I. National Institute for Fusion Science
April 2014 – March 2015

The most inevitable issue for mankind in this century is the energy security. Energy resources alternative to fossil fuels are indispensable for a sustainable society, since there is expanding demand for energy on a global scale due to the explosive population growth and economic development concentrated in developing countries. In addition, the increase in greenhouse gases like carbon dioxide due to continued use of fossil fuels and the depletion of fuel resources will become serious issues.

The realization of the nuclear fusion energy can resolve the serious environmental and energy crisis which human beings are now facing. The fuels for fusion can be obtained from seawater, therefore the fusion energy is virtually inexhaustible. Furthermore, the fusion reaction does not emit carbon dioxide, thus fusion energy can be the ultimate clean energy. The fusion research in the world has progressed year by year based on the steady progress of basic science and advanced technology. On the other hand, critical scientific and technological issues which must be resolved in order to put this energy resource in our hands, still remain.

This annual report summarizes achievements of research activities mainly concerning the fusion study at the National Institute for Fusion Science (NIFS) from April 2014 to March 2015. NIFS is an inter-university research organization, which conducts collaboration research programs under three frameworks, i.e., General Collaboration Research, Large Helical Device (LHD) Collaboration Research and Bilateral Collaboration Research. More than 500 collaborating research themes were proposed by collaborators in universities or institutes across the country. Proposals from abroad are also included.

With comprehensive studies about fusion science, NIFS emphasizes its roles as an inter-university organization as well as a COE in the development of human resources, pouring energy into the education for graduate students who will realize the generation of fusion power in the future. Such an advanced education is performed mainly through the Graduate University for Advanced Studies (Sokendai). In addition, graduate students from partner universities across the nation are also accepted.

In order to promote the scientific and engineering research towards the realization of fusion energy, NIFS conducts three major projects, which are the Large Helical Device Project, the Numerical Simulation Reactor Research Project and the Fusion Engineering Research Project. These three pillars stimulate each other and accelerate development of the first fusion demo reactor (DEMO). Short introductions and summaries for three projects are described as follows.

Large Helical Device Project

The Large Helical Device (LHD) is the world's largest stellarator/heliotron device that confines high temperature plasmas only by external coils. The LHD is equipped with superconducting coils, and, therefore, it has full capability for steady-state operation. Due to distinguished stability in both physics and engineering, the LHD has provided more than 131,000 plasma discharges in these 17 years since the initial operation. This large number of research opportunities has driven the progress not only in fusion research but also in innovative and interdisciplinary studies.

The experiment in the 18th experimental campaign was carried out by newly organized four experimental theme groups, i.e., three plasma physics groups and one engineering science group. The first plasma physics group named “Plasma Improvement Group” deals with mission-oriented themes, aiming at the deuterium experiment which is expected to start in 2017. The group explores the extended plasma parameter regimes, e.g., highest ion and electron temperatures, highest beta values, etc., by confinement improvement. The experimental proposals concerning the edge plasma physics, plasma-wall interactions, steady-state operation, atomic and molecular physics are assigned to the second “Plasma Physics and Engineering Group”. The third group called “Core Plasma Physics Group” deals with plasma transport, MHD and high energy particles. The group is also in charge of the 3-D physics and resonant magnetic perturbation (RMP) experiments. The “Engineering Science Group” conducts the engineering studies to improve the reliability of the superconducting coils and the cryogenic system to be used in the deuterium experiment.

Every research theme is proposed on the domestic and international collaboration programs. All groups have their leaders from both NIFS and universities. A leader from abroad is sometimes assigned, according to the experimental theme. The experimental schedule is arranged and finally determined in the board meeting of the experimental groups, consisting of group leaders. The board meeting is responsible for the all LHD experiment.

Numerical Simulation Reactor Research Project

In 2010, the Numerical Simulation Research Project was launched to evolve the tasks in the theory and simulation research activities at NIFS. Under the international and domestic collaborations on large-scale numerical simulation, the project is aiming to understand and systemize physical mechanisms in fusion plasmas and to realize the numerical test reactor (NTR). In order to make the objective of the project clear, the name of the project was changed to the Numerical Simulation Reactor Research Project (NSRP) in 2014.

In the project, eight research groups are set up to cover a wide range of simulation subjects, i.e., 3D physics, equilibrium and stability, high energy particle, fueling, transport, turbulence, edge physics, plasma-wall interaction, and other basic plasma physics supporting fusion science. Simulation methodology such as multi-scale simulation modeling and scientific visualization is also studied. Most of groups and themes are closely related to the LHD or general torus plasmas like tokamaks, on the other hand, some members in each group are concerned in the basic plasma physics, like solar and/or space plasma.

Most of the numerical study in this project is performed with the Plasma Simulator (PS) in NIFS. It is a massive parallel supercomputer system utilized to promote the NSRP. It has the total peak performance 315 TFlops and the total main memory 40TB. Together with PS, the LHD Numerical Analysis Server (LNAS) is used primarily for the LHD Project including its related simulation studies, and the research collaboration with the universities and the institutes.

Fusion Engineering Research Project

Based on the experience and knowledge obtained so far in LHD experiments, objectives of this project are focused on both the conceptual design of a steady-state fusion demonstration reactor and various engineering research and development, which are needed before entering into the engineering design activities for DEMO. This project consists of three research groups, (1) reactor system design, (2) superconducting magnets, and (3) in-vessel components, with the total 13 task and 44 sub-task groups.

The LHD-type device does not need plasma current. This excellent feature gives a great advantage for realizing a steady-state reactor. Therefore, along with a conceptual design of the helical reactor FFHR-d1 towards DEMO, by integrating design bases established so far on the designs of the FFHR series for commercial power plants, the project is carrying out research on key components, such as the superconducting coil system, high performance blanket, first wall, divertor, and so on. As the center of fusion engineering research for universities, the project enhances domestic and international cooperation to advance reactor design studies and R&D activities as well as to expand basic research lying in interdisciplinary areas.

In addition to the above mentioned 3 major projects which have well-defined missions, NIFS also supports interdisciplinary and basic research, and promotes the coordinated research for ITER-BA cooperation, laser cooperation and academic-industrial cooperation. A cluster of reports of such NIFS collaboration researches in basic plasma physics, plasma applications, and innovating concepts are also available in this annual report.

Lastly, I am grateful to our technical and administrative staff and contractors for their very strong supports of our research activity. All of the achievements are attributed to the tremendous efforts by all collaborators from Japan and abroad.

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