1-2. Research and Development for LHD Upgrade

For achievement of the goal of the LHD project that is to establish a physics basis extrapolated to a helical fusion reactor, the LHD upgrade is executed to explore the high-performance plasmas relevant to the fusion reactor, and the device capacity has been improved. The LHD upgrade is projected based on the deuterium experiments, which is expected to drastically improve the LHD plasma parameters. The LHD upgrade project contains power-up of the heating system and improvement of the particle control with the closed helical divertor, 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

NIFS concluded the Agreements for the environmental conservation and the LHD deuterium experiment with local government bodies of Toki-city, Tajimi-city, Mizunami-city, and Gifu-prefecture in March, 2013. Then, the program development and the preparation for the deuterium experiment have just started.

The extensive study for the deuterium experiment has been executed by collaboration works with universities and research institutes. As the most important physics issue, the definition of mass-dependency (isotope effect) with high accuracy was discussed with a use of the tokamak experimental database.

In the safety management 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. A radiation monitoring system (RMSAFE) successfully works. Development of the precise radiation monitors, especially for the neutron protection and the tritium treatment, was performed toward the planned deuterium experiments in the LHD.

In the tritium treatment system, an extremely low level of tritium monitoring has been developed as the specific technology for the tritium removing/recovering system. The R&Ds were carried out for evaluation of a gaseous tritium recovery system, the tritium monitoring system, and the environmental radioactivity measurement.

In the non-ionizing radiation monitoring and management, measurement and analysis of the burst electromagnetic fields in the LHD has been carried out. The personal RF electromagnetic fields monitoring system was tested. In an educational activity, the fabricated radiation sources were applied to the experience-based radiation education held in the home for the first time.

The precise measurements of the plasma parameters are important issues for the LHD upgrade, for understanding the three dimensional effect on transport and MHD instability in toroidal plasmas. Development of the diagnostics system has been performed for the correlation study between the density/temperature fluctuation driven by the electrostatic turbulence and the magnetic field oscillations driven by the MHD instability.

The integration of the diagnostics data has been developed in two important issues, one is "mapping" and the other is "combination with numerical calculation". The mapping to the flux coordinate at each time-slice of the T_e measurement with the YAG Thomson is done between the shot intervals. The measured data and the calculated data are unified to one analyzed database, which is utilized for the transport analysis performed for all time-slices of the YAG Thomson measurements.

The measurements of turbulence have been developed, such as the phase contrast imaging (PCI) of CO_2 laser, the multichannel reflectometer, and the beam emission spectroscopy (BES) for the density fluctuations, and the electron cyclotron emission (ECE) for the temperature fluctuation with long range correlation. The HIBP has also been developed for the potential fluctuations due to the instability-driven high-energy particles.

Research and development related to the LHD torus and heating systems have been performed for the LHD upgrade and the consequent physics and engineering contribution to a fusion reactor. The closed helical divertor with the cryo-sorption pumping system was installed at 6 toroidal sections for efficient particle control, and the pumping experiments were carried out at one section. Tungsten is a prospective material for the plasma-facing armor in a reactor, and the properties of tungsten coatings on ferrite steel were investigated for high-heat flux load.

As for the development of the heating system, in the 16th campaign in FY2012, the total injection powers of 14MW and 12MW were available in the negative- and the positive-NBI systems, respectively, and the ion temperature was successfully raised to 7.3keV by the NBI heating. The negative-ion-related physics research has been carried out together with the technology developments, as R&D activities for the next-step negative-NBI system. In the ECRH system, one 1MW-class 154GHz gyrotron was operational, and the total injected power of ECRH exceeded 4.6MW including the three 1MW-class 77GHz gyrotrons. As a result, 13.5keV of the electron temperature was achieved at n_e=1x10^{19}m^{-3}. A pair of Field-Aligned-Impedance-Transformer (FAIT) antennas were developed for the ICRF heating experiment. That should contribute to extension of the steady-state plasma performance in the 17th campaign of LHD in FY2013.

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