFS. The Doppler broadening method is the most reliable diagnostics for ion temperature measurement and its two dimensional (2-D) measurement is expected to solve magnetic reconnection in TS-4 merging experiment. They have developed a new 2-D ion temperature measurement system by combining the Doppler spectroscopy with computer tomography technique and sucessfully measured the 2-D contours of ion temperature of merging tokamak plasmas. They also developed 2-D electron temperature measurement system, so called 2-D Thomson scattering system using the multiple reflection of laser light and time-of-flight measurement of scattering lights. The successful result supports the validity of the 2-D Thomson scattering method by multiple reflection and time-of-flight of laser. The efficient data transfer is also demonstrated by the SINET system.

List of Reports

Project type collaboration

P1: "Experiments on the Excitation of an Electron Bernstein Wave in the Internal Coil Device " by Ogawa Y., et al. (Univ. of Tokyo)

P2: "Plasma Simulation Experiments using Versatile Highly Charged Ion Sources" by Nakamura N., et al. (The Univ. of Electro-Communications)

P3: Plasma Heating and Flow Control in a Fast-Flowing Plasma" by Ando A., et al. (Tohoku Univ.)

P4: "Development of Neoclassical-Diffusion-Coefficients Database for Integrated-Transport-Code Analyses of LHD Plasmas " by Yokoyama M., et al. (NIFS)

P5: "Development of High Power Sub-Terahertz Pulse Gyrotron" by Saito T., et al. (Univ. of Fukui)

Dispatch type collaboration

D1: "Development of External Control Knob for Improved Confinement Mode in TU-Heliac" by Kitajima S., et al. (Tohoku Univ.)

D2: "Development of Cesium-Free Deuterium/ Hydrogen Negative-Ion Source Based on Catalytic Ionization Method" by Oohara W., et al. (Yamaguchi Univ.)

D3: "Investigation of Cu Addition MgB_2 Superconducting Long Wire Deformation and Strain Sensitivity Evaluation System of J_c Property " by Yamada S., et al. (NIFS)

D4: "RF Plasma Generation and Current Ramp-up Experiments on the TST-2 Spherical Tokamak" by Takase Y., et al. (Univ. of Tokyo)

D5: "Estimate of Confinement Properties in a Low-Aspect-Ratio RFP using Interferometer " by Masamune S., et al. (Kyoto Inst. Tech.)

D6: "Study on Accessibility of Electron Bernstein Wave to Core Region of Ultra High Beta Plasmas" by Ono Y., et al. (Univ. of Tokyo)

D7: "Investigation of Deuterium Retention in Dust and Redeposited Layers by using Divertor Plasma Simulator" by Ohno N., et al. (Nagoya Univ.)

D8: "Study on the Interaction between Metal Vapor and Plasma using Stabilized High Current Arc" by Uesugi Y., et al. (Kanazawa Univ.)

D9: "Design Fabrication of Tritium Gas Infusion System" by Kawano T., et al. (NIFS)

D10: "Development of SINET Online Data Acquisition and Share System " by Ono Y.,, et al. (Univ. of Tokyo)

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