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 plasmas, which is an inevitable subject for realization of the fusion reactor. The EAST tokamak is characterized by a long pulse discharge accompanied with H-mode based on successful current drive and tungsten divertor operation and related edge plasma physics in the long pulse discharge. The KSTAR tokamak is characterized by the study to mitigate high heat load at divertor due to ELM activity during H-mode transition and the transport study of high-performance plasmas represented by H-mode discharge with edge transport barrier. Various methods, e.g., pellet injection and edge magnetic field modification brought by RMP coils, have been attempted to the KSTAR tokamak with extremely low magnetic error field. On the other hand, LHD is HELICAL-type device, which confines the high-temperature plasma with helical magnetic fields generated by external helical coils. It is characterized by the steady state operation without the necessity of toroidal plasma current unlike tokamaks. Therefore, the properties of LHD plasmas are very distinctive and different from those of tokamak plasmas, e.g., characteristic transport of high-energy particles based on three-dimensional magnetic configuration, edge heat and particle transports based on inherently-equipped stochastic magnetic field lines and disruption-free long-pulse discharge sustainment. By conducting a joint research using above-mentioned three world-class superconducting toroidal devices with entirely unique features, various advanced researches on critical physics issues to be resolved for early realization of the fusion reactor are possible based on the long-pulse sustainment of high-performance plasmas. 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 located near high-temperature plasmas 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 plasmas 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 as follows.

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

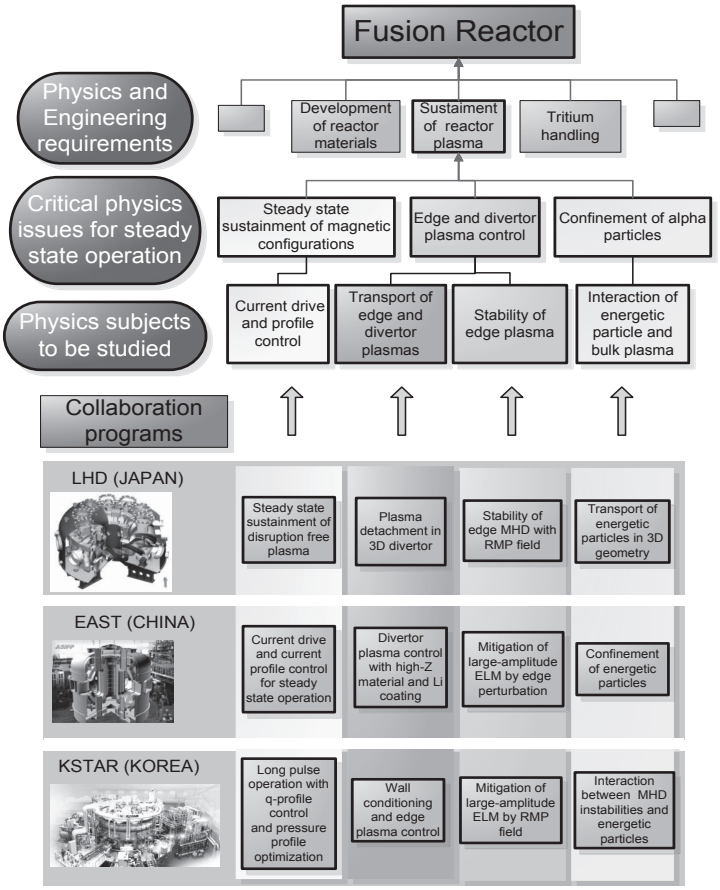

Fig.1 Schematic drawing on Joint Research Project among LHD (NIFS: Japan), EAST (ASIPP: China) and KSTAR (NFRI: Korea). Engineering requirements for the reactor can be reduced through the collaborative studies on critical physics issues specific to steady state sustainment of high-performance plasma. 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 of (I) to (III) categories shown in Fig.1 still remain as open questions for the steady state discharge of high-performance plasmas, i.e., 'Critical physics issues for steady state operation' in the steady state operation, while the category (IV) can contribute to all the categories of (I) to (III). 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 2015

The 7th and the 8th scientific seminars on A3 Foresight Program were held in Chuncheon of Korea during 19th - 22th May 2015 with totally 49 participants and in Gotemba of Japan during 1st - 4th December 2015 with totally 42 participants, respectively. In the seminars the collaborative results were presented with their check and review. The education of young scientists and students were also encouraged. A lot of fruitful discussions are made for four categories mentioned above and the future plan.

The tungsten workshop was also held in Dunghua University in Shanghai of China during 24-25 September 2015 with totally 19 participants from EAST, HL-2A, LHD, Shanghai-EBIT, Tokyo-EBIT, NIFS-coBIT and theoretical gruops. Discussions are made on spectroscopy, atomic structures and spectral modeling of low- and high-ionized tungsten ions for ITER diagnostics.

Main results of scientific collaboration are listed in the following.

[LHD]
1. Education of Chinese young scientists
2. EUV spectroscopy
3. MHD fluctuation in edge plasmas
4. High-energy particle diagnostics
5. Simulation study on wave-particle interaction

[EAST]
1. EUV spectroscopy in EAST for tungsten suppression
2. Neutron and fast ion diagnostics
3. Impurity transport in tungsten and graphite divertor
4. Installation of SX camera system for RMP study
5. PWI study on hydrogen retention with tungsten divertor
6. Simulation studies on edge plasma and dust transports
7. Simulation study on high-energy particles
8. Theory and simulation studies on core plasma transport
9. Atomic physics study on highly charged tungsten ions

[KSTAR]
1. Edge MHD instability for ELM mitigation
2. Fast ion loss and neutron diagnostics
3. PSI study on material surface structure
4. Theory and simulation studies on core plasma transport

Based on the collaboration totally 49 papers were published with A3 program acknowledgement in international journals after peer review by referees and 136 presentations were made in international conferences and meetings. In particular, recent progress on A3 Foresight Program was presented in APFA conference as an invited talk [1]. An EUV spectrometer was newly installed on EAST and tungsten diagnostic was started [2]. An effect of neutrals on the edge impurity transport was studied in LHD [3]. A collisional-radiative model was developed for analysis of visible spectrum from W^{26+} ions as joint work with atomic & molecular physics group [4]. Pressure-driven MHD instabilities were investigated for intrinsic and externally enhanced magnetic stochastic layer [5]. Resistive interchange modes were studied with its destabilization by helically trapped energetic ions [6]. Fast-ion-driven Alfven eigenmodes were simulated for EAST tokamak [7]. A simulation study was done on high-frequency energetic particle driven by geodesic acoustic mode [8]. A shear flow was investigated in the framework of nonlinear multi-scale interactions [9].

A statistical summary for personal exchange between J-C and between J-K listed in Table 1.

Table 1 Statistical Summary of A3 collaboration in FY2015

J→C person (person-day)	17 (298)*
C→J person (person-day)	35 (440)**
J→K person (person-day)	15 (109)
K→J person (person-day)	2 (12)

*included 3 month stay in ASIPP by Japanese SOKENDAI doctor student
**included 6 month stay in NIFS by Chinese USTC doctor student

[1] S.Morita, L.Q.Hu and Y.K.Oh, "Status of A3 Foresight Collaboration among China, Japan and Korea on Critical Physics Issues Specific to Steady State Sustainment of High-Performance Plasmas", 10th Asia Plasma and Fusion Association Conference, 14-18 December, 2015, Gandhinagar, India (invited).
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