15. Department of Engineering and Technical Services

The Department of Engineering and Technical Services (DETS) is involved in the operation and maintenance of research platforms such as the Large Helical Device (LHD) and information facilities such as the research infrastructure network, as well as the design, development, and fabrication of equipment, radiation control, and safety promotion.

The Platform Management Office, which consists of the LHD Section, Computer Section, and Engineering Facilities Section, was established in FY2023. The DETS was reorganized from five divisions in technical fields to 12 teams for each research task, to support the platforms including the LHD which held the 25th experiment campaign from 13 March to 20 June, 2024.

The following is a report on the activities of the DETS.

(H. Hayashi)

Mechanical Systems Technology Division

The main work of this division is the fabrication of experimental equipment. We also take care of technical consultation and experimental parts supplies related to LHD experiments. The number of machined requests was 78, and the production parts total number was 300 in this fiscal year (FY). We also perform maintenance and modification of LHD-related equipment. The main equipment includes: utilities (compressed air, cooling water, GN2), water leak detection equipment, the Local Island Divertor (LID), Boronization, ECH, ICH and NBI.

In addition, we manage the administrative procedures of the department.

The details of some of this division’s activities follow below.

(M. Yokota)

(1) 154 GHz notch filter

We have fabricated a notch filter (Fig. 1) for ECH. It has four cavities and a waveguide in an internal space. In order to decide the parameters of the cavities, we have analyzed the electromagnetic field. The cavities are 1.5 mm in diameter and 1.265 mm deep. The rectangular waveguide is 1.651 mm long and 0.826 mm wide.

(T. Shimizu)

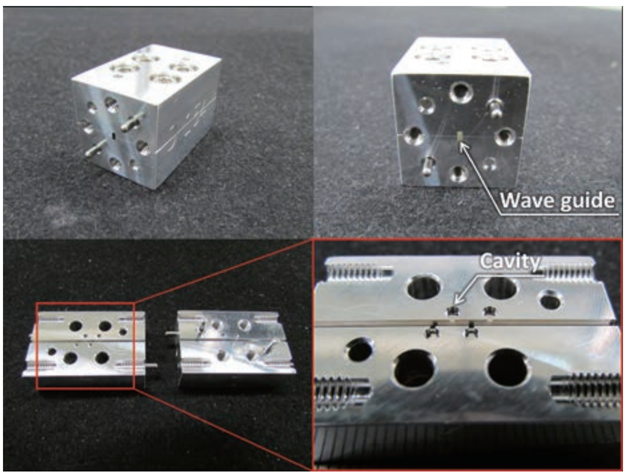

Fig. 1 154 GHz notch filter

(2) Modification of the ECH#4 transmission line

A modification of the ECH#4 transmission line was performed for the 25th LHD experimental campaign. Three aluminum mirrors were newly set in the middle of the transmission line to receive an electron cyclotron emission (ECE) signal from LHD plasmas. This modification made it possible to adjust the polarization of the ECE signal because it can be received through λ/4 and the λ/8 polarizers. A picture of the new transmission line is shown in Fig. 2.

(T. Takeuchi)

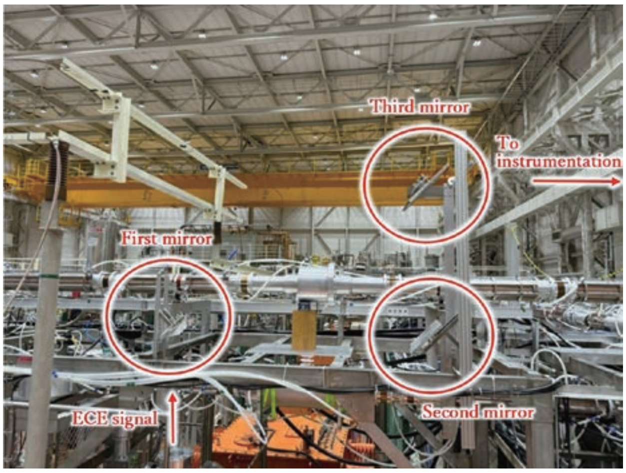

Fig. 2 ECH#4 transmission line

Design and Development Technology Division

This Division provides support for the operation, improvement, and maintenance of LHD, as well as support for collaborative and commissioned research.

(N. Suzuki)

(1) Development of activated carbon derived from unutilized biomass

A cryo-sorption pump equipped with activated carbon as an adsorbent of gas particles has been used in LHD. We have developed activated carbon derived from unutilized biomass suitable for a cryo-sorption pump [1,2].

In this study, we used a Spark Plasma Sintering (SPS) method to sinter powdered activated carbon. SPS is a method to sinter powdered materials, e.g., metals and carbon, by applying pressure and pulsed current heating. Using SPS, we aim to sinter activated carbon without a binder which would inhibit the performance of activated carbon.

In order to investigate the effect of the sintering temperature, we sintered activated carbon derived from rice husks by SPS at various temperatures. The sintering succeeded at each temperature from 650 °C to 1600 °C. As shown in Fig. 3, we found that a specific surface area, which was the principal parameter of activated carbon, became larger as the sintering temperature was reduced. Especially, the specific surface area of the activated carbon sintered at 800 °C or below

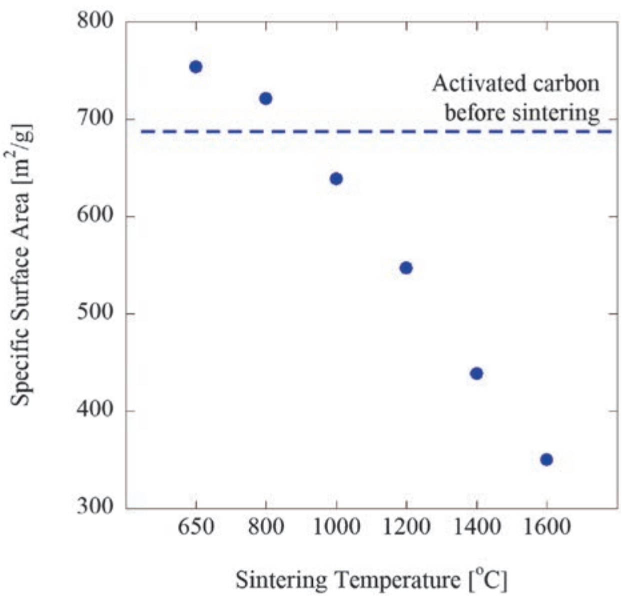

Fig. 3 Specific surface area of activated carbon at each sintering temperature by SPS

and was larger than that of the activated carbon before sintering. We obtained a patent based on this achievement [3].

[1] Y. Yanagihara *et al.*, Plasma Fus. Res. **19**, 1205012 (2024).
[2] Japanese Patent 7301300.
[3] Japanese Patent 7501845.

(Y. Yanagihara)

(2) Developing 3D display functionality for temperature-monitoring application using LabVIEW

The surface temperature inside the vacuum vessel (VV) of LHD is monitored by thermocouples at more than 200 measurement points. Identifying immediately which locations are exposed to severe heat loads during a plasma experiment is greatly important.

Conventional temperature-monitoring systems are limited to displaying measuring points on a two-dimensional diagram. Such a display method is not always appropriate for showing the locations of temperature- measuring points. For example, in the case of the LHD VV with a complicated helical shape, it is difficult to understand the measuring points, since the location displaying image has no alternative but to show an unfolded figure.

To address this issue, we recently updated the temperature-monitoring application using LabVIEW and added a function that can display the location and temperature of each measuring point on a 3D model of the LHD VV (Fig. 4). An auxiliary function to search the TC location with a TC identification number and a feature of the specific view storing were also implemented. Developing 3D displaying functionality with LabVIEW was quite challenging because the software is not suitable for such usage.

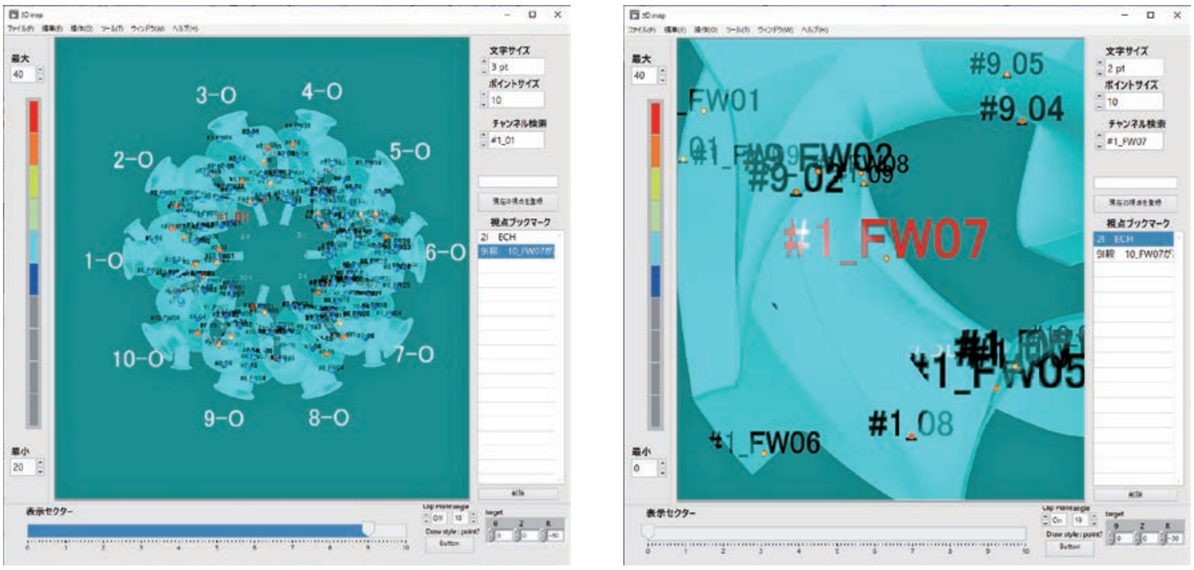

Fig. 4　3D displaying function of the temperature monitoring application

(S. Nakagawa)

Electrical and Electronic Technology Division

The main tasks of this division are the operation and maintenance of plasma-heating devices using high-voltage and high-frequency power supplies and their common facilities. We have also provided technical support for experimental equipment, including electrical and electronic circuits. The details of these activities are as follows.

(T. Kondo)

(1) Electrical and electronic work for experimental equipment

(a) Repair of the impedance matcher

The control circuit of the impedance matcher for the NBI's RF ion source had a malfunction. However, it could not be repaired because its manufacturer had already gone out of business. And so, we developed a new control circuit which has a microcomputer board (STMicroelectronics NV, model STM32) and tested it (Fig. 5).

(Y. Ito)

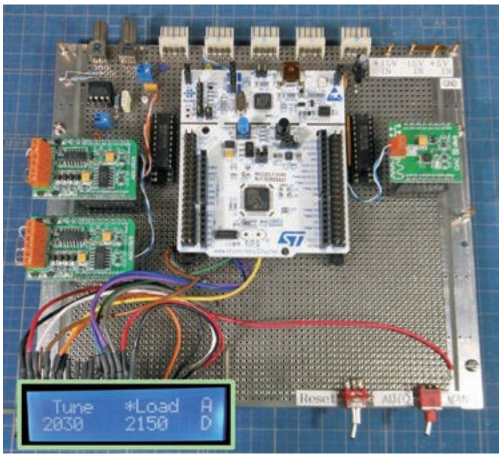

Fig. 5 New control circuit of the impedance matcher for the NBI's RF ion source

(b) Modification of the pump control panel

We modified the control panel of cooling water pumps in the R & D Laboratories to save electric power. The manual operation function of the existing control panel for eight cooling water pumps was retained (Fig. 6) but additional timers and relays to supply cooling water only at set times were built in (Fig. 7).

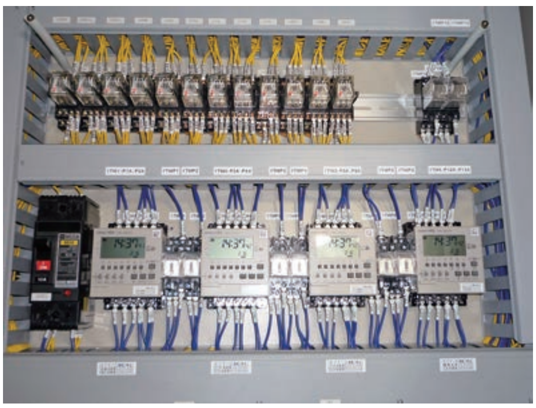

Fig. 6 Additional 2ch timers and relays (8 systems)

Fig. 7 Cooling water pump control panel on/off button (8 systems)

(K. Yasui)

(2) The Operation and maintenance of plasma heating devices for LHD

(a) ECH

We repaired a 28 GHz gyrotron that we uninstalled due to its poor condition in the 24th experimental campaign and operated it for about six months as a joint research project. A 77 GHz gyrotron that had been dormant since 2019 was operated again and worked well too. Before this fiscal year's experimental campaign, the microwave beam-focus location at the plasma-vacuum vessel of LHD was measured and had no significant deviation. In this fiscal year's experimental campaign, we injected power up to 4 MW to assist the plasma experiments of LHD.

(Y. Mizuno)

(b) ICRF

In the ICRF heating system, the output of the amplifier can be switched to an antenna or dummy load by using a coaxial switch. An indicator showing the direction of the amplifier output was fabricated to reduce errors in checking the connection destination of the coaxial switch (Fig. 8). Since its introduction, this system has successfully prevented injection errors. In the future, we plan to integrate this indicator with the amplifier control system and activate an interlock if the switching destination is not correct.

(M. Kanda)

Fig. 8 Indicator of the direction of amplifier output attached to the coaxial switch

(c) NBI

The cooling tower has a risk of freezing cooling water during the winter, and so has been run continuously for 24 hours. We modified the control system of the cooling tower to run the pump only when the outside air temperature drops below near freezing, and to save electric power. This new system has an outside air temperature sensor, and repeats pump runs for ten minutes, stopping for 50 minutes when the outside air temperature at the pump yard dropps below 2 °C. This winter, from December 25 to March 31 (2,352 hours), the outside air temperature fell below 2 °C for 406 hours (17 %). In other words, the pump's operating rate was reduced by one-sixth, which resulted in a 97% reduction in power consumption (50,000 kWh/year, 1 million yen/year Less).

(M. Shibuya)

(d) Motor-Generator (MG)

The MG is used to supply pulsed power for NBI and ECH in the LHD. The MG has supplied power for 5,273 shots in this fiscal year and 715,531 shots since its construction. The operation time was 269 hours.

(Y. Mizuno)

Diagnostics and Analysis Technology Division

We are engaged in the maintenance and improvement of plasma diagnostic devices and a data acquisition system for the LHD. We also conduct radiation measurements and are responsible for radiation control. Regarding the diagnostic devices, until FY2022, the operators performed inspections and maintenance. However, since the contract has ended, all tasks have been taken over by the technical staff. We have been preparing for the LHD experiments scheduled to start at the end of the FY2023 by confirming the startup procedures of the diagnostic devices and organizing manuals.

The improvements implemented in the Heavy Iron Beam Probe (HIBP), the activities related to the data acquisition system, and radiation control are described below.

(H. Hayashi)

(1) Improvement of beam transport from HIBP negative-ion source to tandem accelerator injection

Until FY2022, the beam intensity was insufficient for measurement in high plasma density, due to beam attenuation. Therefore, we developed a new ion source to increase the beam current. When we measured the current of the newly developed ion source at the test stand, it was around 40 μA near the center of the beam. However, when we installed this ion source into the actual HIBP device and measured the current, it was only 25 μA near the center, just before the tandem accelerator. We have optimized the beam transport by adjusting the resistance division of the multi-stage accelerator tube and changing the shape of the equipotential surface to provide an electrostatic lensing function (Fig. 9). As a result, the beam current has increased to about twice its previous value.

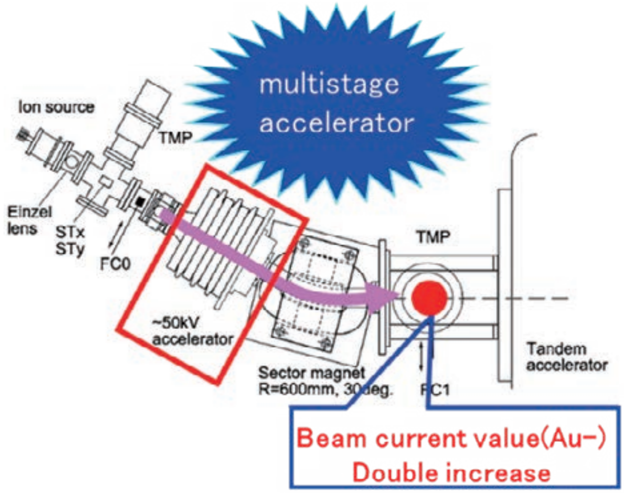

Fig. 9 Beam loss due to multistage accelerator

(H. Takubo)

(2) LHD data acquisition (DAQ) system

In the 25th LHD experimental campaign, the LHD DAQ system acquired data from 6,334 plasma shots, and the total generated data was approximately 232 TB after compression. During this campaign, the communication between the DAQ PC and the digitizers was often abnormal, mainly in the NBI data acquisition. This required the digitizers to be turned off and on again. The long distance of the optical fiber path between the PC and the digitizers may have affected the results, which will be addressed by the next campaign. For long-term storage, we have switched to free-cloud storage using Amazon Web Services.

(M. Ohsuna)

(3) Radiation measurement

To monitor the tritium concentration in the exhaust gas generated in the radiation control area, tritium was collected in water form and measured with a liquid scintillation counter. So far, no tritium exceeding the standard has been confirmed. One of three sampling systems has been measuring tritium concentration in chemical form (HTO, HT, CH3T). Following the completion of the deuterium experiment in December 2022, the system was modified in October 2023 to stop collecting tritium in chemical form. As a result, the work time for monitoring tritium concentration in exhaust was reduced by about 40%.

(M. Nakada, H. Miyake and C. Iwata)

(4) Activation evaluation

In order to evaluate the degree of activation of the LHD torus hall and its basement due to the deuterium plasma experiment, NIFS have conducted a survey in collaboration with the High Energy Accelerator Research Organization (KEK) since 2022. In FY2023, concrete cores were extracted to investigate the degree of activation of the concrete in the floor and walls of the LHD torus hall. Furthermore, to investigate the amount of tritium produced in the concrete by the deuterium plasma experiment, concrete core samples were analyzed, and it was confirmed that the amount of tritium was below the detection limit for all samples.

(S. Kurita and T. Kobuchi)

Control and Information Technology Division

The Control and Information Technology Division is in charge of important engineering tasks in the LHD project, such as system development, project management, and system operation, which are mainly targeted at central control systems, cryogenic systems, coil power supply, and super-conducting coils.

We are also responsible for IT infrastructure, e.g., the LHD experiment network, the NIFS campus information network, and internet servers, in every phase of the project, including requirements analysis, system design, implementation, operation, and user support.

The essential topics of the activities for the last fiscal year are described below.

(S. Takami)

(1) Technical Support for Research Using Liquid Helium (LHe) and Liquid Hydrogen (LH2)

We received a request for technical support for research on understanding the phenomena and detection methods of degradation of the vacuum insulation layer for long-term storage of LHe and LH2. This year, we designed a flange and a frame to be attached to a glass dewar containing liquid hydrogen (Fig. 10). The newly designed flange and frame were sent to the Noshiro

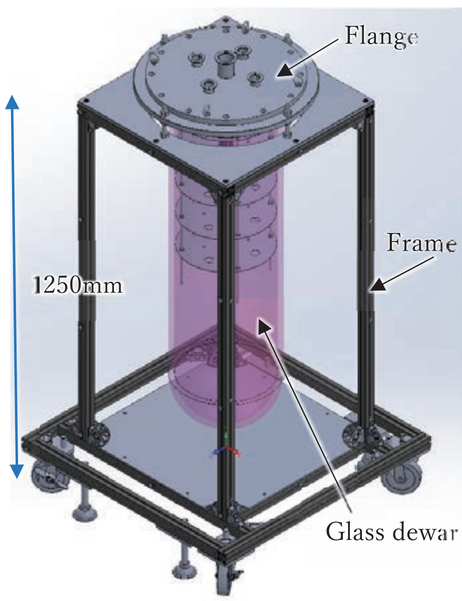

Fig. 10 Assembly drawing of designed flange and frame

Rocket Testing Center in Akita Prefecture, where the experiment was to be conducted, and assembled with the glass dewar on site. The designed parts were assembled without any problems. In the next fiscal year, we plan to provide the necessary equipment and support for experiments.

(S. Takami)

(2) Development of TESPEL Control System for JT-60SA on QST

In the LHD Experiment, a Tracer-Encapsulated Solid Pellet (TESPEL) injector is used for impurity injection. NIFS' engineering department has developed remote-control software for this equipment, and the current LHD has two sets of equipment and software. Also, the JT-60SA experiment system at the National Institutes for Quantum Science and Technology (QST) has a project to introduce a similar TESPEL injector. The NIFS engineering department is also going to develop remote-control software for that injector (Fig. 11). Based on the remote-control software in LHD, we have changed some view and memory addresses of the connected Programmable Logic Controller (PLC). Although JT-60SA is currently in preparation, we have confirmed the operation of the main part, on site. An easily comprehensible operation view was also well received by QST researchers.

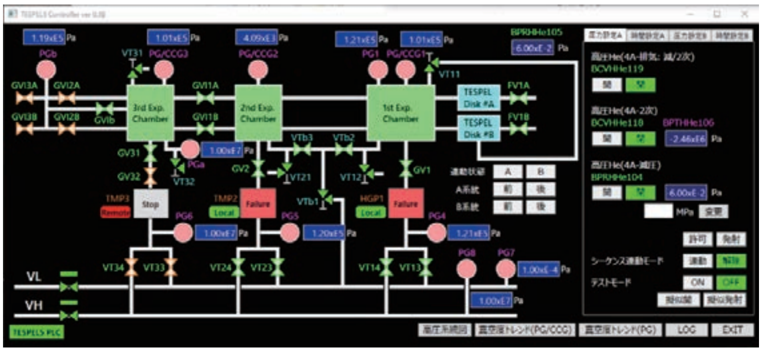

Fig. 11 TESPEL remote-control software operation view

(H. Maeno)

(3) Network Management

The NIFS campus information networks consist of several clusters. We manage the Research Information Cluster (NIFS-LAN) and the LHD Experiment Cluster (LHD-LAN).

The achievements in FY 2023 are as follows:

(a) Introduction Akamai Secure Internet Access Enterprise

Communication by malicious domains and IP addresses during DNS name resolution were prevented by changing the reference source of NIFS DNS servers to Akamai's (Fig. 12). Installation trials began in late June 2023, with the official operation starting in September.

Fig. 12 SIA Block Page

(b) Firmware update for SSL-VPN system

An extremely high severity vulnerability of CVE-2023-46805 was announced in January 2024, and a temporary countermeasure, XML, was applied in January and February. It appears that many institutions were attacked and tampered with, but fortunately, NIFS, which was quick to respond, did not suffer from any tampering. A permanent countermeasure to CVE-2023-46805 was completed with firmware update to 22.3R1.1 in March 2024.

(c) LHD-LAN

It is required in our security policy that network management staff be present when connecting a new device to LHD-LAN. In FY2023, 24 new devices were connected to LHD-LAN, 79 devices were updated, and 23 IP addresses were made available due to device removal.

(T. Inoue and O. Nakamura)

Technical Exchanges

Sixth technical exchange meeting: "computational technology using finite element method"

On February 16, 2024, we held a technical exchange meeting to discuss numerical computational technology based on the finite-element method. This meeting, which was the seventh held hitherto, was attended by six presenters and 24 participants, including those who used a remote web conference application (ZOOM), as shown in Fig. 13. In this meeting, two invitees presented talks under the titles of "Progress of 3D design technology by AI and its industrial application" and "Evaluation of Contact Thermal Conductance of ITER Poloidal Polarimeter Retroreflectors". In addition, four general talks were presented, all of which resulted in lively discussions.

Fig. 13 Group photos of the technical exchange meeting

(T. Murase)

Internship

We accepted internships from three high schools as part of the institute's outreach activities. One example is shown below.

The Mechanical Systems Technology Division receives two senior high school students for internship every year. They are students of the Tajimi Technical High School. They manufacture experimental devices with us for three days. It helps them to learn machine-tool operation techniques (Fig. 14). We gave lectures on the basics of mechanical drafting, TIG* welding and how to make NC programs.

*TIG: tungsten inert gas

Fig. 14 Internship

(K. Okada)