1-2. Research and Development for LHD Upgrade

The LHD upgrade is projected to explore the high-performance plasmas relevant to the fusion reactor, as well as achievement of the goal of the LHD project that is to establish a physics basis extrapolated to a helical fusion reactor. Then, the device capacity has been improved. The LHD upgrade is executed based on the deuterium experiments, which is expected to drastically improve the LHD plasma parameters. The LHD upgrade project contains improvement of the physics and engineering of the LHD-related devices and power-up of the heating systems, together with development of highly precise diagnostics. Also, the safety management research plays an important role in the planned deuterium experiments.

The research and development for the LHD upgrade is categorized as follows;

(1) Study of Deuterium Experiment Program in LHD
(2) Safety Management Research
(3) Diagnostics System
(4) Physics and Engineering of LHD Torus and Heating Systems

The agreements for the environmental conservation and the LHD deuterium experiment were concluded between NIFS and local government bodies of Toki-city, Tajimi-city, Mizunami- city, and Gifu-prefecture in March, 2013. After that, the preparation for the deuterium experiment have been carried out including the program development.

As collaboration works with universities and research institutes, the physics and technical issues for the deuterium experiment have been intensively discussed. A workshop was held in order to share the basic idea of the LHD deuterium experiments, and a symposium was also held in the annual meeting of JSPF in 2013 to accelerate the participation of university collaborators.

The safety managements of experimental devices are major issues in the LHD research. Radiation management system and access-control system were well integrated for safety operation of the LHD and the related devices, and the results are intended to be applied to the LHD upgrade program. The radiation monitoring system (RMSAFE) has successfully worked. For the LHD deuterium experiment, the radiation safety management systems and the precise radiation monitors have been developed.

From a view point of the radiation safety for the deuterium experiment and for future fusion reactors, evaluation of the oxygen effect on the gaseous tritium recovery system, the tritium monitoring system, and the environmental radioactivity measurement have progressed.

For non-ionizing radiation monitoring and management, a visualization technique of the leakage electromagnetic field was proposed, and applied to measure the field distribution around the RF oscillators. In educational activities, the fabricated radiation sources were applied to the radiation education courses in high schools.

Development of the diagnostics system has been performed for precise measurements of the plasma parameters and toward the LHD upgrade. For the deuterium experiment, the planning of the re-arrangement of the diagnostics in LHD has started.

Important issues of how to integrate the experimental data from various diagnostics have progressed. The "quick look" was achieved by plotting the data in the time evolution and radial profiles within 1 min after the discharge. For the "comparison with the data from other diagnostics", the data viewer has been developed in order to integrate the data from various diagnostics.

For studies on plasma response to the perturbation, combination techniques of the instruments giving the perturbation to the plasma and the corresponding diagnostics have been developed. TESPEL is utilized in the cold pulse propagation experiment combined with ECE. The modulation ECH is used for the magnetic topology study combined with MSE spectroscopy and ECE.

Several diagnostics for turbulence study in LHD have progressed, such as PCI of CO_2 laser, multichannel reflectometer and BES for density fluctuations, and ECE for temperature fluctuations. The radial profile of neutral density was evaluated from H-alpha spectrum measured with high dynamic range spectrometer by the de-convolution analysis to study the low recycling wall.

For the LHD upgrade and the consequent physics and engineering contribution to a fusion reactor, research and development related to the LHD torus and heating systems have been performed. A new type of cryosorption pump was proposed for enhancement of the pumping efficiency in the closed helical divertor. High heat loading experiments for tungsten rods, jointed on Cu block with a cooling tube, have been carried out. The dynamics of in-depth migration and retention of hydrogen isotopes in CFCs have been investigated. With the TOKASTAR-2, a small toroidal device, effects of the plasma current on compact stellarator configuration have been investigated.

The development and the operation of the heating system have further extended the LHD plasma parameter regime in FY2013. The total injection powers in the negative- and the positive-NBI systems were 15MW and 12MW, respectively, and the ion temperature was raised to 8.1keV. The negative-ion-related physics research has progressed together with the technology developments, and R&D activities for the next-step negative-NBI system have also been carried out. In the ECRH system, the total injected power into LHD exceeded 4.6MW with three 77GHz and one 154GHz 1MW-gyrotrons. Successful development of the ICRF antenna systems resulted in long-pulse steady-state plasma sustainment with the density over $1x10^{19}m^{-3}$ for about 48min. by 1.2MW of the heating power of ICRF and ECRH in the 17th campaign of LHD.

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