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Project Summary for LHD Deuterium Experiment

ＬＨＤ重水素実験計画の概要

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The project of the deuterium experiment in the Large Helical Device is summarized. The main objective of the deuterium experiment is to investigate the reactor relevant plasmas by improving the plasma performance. The isotope effect is highlighted as a physics issue to be identified for the burning plasmas. Upgrade of the low-energy NBI systems is planned for enhancement of the ion heating power, and 10keV of the ion temperature is expected. The closed helical divertor is installed for efficient particle control. The RF heating systems and the diagnostic systems are also upgraded for the deuterium experiment.

1. Objectives of LHD Deuterium Experiment

The Large Helical Device (LHD) has a plan of the deuterium experiment as the next step of the project. The basic concept of the LHD project is to understand the reactor relevant plasma performance in helical systems and to secure the design of a helical fusion reactor. To achieve it, the LHD plasmas should be also investigated with the view of toroidal plasmas compatible with tokamak plasmas on a scientific base. Considering the LHD project concept, the objectives of the LHD deuterium experiment are summarized as follows;

1. To realize high-performance plasmas by confinement improvement and to provide a wide range of plasma parameter space relevant to the reactor plasmas. As a consequence, scientific research area will be expanded with an increase in the variety of experiments.
2. To clarify the mass dependence (isotope effect) in the plasma confinement, leading to establishment of a model for the burning experiment using deuterium and tritium.
3. To demonstrate that the confinement capability of high-energy ions is relevant to the burning plasmas in helical systems.

2. Main Subjects in LHD Deuterium Experiment

The LHD Deuterium experiment should provide a wide variety of research opportunities. Among them the following subjects are highlighted as main subjects to achieve the objectives;

(a) Confinement improvement and related physics
Research on the isotope effect in the plasma confinement and the related confinement improvement in the deuterium experiments, toward systematic understanding of the toroidal plasmas.

(b) Improvement of MHD stability and expansion of high-β regime
Research on the MHD equilibrium and stability in high-β regime of collisionless plasmas realized by the confinement improvement and the increase in the heating power in the deuterium experiment.

(c) Confinement of high-energy ions
Research on the confinement of high-energy ions, such as ones accelerated by the ICRF D(H) heating scheme with a high-accuracy diagnostic.

(d) Optimization of divertor
Research on the particle and heat control in the peripheral plasma region with the closed helical divertor and improvement of the steady state plasma performance.

(e) Plasma wall interaction
Research on the isotope effects in the plasma wall interaction including the fuel recycling, to understand the behavior in the burning plasmas.

(f) Expansion of experimental approaches
Ion heating experiments by the ICRF heating schemes of H-minority/D-majority and ^{3}He-minority/D-majority.

3. Heating Scenario and Expected Plasma Parameters

In the LHD experiments for over 10 years, favorable compatibility of confinement and MHD stability in the inner-shifted configuration of the magnetic axis is one of the most important achievements. This should be applied to the high-energy ion confinement, and has resulted in the success of the ICRF heating and the perpendicular NBI heating experiments. Therefore, the upgrade of the low-energy perpendicular NBI is planned so that intensive research on the ion transport should be possible by enhancement of the ion heating power. Figure 1 shows a top view of the upgraded NBI systems for the LHD deuterium experiment. Two positive-NBI systems of the perpendicular injection are upgraded to 9MW from 6MW of the injection power by raising the injection energy for the deuterium injection. Although three negative-NBI systems of tangential injection are unchanged in the injection energy and power, the ion heating ratio is improved for low density plasmas by using the deuterium beams. The total deuterium injection power planned is 32MW (18MW of the positive-NBIs and 14MW of the negative-NBIs).

Assuming the energy confinement time twice the ISS95-scaling, the central ion temperature reaches 10keV at $2x10^{19}m^{-3}$ with the above NBI heating. At $1x10^{20}m^{-3}$, 3.8MJ of the plasma stored energy with 5keV of the central plasma temperature and 3% of the β value is also expected.

4. Device Development Program

The project of the LHD deuterium experiment will start after concluding the Agreement with local government bodies. The period of the deuterium experiment is scheduled for 9 years following around 3-year's preparation, such as construction of the tritium removal system, the neutron shielding system, the radiation safety monitor system, and the management system for the radiation-controlled area. In addition to the upgrade of the NBI systems, various device developments are programmed for the deuterium experiment.

4.1 *Closed helical divertor*

The active control of the peripheral plasmas by exhausting the fuel and impurity particles is planned with the closed helical divertor. In all inboard-side divertor area, closed-type helical divertors with baffle structure are installed, equipped with a pumping system under the dome. Figure 2 shows one section of the closed helical divertor. Improvement of the plasma performance is expected by controlling and pumping the fuel and impurity particles in the deuterium experiment.

4.2 *RF heating system*

For production of high-temperature plasmas and local control of the plasma potential and the rotational transform by the ECCD, the ECH system is upgraded to 6MW with 77 and 154GHz gyrotrons. Steady state heating is also possible at 1MW.

In the deuterium experiments, various ICRF heating scenarios can be applied, such as the D(H) and $D(^3He)$ heating schemes, the second-harmonic heating, and higher-harmonic heating in high-β plasmas. The ICRF heating system is upgraded to 6MW, which is available to steady-state heating experiments with around 3MW.

4.3 *Diagnostic system*

Neutron diagnostic system is greatly important not only for the measurement of plasma performance, but also for the radiation safety monitor. Fission chambers and scintillation counters are installed with precise calibration.

High-energy particle diagnostics system is also important to investigate the confinement capability of the high-energy ions in helical systems. The collective Thomson Scattering system and the loss ion probe system are planned.

Three-dimensional measurements are highlighted for deep understanding of the LHD deuterium plasma transport. The multi-channel ECE system is planned, including the microwave reflectometry and the BES system.

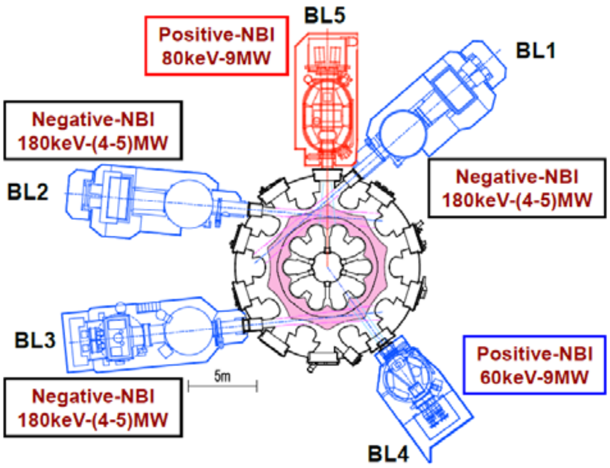

Fig.1. Top view of the upgraded NBI systems for the LHD deuterium experiment.

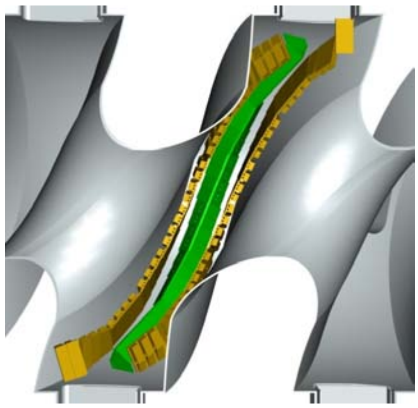

Fig.2. One section of the closed helical divertor.