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, i.e., the establishment of the physics basis for helical fusion reactor. The upgrade of LHD is

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) Diagnostic System

(4) Physics and Engineering of LHD Torus and Heating Systems

The agreement for the environmental conservation and the LHD deuterium experiment was concluded between NIFS and the 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 discussed, intensively. A workshop was held in order to share the basic idea of the LHD deuterium experiments, and a symposium was also held in the Plasma Conference 2014 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, tritium is one of the key issues. The removing system from the exhaust gas of the LHD vacuum pumping system, the evaluation of the tritium monitoring system and that of 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. Neutron diagnostic is one of the key diagnostics at the deuterium experiment in the point of view of radiation safety control as well as that of plasma physics. A Neutron Flux Monitoring system was fabricated and partly installed in the Fiscal Year (FY) of 2014.

Development of heating system is inevitable for fusion relevant devices, such as ITER and DEMO, as well as the LHD experiments. Plasma heating and control by the high-energy Neutral Beam (NB) injection are most prospective to realize the burning fusion plasmas. The LHD is equipped with five NB Injectors (NBI) as main heating devices. The NBIs consist of three negative-ion based NBI and two positive-ion based NBIs. The total maximum injection powers of 14MW and 11MW were achieved during the 18^{th} campaign for negative-ion based NBI and positive-ion based NBI, respectively. The high power operation of NBI contributed to the extension of LHD plasma parameters, such as the achievement of 4.1% β-value at 1-T operation and the simultaneous achievement of high ion temperature of 6keV and high electron temperature of 7keV. 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 5.4MW with three 77GHz and one 154GHz 1MW-gyrotrons. Successful operation of the ICRF heating systems were carried. Its maximum heating power reached 4.5MW for 100ms operation and 3.9MW for 30s.

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