16. Department of Engineering and Technical Services

The Department of Engineering and Technical Services covers a wide range of work in the design, fabrication, construction, and operation of experimental devices in the fields of software and hardware.

The department consists of the following five divisions. The Fabrication Technology Division oversees the construction of small devices and the quality control of parts for all divisions. The Device Technology Division works on the Large Helical Device (LHD) and its peripheral devices, except for heating and diagnostic ones. The Plasma Heating Technology Division supports ECH, ICRF and NBI systems. The Diagnostic Technology Division supports plasma diagnostic and radiation measurement devices, and oversees radiation control. Finally, the Control Technology Division concentrates on central control, cryogenic and current control systems, and the NIFS network.

The total number of staff is now 57 (2021). We have carried out development, operation and maintenance of the LHD and those peripheral devices, together with approximately 57 operators.

In FY2021 the Symposium on Technology in Laboratories and the 5th Symposium on computational technology, using finite element methods, were held at NIFS under the auspices of the Department of Engineering and Technical Services.

(Hiromi 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 84, and the production parts total number was 291 in this fiscal year (FY). The total numbers of electronic engineering requests and articles were 16 and 23, respectively. The details of some of this division’s activities follow below.

(M. Yokota)

(1) Focusing mirror for ECE

We have fabricated a focusing mirror (Fig. 1) for the Electron Cyclotron Emission (ECE) diagnostic. It has a spherical shape, and a radius of 1200 mm.

The material of the mirror is an aluminum alloy; the size of the mirror is 500 mm length and 350 mm width. It took 26 hours to complete the cutting process. This is the largest focusing mirror we have ever fabricated.

(K. Okada)

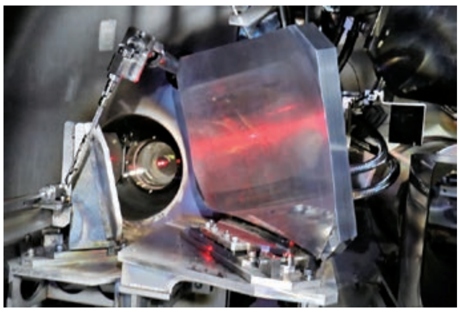

Fig. 1 Focusing mirror for ECE.

(2) 154 GHz Notch filter

We have fabricated a notch filter (Fig. 2) for ECE. It has four cavities and a waveguide in an internal space.

In order to decide the parameter of the cavity, we have analyzed the electromagnetic field.

The cavity has a diameter of 1.5 mm and a depth of 0.655 mm. The rectangular waveguide has a length of 1.651 mm and a width of 0.826 mm.

(T. Shimizu)

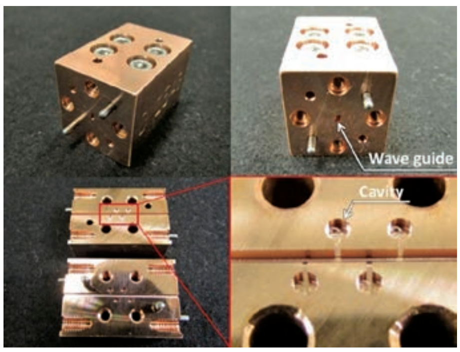

Fig. 2 154GHz Notch filter.

(3) Fabrication of DC offset voltage canceller

The circuits are cancelling DC offset voltage included in the output signal of ECE diagnostics.

The circuits of 12 channels are manufactured with an isolation amplifier (Fig. 3).

(Y. Ito)

Fig. 3 DC offset voltage canceller.

(4) 4ch LPF Amplifier

This LPF (Fig. 4) was made for ECE measurement.

An amplifier with an amplification factor of 1 to 6 times was mounted in the previous stage. A pie-type filter consisting of one inductor and two capacitors was mounted in the middle stage. The cutoff frequency was designed around 1.25 MHz. A buffer amplifier with an amplification factor of 1 was mounted in the latter stage.

We have succeeded in manufacturing products according to the required specifications and they are used for measurement.

(H. Furuta)

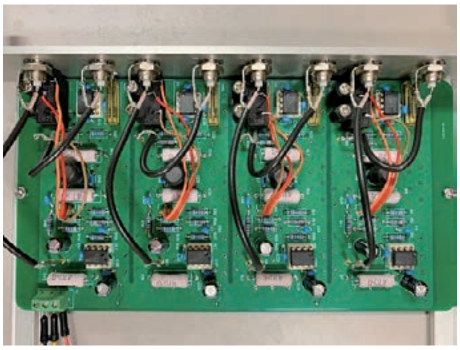

Fig. 4 4ch LPF Amplifier.

2. Device Technology Division

This Division supports the operation, improvement, and maintenance of the LHD.

(1) LHD operation

We started pumping the cryostat vessel for cryogenic components on August 19, 2021 and pumping the plasma vacuum vessel on August 20, 2021. Subsequently we checked for air leakage from the flanges on the plasma vacuum vessel. Thirty flanges were inspected. Consequently, we did not observe any leakage.

The pressure of the cryostat vessel reached an adiabatic condition ($< 2 \times 10^{-2}$ Pa) on August 20, 2021, and the pressure of the plasma vacuum vessel was below 1×10^{-5} Pa on August 30, 2021.

The LHD experiments of the 23rd LHD experimental campaign were started on October 14, 2021 and carried out until February 17, 2022. The total number of days of the plasma experiments was 61.

During this experimental campaign, the vacuum pumping system and the LHD utilities (for example, compressed air, water-cooling and GN2-supply systems) continued to operate without problems. The LHD operation was completed on March 11, 2022.

(N. Suzuki)

(2) Installation of an additional pumping system

To increase the pumping speed for helium we installed an additional pumping system with two turbo molecular pumps at the 6O port of the LHD, as shown in Fig. 5. The reason for increasing the pumping speed for helium was to support the helium beam experiments by NBI#5. The design pumping speed for helium was estimated at 10 m^3/s. The measurement result of the pumping speed was about 9.5 m^3/s for helium.

Fig. 5 The additional pumping system with two turbo molecular pumps.

(N. Suzuki)

(3) Development of tungsten divertor component via advanced bonding technique

We developed a technique for bonding tungsten (W) to chromium zirconium copper (CuCrZr) alloy, i.e., the powder solid bonding method (PSB). In this fiscal year, a W divertor component was fabricated via the PSB method. The divertor component comprises W plates, a CuCrZr alloy and a backplate made of SUS316. Helical cooling channels are provided inside the CuCrZr alloy. Helical flow pulls away the thick temperature boundary layer between the coolant and the CuCrZr alloy, and the contact heat transfer coefficient is effectively increased. Thus, the heat removal performance of the W divertor component is significantly better than that of a straight cooling channel. In the 24th experimental campaign, the W divertor component will be employed in an insertable divertor test module, installed at the 9.5L port of the LHD, to verify material damage in the plasma experimental environment, shown in Fig. 6.

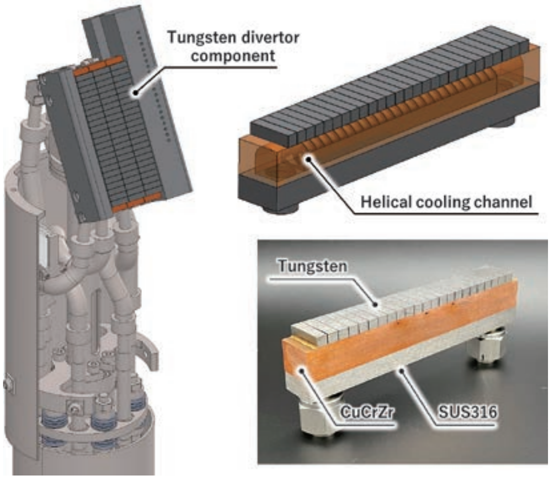

Fig. 6 Tungsten divertor component employed in an insertable divertor test module.

(T. Murase)

3. Plasma Heating Technology Division

The main tasks of this division are the operation and maintenance of three different individual 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 deuterium plasma experiments. The details of these activities are as follows.

(T. Kondo)

(1) ECH

During the 23rd experimental campaign, we injected power up to 5MW to assist plasma experiments. That contributed to achieving high performance plasma with high ion and electron temperatures. Low power and long pulse injection can sustain ECH plasma. Some trouble occurred, but all ECH technical staff of the LHD experimental group contributed to the various plasma experiments.

We developed a switching device for a corrugated waveguide for 154GHz-ECH plasma heating. It can switch from the normal pathway to an experimental one with flat and spiral-mirrors by remote-controlled switching ones. (Fig. 7)

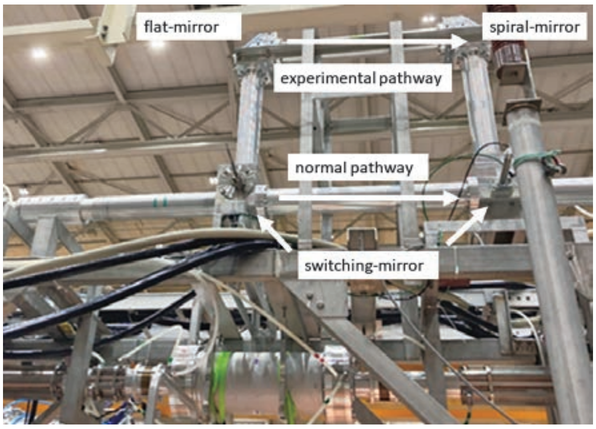

Fig. 7 A picture of the switching device for the ECH waveguide.

(Y. Mizuno and T. Takeuchi)

(2) ICH

(a) The operation of ICH in the 23rd experimental campaign of LHD experiments

In the 23rd experimental campaign, we carried out the LHD experiment with a total of two antennas with four straps, that is, the HAS (Handshake type) antenna with two straps at the 3.5U&L ports and the FAIT (Field-Aligned Impedance-Transforming) antenna with two 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 transmitter of #3 and #4 were connected to the 3.5U&L antenna straps and the transmitters of #6A and #6B were connected to the 4.5U&L antenna straps. The total injection power from the four antenna straps into the plasma reached about 3.2 MW in a short pulse of 0.6 seconds at an RF wave frequency of 38.47 MHz.

(b) Pump control for improved impedance matching

In the Ion Cyclotron Range of Frequencies (ICRF) heating, the oil level inside the stub tuner was controlled only by the cylinder, which reduced reflected power from the antenna. However, since the rate of change of the liquid level became insufficient, due to antenna improvement, a pump was also used for its control. Fig. 8 shows the experimental results. The updated system reduced the reflected power.

(G. Nomura and M. Kanda)

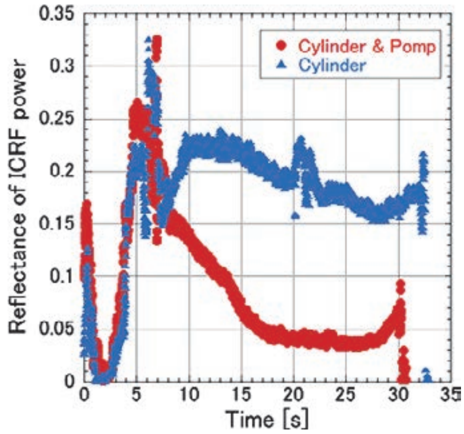

Fig. 8 A Reflectance of ICRF power.

(3) NBI

(a) The operation of NBI in the 23rd campaign of LHD experiments

In the 23rd campaign, approximately 8,000 shots of beams were injected into the LHD plasmas with three negative-NBIs (BL1, BL2, and BL3). The maximum injection power in this campaign was about 12 MW. As for the positive-NBIs (BL4 and BL5), the maximum total injection power was about 20 MW.

(b) Maintenance of the liquid nitrogen supply facility in LHD-NBIs

The transfer tube for liquid nitrogen consumed in the cryopumps of LHD-NBIs has a double-layered structure, composed of an inner and an outer tube. The space between these tubes is constantly evacuated to thermally insulate from the outer tube the inner ones, which reaches liquid nitrogen temperature when the cryopumps are operating. But we must evacuate this vacuum insulation layer of the transfer tubes periodically, because the degree of vacuum in this space gradually degrades over time. Thus, after the 23rd LHD experimental campaign, the vacuum insulation layer of the transfer tubes in NBI #5 was evacuated by a turbo-molecular pump up to 5×10^{-4} Pa at the pump head.

(M. Sato and H. Sekiguchi)

(4) Motor-Generator (MG) and Cooling water facility

(a) MG

An MG is used to supply pulsed power to NBI and ECH for the LHD. The MG has supplied power for 19,991 shots in this fiscal year and 694,464 since its construction. The operation time was 1,081 hours. A diagnosis of the insulation was performed for the generator and motor. Neither had a problem except for a corona discharge. There is no ozone odor, and we continue using it.

(b) Cooling water facility

The cooling water facility supplies pure water to ECH, ICH, and NBI. A 450A electric butterfly valve for ECH, a 350A one for ICH and a 350A glove valve for ICH were replaced as they had become too old. Two pump motors were serviced at the factory. For one, a stator wedge was missing, which was in a dangerous state.

(Y. Mizuno)

4. Diagnostics Technology Division

This division mainly supports the development, operation and maintenance of plasma diagnostic and radiation measurement devices for the LHD. In addition, we also have taken charge of radiation control.

(T. Kobuchi)

(1) Plasma diagnostic device

Some plasma diagnostics devices have functioned for more than 20 years and thus require maintenance.

In the Nd:YAG Thomson scattering system, the CAMAC control PC sometimes did not start normally. The system applies high voltage to the polychromator, and is an old one, working on Windows NT. We renewed the CAMAC controller and its control program that is compatible with Windows 10, then we replaced the PC with a new one at the end of the fiscal year. The new CAMAC controller is shown in Fig. 9. And it was confirmed that the new system operates normally.

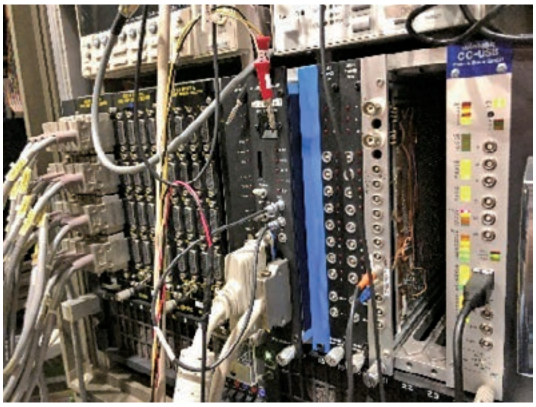

Fig. 9 The rightmost module is the newly added controller.

There are many observation windows on the LHD, and there is a shutter system that protects them from coating. Because the system uses serial communication, we improved it by use of Ethernet last year. We also renewed the operational program. Because we used the new standard Ethernet, equipment replacement has become easier. Even if the equipment breaks down, we can find a replacement. And the operability has been improved by updating the operation program. Though there were seven operational windows for each of the seven PLCs in the old program, they were combined into one window. It became easier to find the switch to operate. The old and new operation screens are shown in Figs. 10 and 11.

Fig. 10 The old operation screen.

Fig. 11 The new operation screen.

(Hiroshi Hayashi and T. Nishimura)

(2) LHD data acquisition (DAQ) system

The LHD data acquisition system operated almost steadily and acquired a total data volume of approximately 320 TB in compressed size in the 23rd experimental campaign. Before this campaign, we had prepared many spare HDD RAIDs and much optical storage, but we increased it further because the capacity of the optical disk became insufficient at the end of this campaign. Now the cartridge of the optical disk storage system is full. Therefore there is a possibility that a major change for long-term storage systems will be required before the 24th experimental campaign.

(M. Ohsuna)

(3) NIFS Article Information System (NAIS) and Zoom reservation system development

In order to streamline registration jobs in the NIFS Repository, we arranged for its manuscripts to be uploaded from the NIFS Article Information System (NAIS) and published to the Internet. As a result, registration information of the NIFS Repository can be shared on NAIS, and research deliverables can be published to the Internet, using the information of NAIS.

Regarding reservations for using Zoom in NIFS, we have changed the application process for submitting an Excel file, so that instead, a form can be submitted from a web browser. This saves the applicant the effort of creating an Excel file. In addition, since the application details are described and sent in an email, the person requiring the reservation does not have to open the Excel file, and the work can be streamlined. (Link: http://resomini.nifs.ac.jp/~sakamoto/zoom/index.html)

(M. Nonomura)

(4) Radiation control

In order to have stable management of radiation safety control, we have carried out the operation and maintenance of three high-purity germanium (HPGe) detectors, seven liquid scintillation counters, a 2π gas-flow counter, an auto well gamma system, three stack tritium monitoring systems, two gas ones, two dust and a drain water one.

A 2π gas-flow counter and an auto well gamma system are used for smear inspection. There are about 1,300 samples with about 150 smear inspection requests a year. These requests used to be put in by a paper application form and were approved by circulation of them by a few department managers. The approval took several days. Therefore, for the purpose of making it paperless, speeding up the approval process, and automatic evaluation of measurement results, we have developed a web-based application system to apply and to approve them online. The automatic evaluation has made it possible to report results faster and more accurately than before. This has made it possible to obtain approval on the same day of evaluation.

(M. Nakada and S. Hashimoto)

5. Control Technology Division

The Control 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 on the central control and cryogenic systems, coil power supply and super-conducting coils.

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

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

(H. Ogawa)

(1) LHD cryogenic system for superconducting coils

The cryogenic system operation in the 23rd experimental campaign was performed without a significant accident. Fig. 12 shows the operation result. From August 25th 2021, the He purification operation in the LHD cryogenic system was begun. After that the coil cool-down operation was started on September 8th 2021 and finished on October 4th 2021. (Cool-down time was 622 hours) After approximately five months of plasma experiments, the coil warm-up operation was performed from February 18th to March 11th 2022 (warm-up time was 482 hours). He compressors continuously operated during the cryogenic system operation phase, without any accidents suspending their operation. The total operation period of He compressors was 4750 hours and their operation rates were 100 %.

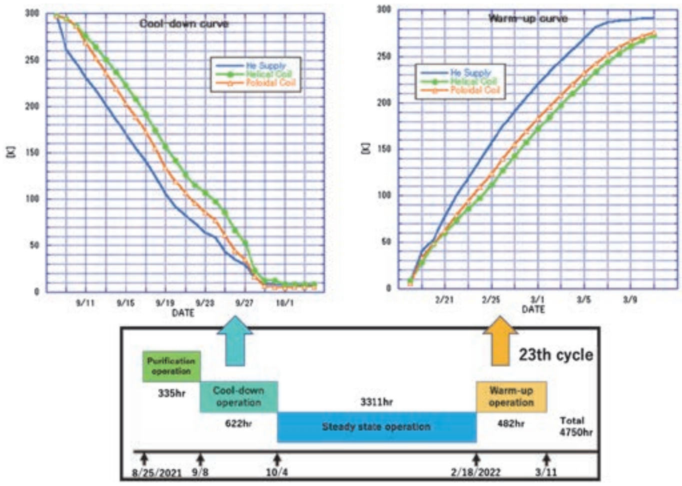

Fig. 12 The operation result of the LHD Cryogenic system for the 23rd experimental campaign.

(H. Tanoue and H. Noguchi)

(2) Implementation of remote operation system for Oroshhi2

In the Oroshhi2, we have been modifying the control system to realize a more secure and efficient operation. In F.Y. 2021, we introduced a touch-panel emulator which is compatible with Windows OS. It enables operation and monitoring not only from a physical touch-panel, but also from a remote Windows terminal. The terminal maintains a high level of security by allowing remote desktop connection under strict user management and connection source management policy.

We will develop additional functions, e.g. automated alert notification through email and customizable data logging, to improve usability.

(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 2021 are as follows:

(a) Replacement of the barrier L3 switch

The replacement plan was to expand the uplink from 10GbE to 100GbE. However, due to SINET access line procurement, we decided to maintain the current speed of 10GbE x 4 for the time being.

(b) Update the SSL-VPN system

We updated the SSL-VPN system from BIG-IP (F5 Networks) to PSA5000 (Pulse Secure).

Security level is enhanced by introducing two-factor authentications, using a client certificate in cooperation with an authentication server (NetAttest EPS).

(c) LHD-LAN

Our security policy requires that the network management staff needs to be present when connecting a new device to the LHD-LAN.

In FY2021 43 new devices were connected to the LHD-LAN and 53 devices were updated. Furthermore, 36 IP addresses became available due to device removal (disconnection from LHD-LAN).

(T. Inoue and O. Nakamura)

6. Symposium on Technology in Laboratories

The Symposium on Technology in Laboratories was held online, using Zoom Cloud Meeting, on March 10–11 2022. The National Institute for Fusion Science (NIFS) hosted this event. There were 253 participants from 43: Japanese universities, national laboratories, and technical colleges. Fig. 13 shows a gallery view of some participants of the Zoom meeting.

35 oral reports were presented in five technical groups. After each oral session we tried to have an exchange session, with each presenter using the breakout room in a Zoom meeting. This attempt was well received because it was possible to freely discuss matters, as in a poster session.

In addition, we had two online tours, each to show the Large Helical Device and the Helium liquefaction refrigeration system. About 100 participants engaged. The tours were also well received because participants could see areas they were not able to enter and view in the onsite tours.

Fig. 13　Participants in the Zoom meeting.

(T. Kobuchi)

7. Fifth technical exchange meeting: "Computational technology using finite element method"

On March 29 2022 we held a technical exchange meeting to discuss numerical computational technology, based on the finite element method. This meeting, the fifth hitherto, was attended by seven presenters and 43 participants, including those who used a remote web conference application (ZOOM), as shown in Figure 14. In this meeting, two talks by invitation were presented under the titles of "Introduction of ANSYS-centric solutions provided by Cybernet Systems, Inc." and "Optimization of electromagnetic analyses using the finite element method for the design of ICRF antennas in the LHD." In addition, five general talks were presented, all of which resulted in lively discussions.

(T. Murase)

Fig. 14　Group photos of the technical exchange meeting, (a) at the NIFS site and (b) in the ZOOM system.