4. JSPS A3 (China, Japan and Korea) Foresight Program

I. Project title

Study on critical physics issues specific to steady state sustainment of high-performance plasmas

II. Period of cooperation

August 2012 - July 2017

III. A3 foresight program in the field of plasma physics

The three countries, China, Japan and Korea (C-J-K), have recently built large toroidal devices called EAST, LHD and KSTAR having superconducting magnetic coils, respectively, and have successfully started the academic research aimed at the steady-state operation of high-performance plasma, which is an inevitable subject for the realization of fusion reactor. The EAST tokamak is characterized by a long pulse discharge with successful current drive and edge plasma physics research using high-Z plasma-facing components such as molybdenum and tungsten with high melting point. The KSTAR tokamak is characterized by the transport study on high-performance plasmas represented by H-mode discharge with edge transport barrier and the study for heat load mitigation of ELM activity in H-mode using various methods, e.g., pellet injection and stochastic magnetic field excited by RMP coils and so on. On the other hand, LHD is the largest HELICAL-type device, which confines the high-temperature plasma with the helical magnetic field generated by external helical coils alone. It is characterized by the steady state operation without the necessity of toroidal plasma current unlike tokamaks. Therefore, the properties of the LHD plasma are very distinctive and different from those of tokamak plasmas, e.g., the characteristic transport of high-energy particles based on three-dimensional magnetic configuration, the edge heat and particle transports based on inherently-equipped stochastic magnetic field and the disruption-free sustainment of long pulse plasma. By conducting joint research using the three world-class superconducting toroidal devices with entirely unique features, various advanced researches on critical physics issues to be resolved are possible toward the steady state operation of high-performance plasma. The proposed joint project will be certainly able to promote further development of plasma physics studies and fusion researches conducted by the three countries of C-J-K.

IV. Significant cooperative activities

When a discharge is longer, the handling of high heat load over the divertor and the first wall surrounding high-temperature plasma becomes a vital issue because it creates an entirely different situation from what has been studied in normal conducting toroidal devices with the discharge length strictly limited. The issue is a common and challenging subject among the three different devices in the three countries of C-J-K. The study of critical physics for the steady state operation of high-performance plasma is made possible only by superconducting devices and will produce important results for the first time with the three superconducting devices of C-J-K. Then, as the study focusing only on the critical physics that is revealed for the first time by the steady state discharge of high-performance plasmas, the following three critical physics issues are listed up for the joint research among C-J-K as shown in Fig.1. From 2013 the category IV is newly created for covering three experimental categories of I-III.

(I) Steady state sustainment of magnetic configuration
(II) Edge and divertor plasma control
(III) Confinement of alpha particles
(IV) Theory and simulation

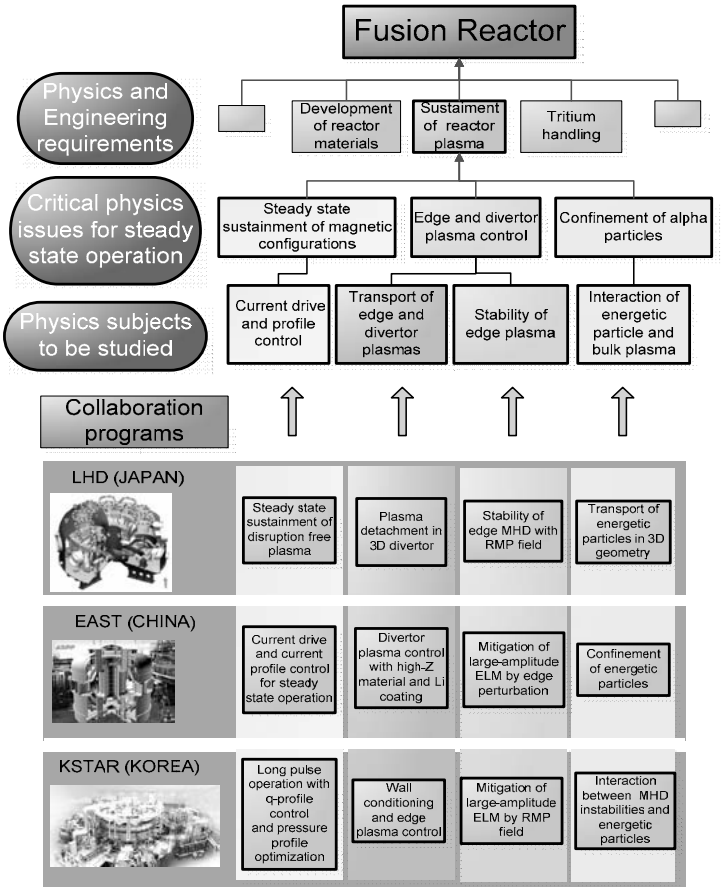

Fig.1 Schematic drawing on Joint Research Project among LHD (NIFS: Japan), EAST (ASIPP: China) and KSTAR (NFRI: Korea). Engineering requirements for the reactor can be reduced through the collaborative studies on critical physics issues specific to steady state sustainment of high-performance plasma. This Joint Research Project quests three 'Critical physics issues' for the steady state operation and these issues consist of four key 'Physics subjects' to be studied. The collaborative research is coordinated among 'Collaboration programs' by considering the characteristics and capability of three devices.

The three issues still remain as open questions for the steady state discharge of high-performance plasma, i.e., 'Critical physics issues for steady state operation' in the steady state operation as shown in Fig.1. The issues involved three unresolved subjects, which have to be studied through the present Joint Research. Individual studies should be along with the planned 'Collaboration programs' (also see Fig.1), which consider the characteristics of each of the devices.

V. Activities in FY 2013

The third seminar was held in Beijing of China on 20th - 23rd May 2013 as the scientific seminar to discuss the year's schedule and collaborative results in addition to the education of young scientists. Totally 76 scientists joined the seminar and several stuffs at the promotion in three countries supporting the A3 foresight program, JSPS in Japan, NSFC in China and NRF in Korea, also attended in this seminar for understanding the status and encouraging the future activities. The seminar proceeding is summarized as NIFS-PROC-95 [1]. In category I, threshold of mode penetration and development of high-time resolution Thomson scattering system in LHD, LHCD experiments, radiation power measurement, density fluctuations during L-H transition, development of TVTS diagnostic system and the first rest of pellet injection in EAST and a plan for sawtooth control by ECH in KSTAR were mainly discussed. In category II, problems of tungsten diagnostics in fusion devices, tungsten line emission measurement, hydrogen isotope inventories of co-deposited carbon layer, carbon distribution of detached plasmas, MHD spectroscopy using energetic particle driven modes, nonlinear MHD modeling of resonant magnetic perturbation and MHD simulation of 2.5D Rayleigh-Taylor instability in LHD, simulation of SOL/divertor plasmas, impurity transport with DIVIMP modeling, W/Cu materials, divertor particle and heat flux scaling, molecular dynamics simulation of tungsten divertor and deuterium retention with full graphite wall and development of EUV spectrometer in EAST and so on were discussed in addition to future plan of tungsten installation in KSTAR. In category III, fast ion loss probe detectors in LHD, KSTAR and EAST, ECE bursts, magnetic fluctuations on confinement and long-lived saturated mode during ELM-free H mode in EAST were discussed in addition to ELM mitigation studies in KSTAR.

The fourth scientific seminar was held in Gyeongju of Korea during 3rd - 4th November 2013 before 9th Asia Plasma and Fusion Association Conference (APFA) as the workshop to discuss the status and future direction based on experimental plans of each device. Present status of KSTAR, J-TEXT (HUST) and KTX (USTC) were introduced for future collaboration. Technical issues for steady state operation of KSTAR including real-time NTM control, MHD study for long pulse operation in LHD and plasma control and reconstruction of magnetic surfaces in EAST were discussed at category I. Status of collaboration and future direction of impurity study and progress of PWI collaboration were discussed in addition to edge plasma physics in EAST and KSTAR at Category II. In category II, ELM mitigation and suppression with low-n RMP and edge MHD instabilities among LHD, KSTAR and EAST were also discussed. Fast-ion diagnostics among three countries were discussed at category III in addition to the result of energetic particle measurement. Theory and simulation were also discussed on progress of collaborative study.

Main results of scientific collaboration are listed in the following.

[LHD]
1. Education of Chinese young scientist at EUV spectroscopy in LHD (3 months stay at NIFS)
2. Education of Korean young scientist at fast-ion driven instability in LHD (3 months stay at NIFS)

[EAST]
1. Development of EUV spectrometer in EAST for tungsten divertor study
2. Development of neutron diagnostic system in EAST for neutral beam injection
3. Collisional-radiative model analysis of He-beam probe for edge temperature and density measurements
4. Response of RMP in EAST
5. Progress of PWI study in EAST for hydrogen retention and material surface structure
6. Edge plasma and dust simulation in EAST
7. Theory and simulation studies on core plasma transport

[KSTAR]
1. Edge MHD instability in KSTAR for ELM mitigation
2. Development of escaping fast ion measurement in KSTAR
3. Collaboration of atomic molecular study in NRFI
4. Theory and simulation studies on core plasma transport

The statistical summary for personal exchange between Japan and China and between Japan and Korea is listed in Table 1.

Table 1 Statistical Summary of A3 collaboration in FY2013 (including scientific collaboration and seminars)

J→C person (person-day)	42 (243)
C→J person (person-day)	2 (62)
J→K person (person-day)	13 (60)
K→J person (person-day)	7 (56)

References

[1] Proceedings of the third meeting for A3 Foresight Program Workshop on Critical Physics Issues Specific to Steady State Sustainment of High-Performance Plasmas, 20-23 May, 2013, Beijing, China, NIFS-PROC-95 (2013), edited by Hu L.Q., Morita S. and Oh Y.-K.

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