9. Bilateral Collaboration Research Program

The bilateral collaboration research program started in FY2004 as the third collaboration framework of NIFS. The purpose of this program is to enforce the activities of nuclear fusion research in universities by using their middle-size experimental facilities. The current program involves six university research centers;

- Plasma Research Center, University of Tsukuba
- Laboratory of Complex Energy Process, Institute of Advanced Energy, Kyoto University
- Institute of Laser Engineering, Osaka University
- Advanced Fusion Research Center, Research Institute for Applied Mechanics, Kyushu University
- Hydrogen Isotope Research Center (HIRC) of University of Toyama
- International Research Center for Nuclear Material Science (IRCNMS), Institute for Material Research, Tohoku University.

The latter two institutes were incorporated in the frame work of bilateral collaboration research program in FY2010 to extend the research field towards the fusion engineering because both institutes have special facility to promote fusion engineering research, that is, neutron irradiation in IRCNMS and tritium handling in HIRC. The facilities in other four institutes are for fusion plasma experiments.

In this collaborative program, each research center can have its own collaboration programs using its major facility so that the researchers of other universities can visit and carry out their collaborative research there as if the facility belongs to NIFS. It is unique and important that all these activities are supported financially by NIFS as the research subjects of NIFS bilateral collaboration research program. The subjects of the bilateral research program are subscribed from all over Japan every year as one of the three frame works of NIFS Collaboration Program. The collaboration committee, which is organized under the administrative board of NIFS, examines and selects the subjects.

From FY2010, the second mid-term period started in NINS as well as in all national universities in Japan. In this plan, NIFS enounces to promote (1) the pursuit of high performance plasma in LHD, (2) developing of simulation study to build numerical test reactor, and (3) fusion engineering research for the helical DEMO. These objectives are to be attained by enhancing collaborative research.

The extension of the Bilateral Collaboration towards fusion engineering studies is one of the important actions of the mid-term plan. The IRCNMS Tohoku Uni. and the HIRC Univ. Toyama now collaborate with other four plasma research centers, main topics of which is evaluation of first wall material that suffered from high heat or particle flux.

It is also recommended that the cooperating program among four plasma research institutes is endorsed. The high power gyrotron is the key component in this collaboration. Univ. Tsukuba has capability of developing high performance gyrotron which can be used for high-density plasma as well as driving electric current in toroidal plasma. Then the collaborating program has started that Univ. Tsukuba develops a gyrotron and will serve it to Kyushu Univ. and Kyoto Univ. as a new power source.

The topics of this year are;

(1) A new divertor module (D-module) was installed on the west end of GAMMA 10 mirror machine in Univ. Tukuba for divertor plasma simulation (PDX). The module has closed divetor structure with V shaped plates which can change the plate angle. It also enables to feed gasses to the divertor region and to control the pumping speed of the compressed region. The ITER level heat flux density (10 MW/m^2) at the 30 cm from the mirror throat was obtained. Using the modulated ECH power, intermittent heat pulse simulating the ELM like heat pulse was produced. The energy density is 0.05 MJ/m^2 was obtained.
In gyrotron development, the output of 1.8 MW for 1 s., the world record, was achieved in collaboration with NIFS. Based on this, we have been developing 154 GHz 1 MW tube for LHD high density plasma 5) and obtained the more than 1 MW for 1 s. In the development of 1MW-28 GHz gyrotron for GAMMA 10, the design of the electron gun and window was improved for higher power and dual frequency operation. As a result, 1.25 MW operation has been successfully obtained. In long pulse operation, 0.6 MW x 2 s has been also obtained with the modified tube. The collaboration with Kyushu Univ. has been progressed for the QUEST EBW and ECH/ECCD studies. The Tsukuba 28 GHz gyrotron has been installed on the QUEST site and the collaborative experiments will be done in the next FY.

(2) In Heliotron J of Kyoto Univ., the six schemes for the collaboration research have been selected; (1) confinement improvement and related plasma structural formation using field configuration control, (2) instability control using field configuration control, (3) ECH/EBW heating mechanism, (4) toroidal current control, (5) fuelling control and heat/particle removal, (6) physical and engineering design study of FIR interferometer. As for the fast ion confinement, energetic-ion-driven MHD instability is observed. The frequencies of the m = 2/ n = 1 mode are in the range from 50 kHz to 95 kHz. This mode has dependence of as expected from theoretical analysis. The iota dependence of the shear Alfvén spectra is also investigated experimentally and theoretically. The two different GAE modes are observed;

one of which increases with iota and the other decreases. This tendency is reproduced in the numerical simulations. The fuel control using a supersonic molecular-beam injection (SMBI) and high-intensity gas-puff (HIGP) is investigated aiming at optimization of gas-fuelling scenario. The electron and ion temperature of the plasma core region is higher and a peaked density profile is observed in the SMBI case.

(3) At ILE Osaka University, elemental researches to develop fast plasma heating applicable to fusion reactor technology development have been conducted using the fast ignition of deuterium targets. The researches consist of laser development, target fabrication, simulation technology and integrated implosion experiments. The improvement of laser system was continued. A 20μm-thick DLC (diamond-like carbon) cone, which is expected to improve the coupling efficiency, was fabricated successfully using a brass mandrel coated with a thin gold layer that enables stable growth of DLC on the mandrel. Fundamental physics including the hot electron generation, transport through the cone and the plasma surrounding the fuel core, energy deposition to the fuel plasma have been studied by using newly designed fundamental experiment plat form targets. Many advanced plasma diagnostics such as many kinds of absolutely calibrated hard x-ray spectrometers and neutron detectors guarded with high-performance collimators and shielding were developed and applied.

(4) In the QUEST Kyushu Univ., rf driven non-inductive plasma production and sustainment have been demonstrated in various magnetic configurations. In the inboard limiter configuration, current start-up has been dominated by stagnated electrons at the optimized B_z/B_t ~ a few %. Typical parameters are: I_p =10 kA for 0.7 s for P_{rf}= 30 kW and B_t=0.13T, B_z=30 G; R=0.58m a=0.36m, and A=1.6. The duration of the limiter plasma could be extended to ~ 300 sec at 60 kW and I_p ~10 kA. The divertor configuration was achieved by applying the additional divertor fields and typical parameters of the divertor plasma are: I_p =15 kA, P_{rf}~ 100 kW, B_t=0.11T, R=0.76m, a = 0.38 m, A=2, κ=1.65.
Single-null and double-null configurations could be controlled by adjusting the horizontal B_h field without changing PF coils. The duration of divertor plasma could be extended ~ 40 sec at P_{rf} ~ 60 kW.
A new current start-up scenario based on the toroidal precession of the energetic trapped electrons has been demonstrated at higher B_z/B_t >10 % and strongly curved B_z field. This has been achieved by only using divertor coils. Typical parameters are: Ip =10 kA, Prf ~ 100 kW a = 0.27 m, R0 = 0.79 m, △/a = 0.4, $\varepsilon\beta_p$ =1.5 and κ<1. The maximum Ip of 35 kA and maximum duration of 180 sec are achieved in this configuration.

(5) At HIRC Univ. Toyama, behavior of hydrogen on and in the plasma facing materials under the influence of plasma and impurities exposure is a current issue. Basic studies were carried out on the behavior of hydrogen isotope in the surface layer irradiated by hydrogen or helium. The effects of mixed surface layer (mostly carbon) of the metallic surface (w or SUS) on the hydrogen isotope behavior were studied. Collaborative researches done in this area are; effects of surface mixing layers of tungsten on hydrogen isotope behavior, tritium inventory and removal on deposition layer in LHD, correlation between crystal structure change and tritium retention on mixed-layer of first wall, tritium adsorption properties on helium irradiated tungsten, effects of plasma exposure on tritium behavior of plasma facing materials, tritium retention of co-deposited carbon film and tungsten, and so on. Also, studies on improvement of tritium safe-handling techniques are carried out.

(6) At the IMR-Oarai Center a TDS (Thermal Deposition Spectrometer) with an ion gun and two Q mass (high and standard resolutions) detectors was improved in the vacuum system and mass number identification of elements have been made for completion. The apparatus allows us to obtain thermal desorption spectra against temperature for hydrogen isotopes or helium implanted by the ion gun, thereby enabling assessments of their retention and trapping energy by lattice defects induced by reactor or accelerator irradiation in structural and functional radioactive materials. The first attempt of evaluation of radiation effect on tungsten shows that the present TDS system works well to clarify the effects of neutron irradiation on the behavior of hydrogen isotopes and helium in W materials with various microstructures.

In this year, 106 subjects were adopted in this category, among which were 24 at Tsukuba University, 18 at Kyoto University, 20 at Osaka University, 24 at Kyushu University, 11 at Univ. Toyama, 8 at Tohoku Univ. and 1 at NIFS (Activity on all-Japan ST research program). All of these collaborations have been carried out successfully.

Among these subjects, 19 topics from University of Tsukuba, 12 from Kyoto University, 16 from Osaka University, 18 from Kyushu university, 10 from Univ. Toyama, 6 from Tohoku university and 1 from NIFS are reported here.

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