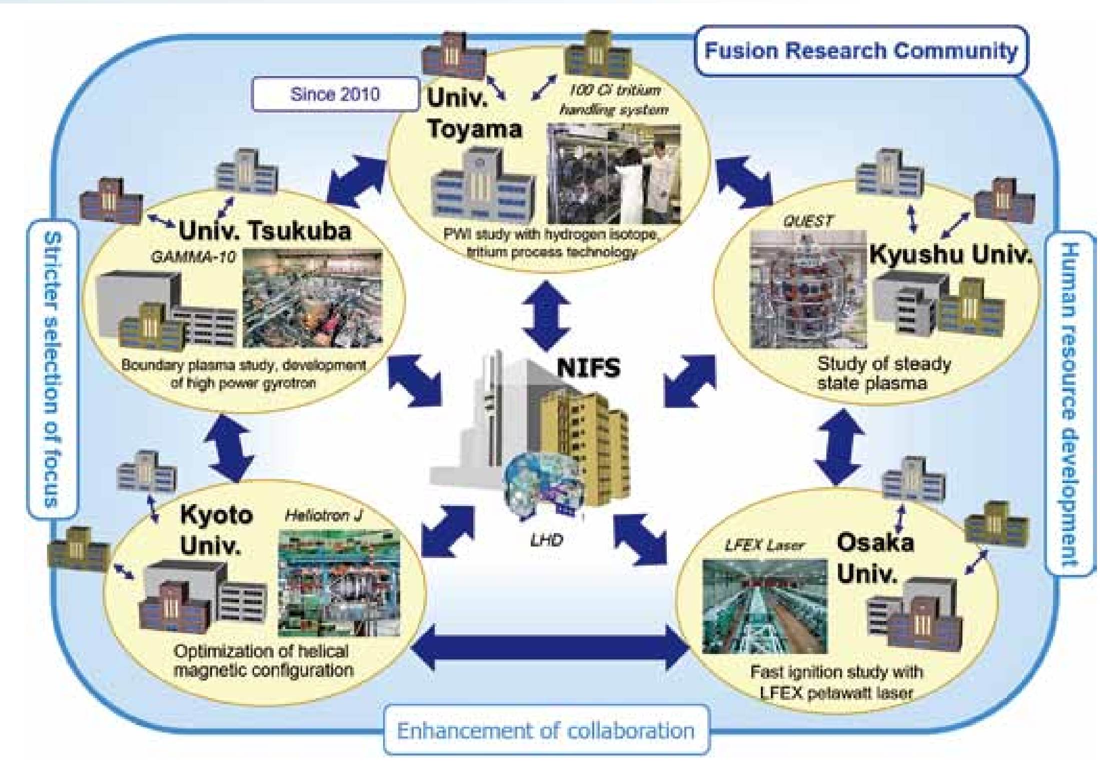
8. Bilateral Collaboration Research Program

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 university researchers in Japan. The current program involves 5 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, University of Toyama

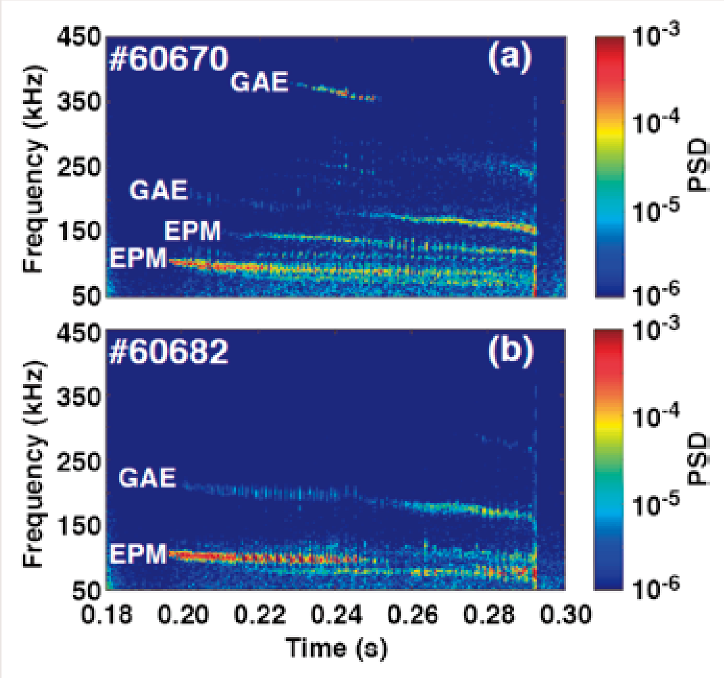
In BCRP, each research center can have its own collaboration programs using its main facility. Researchers at other universities can visit the research center and carry out their own collaboration research there, as if the facility belongs to NIFS. That is, all these activities are supported financially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

(T. Morisaki)



Schematic of the Bilateral Collaboration Research Program

Kyoto University



Suppression of MHD instabilities by ECCD in Heliotron J: (a) without ECCD and (b) with ECCD

Highlight

Suppression of MHD instabilities by ECCD in Heliotron J

Fast-ion-driven MHD instabilities are suppressed by using ECCD in Heliotron J for an NBI+ECH plasma. The upper figure shows global Alfvén eigenmode (GAE) and energetic particle mode (EPM) for no ECCD case. By applying ECCD (0.6 kA), the GAE is strongly suppressed as shown in the lower figure.

Study of suppression of fast-ion-driven MHD instabilities by ECH/ECCD [1]:

ECH and ECCD are utilized to control MHD instabilities in toroidal plasma confinement devices. In Heliotron J having almost zero magnetic shear in a whole plasma region in vacuum, both negative and positive magnetic shear induced by co- and counter- EC-driven plasma current suppress the observed fast-ion-driven MHD instabilities such as EPMs shown in Fig. 1(a) and (b), and GAEs. Regarding the ECCD effect on fast-ion-driven MHD instabilities, continuum damping whose rate is related to magnetic shear regardless of its sign is a key physical mechanism to suppress the observed fast-ion-driven MHD instabilities.

We also observed the ECH effect on fast-ion-driven MHD instabilities in Heliotron J. Some fast-ion-driven MHD instabilities are stabilized and the others are destabilized by ECH depending on ECH power, deposition location and magnetic configuration in Heliotron J. The GAE amplitude decreases with increasing ECH power for on-axis ECH (Fig. 1(c)). When ECH deposition is close to the GAE location r/a ~ 0.6, the GAE amplitude is larger than that for on-axis ECH (Fig. 1(d)). These dependences indicate that both the change of fast ion profile by ECH through the change of electron density and temperature, and/or the collisional damping due to trapped fast electrons may affect the Alfvén eigenmode stability.

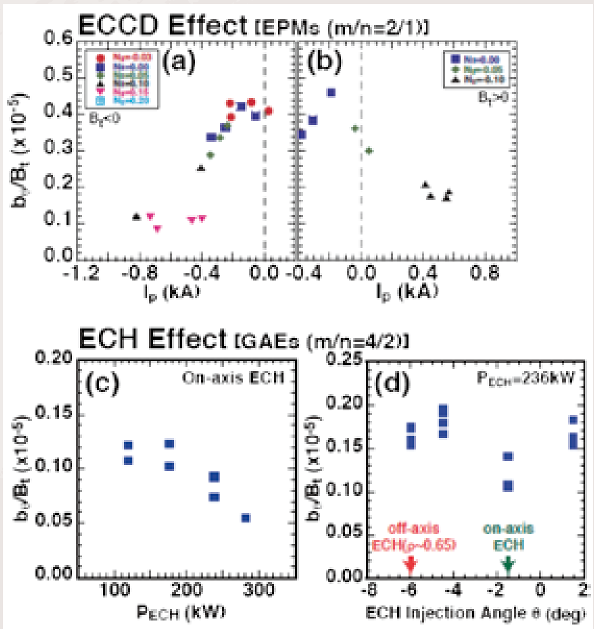


Fig. 1 (a) and (b): Dependence of EPM on EC-driven plasma current. Dependence of GAE on (c) ECH power and (d) ECH deposition location in Heliotron J.

Research Topics from Bilateral Collaboration Program in Heliotron J

The common objectives of the researches in Heliotron J under this Bilateral Collaboration Program are to investigate experimentally/theoretically the transport and stability of fusion plasma in advanced helical-field, and to improve the plasma performance through advanced helical-field control. Picked up in FY2017 are the following seven key topics; (1) experimental observation of rational-surface effect on e-ITB formation, (2) relationship of density fluctuation to H-mode transition in high density plasmas, (3) comprehensive study of fast ion behavior in ICRF+NBI heating, (4) long-range correlation and hydrogen-isotope effect in edge turbulence, (5) suppression of fast-ion-driven MHD instabilities using ECH/ECCD, (6) measurement of fast-ion loss accompanied with MHD fluctuations and (7) development of ice-pellet injector for steady and stable operation.

Poloidal flow measurement using charge-exchange recombination spectroscopy (CXRS) [2]: The radial electric field in helical devices is a key parameter for the transport in the low collisional region. The improvement of poloidal-flow velocity measurement by CXRS for the estimation of radial electric field is necessary although the parallel-flow velocity has been measured successfully in Heliotron J. The main issue is to determine the wave length of the measured spectrum and the stability of the calibration of the absolute wave length. A new spectrometer and a new CCD camera are installed to get stronger signals. Using the new camera, the signal becomes four times as large as the previous one. The wave-length calibration is also changed to use the line spectrum of Sm ramp. The resultant error of wave length is reduced from 2.8×10^{-3} nm to 9.1×10^{-4} nm, corresponding to 1.7 km/s and 0.51 km/s in velocity, respectively. The poloidal velocity is now measurable within this error, which is considered to be sufficient for the determination of poloidal velocity. A result from the CXRS measurement is shown in Fig. 2, where the poloidal flow is in the electron diamagnetic direction in an NBI plasma and the ion diamagnetic flow is observed in the central region for additional ECH injection.

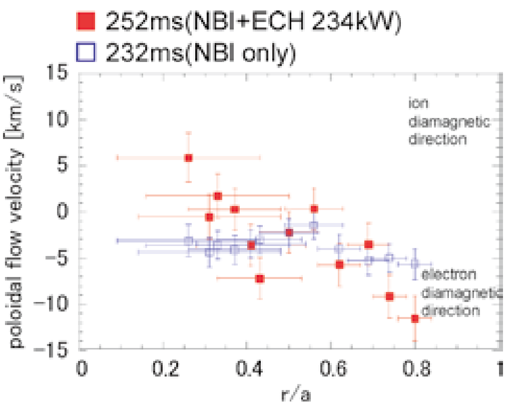


Fig. 2 Poloidal flow velocity profile for NBI+ECH and NBI only plasmas. Balanced injection is made using two opposite tangential beam lines for NBI heating.

Interaction of fast ions and MHD instabilities [3]: The confinement of alpha particles generated in fusion reactions, is important since alpha particles are utilized as heat source. MHD instabilities sometimes affect fast-ion confinement via resonant or non-resonant interactions. In Heliotron J, fast-ion-driven MHD instabilities, such as GAE and EPM, are observed. A lost-ion probe of Faraday-cup type has been used for the measurement of fast-ion confinement, however, the high noise level prevents from the correct calibration of the detector. For the reduction of noise, a scintillator type detector is introduced. The fluorescent light on the scintillator are divided into two, then they are detected by PMTs and CCD camera. For the fluctuation measurement, 9-channel PMT signals are used, of which frequency response is up to 200 kHz. The EPMs are observed in a counter-NBI plasma with this detector in Heliotron J. The observation grid map on the scintillator surface for energy and pitch angle is illustrated in Fig. 3. The energy range is indicated by proton Larmor radius. In Fig. 4, (a) magnetic fluctuation, (b) SLIP (PMT) signal in ch. 5, (c) line-averaged electron density, (d) heating timing are shown. The EPMs are observed in (a) and (b).

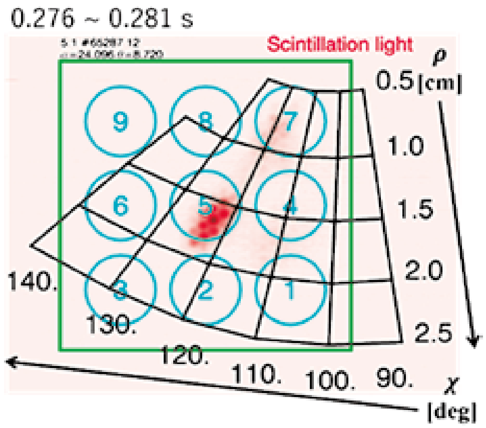


Fig. 3 The observation grid map on the scintillator surface for energy and pitch angle. Blue circles indicate the observation area of each PMT channel. The red part indicate CCD scintillating area observed by a CCD camera.

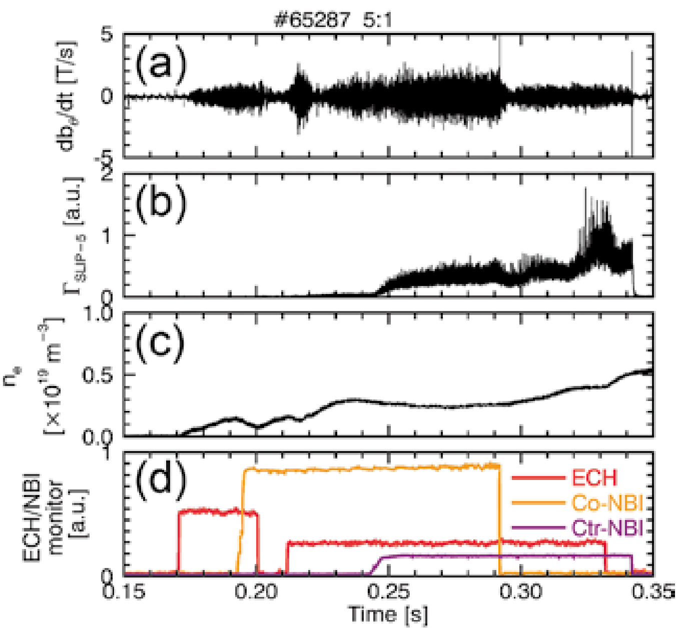


Fig. 4 Time traces of fluctuations, density, and heating timing for the combination heating of NBI and EC heating. (a) Mirnov coil signal, (b) SLIP (PMT) signal of channel 5, (c) line-averaged electron density, and (d) timing chart of heating devices.

[1] S. Yamamoto, *et al.*, "Suppression of fast-ion-driven MHD instabilities by ECH/ECCD on Heliotron J", Nucl. Fusion **57** (2017) 126065.

[2] S. Tanohira, *et al.*, "Poloidal Flow Measurement with Charge-Exchange Recombination Spectroscopy in Heliotron J (2)", Plasma Conf. 2017 (20-24 Nov. 2017, Himeji), 23P-12.

[3] S. Yamamoto, *et al.*, "Study of interplay between fast-ions and MHD instabilities in Heliotron J", Plasma Conf. 2017 (20-24 Nov. 2017, Himeji), 22Cp-05.

(K. Nagasaki)

8. Bilateral Collaboration Research Program

University of Tsukuba

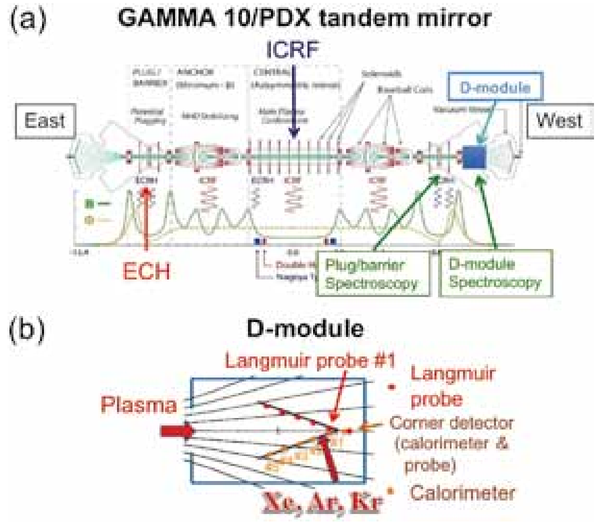


Fig. 1 Schematic view of GAMMA 10/PDX (a) and D-module (b).

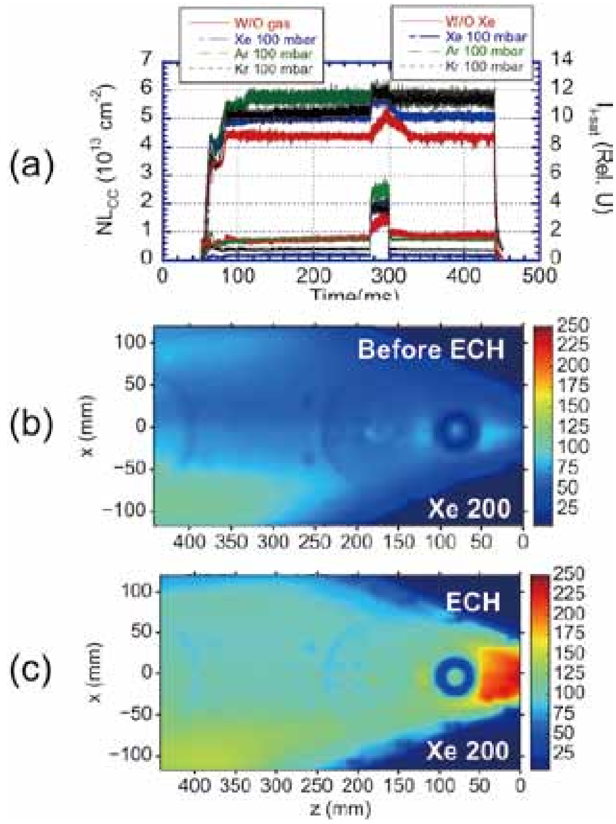


Fig. 2 Results of detached to attached transition experiments: Time evolution of line-density in the upstream plasma (central-cell) and ion flux measured at the corner of the V-shaped target in the D-module (a). Two-dimensional visible image in front of the V-shaped target before ECH (b) and during ECH (c).

Highlight

Study of boundary plasmas by making use of open magnetic field configuration and development in high power gyrotrons towards the DEMO project

Divertor simulation experiments in the large tandem mirror device (GAMMA 10/PDX) have been extensively performed using plasma flow with high ion energy. By using divertor simulation experimental module (D-module) installed at the east end-mirror exit of GAMMA 10/PDX, characterization of detached plasmas was performed. In the gas injection experiments for detached plasma formation, additional heating pulses of ECH were applied in the upstream region and the effect of plasma heating on the detached plasma was investigated. It was found that ion flux and heat flux were abruptly increased during ECH and the detached to attached transition phenomena were clearly observed. Puff and pump experiments were also successfully performed in the D-module and the effect of the exit door of the module was precisely evaluated.

A test of a new 28/35 GHz dual-frequency gyrotron (2 MW for 3 s and 0.4 MW CW) was carried out and the cooling characteristics of a double-disk sapphire window were evaluated. It was confirmed that the operation of 0.4MW with CW at 28 GHz is possible at with a coolant flow rate of more than 30 L/min. For the development of diagnostics, we developed the new multi-pass Thomson scattering (MPTS) system with the laser amplification system to increase the pass number of the MPTS signals. The laser amplification system can improve the degraded laser power after six passed in the multi-pass system to the initial laser power.

In the Plasma Research Center, University of Tsukuba, studies on boundary plasmas by making best use of the large tandem mirror GAMMA 10/PDX have been performed together with the development of high-power gyrotrons under the bilateral collaboration research program. Since FY2010 the number of the research subjects of the program in PRC continues to increase and in FY2017 a total of 31 subjects were accepted including the base subject. Figure 1(a) shows the schematic view of GAMMA 10/PDX which has open magnetic field configuration. By using the high heat plasma flow produced with high-power ICRF and ECH systems, divertor-simulation experiments have been performed at the end-cell region.

In ICRF heating studies, initial experiments were performed to reveal the excitation efficiency of a slow Alfvén wave in a high-density regime, and to develop a novel heating method applicable to a high-density regime. The target high-density plasma, the maximum of ~1×10^{19} m^{-3}, was produced by ECH in the central-cell. Under the standard slow wave heating, the axial variation of the phase fluctuation intensities of the 6.36 MHz slow wave was measured by a microwave reflectometer with fast antenna switching capability.

A number of divertor simulation experiments were performed using the divertor simulation experimental module (D-module) installed on the west end as shown in Fig. 1 (b). This module consists of a rectangle box made of stainless steel and V-shaped tungsten target plates in closed divertor structure. Hydrogen and several kinds of radiator gasses (N_2, Ne, Ar, Kr, and Xe) are injected into D-module. In the gas injection experiments for detached plasma formation, additional heating pulses (ECH 150 kW) were applied in the east plug/barrier-cell and the effect of plasma heating on the detached plasma was investigated. It was found that the ion flux and heat flux were abruptly increased during ECH and the detached to attached transition phenomena were clearly observed. In order to evaluate the effect of leakage of neutral gas on plasma detachment, we conducted an experiment of gas puff and pump. Hydrogen gas was supplied to the divertor simulation plasma when the exhaust door, which was attached on the backside of the D-module, was closed and opened. In both cases, the electron temperature near the corner of the V-shaped target is observed to be from ~20 eV to ~2 eV. The electron density near the corner first increased and then decreased, indicating a rollover. After the rollover, the decrease in the electron density with the door open was smaller than that with the door closed. When the electron temperature was ~2 eV, the vibrational and rotational temperature of hydrogen molecule with the door open were almost the same as those with the door closed. The total neutral pressure in the D-module was about one-third of that with the door closed, suggesting hydrogen molecule density near the target was smaller than that with the door closed.

In addition to the divertor simulation experiments, the development of high power gyrotrons has also progressed. In FY2017, the cooling characteristics of a double-disk sapphire window were evaluated in an experimental test of the new 28/35 GHz dual-frequency gyrotron (2 MW for 3 s and 0.4 MW CW) for QUEST, NSTX-U, Heliotron J, and GAMMA 10/PDX. Temperature evolution at the center of the output window was measured by an infrared (IR) camera during and after the oscillation of 2 s for 0.45 MW and the heat transfer coefficient versus the flow rate of the double disk window coolant was estimated. The calculated window temperature is saturated to about 80 °C with an output power of 0.4 MW and a heat transfer coefficient of 0.15 W/cm^2K. It was confirmed that the operation of 0.4MW with CW at 28 GHz is possible at a coolant flow rate of more than 30 L/min. A long pulse operation test was conducted up to 2.8 s with 0.46 MW. Detailed designs of a 14 GHz 1 MW gyrotron have been started for actual fabrication.

The optical collection system for Thomson scattering (TS) light consists of three spherical mirrors and nine bundled optical fibers. The measurable radial positions of TS system are normally 5 cm intervals in the region of ±20 cm. By using the lab jack system, we can change the bundled optical fibers position, which enable to measure radial profiles of electron temperature and density in more detail. We developed the new multi-pass Thomson scattering (MPTS) system with the laser amplification system to increase the pass number of the MPTS signals. The laser amplification system can improve the degraded laser power with six-times-passed in the multi-pass system to the initial laser power. We successfully obtained the continued multi-pass signals after the laser amplification system in the gas scattering experiments.

(Y. Nakashima)

8. Bilateral Collaboration Research Program

University of Toyama

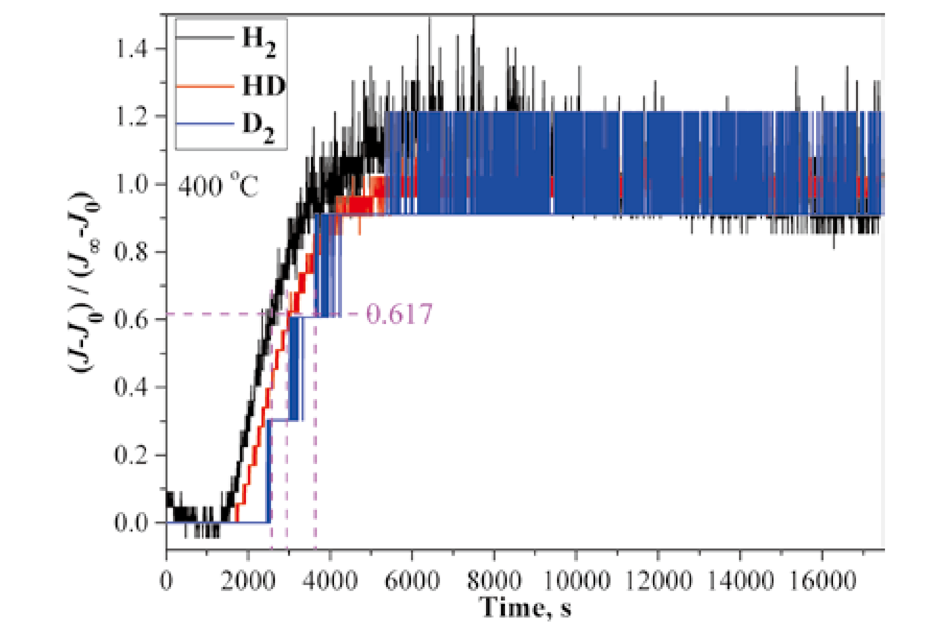


Fig. Permeation curves of H_2, HD and D_2 under exposure to H_2-D_2 mixture gas, showing faster diffusion of H than D.

Highlight

CuCrZr alloy and oxide dispersion strengthened Cu alloy are candidates of heat sink materials of fusion reactors. Evaluation of tritium permeation to coolant through these alloys is important for assessment of safety and tritium self-sustenance. From these viewpoints, permeability, diffusivity and solubility of hydrogen and deuterium were examined by permeation tests using H_2, D_2, and H_2-D_2 mixture gases. Clear isotope effects were observed on permeability and diffusivity; the values obtained for hydrogen were larger than those for deuterium by a factor of $\sqrt{2}$. Namely, the difference between H and D corresponded to ratio of square root of mass.

The titles and principal investigators of research projects performed in U. Toyama in 2017 are listed below.

(1) Isotope effects on trapping and release of hydrogen isotopes in fusion reactor materials (Y. Hatano, U. Toyama)
(2) Hydrogen isotope transport through plasma modified fusion reactor materials (H. T. Lee, Osaka U.)
(3) Hydrogen isotope behavior for W with controlled damage profile (Y. Oya, Shizuoka U.)
(4) Tritium removal from tungsten by isotope exchange (Y. Nobuta, Hokkaido U.)
(5) Tritium removal on deposited layers by glow discharge cleanings (N. Ashikawa, NIFS.)
(6) Evaluation of diffusion, retention and desorption of hydrogen isotopes implanted (N. Yoshida, Kyushu U.)
(7) Tritium retention on facing materials modified by plasma wall interactions (K. Tokunaga, Kyushu U.)
(8) Helium and deuterium retention behavior in simultaneous implanted tungsten (Q. Zhou)
(9) A study of synthesis of high-concentration tritium water (Y. Arikawa, Osaka U.)
(10) Evaluation of the refractive index of solid DT fuel for inertial confinement fusion targets (K. Yamanoi, Osaka U.)
(11) Evaluation of hydrogen isotope retention and release of SiC/SiC composite for fusion reactor (H. Kishimoto, Muroran Inst. Technol.)
(12) Double-strand breaks in a genome-sized DNA caused by β-ray using fluorescence microscopy (T. Kenmotsu, Doshisha U.)

For the evaluation of hydrogen isotope transport and retention in plasma-facing components, tritium penetration profiles in W samples with various microstructures were investigated at 300 and 573 K. The samples were pre-implanted by 1 keV D ion irradiation and then loaded with T from the gas phase. Samples were sectioned by etching and the radioactivity of the residual T was measured by imaging plate technique. Penetration distance was calculated from sample mass loss measurements following successive etching steps. The penetration profiles can be fitted well with an error function - indicating the inward transport of T is diffusion limited. Very little dependence on W microstructure was observed. Comparing the values at 300 and 573 K, an activation energy of ~0.2 eV was estimated, which is lower than the range of reported activation energy for diffusion of solute hydrogen in W (0.2~0.4 eV). This suggests that T transport by D-T exchange is governed by a characteristic rate constant that is very weakly dependent on temperature.

Tungsten specimens with various depth profiles of radiation-induced defects were prepared and deuterium retention was studied. The total D retentions in the specimen decreased with increasing concentration of damages induced near the surface region.

To develop efficient tritium removal technique from plasma-facing components, tritium release from polycrystalline tungsten in D_2 gas atmosphere was examined at elevated temperatures. Clear enhancement of tritium release was observed under the presence of D.

Tritium removal from deposited carbon and tungsten layers by glow discharge cleaning technique was also investigated. Comparable tritium removal efficiency was observed for H and He glow discharges in the case of W, though H discharge was far more effective in the case of carbon.

A model to evaluate transportation of tritium, radiation-induced defects, and heat in solid materials was developed. The concentration of radiation-induced defects under heavy ion implantation was successfully estimated by considering annihilation, diffusion, accumulation, and recombination.

A new laser fusion target using a 200-μm diameter CH capsule filled with 0.1-1% tritium containing deuterium oxide water liquid was designed. Tritium is used as a tracer material to measure the fusion plasma ion temperature diagnostics.

To examine performances of SiC as a constituent material of plasma-facing components and tritium breeding blankets, specimens of three types of SiC/SiC composites were prepared: monolithic SiC plates of α-SiC and β-SiC and a NITE SiC/SiC composite plate consisted of β-SiC. Retention of hydrogen isotopes including tritium will be examined.

Quantitative evaluation on the double-strand breaks of genome-sized giant DNA (T4 DNA; 166 kbp) caused by photon irradiation was performed at difference concentrations of PEG, Polyethylene Glycol, to compare with the effects of tritium β-ray irradiation. It has become clear that PEG decreases the probability of double-strand breaks.

(Y. Hatano)

8. Bilateral Collaboration Research Program

Osaka University

Fast Ignition of Super High-Dense Plasmas

Laser-driven inertial confinement fusion by the Fast Ignition (FI) scheme has been intensively studied as the FIREX-1 project at the Institute of Laser Engineering, Osaka University. The researches consist of target fabrication, laser development, fundamental and integrated implosion experiments, simulation technology and reactor target design, and reactor technology development. In FY2017, following progress was made through Bilateral Collaboration Research Program with NIFS and other collaborators from universities and institutes (2016NIFS12KUGK057 as the base project and 18 other individual programs).

Fundamental and Integrated Plasma Experiments

In FY 2016, heating experiment of Cu-doped target was performed and the temperature of the heated plasma was found to be as high as 1.7 keV by x-ray spectroscopy. However, the ion temperature measurement by neutron time-of flight method was not performed. Recently, a new scheme to produce a target in which Cu-doped D_2O fuel liquid is filled has been developed. Both Cu for x-ray spectroscopic measurement and D for neutron measurement were simultaneously contained in a capsule. Electron temperature of the heated plasma was measured to be about 1.2 keV from the Cu x-ray spectrum. The neutron signal was obtained at the same time, and the ion temperature was estimated to be 1-1.5 keV from the total neutron yield. These results indicate that the ions were heated by thermal relaxation from the electrons. The heating efficiency from the heating laser energy to the fuel thermal energy was estimated to be about 5%.

High-density implosion of solid sphere target by using a tailored laser pulse has been proposed as a high-performance FI scheme. An experimental program has been started by introducing an arbitrary pulse-shape modulator after a fiber oscillator. Required pulse contrast of the foot pulse to the main pulse is 1:300. Achieved main beam energy balance was as good as 6%. In FY 2018, more precise control of both the pulse shape and the energy balance will be established.

Theory and Simulation, Target Design

Integrated simulations for implosion and fast-heating experiments with applied magnetic field for collimation of the electron flow have been performed by using the integrated simulation code, "FI^3." Calculated ion temperature and the heating efficiency were 1.7 keV and 6%, respectively, which are in good agreement with the experimental results. For further improvement of the heated plasma performance, target design activities have been continued taking into account of laser pulse tailoring, cone geometry, and control of electron flow with laser-plasma interaction and applied magnetic field.

Target Fabrication and Reactor Technology

Solid sphere target with doped Cu as tracer atoms for x-ray spectroscopic diagnostics was developed. Solid spheres made of Cupper Oleate ($Cu(C_{18}H_{33}O_2)_2$) were successfully produced with recently developed micro-fluid device. The target has a diameter of 200 microns, sphericity of better than 97%, and 10wt% of Cu content, which all meet the requirements for experiments. Cu x-ray spectrum emitted from the imploded core plasma gives detailed information on spatial distribution of the fast electrons generated by irradiation of the heating laser beams

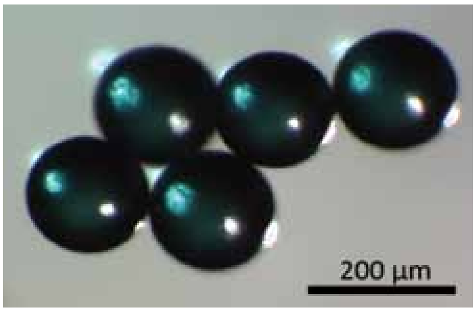


Fig. 1 Solid sphere target made of Cupper Oleate (Cu(C18H33O2)2).

as well as the core plasma temperature and heating efficiency.

Preparation for target injection experiment has been made in FY2017. A tracking system of the injected target that has been developed in Ibaraki University was installed in the target injection system. The position of the injected target can be accurately monitored by using Arago's spot technique with probing laser beams. The shape of the dummy targets for this injection experiment will be improved in FY2018 in order to generate a brighter Arago's spot.

Operation and improvement of LFEX Laser system

LFEX laser (Fig. 2, left) for plasma heating in fast ignition experiments was operated stably in FY2017. Four beams of LFEX delivered a total output energy of 2 kJ in a 1-ps pulse. Spatial uniformity of the amplifier gain was improved by installing trigger meshes around the flash lamps in the amplifier case to straighten the discharge path. This also contributes to long-life operation of the flash lamps.

Fig. 2 View of amplifier chains of LFEX and GEKKO-XII lasers.

Individual Collaborations

In parallel to the main project described above, 18 other collaborations by individual researchers including two from abroad have been performed. Those were on electron-driven fast ignition (8 collaborations), ion-driven fast ignition (4), alternative scheme of laser-driven inertial fusion (1), diagnostics of high-temperature and high-density plasmas (3), and reactor technology (2). Nine collaborations were ones continued from the previous year(s) and 9 were newly accepted in FY2017.

(R. Kodama)

8. Bilateral Collaboration Research Program

Kyushu University

Research activities on QUEST in FY2017.

We will summarize the activities on advanced fusion research center, research institute for applied mechanics in Kyushu University during April 2016-March 2017. The QUEST experiments were executed during 12th May-5th Aug. (2017 Spring/Summer; shotno 34700-35819) and 30th Nov.-9th Mar. (2017 Autumn/Winter; shotno 35820-36662). Main topics of the QUEST experiments in FY2017 are listed below.

1) The highest plasma current discharge of 85kA in non-inductive current drive was obtained by 28 GHz microwave injection which developed with Tsukuba University (Gyrotron) and NIFS (polarizer) (shotno 35682). The plasma current was tentatively obtained.
2) The polarized and focused microwave of 28GHz was injected and high density plasmas up to 8×10^{18} m^{-3} measured with Thomson scattering system which has been developed by the University of Tokyo. The density is close to plasma cutoff of 28GHz (9.7×10^{18} m^{-3}). The plasma will be good for a target of electron Bernstein wave heating/current drive.
3) A Thomson scattering system was used to measure electron temperature and density profiles for various discharges. Typical parameters are about 5 eV and about 3.0×10^{18} m^{-3} for a discharge sustained by the ECH with a frequency of 28 GHz, and about 1 eV and about 8.0×10^{18} m^{-3} for a CHI discharge. Note that the CHI plasma stayed at the lower region of the vacuum vessel, and these values seem to represent the edge parameters.
4) In the fiscal year of 2017, several important facilities have been transported from the National Institute for Fusion Science for the sake of off-line evaluation of the possible implementation of the liquid metal divertor concept in QUEST. These include the following: 1. a liquid metal circulation loop driven by an electric magnetic pump; 2. a TDS (thermal desorption spectrometry) facility for the evaluation of hydrogen isotopes uptake by liquid metals. It is expected that these facilities will be in operation in the fiscal year of 2018.
5) New design of permeation probe system has been proposed in order to evaluate membrane contamination due to impurity deposition that can affect calibration factor of the probe. Installation of the system is under preparation for the next QUEST experiments.
6) To examine the drift compensation of the in-vessl Mirnov type sensors by using ex-vessel hall sensors and the reconstruction of magnetic surface with both sensors, the installing hall sensors addition to exist eight sensors and providing relevant data acquisition system have been launched.
7) For successful operation of CHI in QUEST, the poloidal coil operation scenario of NSTX have been analyzed numerically on shot number #118346, which shows the successful CHI plasma current start-up. Tracing of 3D magnetic field line shows that careful choice of the PF coil current is important and the lower diverter coil should be reduced during the CHI operation in QUEST.
8) Grad-Shafranov equation with anisotropic pressure profile was investigated by COMSOL starting from a Solov'ev analytical solution and the current density profile tends to shift outward qualitatively.
9) The W samples were installed in the plasma facing wallsQUEST and exposed more than 4000 shots of hydrogen plasma in each 2015AW, 2016SS and 2016AW campaign. After plasma operation, the additional D2+ implantation and thereafter TDS experiment were performed. Major D desorption temperature for 2015AW Top sample was found at 400 K, but that for 2016SS and 2016AW Top sample was located at around 600 K, indicating that D trapping by vacancies would be the major trapping states.
10) A visible spectroscopy system installed at MH16 port was upgraded to observe the entire radial distribution in the midplane and vertical distribution in the poloidal section. A 28 GHz discharge (#35788) was measured and the distributions of the ion emissivity, temperature, and velocity were obtained.
11) In a tokamak plasma of ~40 kA produced by 28 GHz microwaves, about 20 % of total current extracted from the upper divertor plates by divertor biasing reached the grounded lower divertor plate. The ratio of electron saturation current to the ion one in the biased plate was about 7 to 13, of which ratio is about 1/4 of the square root of proton to electron mass ratio.
12) TDS measurements after post-irradiation with deuterium ions for the samples exposed to the QUEST plasma revealed that a large amount of hydrogen isotope was trapped by the carbon-dominated mixed-material layer. In addition, the reduction of the carbon concentration in the deposition layer suppressed a large D desorption.
13) New in-vessel 3-rod antenna for ion cyclotron emission measurement in QUEST has been designed.
    Heat resistant property of the antenna is improved compared to the previous design by using Zirconium copper as material of rods.
14) Samples of vacuum plasma spray (VPS) and atmospheric plasma spray (APS) tungsten were exposed to plasma in QUEST

in 2016 autumn-winter experimental campaign. Thermal desorption measurements showed the hydrogen retention in APS-W was smaller than that in VPS-W by an order of magnitude.

15) A low energy ion source (10 kev) for QUEST NBI was studied with beam trajectory simulations [1]. Low divergence angle of around 0.5 degree was obtained at 100 mA/cm^2 H+ beam current density with optimization of extraction aperture diameter and gap length between grids. It will enable generation of 20 A, 200 kW ion beams with multi-aperture grid extraction area of 200 cm^2. NBI power above 100 kW will be possible supposing beam transport efficiency of 80 % and neutralization of 85 %.
16) The central control system and peripheral sub-control systems are modified by using recent advance in technology actively topromote experiments effectively. Especially, in 2017, the pumping control system of main vacuum vessel is modified. The information such as vacuum gages is shared between sub-systems by Ethernet and the user interfaces are provided not in hardware but in software.
17) High-performance date replication tests have been carried out between the LHD data repository (Toki) and the ITER remote experimentation center (REC, Rokkasho): (i) Shot-by-shot 30 GB data replication synchronously on LHD sequence, and (ii) bulk replication of the whole 430 TB repository. Both were successfully achieved with (i) 6 Gbps and (ii) 4 Gbps speeds, which have revealed that not only the networking technology but also the storage optimization should be mandatory for exchanging big data.
18) The equilibrium and flow reversal of the simple magnetized plasma are examined with respect to the pitch angle of the applied vertical filed. The peak of the density decay time at a certain pitch angle is experimentally found and is modeled by the global equilibrium equations (EXB drift and parallel flow).
19) The CT drift tube in between the CT injector and QUEST was newly designed and made to avert the deterioration of CT plasma parameters. The CT guiding tube made of oxygen-free high-conductivity copper, is installed inside the 316 SS drift tube for conservation of CT magnetic flux. The new drift tube would lead to improve CT fueling efficiency.
20) Last year, the magnetic fluctuation signals were able to acquire by installing magnetic probes with outer diameter 22φ, 500 turn.
    This year the modified hybrid probe (including triple probes) will be installed.
21) Temperature dependence of tritium retention behavior in stainless steel type 316L under irradiation of tritium ions has been examined using β-ray induced X-ray spectrometry. The amount of surface tritium decreased with temperature rise, while it contrarily increased above 523 K, indicating that tritium retention strongly depends on material temperature as well as ion energy.
22) Electron cyclotron non-inductive plasma start-up of an 80 kA level has been achieved with a polarized 28 GHz focusing beam. The obtained electron density was one order of magnitude higher, compared to the previous experiments with no polarized focusing-beam. The electron temperature decreased with the increasing density beyond the cutoff, then the hard X-ray (HX) count started to increase. The HXs with 60 keV energy range were measured at the forward tangential viewing resonant radius for current- carrying electrons.
23) By modifying capacitor bank power supply to allow the injector current to be reduced to zero more rapidly, and by using the upper center stack coil to pull the evolving CHI plasma closer to the center stack, transient Coaxial Helicity Injection (CHI) plasma evolved into a configuration that is more favorable for the formation of closed flux surfaces. Under these conditions, 46kA of toroidal current was generated. This also resulted in the first observation of some toroidal current persistence after the injector current was decreased to zero. This is a significant improvement for transient CHI on QUEST.

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