1-2. Research and Development for LHD Upgrade

A goal of the LHD project is to establish a physics basis extrapolated to a helical fusion reactor. For this the LHD upgrade is projected to explore high-performance plasmas relevant to the fusion reactor. The LHD upgrade is based on the deuterium experiments, which is expected to improve the LHD plasma parameters drastically. In addition, power-up of the heating system and improvement of the particle control with the closed helical divertor are programmed as main items in the LHD upgrade, together with development of highly precise diagnostics. For the planned deuterium experiments, the safety management research should also be carried out.

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

(1) Preparatory Study for Deuterium Experiment
(2) Safety Management Research
(3) Diagnostic Systems
(4) Physics and Engineering of LHD Torus and Heating Systems

Presently, study for the deuterium experiment is restricted to the program development, in which a wide range of views from university researchers are incorporated through workshops and collaboration research. The most important physics issue to be clarified in the deuterium experiment is the isotope effect, i.e., the mass dependency of the plasma properties. For this issue, intensive discussion was made among the cooperative research group. Preparatory studies for the deuterium experiment are carried out at the universities. Precise measurement of the neutron yield is quite important for the safety management in the deuterium experiment, and the related study was made at Nagoya University. The deuterium retention has an influence on the isotope effect, and the related study was also made at Nagoya University.

The safety management research is directed to the present LHD experiments, and the results are intended to be applied to the future LHD upgrade program. The radiation safety issues for the LHD, the heating devices, and the HIBP accelerator were well managed together with the access control system. The radiation monitoring system (RMSAFE) also worked successfully.

The radiation safety management issue for the planned deuterium experiment is to develop precise radiation monitors and related technologies. For an extremely low level of tritium, the specific technologies of monitoring and removing/recovering are developed. The environmental tritium concentration is also measured. As an accurate evaluation method of the neutron dose, passive personal neutron dosimeters have been developed.

One of the other activities is non-ionizing radiation monitoring and management. Leakage of the static magnetic field and the electromagnetic waves would be concerned in a magnetic fusion facility. Measurement and analysis of the burst electromagnetic fields have been performed in the LHD, and a personal monitoring system for the RF electromagnetic fields was tested. For an educational use, a disk-shaped radiation source is proposed, which is made from natural materials containing weak radio-active components. These disks are used as portable weak radiation sources.

For the LHD upgrade, precise measurement of the plasma parameters is required in a three-dimensional helical configuration. The presently operated diagnostic systems, such as the YAG laser Thomson scattering system, the ECE system, and a 13-channel far infrared laser interferometer, have proven as reliable and precise diagnostics for the profile measurement, and their performance should be available in the LHD upgrade.

To obtain the fine structure of the density profile, a new type of reflectometer using an ultra-short sub-cycle pulse has been developed. Doppler reflectometry has also been developed to measure the perpendicular velocity of the electron density fluctuations. A heavy ion beam probe (HIBP) is being developed to measure potential and density fluctuation in high temperature plasmas.

For multi-dimensional measurements of the non-axisymmetric LHD plasma, 2-D or 3-D imaging diagnostics are under intensive development. A 3-D imaging system has been developed for the measurement of an electron temperature profile and its fluctuations and for the density fluctuation measurements.

Research and development related to the LHD torus and heating systems has been executed for the LHD upgrade and the consequent physics and engineering contribution to a fusion reactor. Efficient particle control by fueling and pumping is one of the key issues in the LHD. The closed helical divertor system is installed in FY2011, and a design study of the cryo-sorption pumping system is carried out. Observation of the dust behavior and investigation of the tungsten properties are made as subjects related to the plasma-wall interaction.

Development of the heating system is quite important to fusion relevant devices, as well as the LHD upgrade project. A positive-NBI was upgraded in FY2010, and the total injection power was increased to 26MW with both negative- and positive-NBIs, which contributed to the achievement of 6.5keV of the ion temperature. The R&D activities for the NBI development are also carried out for the next-step negative-NBI system. In the ECH system, three 77GHz gyrotrons are successfully operated for the plasma experiments, and the total injected power into the LHD exceeded 3.7MW, which contributed to achieve 20keV of the electron temperature. In the ICH system, a toroidal phasing antenna was designed and installed in the LHD, and the heating characteristics were investigated.

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