I. National Institute for Fusion Science
April 2015 – March 2016

Energy resources that are alternatives 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 such as carbon dioxide due to continued use of fossil fuels and the depletion of fuel resources will become serious issues. The realization of 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 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 around 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 place this energy resource in our hands still remain.

This annual report summarizes achievements of research activities mainly concerning fusion at the National Institute for Fusion Science (NIFS) from April 2015 through March 2016. NIFS is an inter-university research organization, which conducts collaboration research programs under three frameworks, General Collaboration Research, Large Helical Device (LHD) Collaboration Research, and Bilateral Collaboration Research. More than 500 collaborative research themes were proposed by collaborators in universities and research institutes across the country. Proposals from abroad were also included.

With comprehensive studies on fusion science, NIFS emphasizes its roles as an inter-university organization as well as a Center of Excellence in the development of human resources, pouring energy into education for graduate students who will realize the generation of fusion power in the future. Such an advanced education is conducted primarily 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. These 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 of these three projects follow below.

Large Helical Device Project

The Large Helical Device (LHD) is the largest class 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 eighteen years since the initial operation. This large number of research opportunities has driven progress not only in fusion research but also in innovative and interdisciplinary studies.

Every research theme in the LHD project is proposed in the domestic and international collaboration programs, and is performed by four experiment theme groups. The first plasma physics group, the “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, and other topics by confinement improvement. The experimental proposals concerning the edge plasma physics, plasma-wall interactions, steady-state operation, and atomic and molecular physics are assigned to the second group, the “Plasma Physics and Engineering Group.” The third group, the “Core Plasma Physics Group,” deals with plasma transport, MHD, and high energy particles. This group is also in charge of the 3-D physics and resonant magnetic perturbation 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. The leaders of these groups come from both NIFS and universities. Also, a leader from abroad is sometimes assigned, according to the experimental theme. The experimental schedule is arranged and finally determined by the group leaders at the board meeting of the experimental groups. The board meeting is responsible for all of the LHD experiment.

It was unfortunate that the experiment in FY2015 was cancelled due to the fire which broke out in a part of the cooling system for the superconducting coils on August 4. I am very sorry for the serious impact upon the collaboration programs. Although the LHD could provide no new experimental data, many valuable results were newly produced by collaborators in universities and research institutes, together with the NIFS staff, by utilizing accumulated experimental data up to the 18th experiment campaign. I thank all of the collaborators again for their excellent contributions.

Numerical Simulation Reactor Research Project

This project has been launched to continue the tasks in the theory and simulation research activities at NIFS. Under intensive international and domestic collaborations on large-scale numerical simulation, the project aims to understand and systemize physical mechanisms in fusion plasmas and to realize ultimately the numerical test reactor (NTR), which will be an integrated predictive modeling for plasma behaviors in a whole machine range.

In order to make this approach effective, eight research groups have been established, and these groups will cover a wide range of simulation subjects, including 3D equilibrium of core plasmas and its stability, high energy particle physics, plasma heating, plasma transport, micro and macro turbulence, burning plasma physics, fueling, periphery plasmas, plasma-wall interaction, other basic plasma physics supporting fusion science, and simulation methodology such as multi-scale simulation modeling and scientific visualization. The project was renamed as the Numerical Simulation Reactor Research Project (NSRP) in order to accelerate the research activity towards the construction of the NTR in 2014.

We have promoted the NSRP activities to develop and improve various simulation codes as a basis of the NTR, covering fluid, kinetic, hybrid, multi-scale, integral transport codes and other topics. By effective use of the Plasma Simulator replaced in 2015, we have applied them to magnetic fusion plasmas including LHD plasmas, and clarified new physical pictures on three-dimensional equilibria, transports, instabilities, and nonlinear evolutions.

Fusion Engineering Research Project

This project focuses 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. The project consists of three research groups, reactor system design, superconducting magnet, and in-vessel components.

The LHD-type device does not need plasma current, and this provides a great advantage for realizing a reactor. Therefore, along with a conceptual design of the helical reactor FFHR-d1 towards DEMO by integrating design bases established so far on the design studies of the FFHR series for commercial power plants, the project is carrying out research on key components, such as the superconducting magnet system, high performance blanket, first wall and divertors, and other topics. 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 in interdisciplinary areas.

In addition to the above mentioned three major projects, NIFS also supports interdisciplinary and basic research, and promotes the coordinated research for ITER-BA cooperation, laser cooperation, and academic-industrial cooperation. A group of reports regarding NIFS collaboration research in basic plasma physics, plasma applications, and innovative concepts are also available in this annual report.

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

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