PREFACE

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Currently, fusion energy research is progressing rapidly. The fusion triple product nτT has improved by one million times during 50 years of fusion research, from tabletop devices to the big science, i.e., breakeven experiment. Now, the era of the experimental reactor ITER—which will produce more than 500 MW of real thermal energy—has started. The recent progress was highlighted at the 50-year-anniversary International Atomic Energy Agency (IAEA) Fusion Energy Conference (FEC) 2008 in Geneva. This conference would be recorded as a landmark conference addressing the environmental problems of Earth in contrast to the 2nd IAEA FEC 1958 in Geneva, at which fusion energy research was declassified and peaceful usage started. We have been achieving the long-term integration of physics and engineering necessary for energy development. At the same time we have been promoting the development of research that follows the critical path and securing the basic sciences and supporting technologies necessary for fusion research. We also have continually disseminated scientific results and led the development of advanced science and technology in the field of nuclear fusion. Necessary human resources have been trained steadily. In IAEA FEC 2008, I concluded my summary talk with these sentences: "The Dream is Alive. Now Fusion Energy is an Achievable Goal!"

This special issue for the Large Helical Device (LHD) Project is devoted to recognizing the progress of fruitful heliotron research during the past 20 years since the National Institute for Fusion Science (NIFS) was founded, which contributes to the world progress of fusion research. The heliotron magnetic configuration was first proposed by Prof. K. Uo in 1958, which was before tokamak research was begun by Prof. L. Artsimovich (1960). The heliotron configuration has an intrinsic advantage of steady-state, current-less, stable disruption-less plasma operation. In Japan, this research line has a long history continuously developed by three generations of machines: Heliotron D (Kyoto University, 1970–1979), Heliotron E (Kyoto University, 1980–1998), and the LHD (NIFS, 1998–present). Heliotron D was the first generation, which was an epoch-making machine producing several hundreds of electron volts. Heliotron E was the proof-of-principle machine producing 1 keV. And, the LHD is the scientific demonstration–sized large machine possibly producing 10 keV and realizing the plasma regime close to the breakeven condition. This special issue is devoted to review of the LHD project as the 20th-anniversary issue for the NIFS.

The NIFS was founded on May 29, 1989, to conduct the LHD project. The LHD is the first large-scale helical device in the world. Characteristic and interesting physics and engineering features of the heliotron magnetic field with 1-GJ level, the world's biggest superconducting magnet system, has enabled us to explore the innovative approach of net current-free plasmas. The 8-year-long construction of the LHD was completed very successfully, and the first plasma was ignited on March 31, 1998, which was exactly on time according to the original schedule. After that, the LHD has been producing a wealth of achievements. I am grateful for the opportunity to contribute to the founding of the NIFS in 1989, to the 8 years of difficult construction of the LHD, and to 11 years of interesting experiments since 1998 as the leading scientist. I am fortunate to have worked with many skillful scientists and engineers, and I would like to thank them.

The NIFS is a unique interuniversity research organization responsible for stimulating collaborations with domestic and international universities and research institutes. The papers in this special issue consist of fruitful results achieved by all the people participating in this project. It is not necessary to explain the importance of the collaboration in science and engineering, which is now, for example, realized by the ITER project. The NIFS executed this approach more than 20 years ago, demonstrating the synergy effect among different organizations in the world. To elucidate this is another objective of this special issue.

Nowadays, it is possible to produce plasmas with 10 keV every 3 minutes. The maximum density reaches $10^{15}/cm^3$ by the internal diffusion barrier, which is exploring the new ignition conditions of extremely high density plasma with lower temperature. The β value achieved is more than 5%. These are the typical results of the LHD, which makes it possible to design many interesting experiments related to transport and stability for the scientific demonstration of fusion. The LHD experiments have produced numerous innovations in physics and technology. In any project, innovation is necessary to step up to the next stage.

On this occasion, on behalf of my all colleagues, I would like to express to Prof. A. Iiyoshi my most profound esteem for his leadership as a founder of the NIFS. I also would like to express my deepest gratitude posthumously to Prof. J. Yamamoto, Prof. M. Wakatani, Prof. H. Kaneko, and Prof. T. Hayashi for their great contributions to the LHD project. Their legacy is highly appreciated.

Fusion research has been realizing rapid progress due to the worldwide integration of science and technology. Now these efforts convince us that fusion energy is accessible, with clearly defined critical paths. An intensive and comprehensive approach with innovation is required to resolve the critical issues. This is the goal of the LHD project, and this approach also attracts and arouses diversified scientific interest.

Finally, I would like to thank Dr. Nermin Uckan for her great encouragement in promoting this special issue of *Fusion Science and Technology*.