15. Department of Engineering and Technical Services

The Department of Engineering and Technical Services 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 Department of Engineering and Technical Services contributes greatly to the creation of results in fusion research through advanced and specialized technical support. The department consists of five divisions, and the total number of staff is now 56 (2022).

And as shown in Chapter 6, the 2022 NIFS External Peer Review Committee conducted an external evaluation of the "Department of Engineering and Technical Services."

(H. Hayashi)

1. Fabrication 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 the LHD experiment. In addition, we manage the administrative procedures of the department.

The number of machined requests was 76, and the production parts total number was 278 in this fiscal year (FY). The total numbers of electronic engineering requests and articles were 13 and 22, respectively. The details of some of this division's activities follow below.

(M. Yokota)

(1) 2.5-inch corrugated miter bend for microwave at a frequency of 70–330 GHz

We have fabricated 22 corrugated miter bends (Fig. 1). The miter bend is a component of a vacuum waveguide system that is installed in part of the 90-degree bend. In order to improve the transmission efficiency of a 2.5-inch corrugated waveguide, it is necessary to cut corrugated slots on the surface of the inside diameter of the miter bend. The parameters of the rectangular corrugation are a width of 0.3 mm, a depth of 0.3 mm, and a period length of 0.46 mm. These are going to be used in joint research with QST.

(K. Okada)

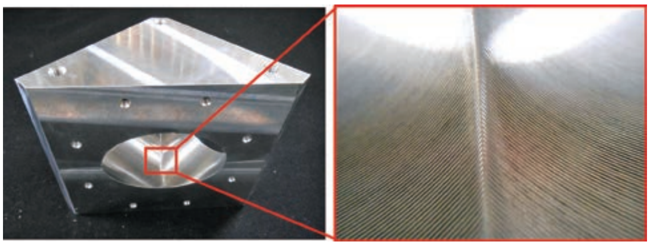

Fig. 1 2.5-inch corrugated miter bend

(2) 74.6 GHz Notch filter

We have fabricated a Notch filter (Fig. 2) for CTS. It has 24 cavities and an internal waveguide.

In order to determine a parameter of the cavity, we have analyzed the electromagnetic field. The cavity has a diameter of 3.0 mm and a depth of 3.05 mm to 3.10 mm. The rectangular waveguide has a length of 3.10 mm and a width of 1.55 mm.

(T. Shimizu)

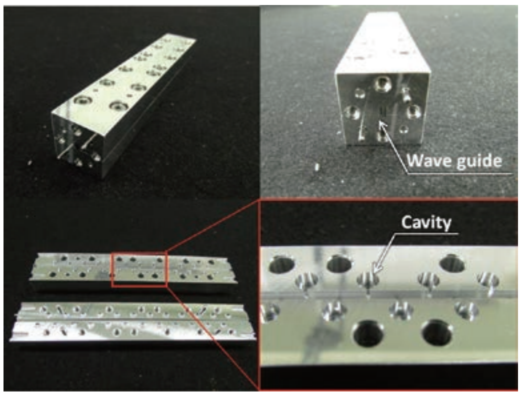

Fig. 2 74.6 GHz Notch filter

(3) Improvement of a 35-channel PN photodiode array amplifier

A 35-channel PN photodiode array amplifier is used to amplify the emission spectral signal when solid hydrogen pellets melt in plasma (Fig. 3). By dividing the previously constructed amplifier circuit board into separate boards for each of the two channels, we were able to reduce the noise by half.

(Y. Ito)

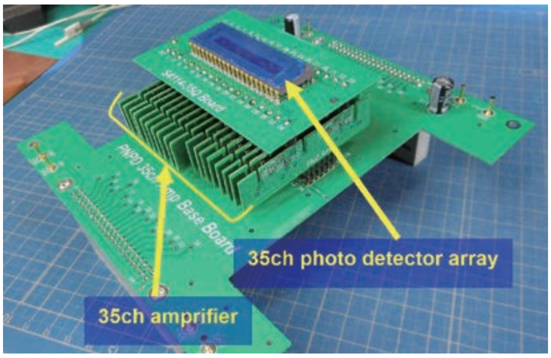

Fig. 3 35-channel PN photo diode array amplifier

(4) 16-channel level converter

We made a 16-channel level converter (Fig. 4). The vertical column is one channel, and each channel is implemented on an independent board with a shared power supply.

Each channel has voltage input, contact input, voltage output, and contact output from top to bottom. An internal switch changes the output between inverted and non-inverted.

(H. Furuta)

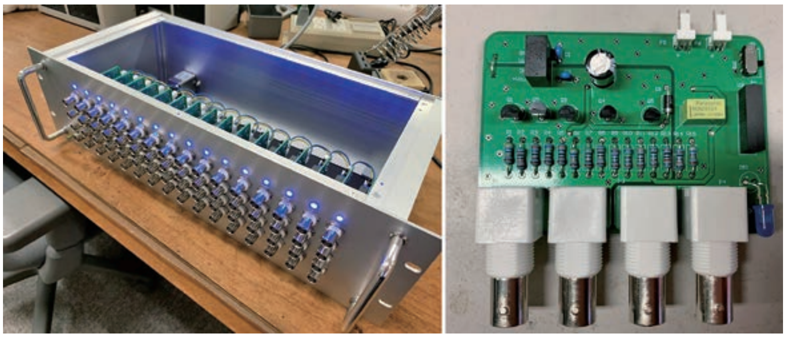

Fig. 4 16-channel level converter

2. Device Technology Division

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

(1) LHD operation

We started pumping a cryostat vessel for cryogenic components on August 10, 2022, and a plasma vacuum vessel on August 12, 2022. Subsequently, we checked for air leakage from the maintained flanges installed on the plasma vacuum vessel. As a result, we found leakage at a gate valve and repaired it.

The vacuum pressure of the cryostat vessel reached an adiabatic condition ($< 2 \times 10^{-2}$ Pa) on August 12, 2022, and the vacuum pressure of the plasma vacuum vessel was below 1×10^{-5} Pa on August 30, 2022.

The 24th LHD experimental campaign started on September 29, 2022, and was carried out until December 27, 2022. The total number of days of the plasma experiments was 53.

During this experimental campaign, the vacuum pumping system and the LHD utilities (for example, compressed air, water cooling, and GN2-supply systems) continued operating without problems. The 24th LHD operation was completed on January 27, 2023.

(N. Suzuki)

(2) Technical cooperation with universities and research institutions

We provided technical cooperation to universities and research institutions through numerical analysis and instrument development. An example of our achievement is shown below.

Based on the request of the Research Institute for Applied Mechanics at Kyushu University, we calculated the electromagnetic force generated on aluminum bus bars when the current for magnetic field coils flows through the bus bars installed in QUEST. The calculation was performed by the finite element analysis software ANSYS. An example of the analysis result is shown in Fig. 5. Based on the result of this analysis, we recommended that the material of the supporting structure for the aluminum bus bars be changed from SS400 to SUS.

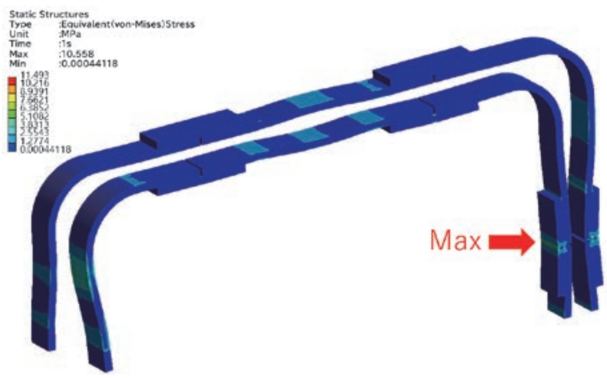

Fig. 5 Example of electromagnetic force analysis results for aluminum bus bars

(N. Suzuki and Y. Yanagihara)

(3) Development of an Electrostatic Deflector in a New Negative Ion Source for a Heavy Ion Beam Probe

Plasma potential, which is an important parameter for studying plasma, can be measured by a Heavy Ion Beam Probe (HIBP). A new ion source has been developed and installed in the actual HIBP to enable measurement even in high-density regions of plasma. Although the beam current was increased from 23 μA to 45 μA compared to the old ion source, it could not reach the target of 100 μA. The reason for the lack of current was found to be that the beam was off-center by about 6 mm from the short-tube center by measuring the beam profile. Therefore, we fabricated a new electrostatic deflector and installed it to adjust the beam alignment. The 3D-CAD drawing and photo of the electrostatic deflector are shown in Fig. 6. As a result of the modification, the effective beam current increased by about 1.38 times.

(H. Takubo)

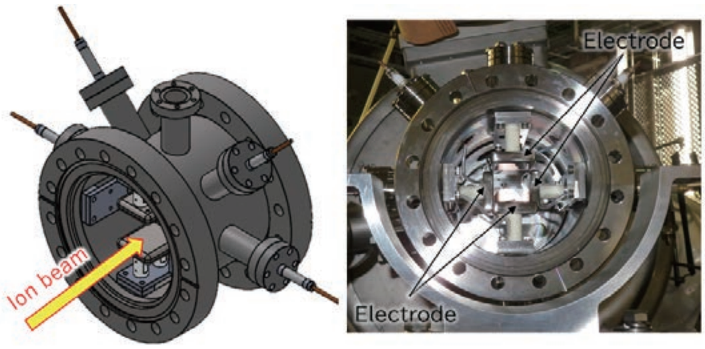

Fig. 6 Electrostatic Deflector for HIBP

3. Plasma Heating Technology Division

The main tasks of this division are the operation and maintenance of three different types of plasma heating devices and their common facilities. We have also provided technical support for improving, developing, and newly installing these devices. In this fiscal year, we mainly carried out device improvement and modification for the LHD plasma experiment and common facilities. The details of these activities are as follows.

(T. Kondo)

(1) ECH

During the 24th experimental campaign, we injected power up to 5 MW to assist plasma experiments. That contributed to the high performance of plasma with high ion and electron temperatures. Low power and long pulse injections could sustain the ECH plasma. One of the 77 GHz gyrotrons did not work well because of minor damage to the ceramic insulator for the hot cathode. Its operation was difficult because the electron beam current was unstable.

(Y. Mizuno)

(2) ICH

(a) The operation of ICH in the 24th experimental campaign of LHD experiments

In this campaign, we carried out the LHD experiment in total with two antennas with four antenna straps, that is, the HAS (Handshake type) antenna with two antenna straps at the 3.5U&L ports and the FAIT (Field-Aligned Impedance-Transforming) antenna with two antenna straps at the 4.5U&L ports of the LHD.

We decided on the combination of an RF transmitter and an antenna strap. Then the transmitters of #3 and #4 were connected to the 3.5U&L antenna straps, and the transmitters of #6A and #5B were connected to the 4.5U&L antenna straps. The total injection power from the four antenna straps into the plasma reached about 3.35 MW in a short pulse of four seconds at an RF wave frequency of 38.47 MHz.

(b) Installation of magnetostrictive type silicon oil level sensors for liquid stub tuners

A differential pressure gauge had been used to measure the oil level inside a liquid stub tuner until the 23rd cycle experiment. However, several noise problems caused by plasma discharge caused an error in the oil level measurement of up to 200 mm. In the 24th cycle experiment, magnetostrictive type oil level sensors were installed in oil tanks and, as a result, could measure the oil level without problems during plasma discharge.

(G. Nomura and M. Kanda)

(3) NBI

(a) The operation of NBI in the 24th campaign of LHD experiments

In this campaign, approximately 8,000 shots of beams were injected into LHD plasmas with three negative-NBIs (BL1, BL2, and BL3). The maximum injection power in this campaign was about 12 MW. As for positive-NBIs (BL4 and BL5), the maximum total injection power was about 18 MW. The NBIs had a few problems. For example, BL1 had a water leak in the extraction grids for ion sources and had to be injected with one out of two ion sources in the last two weeks of this campaign, and BL3 had a failure of a roughing vacuum pump.

(b) Installation of the small cooling water pumps for electric power savings

The NBI test facility has a 250 kW cooling water pump for the NBI heat load. While the cryopump is running, the cooling water pump cannot be stopped because the liquid nitrogen for the cryopump freezes the water inside the cooling pipes near the cryopump. The night electric power had been too much, so we added a 22 kW pump only for the cryopump operation at night. This small cooling water pump reduced electric power by about 70% compared with the past.

(M. Sato and M. Shibuya)

Fig. 7 Cooling water pumps

(4) Motor-Generator (MG) and cooling water facility for plasma heating devices

(a) MG

An MG is used to supply pulsed power to the NBI and the ECH for the LHD. The MG has supplied power for 15,794 shots in this fiscal year and 710,258 shots since its construction. The operation time was 864 hours.

(b) Cooling water facility

Three pump motors had been factory refurbished. The overhaul maintenance for pump motors, which has continued since last year, is over.

(Y. Mizuno)

4. Diagnostics Technology Division

Some plasma diagnostics devices have functioned for more than 20 years and thus require maintenance. This division mainly supports the operation, maintenance, and development of plasma diagnostics devices and radiation measurement devices for the LHD. In the LHD experimental campaign, we operated the diagnostics shutter system on experimental days. In addition, we have taken charge of radiation control.

(T. Kobuchi)

(1) Plasma diagnostic device

We supported the fast Thomson scattering diagnostic that measures the electron temperature and density in the LHD plasma. We have started up and shut down the operation of the system and changed its settings. We have also adjusted the schedule of measurement requests.

(H. Hashimoto)

(2) LHD data acquisition (DAQ) system

In the 24th LHD experimental campaign, the LHD DAQ system acquired data for about 8,000 plasma shots, and the total data generated was approximately 292 TB in compressed size. During the campaign, two DAQ PCs failed, and we responded by replacing one with a new computer and the other with a new storage disk. In addition, several DAQ PCs were migrated from Windows to Linux operating systems. Since this will lead to cost reduction, we plan to migrate them one by one in the future. The remaining capacity of the optical disks for long-term storage is about 30 TB, so it will be necessary to switch to new media for the next campaign.

(M. Ohsuna)

(3) Fusion Diagnostics Data Repository System and NIFS Article Information System (NAIS) development

We have developed a worldwide web system to publish raw data acquired in LHD plasma experiments. This system allows users to view and download the data via the Internet. Fig. 8 and Fig. 9 show search pages for acquired LHD experimental data.

To log in to the NIFS Article Information System (NAIS), you used to need this system account. But we have

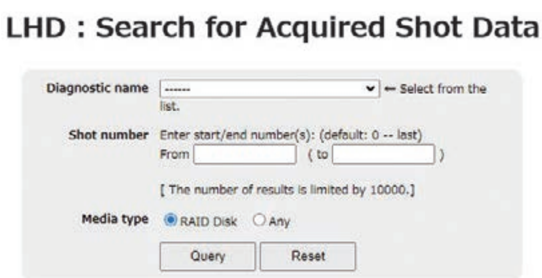

Fig. 8 Searching page for acquired shot data

introduced Shibboleth authentication to achieve a single sign-in. Therefore, users can log in with an account that is common to other systems.
(Link: https://nais.nifs.ac.jp/article/center)

(M. Nonomura)

Fig. 9 Searching page for acquired diagnostic data

(4) Radiation control

In order to control the safety of radioactivity, we carried out the operation and maintenance of three high-purity germanium (HPGe) detectors, seven liquid scintillation counters, a 2π gas-flow counter, and an auto well gamma system.

The concentration of drainage water, which is generated in the radiation controlled area, is measured using a liquid scintillation counter and an auto well gamma system. After confirming that the radioactivity concentration of drainage water is below the management value of NIFS, it is discharged. In the 2022 fiscal year, the radioactivity concentration of drainage water was measured 45 times.

To assess the impact of the deuterium experiments, we monitored the environmental radiation in the atmosphere, depositions, and river water. Among these results, the ^{7}Be concentrations in atmospheric aerosols and depositions from January 2014 to January 2023 showed that there was no impact on the surrounding environment due to the deuterium experiments, because the concentrations were within the range of environmental variations and ranged as other locations near NIFS.

Furthermore, atmospheric tritiated water vapor (HTO) has been collected every month by using a passive-type sampler since June 2015. The results of monitoring suggested that there were no clear experimental impacts in the vicinity of NIFS.

These monitoring reports were presented at the 24th Environmental Radiology Conference held at the High Energy Accelerator Research Organization in March 2023.

(M. Nakada, S. Kurita and C. Iwata)

5. Control Technology Division

The Control Technology Division is in charge of the 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 the 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.

(T. Inoue)

(1) LHD cryogenic system for superconducting coils

We have been making databases with maintenance information for all components of the LHD cryogenic system since 2020. So far, the database has found some components of the cryogenic system that require replacement. As a result, the cryogenic system operation in the 24th experimental campaign was performed without a significant accident. Fig. 10 shows the operation result. On August 19th, 2022, the He purification operation was begun. After that, the coil cool-down operation was performed in 607 hours. After approximately three months of plasma experiments, the coil warm-up operation was performed from December 28th to January 18th, 2023. The total operation period of the He compressors was 3628 hours, and their operation rates were 100%.

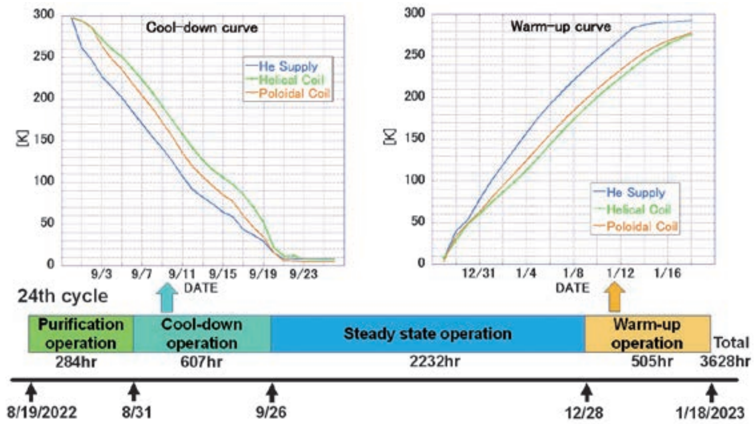

Fig. 10 The operation results of the LHD Cryogenic system for the 24th experimental campaign

(H. Tanoue and H. Noguchi)

(2) Management of utilities at the control building

We are in charge of managing the various utilities installed at the control building.

A 150-inch projector, an audio system, and personal computers for presentation are the most essential utilities for LHD operation and collaboration. And we also maintain a multi-function printer (MFP) for general purposes, four printers for experiment summary output, and a copy machine in the control room (Fig. 11). This fiscal year, the degraded MFP and two printers were updated.

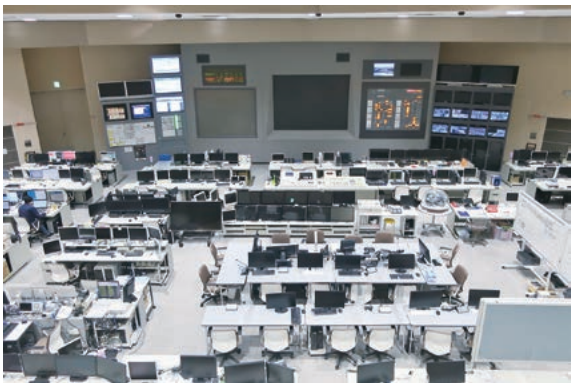

Fig. 11 Overview of the control room

There is a dedicated UPS on the first basement floor. It supplies electric power up to 200kVA/10min stably to the experimental infrastructure systems, such as the LABCOM data acquisition system, the Central Control System, and LHD-LAN devices.

We are responsible for not only device management but also fiscal budget management, user support, and IT system development for efficient administration. We will continue to maintain the control building as a center for research activities.

(H. Ogawa)

(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 2022 are as follows:

(a) Replacement of the edge switch

The edge switches in a research building, an administration building, and an experimental building have been replaced.

(b) SSL-VPN system update

Updated the SSL-VPN system from PSA5000 (Ivanti) to ISA8000 (Ivanti) (Fig. 12).

Fig. 12 SL-VPN System

The number of simultaneous connections has been upgraded from 2500 to 25000, and the interface has been upgraded from 1G to 10G. As a security measure, we continued to use two-factor authentication with client certificates.

(c) LHD-LAN

It is required in our security policy that the network management staff be present when connecting a new device to LHD-LAN. In FY2022, 22 new devices were connected to LHD-LAN, 59 devices were updated, and 16 IP addresses were made available due to device removal.

(T. Inoue and O. Nakamura)

6. An external evaluation of the Department of Engineering and Technical Services (DETS)

DETS was externally evaluated by the “2022 NIFS External Peer Review Committee” from the following six perspectives. Overall, we received high ratings of Excellent, outstanding, and Commendable. And we also received many suggestions and comments.

Evaluation perspectives

1) Contributed to deuterium experiments in LHD?
2) Contributed to the maintenance and utilization of the research platform in NIFS?
3) Are safety and health initiatives sufficient?
4) As an Inter-University Research Institution, have they conducted technical collaboration, exchange, and cooperation with universities and research institutes?
5) Has the technical experience and knowledge accumulated so far been utilized in industry-academia cooperation activities?
6) Is there an environment that supports the autonomy of individual technical staff members, together with a systematic effort to improve and pass on techniques?

(H. Hayashi)

7. Mission realization strategy project

The National Institutes of Natural Sciences started the “Mission Realization Strategy Project” in FY2022. The project was invited as a development project with the theme of contributing to the SDGs through the social implementation of fusion technology.

We proposed a six-year project on unutilized biomass as agricultural waste, and as a result of the screening, the project was adopted in June 2022. In this project, we aim to create biomass-derived high-performance activated carbon by utilizing our knowledge of activated carbon through the development of the closed divertor pumping system and metal bonding and sintering technology.

In FY2022, the experimental environment was improved by installing a tube heating device for carbonizing rice straw and a rotary kiln device (Fig. 13 (a)) for the activation process, as well as a spark plasma sintering device (Fig. 13 (b)) for conducting silica removal tests. In parallel, research on removing silica from the inside of rice straws was conducted, and as a result, efficient silica removal was successfully achieved using a vacuum heating device. We applied for a domestic patent for this achievement. We also made an oral presentation for our project at the International Symposium “KRIS2023” held by the National Institution of Technology, Japan (Fig. 13 (c)). We have also started collaborative research with Walailak University in Thailand for international joint research (Fig. 13 (d)).

Fig. 13 (a) Rotary kiln device (b) Spark plasma sintering device (c) Presentation in KRIS2023 (d) Group photo at the visit to Warailak University

(T. Murase)

8. Technical Exchanges

(1) Technical Exchanges to improve technical skills

Technical exchanges between our department and other institutes or universities were held in order to improve the technical skills of the staff. In this FY, we invited Mr. Sugisawa and Mr. Nakajima (Tohoku University) on February 13–16, 2023 (Fig. 14), and Mr. Aida and Mr. Haga (Tohoku University) on February 20–22, 2023 (Fig. 15).

Fig. 14 NC machine

Fig. 15 Measurement and control

(M. Yokota)

(2) Sixth technical exchange meeting: “Computational technology using the finite element method”

On February 17, 2023, we held a technical exchange meeting to discuss numerical computational technology based on the finite element method. This meeting, which was the sixth held hitherto, was attended by seven presenters and 41 participants, including those who used a remote web conference application (ZOOM), as shown in Fig. 16. In this meeting, two invited talks were presented under the titles “Possibilities of Ansys” and “Generation and propagation of electron cyclotron waves in the millimeter wave band with helical wavefronts.” In addition, five general talks were presented, all of which resulted in lively discussions.

(T. Murase)

Fig. 16 Group photos of the technical exchange meeting (a) at the NIFS site and (b) at the ZOOM system