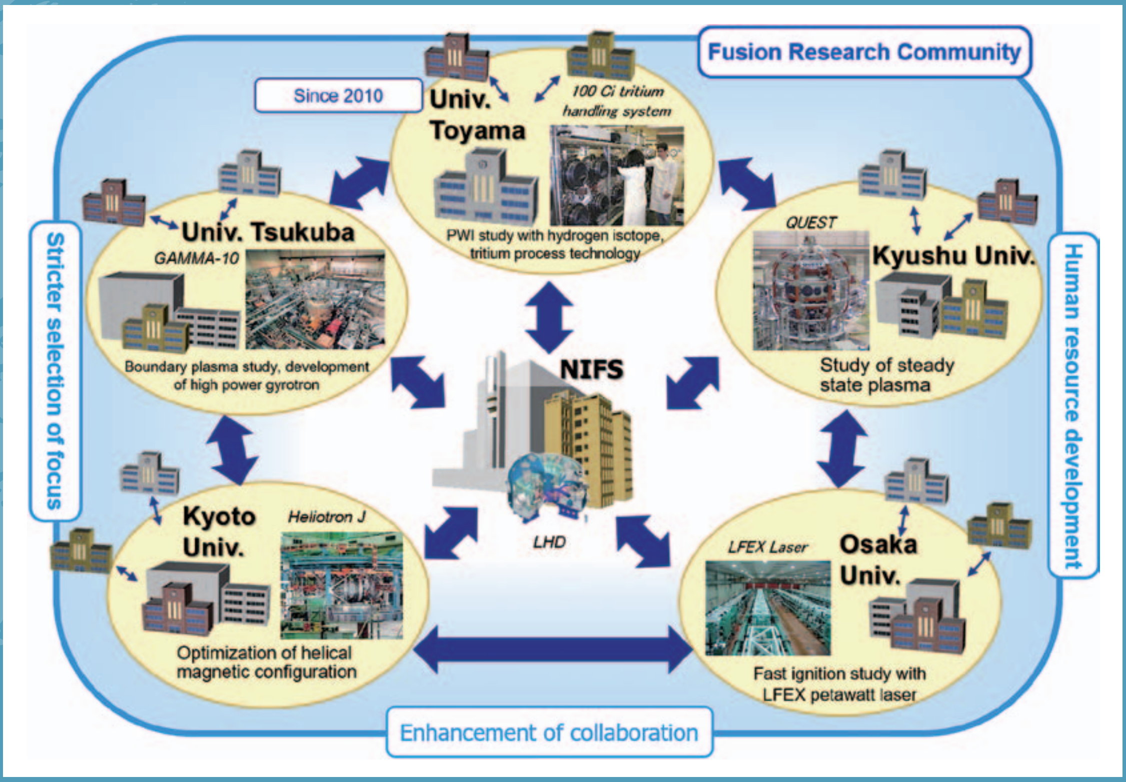
7. Bilateral Collaboration Research Program

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)


Fusion Research Community
Since 2010
Univ. Toyama
100 Ci tritium handling system
PWI study with hydrogen isotope, tritium process technology
Univ. Tsukuba
GAMMA-10
Boundary plasma study, development of high power gyrotron
QUEST
Kyushu Univ.
Study of steady state plasma
NIFS
LHD
Kyoto Univ.
Heliotron J
Optimization of helical magnetic configuration
LFEX Laser
Osaka Univ.
Fast ignition study with LFEX petawatt laser
Stricter selection of focus
Human resource development
Enhancement of collaboration

University of Tsukuba

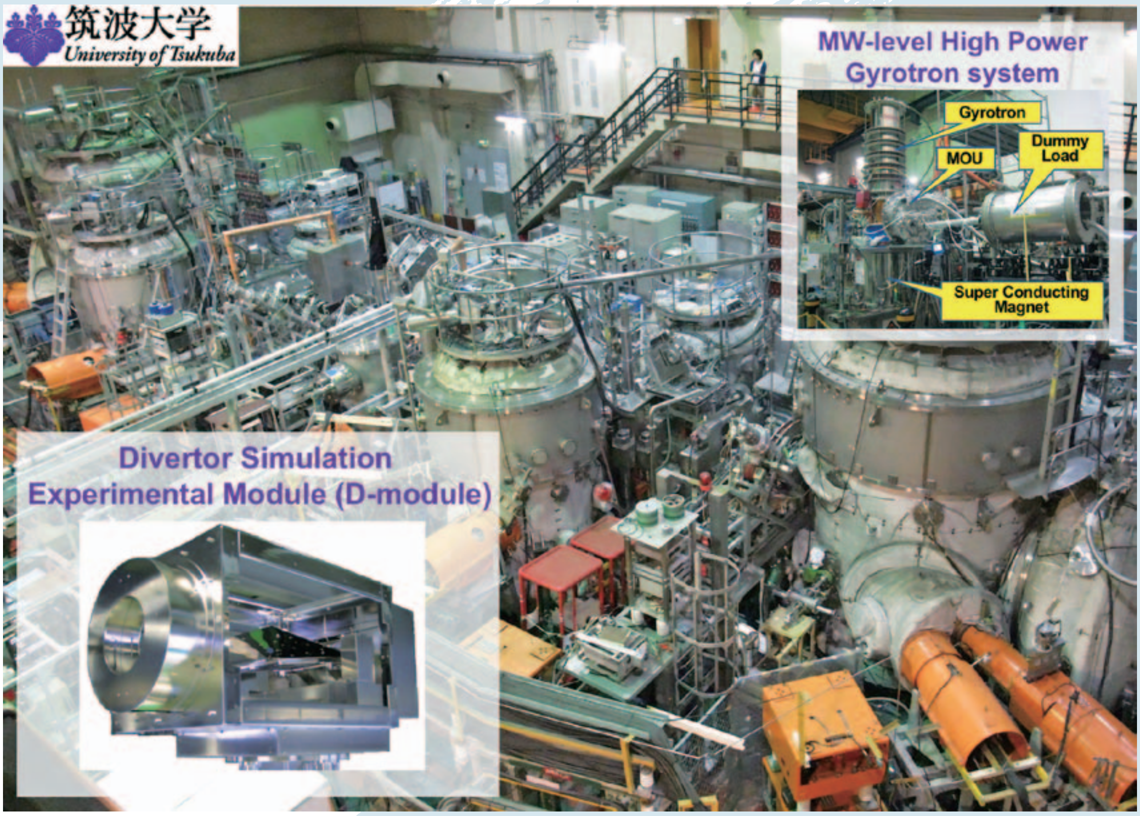


Fig. 1 Bird's eye view of GAMMA 10/PDX.

Highlight

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

GAMMA 10/PDX (Fig.1) is the world's largest tandem mirror device and has many plasma production/heating devices with the same scale of present-day fusion devices. By using the controllability of end-loss plasma flow, divertor-simulation experiments at the end region have been performed with strong ICRF and ECH systems. By using divertor simulation experimental module (D-module) installed at the west end region of GAMMA 10/PDX, characterizations of detached plasmas have been performed. A physical mechanism of the effective plasma detachment by the additional N_2+H_2 gas injection into the D-module has been investigated. The effect of an angle of the V-shaped target on the plasma detachment has been studied. Gyrotrons with wide range of frequencies from 14 to 300 GHz have been developed. A test of a new 28/35 GHz dual-frequency gyrotron was carried out. A double disk window of sapphire has been developed for high power and long duration gyrotrons. The new linear plasma device with superconducting coils is designed and under construction to contribute to the DEMO divertor design.

In the Plasma Research Center, University of Tsukuba, studies of boundary plasma and development of high-power gyrotrons have been performed under the bilateral collaboration research program. In FY2019, 26 subjects including the base subject were accepted and were productive in a number of excellent results.

Effects of a divertor target angle and a combination of N_2 and H_2 puffing on the plasma detachment have been investigated. A divertor target angle is expected to affect plasma detachment through the change of hydrogen recycling processes. Experiments of different target angles have been conducted using a variable angle V-shaped target system in the D-module to study detailed physical mechanisms of dependence of the target angle on the plasma detachment. Figure 2 shows images for different target angles, which are obtained during the hydrogen discharge in the D-module using a high-speed camera with a bandpass filter of H_α. It is found that the intensity decreases near the corner of the V shaped target plate as the angle is decreased, even though no additional gas is injected. In the case of the smallest opening angle, ion fluxes near the corner of the target clearly decrease in spite of no additional gas seeding. Such a flux drop is possibly attributed in the local neutral pressure build-up near the corner of the target caused by hydrogen recycling processes. As for the experiments of a combination of N_2 and H_2 puffing into the D-module, a clear decrease of ion flux to the divertor target in the D-module has been observed. The observed spectrum emissions ratio of H_α and H_β decreased during the combination puffing, indicating that the importance of the plasma chemical processes involving N and N_2 related reactions indicate that N-MAR is? on the decrease in ion flux and plasma density.

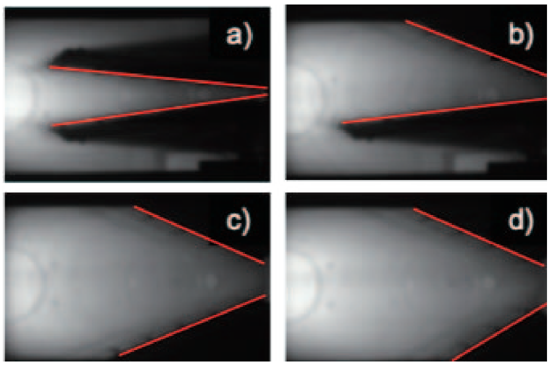


Fig. 2 High-speed camera images with H_α filter of different target angle (a) 16°, (b) 30°, (c) 45° and (d) 55°. Red lines show the position of target plate.

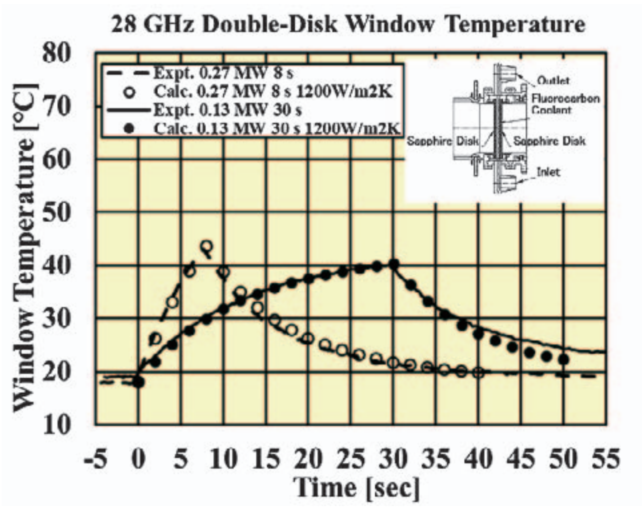


Fig. 3 Dependence of measured and calculated window temperatures on the gyrotron operation time. The insert shows a structural cross-section of the double disk sapphire window.

In the 2019 experimental test of a 28/35 GHz dual-frequency gyrotron (2 MW for 3 s and 0.4 MW CW at 28 GHz) for QUEST, NSTX-U, Heliotron J, and GAMMA 10/PDX, the cooling characteristics of a double-disk sapphire window were evaluated, because window cooling performance is a critical quantity limiting the CW power. The time evolutions of the measured and calculated window temperatures of the gyrotron with the 28 GHz operation are shown in Fig. 3. At the operation of 0.13 MW and 30 s, the measured window temperature increased during the operation period and tended to saturate at approximately 42 °C (solid curve). The heat transfer coefficient h from the sapphire disk to coolant is estimated to be 1200–1500 W/m^2 K by comparing calculated results and the experimental measurements. The calculated result for 0.13 MW and 30 s oscillation with 1200 W/m^2 K is plotted with closed circles. Further, the measured and calculated results with 1500 W/m^2 K for 0.27 MW and 8 s oscillation are plotted with a dashed curve and open circles, respectively. These results show that the operation of 0.4 MW with CW at 28 GHz is possible.

A dual-path YAG-Thomson scattering (TS) system has been constructed for measuring electron temperatures and densities both in the central and the end cells of GAMMA 10/PDX. The electron temperatures and densities both in the central and end cells have successfully been obtained in a single plasma shot. A multichannel (multi-frequency) Doppler reflectometer using a frequency comb generator has been developed to clarify the spatiotemporal structure of fluctuation flows.

(M. Sakamoto)

Kyoto University

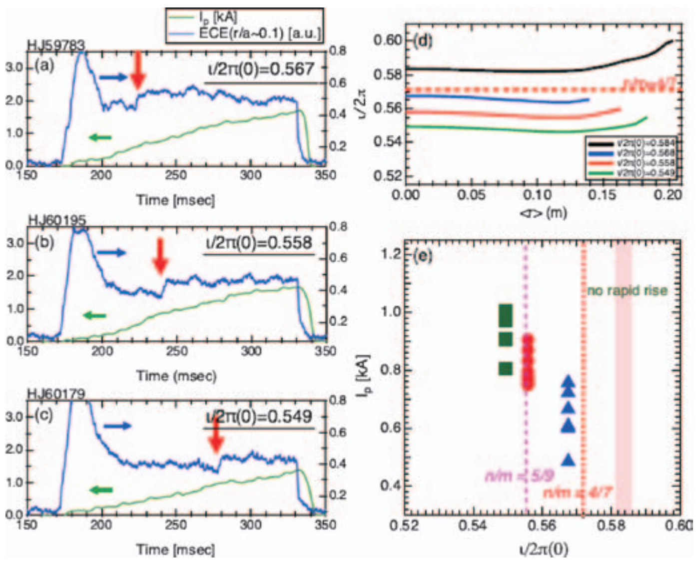


Fig. 1 ECE signals and plasma currents for different rotational transform profiles: (a) ι/2π(0)0=.549, (b) ι/2π(0)0=.558, and (c) ι/2π(0)0=.567. (d) Vacuum rotational transform profiles and (e) current at the start of the expansion of eITB as a function of ι/2π(0) for the vacuum magnetic field.

Highlight

Reformation of the electron internal transport barrier (eITB) with the appearance of a magnetic island:

When realizing future fusion reactors, their stationary burning state must be maintained and the heat flux to the divertor must be reduced. These essentially require stationary internal transport barrier (ITB) plasma with a fast control system. However, the time scale for determining the position of the foot point of an ITB is not clearly understood even though its understanding is indispensable for fast profile control. To clarify the role of the rational surface and/or magnetic island in the structural formation, the eITB formations for other magnetic configurations with rotational transform values of ι/2π(0) = 0.549, 0.558, 0.567, and 0.584 were investigated. The profiles of the rotational trans-form are shown in Fig. 1 (d). In addition, the plasma with eITB was produced by a centrally focused 70 GHz ECH (P_{inj} ~ 270 W). Figure 1 (a–c) show the ECE signals and plasma currents for the different rotational transform profiles. The structural formation was delayed with the decrease in the rotational transform values. In contrast, no structure was formed for the magnetic configuration of ι/2π(0) = 0.584. Figure 1 (e) shows the current at the start of the expansion as a function of ι/2π(0) of the vacuum magnetic field. The required plasma current to the expansion decreased with the decrease in the rotational transform values except the rotational profile at ι/2π(0) = 0.584. The n/m = 4/7 rational surface is important because it is a candidate in which the magnetic island is produced owing to the n = 4 toroidal periodicity of the vacuum magnetic field of Heliotron J. The n/m = 4/7 is larger at ι/2π(0) = 0.567 and smaller at ι/2π(0) = 0.584. As the bootstrap current is driven in the direction of the rotational-transform increase, the 4/7th rational surface cannot be produced at ι/2π(0) = 0.584. Consequently, the small differences between the 4/7th rational surface and rotational transform values reduce the required plasma current for a structure formation, except at ι/2π(0) = 0.584. Although there exist other low-order rational surfaces (e.g., n/m = 5/9 ~ 0.556), at which the possibility of the formation of a magnetic island is low, around the n/m = 4/7 rational surface, the structural formation is only related to that particular rational surface. This result strongly suggests that the movement of the eITB foot point is affected by the existence of a magnetic island instead of a rational surface.

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 FY2019 are the following seven key topics; (1) studies of plasma confinement improvement and related plasma self-organization through advanced helical magnetic field control, (2) study of plasma profile, plasma flow, and plasma current control for the confinement improvement, (3) study of fluctuation-structure formation and its control in plasma core region and peripheral region, (4) investigation of MHD instabilities of energetic particle modes and their control, (5) extension of high-density operation region, (6) optimization of particle supply and heating scenario, and (7) empirical research of new experimental methods and analysis methods.

Radial electric field during the formation of the electron internal transport barrier (eITB):
Radial electric field in plasmas of helical plasma confinement devices significantly contributes to the neo-classical transport. It is estimated using plasma flow velocity from the charge-exchange recombination spectroscopy (CX-RS) for Heliotron J plasmas. The radial electric field is investigated in NBI and/or ECH plasmas during eITB appearance. In an NBI plasma, negative radial electric field that means “ion root” is observed in whole plasma radial position. This electric field is almost explained by the neoclassical theory. Superimposing ECH in an NBI plasma, the electron temperature is increased and the density in the core region is decreased, then, the eITB appears in the core region. In this region, the radial electric field becomes positive, “electron root” in this region. In the region of the normalized radius larger than 0.4, the electric field is negative as the NBI case. The radial electric field in the core region changes from negative (ion root) to positive (electron root) during the formation of eITB. There are two solutions of radial electric field from 0.4 to 0.7 in normalized radius from the ambipolar condition of neoclassical theory, one is positive and the other is negative. The electric field beyond 0.4 in normalized radius is supposed to be ion root among two solutions.

Bumpiness dependence of electron confinement, and temperature and density distributions:
Magnetic field ripple in the toroidal direction (bumpiness) in Heliotron J magnetic configuration is one of key parameters to control neoclassical particle transport and high energy particle confinement. The global plasma confinement has been studied for ECH and/or NBI heating plasmas and its bumpiness dependence was clarified. For the next step, the electron temperature and density distributions, and kinetic stored energy are measured by using a Thomson scattering measurement system to investigate electron confinement properties in ECH plasmas under the condition of 270 kW in injection power. The line-averaged electron density is in the range from 0.5 to 1.5×10^{19} m^{-3}. The high and the medium bumpiness configurations are almost the same for the stored energy, while the stored energy is low in the low bumpiness configuration. The central electron temperature is also low in the low bumpiness case. The higher bumpiness case than already investigated cases, the stored energy becomes lower than that in the low bumpiness case. The anomalous transport is planned to study, since it is significant in the peripheral region in the plasma.

Proceeding research has been achieved with collaborative researchers under Bilateral Collaboration Program in Heliotron J project. The field configuration research including bumpiness dependence is advanced, and the fast local-fluctuation measurement is prepared by improvement of BES sensitivity. The 0.7-mmϕ pellet injector has been installed for the high-density operation. A laser blow-off system for the impurity transport measurement, and a multi-path Thomson scattering system for the high reliability measurement will be available soon. Making effort to extend the plasma operation region, comprehend plasma self-organization and control instabilities according to the confinement field optimization, we seek the way to the high-beta plasma research.

(K. Nagasaki)

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 FY2019, the following progress was made through Bilateral Collaboration Research Program with NIFS and other collaborators from universities and institutes (NIFS12KUGK057 as the base project).

Fundamental and Integrated Plasma Experiments

The energy distribution of laser-accelerated electrons is one of the most important factors to determine plasma heating efficiency. We investigated experimentally and numerically the dependence of their energy distribution on the pulse duration. In the conventional model, their mean kinetic energy depends on the ponderomotive force of the incident laser light, namely $I_L \lambda_L^2$, here I_L and λ_L are laser intensity and wavelength, respectively. However, this understanding is not adaptable in the case in which the pulse duration exceeds 1 ps. Giant electric and magnetic fields grow very rapidly in the laser-plasma interaction zone after a few ps. The electrons are trapped in the zone, and experience acceleration by laser light multiple times. This is the loop-injected-direct-acceleration (LIDA) mechanism. We are now investigating how the pulse duration affects the plasma heating efficiency.

Target Fabrication

We fabricated disk-shaped resorcinol-formaldehyde (RF) target for laser plasma experiments. To make disk-shaped and polymerized targets at room temperature, a thin film holder was filled with deuterated resorcinol, formaldehyde, and heavy water. After polymerization, the heavy water was replaced with acetone, and the target was dried using the supercritical drying method. The fabricated target has a thickness of 100 μm and a density of ~ 100 mg/cm^3.

Theory and Simulation

The petapascal pressure achieved in the FIREX experiment was confirmed by two-dimensional particle-in-cell (2D PICLS) simulations. Figure 1 (a) shows the time evolution of the heated region indicated with contour lines of 1 keV from the heating laser peak time (t = 0) for the cases with the density profile at the maximum compression timing (t_{exp} = 0.72 ns). The heating laser is irradiated from the right side through the cone and it heats directly the front edge of the dense plasma core owing to the high contrast laser light. The electron temperature evolves temporally via the thermal heat transport to the core by diffusive heating. The heat wave propagates with velocity > 10 μm/ps even after the heating laser irradiation terminated, and then the core region (X < 40 μm) is heated over 1 keV electron temperature at t = 4.8 ps. Figure 1 (b) shows the two-dimensional pressure distribution at t = 4.8 ps. The pressure of the core region (X < 40 μm) starts from 2 PPa at the front edge to 0.5 PPa at the other side (X ≃ –10 μm). Figure 1 (c) shows the bulk electron temperature on the density distribution of the doped copper having the charge states $Z \geq 27$. The doped copper densities with $Z \geq 27$ indicate the position where Cu-He$_\alpha$ photons are coming from. We see that the doped copper ions inside the core region get $Z \geq 27$, namely, the large amount of Heα emissions are coming from the core. The core region at the maximum compression is heated to 1–2 keV, which is consistent with the experimental observation. The electron phase plots of the longitudinal momentum are shown in Figs. 1 (d) and 1 (e). The diffusive feature is seen from the heating surface (X ~ 70 μm). This PIC simulation reveals that diffusive heating is the heating process which can locally heat up the front region to the core region over petapascal pressure.

Improvement of GXII and LFEX laser system

Temporal waveform shaping has been demonstrated in both GXII and LFEX laser systems. Temporally multi-stepped implosion laser pulses are effective for compressing plasma target. In the GXII laser system, three-

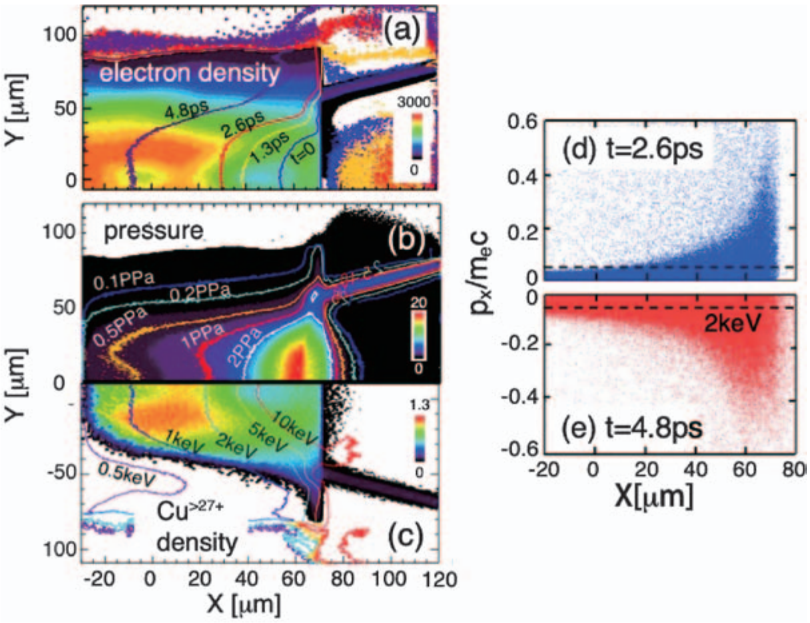


Fig. 1 PIC simulation at the maximum compression (t_{exp} = 0.72 ns): (a) The propagation of heat wave indicated by 1 keV contour lines on the electron density [n_c]. (b) Pressure distributions with the contour lines (petapascal). (c) Electron temperature distribution on the doped copper density [n_c] with charge state $Z \geq 27$, which indicates the position where the He$_\alpha$ emissions come from. The contours are plotted at t = 4.8 ps after the heating laser peak time. (c), (d) The electron phase plots, X – p_x/m$_e$c, at 2.6 ps (d) and 4.8 ps (e) from the peak time of LFEX. The phase plot is vertically symmetric, so that only the upper and lower halves are shown due to the space limitation.

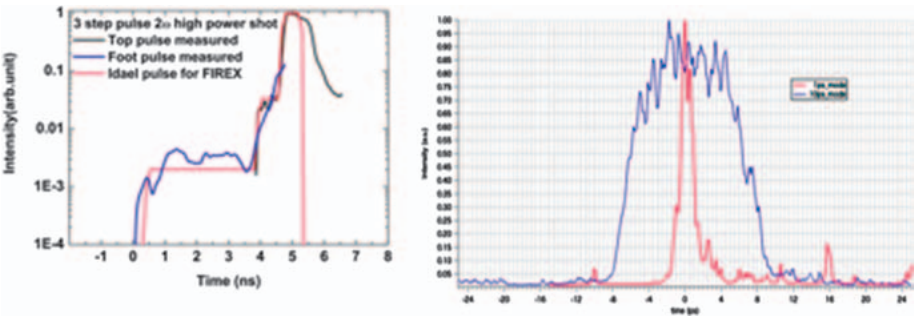


Fig. 2 The obtained three-stepped pulse shaping in GXII laser system (left), and flattop pulse demonstration after the pulse stretcher of the LFEX laser (right).

stepped pulse shaping of the amplified pulse has been demonstrated by adding a fiber wave-shaper after the fiber oscillator, as shown in Fig. 2 (left). The shaping is controllable with programming of the software to generate an arbitrary waveform.

On the other hand, a longer pulse duration than 1 ps which is still in use has been required for heating a high-density plasma. A 10-ps flattop pulse can be generated by putting a spectral phase modulator into the pulse stretcher, as shown in Fig. 2 (right).

Individual Collaborations

In parallel to the main base project, 16 other collaborations by individual researchers including two from abroad as described below have been performed. Those collaborations were on electron-driven fast ignition (7 collaborations), ion-driven fast ignition (1), alternative scheme of laser-driven inertial fusion (3), diagnostics of high-temperature and high-density plasmas (4), and reactor technology (1). 12 were projects continued from the previous year(s) and 4 were newly accepted in FY2018.

(R. Kodama, H. Shiraga, S. Fujioka, K. Yamanoi, Y. Sentoku and J. Kawanaka)

Kyushu University

Research activities on QUEST in FY2019

We will summarize the activities of the Advanced Fusion Research Center, Research Institute for Applied Mechanics in Kyushu University during April 2019 – March 2020. The QUEST experiments were executed during 9th April – 27th Sep. (2019 Spring/Summer; shot no. 38975–41263) and 8th Oct. – 14th Feb. (2019 Autumn/Winter; shot no. 41264–42538). Main topics of the QUEST experiments in FY2019 are listed below.

1) The highest plasma current discharge of more than 100kA in non-inductive current drive adding a bit of ohmic heating was obtained by 28 GHz microwave injection which was developed with Tsukuba University (Gyrotron) and NIFS (polarizer) (shot no. 40527). The control of refractive index parallel to the magnetic field, N// could give us the controllability of electron temperature up to 500 eV at N//~0. Superimposed Ohmic heating provided an 800 eV in electron temperature.
2) The water-cooling of the hot wall during plasma discharges were successfully executed and the plasma duration was extended. The sequence of plasma termination was the same in both with and without water cooling of the hot wall. The value of H^+ was gradually increasing around the mid-plane area where no hot wall was equipped, and then a bright area around the center stack in the ion drift direction was developed just before the plasma termination. This indicated that the unknown outgassing due to active recycling was made in the mid-plane area. It was found that the key issue to extending plasma duration is to reduce the unknown outgassing in the mid-plane area.
3) Experiments were conducted with 8.3 GHz RF heating for 600 sec pulse, where permeation probe data were obtained. Analysis of diffusion transport in the PdCu film shows that atomic flux of order of 10^15 atoms/m^2/s reaches the first wall during the discharge. Dynamics of the atomic flux with a time scale of ~ 100 sec is observed.
4) In order to increase ohmic plasma current upto two times, double swing of center solenoid current must be enabled. To alternate two mono-polar positive and negative thyristor power supplies, IGBT switches were installed. Analyzing the low-speed interlock sequence, high-speed interlock circuit was designed and installed. Due to the current monitor error, however, IGBT's were injured. Such an error will be taken into account in the interlock system.
5) The system of QUEST is networked and implemented as software to reduce the burden of human work. Examples are systems for monitoring the cooling water of the PF coil using a clamp-on type ultrasonic flow meter and for monitoring the coil temperature directly using a 3-wire Pt100, etc. These are composed of software and can be operated flexibly according to experiments, and information is transmitted to a distant central control system via a network.
6) Temperature dependence of retention of tritium ions (EDT+=0.5 keV) impinged into tungsten at higher temperatures has been examined, and an interesting tendency of tritium retention was observed and the minimum was 523 K. It was suggested from the present examinations that change in the tritium retention strongly depends on release rate of tritium molecules from the surface in comparison with diffusion rate into the bulk.
7) Asymmetric deposition/erosion has been observed on the first wall in QUEST. To understand the mechanism of the asymmetry formation, Mach probes which can measure a plasma flow are planned to be installed at the top and the bottom of an outer port. Directional material probes on which a direction of a deposition layer formation can be observed are also planned to be installed near Mach probes. They will be installed in experiments in 2020.
8) Divertor biasing using several electrodes arranged toroidally every 90 degrees was attempted for divertor heat load control. It showed noticeable expansion of particle flux to the upper divertor plate. The method also produced several SOL-current filaments, which can generate resonant magnetic perturbations (RMPs) for edge plasma control.

9) Electron Bernstein wave (EBW) heating/current drive is one of the key issues to attain a steady state tokamak configuration in the QUEST. The collective scattering system utilizing the 400 GHz gyrotron and quasi-optical system including transmission, antenna, and reflector gratings are under detailed design to detect EBW in the core of the QUEST. The 400 GHz gyrotron developed in the Univ. of Fukui was transferred to be installed on the QUEST during FY2019.
10) For vertical plasma position control to extend the operation regime, simultaneous equation with 6x6 consisting of four vacuum chamber currents, one pair of the horizontal coil, and the plasma current are solved with PD control prior to dividing into the many vacuum chamber currents. As the mass-less approximation behaves opposite, we have used the equation with the plasma mass.
11) Correlation between surface chemical state and hydrogen isotope retention for tungsten exposed to hydrogen plasma in 2019S/S and A/W campaign was studied by XPS and TDS. Additional D implantation was performed these samples to reveal the D trapping efficiency after hydrogen plasma exposure. In the present campaigns, the damage was not accumulated, which also reflects the lower D retention, suggesting that a stable plasma would reduce the plasma wall interaction.
12) We investigated the possibility of PFC surface thermometry using the rotational-temperature of H2 d-state, which was previously reported in TEXTOR and PICES. The temperature obtained on an edge viewing chord was approximately 500 K and close to the surface temperature of 473 K. We plan to study the effects of collisional processes and surface reactions on the obtained temperature.
13) To locate the fundamental resonance layer of 28 GHz electron cyclotron frequency in the QUEST vacuum vessel, twice the strength of toroidal field is requested, where the total current in the central stack is 1.6 MA. The use of high temperature super conducting wire made of REBCO material is proposed for the development of a new toroidal coil.
14) It is expected that the combination of current ramping up by CS and current sustainment by RF current drive is effective for stable divertor configurations. In order to verify the operation scenario, numerical simulations of QUEST plasma with coils and vacuum vessel were introduced.
15) The driving mechanism of the toroidal flow by ECH is investigated, assuming an essential role of $J \times B$ torque due to the radial diffusion of ECH supra-thermal electrons. The 3D magnetic ripples and the large orbit size of supra-thermal electrons enhance the radial diffusion in QUEST. The GNET code is prepared to evaluate the supra-thermal electron behaviors and radial current in the QUEST plasma.
16) A novel fast–electron measurement instrument has been designed to investigate a fast–electron dynamics and its role in a non–inductive ST plasma startup with ECH/CD on QUEST. Asynchronous counting of two thin scintillators mounted in a box with an appropriate hole gives a pure fast–electron energy distribution while eliminating the effects of X-rays.
17) Hydrogen retention processes occurring on the plasma-facing walls in QUEST and in-vessel material migration were investigated using a technique of a transmission electron microscopy and elastic recoil detection analysis. It was found that hydrogen would be trapped by the carbon-dominated mixed-material layer.

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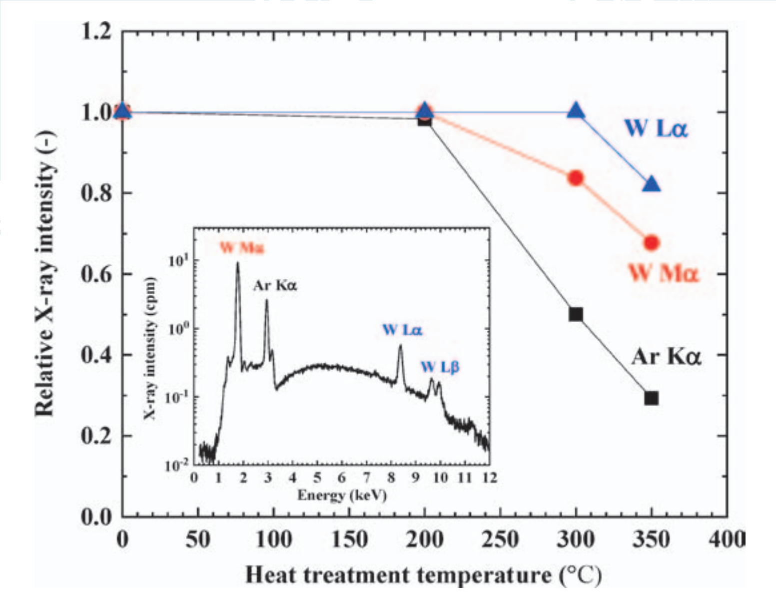

β-ray induced X-ray spectrum from tritium-charged Fe-ion irradiated W and change in intensity of characteristic X-rays by heat treatment

Highlight

Research Activities in Hydrogen Isotope Research Center, Organization for Promotion of Research, University of Toyama

Development of tritium (T) removal technique from plasma-facing materials (PFMs) used in a fusion reactor is important for safe and cost-effective disposal. Lattice defects induced by neutron irradiation in tungsten (W) act as traps against hydrogen isotopes. In this study, T release from a W sample irradiated with heavy ions and the non-irradiated sample were examined at 200–350 °C to evaluate the effects of irradiation defects on T removal. A plate of W irradiated with 6.4 MeV Fe ions to 0.5 displacement per atom was exposed to a mixture gas of deuterium (D) and T at 500 °C together with the non-irradiated sample. Then, the sample was heated one by one under Ar gas flow sequentially to 200, 300 and 350 °C. T retention in the irradiated sample was clearly higher than that in the non-irradiated sample due to trapping effects by radiation-induced defects. The heat treatment at 200–300 °C resulted in T release solely from non-irradiated sample and non-damaged zone of the irradiated sample. Clear T release from the damaged zone started at 350 °C and the rate of release was controlled by diffusion of T in the damaged zone. The majority of T was released as HTO.

[*Isotope effects on trapping and release of hydrogen isotopes in fusion reactor materials (Y. Hatano, U. Toyama)*]

Hydrogen isotope transport through plasma modified fusion reactor materials: Experiments were performed to study the effect of rhenium (Re) addition on hydrogen isotope transport and trapping in undamaged tungsten (W). In comparison to pure-W, W-Re alloy (3 wt.%) was observed to trap lower and higher amounts of T at 473 K and 673 K, respectively. The retention behavior was similar at 573 K. Self-consistent modeling of the TDS profiles constrained by the T depth profiles qualitatively indicates such temperature dependency is due to higher trapping energies (<0.5 eV) in W-Re. (H. T. Lee, Osaka U.)

High temperature and high flux irradiation effect on hydrogen isotope retention in damaged W: The effect of high temperature and high flux irradiation on the hydrogen isotope retention behavior in damaged tungsten was studied. It was found that the types of irradiation damage were not changed, but the amount of damages were reduced due to annealing at high temperature. In addition, the D retention behavior was affected by formation of blisters on the surface caused by high temperature and high flux plasma. (Y. Oya, Shizuoka U.)

Hydrogen isotope exchange in tungsten with irradiation damage: Successive exposure to tritium gas and deuterium gas was performed at elevated temperatures for W samples with irradiation defects created by helium (He) ion irradiation to investigate the effects of hydrogen isotope exchange on T removal. It was found that the heat treatment in deuterium gas was more effective for removal of T retained in a deep region of sample compared to the case of heating in a vacuum. (Y. Nobuta, Hokkaido U.)

Hydrogen isotope exchange on metaric plasma facing walls: Specimens for hydrogen isotopic exchanges by glow discharge cleanings on stainless steel were produced. Based on previous experiments in Univ. of Toyama, tungsten, which is a candidate material for the DEMO reactor, has a low sputtering rate by deuterium, and then it was not useful for the laboratory experiment due to limited experimental time. Remaining tritium on surfaces of stainless steel measured by ITP shows lower amounts to compare with that on tungsten, and it is also a preferable sample condition. Using the stainless steel, an evaluation of experimental conditions will be obtained.
(N. Ashikawa, NIFS)

Tritium retention on facing materials modified by plasma wall interactions: ITER specification W (SR-W) and its recrystallized W (RC-W) were irradiated by high energy electron beam. Before and after that, positron annihilation experiment and EBSD (Electron Back Scatter Diffraction Patterns) analyses were carried out to identify the radiation defect. Tritium exposure experiments on the specimens have been carried out using the tritium (T) exposure device. (K. Tokunaga, Kyushu U.)

Impact of bulk helium retention and damages introduction on hydrogen isotope retention behavior in tungsten: Effects of high energy He irradiation and damage introduction at high temperatures on hydrogen isotope retention in W were investigated. The results showed that weak trapping sites such as vacancies with higher concentration were produced during single energetic He^+ irradiation events. Fe^{3+}-He^+ simultaneous irradiation promoted the formation of He_xV_y complexes, which reduced the concentration of vacancy trapping sites. (F. Sun, Shizuoka U.)

The production of high purity deuterium-tritium water for laser fusion fuel: At Institute of Laser Engineering Osaka University (ILE-Osaka) a tritium-water doped target for inertial confinement fusion (ICF) has been developed. H_2O water (which is mimic of T_2O water) doping to a D_2O-filled with a real-size ICF target was firstly succeeded by using a testing system which was developed in this study. (Y. Arikawa, Osaka U.)

Gamma-ray irradiation effect on hydrogen isotopes at fusion material surfaces: The D retention in yttrium oxide, silicon carbide, and zirconium oxide coatings decreased after γ-ray irradiation in the dose rate of 2.43 Gy/s, while no clear change in the retention was observed at the lower dose rate. From these results, the γ-ray irradiation effect on deuterium retention would have a threshold dose rate. (T. Chikada, Shizuoka U.)

Evaluation of hydrogen isotope retention and release of SiC and SiC/SiC composite: The NITE SiC/SiC composites consist of β-SiC matrix and β-SiC fibers and carbon matrix/fiber interface. Basic inventory and release behaviors of hydrogen isotopes in SiC, and the effects of fibers and carbon interface in the SiC/SiC composites need to be revealed for the design of fusion components. In this research, α-SiC, β-SiC and NITE SiC/SiC composite plates were prepared. Observation of their surfaces by a scanning-electron microscope was followed by irradiation of 3 keV DT^+ ions at room temperature. T desorption tests will be performed.
(H. Kishimoto, Muroran Inst. Technol.)

Development of methodology and quantitative measurement on double-strand breaks of genome-sized DNA caused by beta-ray: We have developed an appreciation tool to detect an outline of giant DNA molecules in an aqueous solution and count number of double-strand breaks in real-time observation, adopting a canny method of Open CV. The tool has succeeded in detecting outline of DNA in a movie of DNA under Brownian motion. Based on the tool, we will establish a methodology of real-time observation on double-strand breaks of DNA in a quantitative manner. (T. Kenmotsu, Doshisha U.)