8. Bilateral Collaboration Research Program

The purpose of the Bilateral Collaboration Research Program (BCRP) is to enforce the activities of nuclear fusion research in the universities by using their middle-size experimental facilities of the specific university research centers as the joint-use facilities for all the university researchers in Japan. The current program involves 6 university research centers, as follows,

- 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 BCRP started in FY2003 with 4 plasma research centers in 4 universities, i.e., Tsukuba, Kyoto, Osaka and Kyushu. The HIRC in University of Toyama and IRCNMS in Tohoku University were incorporated into the BCRP frame work in FY2010 to extend the research field from plasma physics to the fusion engineering because each institute has special facility to promote fusion engineering research of tritium handling and neutron irradiation

In the BCRP, each research center can have its own collaboration programs using its main facility. Researchers in other universities can visit the research center and carry out their own collaboration research there, as if the facility belongs to NIFS, which is the unique and important point, i.e., all these activities are supported financially by NIFS as the research subjects in the BCRP. The BCRP subjects are subscribed from all over Japan every year as one of the three frame works of NIFS Collaboration Program. The collaboration research committee, which is organized under the administrative board of NIFS, examines and selects the subjects.

Features of each device or theme in each university research center, and main results obtained in the BCRP in FY2015 are described as follows;

(1) University of Tsukuba

The GAMMA 10/PDX device has open magnetic field configuration where improvement of the plasma confinement with potential formations in both parallel and perpendicular directions to the magnetic field line has been demonstrated. Changing the plasma parameter widely, divertor simulation experiments in the end-cell region have been performed with strong ICRF and ECH heating. The ITER relevant level heat flux of $\geq$10 MW/m^2 at the end-cell has been obtained. We achieved the highest heat flux of 15 MW/m^2 by superimposing a short pulse of ECH on the ICRF-heated plasma.

Recently, the divertor simulation experimental module (D-module) has been installed on the west end of the device, which has a V-shaped target plate with closed divertor structure. The angle of the V-shaped target plate can be changed, and the pumping speed in the D-module is controllable. Two tungsten plates are mounted on the V-shaped target, which can be heated up to 300 degrees centigrade to investigate interaction between plasma and wall materials. Several kinds of gasses are injected into the D-module to realize the detached plasma operation. In addition to the divertor simulation experiments, development of high power gyrotrons is also main subject of the GAMMA 10/PDX device.

(2) Kyoto University

The main subject, which is assigned to Heliotron J Group for the BCRP is “Study on the confinement optimization and stability control for an advanced helical system”. From FY 2011, two additional subjects are also promoted for strongly linked studies among multi research-centers; (a) “Study of ECH/EBW heating and current drive” and (b) “Study of heat/particle control (edge plasma control)”.

A pre-ionization method with a low-power (<20kW) 2.45 GHz micro wave injection scheme successfully accelerates the sound start-up of NBI plasma at the magnetic field strength from 0.6 T to 1.3 T. The ECE measurement confirmed the production of high energy electrons. Controlling the gas-fueling and NBI timing increases electron density effectively up to 0.5×10^{19} m^{-3} in the pre-ionization phase. Further gas puffing in a later timing easily increases electron density more than1.0×10^{19} m^{-3}.

The fast ion generation and confinement were studied by using ICRF minority heating (H minority and D majority) and NBI heating. The energy range is extended from the injection energy of the NBI of 25 to 60 keV during the ICRF pulse for a medium density operation (1×10^{19} m^{-3}) in the low iota configuration. This configuration is better for the fast ion generation and confinement from the viewpoint of the neo-classical theory than the high bumpiness configuration. The Monte-Carlo calculation also shows that the larger high energy tail in the ion energy distribution is formed in the lower iota configuration.

(3) Osaka University

Recent progress of the fast ignition inertial confinement fusion demonstration is as follows,

Fraction of low energy (< 1 MeV) component of the relativistic electron beam (REB), which efficiently heats the fuel core, increases by the factor of 4 by enhancing pulse contrast of heating laser and removing preformed plasma sources.

Kilo-tesla magnetic field is studied to guide the diverging REB to the fuel core. The transport simulation of the REB accelerated by the heating laser in the externally applied and compressed magnetic field indicates that the REB can be guided efficiently to the fuel core. The integrated simulation shows > 4% of the heating efficiency, and > 4 keV of ion temperature, which can be achieved by using the GEKKO-XII and the LFEX lasers, together with the properly designed cone-fuel and the external magnetic field.

(4) Kyushu University

The QUEST project focuses on the steady state operation of spherical tokamak (ST), taking power and particle balance with wall behavior into consideration. QUEST takes advantage of maintaining the plasmas for a long time.

In FY2015, the hot wall operating at 473 K was available. During the experimental campaign, discharges for 1000 s could be obtained by 8.2 GHz RF with and without additional hydrogen gas puffing. Since water-cooling channel have not been installed yet, we could only heat the wall up. The 28 GHz gyrotron was set up and could be operated up to 140 kW, 2 sec. Finally, plasma current of more than 30 kA could be achieved in fully non-inductive current drive manner. New transmission system with several mirrors have been available, which has capability of controlling injection angle, mode and polarization.

It was found that the hot wall may have the capability to control hydrogen recycling during 2015 experimental campaigns. The gyrotron and transmission line, which were newly installed in 2015, were available, and could be operated well.

(5) University of Toyama

In FY2015, penetration of hydrogen isotopes from the environment into reduced activation ferritic/martensitic steel F82H was examined. The specimens used were plates of F82H irradiated with 20 MeV W ions to 0.54 dpa at the damage peak situated at a depth of ~2 μm from the surface. In the first experiment, the irradiated F82H specimen was exposed to D_2O vapor at room temperature for 1 year. In the second experiment, the irradiated F82H specimen was exposed to D_2 gas at 0.1 MPa and 473 K for 5 h. Retention of hydrogen isotopes was measured using thermal desorption spectroscopy (TDS) for several months after the D_2 gas exposure. It was observed that the concentration of D in the specimen was much higher than the detection limit, and D was concentrated in the near-surface region damaged with W ions. It is therefore clear that D penetrated into the F82H steel specimen via the reaction $x D_2O + Fe \rightarrow FeO_x + 2D$ and got trapped at radiation induced defects. These observations indicated that, if steel specimens are kept in air, H penetrate into the samples via oxidation with H_2O vapor in air. Although no H was intentionally introduced into the specimen, the amount of desorbed H was much larger than that of D. In addition, the desorption peaks of H_2, HD and D_2 appeared at the same temperature. These results suggested that H from air via the above-mentioned reaction and/or that present in the specimen as an impurity occupied the defects together with D.

(6) Tohoku University

This project aims to develop experimental apparatus and systems to investigate plasma-materials interaction (PMI) of fusion materials, as the fundamental project for all the other nine projects in the collaborative studies of NIFS and International Research Center for Nuclear Materials Science, Tohoku University. (IMR-Oarai).

In 2015, the compact diverter plasma simulator, C-DPS, was installed to the IG-TDS apparatus in the framework of collaboration with LHD project (leader: prof. Ohno, Nagoya University). This combination enables us to perform TDS analysis after plasma irradiation without exposure to the air. This system, C-DPS/IG-TDS located in radio-isotope controlled area, is a unique system in the world, which can analyze radio-active specimen. C- DPS/IG-TDS is expected to provide valuable information for plasma-materials interaction, especially for neutron- irradiated specimen.

In this year, 115 subjects were adopted in this category, among which were 26 at University of Tsukuba, 22 at Kyoto University, 23 at Osaka University, 21 at Kyushu University, 13 at University of Toyama, and 10 at Tohoku University. All of these collaborations have been carried out successfully.

Among these subjects, 25 topics from Tsukuba, 21 from Kyoto, 22 from Osaka, 18 from Kyushu, 11 from Toyama, and 9 from Tohoku are reported.

(Morisaki, T.)