10. International Collaboration

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 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 the long pulse discharge accompanied with H-mode based on successful current drive and tungsten divertor operation. The KSTAR tokamak is characterized by studies on the divertor heat load mitigation and the MHD turbulence based on high-performance plasmas with extremely low magnetic error field. On the other hand, LHD is characterized by the steady state operation without toroidal plasma current based on magnetic fields generated by external helical coils. Therefore, the LHD plasma has distinctive properties against tokamak plasmas, e.g., characteristic transport of high-energy particles based on three-dimensional magnetic structure, edge heat and particle transports based on inherently-equipped stochastic magnetic fields. By conducting a joint research among three superconducting devices with entirely unique features, various advanced studies 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.

IV. Significant cooperative activities

When the discharge is longer, the handling of high heat load on the divertor and the first wall becomes a vital issue and a challenging subject among the three devices. The study of critical physics for the steady state operation of high-performance plasmas is made possible only by superconducting devices. The following three critical physics issues are then listed up for the joint research among C-J-K as shown in Fig.1. The category IV covers 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

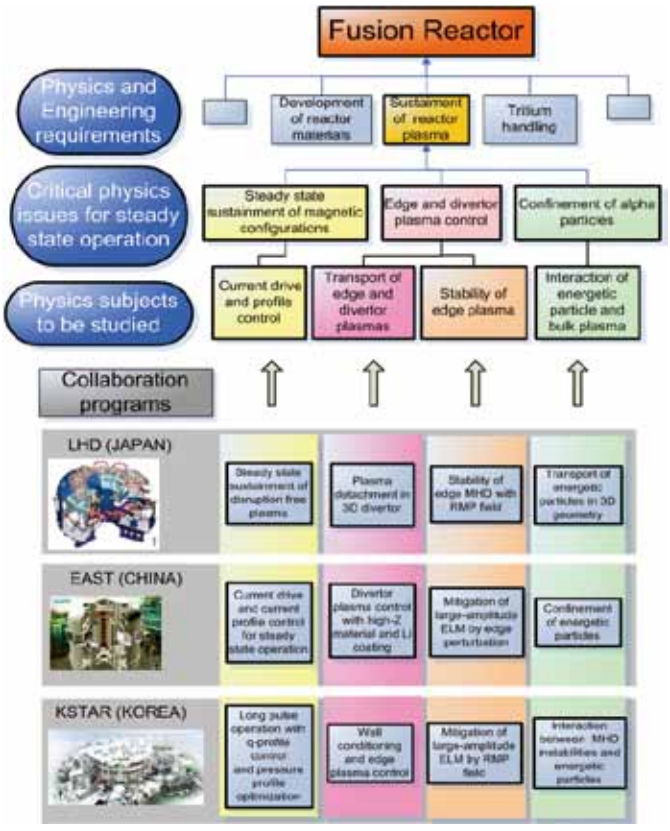

Fig. 1 Schematic drawing on Joint Research Project among LHD (NIFS: Japan), EAST (ASIPP: China) and KSTAR (NFRI: Korea). This Joint Research Project quests three 'Critical physics issues' for the steady state operation and these issues consist of four key 'Physics subjects' to be studied. The collaborative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

V. Activities in FY 2016

The 9th and the 10th scientific seminars on A3 Foresight Program were held in Yinchuan of China during 17 - 20 May 2016 with totally 51 participants and in Jeju of Korea during 22 - 25 November 2016 with totally 60 participants, respectively. In the seminars the collaborative results were presented with their check and review in addition to future plans. Many young scientists and graduate students were also invited for the oral presentation.

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. Neutron diagnostics
5. Simulation study on wave-particle interaction

[KSTAR]
1. Edge MHD instability for ELM mitigation
2. Neutron diagnostics and fast ion behaviors
3. PSI study on material surface structure
4. Simulation study on core transport and MHD turbulence

[EAST]
1. EUV spectroscopy for tungsten suppression
2. Neutron and fast ion diagnostics
3. Development of SX camera system for RMP study
4. PWI study on hydrogen retention with tungsten divertor
5. Simulation studies on edge plasma and dust transports
6. Simulation study on high-energy particles
7. Theory and simulation studies on core plasma transport

Based on the collaboration totally 47 papers were published with A3 program acknowledgement in international journals after peer review by referees and 42 presentations were made in international conferences in addition to 106 presentations in the A3 seminars. Recent progress on A3 Foresight Program was also presented in 13th APPC conference as an oral talk [1]. Tungsten behavior was studied during H-mode discharges and LHW heating was found to be effective to suppress the accumulation [2]. The impurity transport in stochastic magnetic field layer was studied in LHD [3]. A VUV telescope system for 2-D fluctuation measurement was upgraded by increasing the frame rate up to 6000 fps [4]. It was found that the resistive interchange mode could be suppressed by applying ECH heating above a threshold power [5]. Triton burnup was measured in KSTAR using a neutron activation system [6]. A new type scintillator-based fast ion loss detector was installed on EAST to investigate fast ion behaviors during NBI and ICRF heating phases [7]. Recent status on the fast ion diagnostics among EAST, KSTAR and LHD was reported as the A3 program collaboration [8]. Kinetic MHD hybrid simulations were carried out to study fishbone modes excited by fast ions on EAST [9].

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

Table 1 A3 collaboration in FY2016

J→C person (person-day)	30 (195)*
C→J person (person-day)	31 (326)**
J→K person (person-day)	17 (91)
K→J person (person-day)	0 (0)

*included 4 week stay in ASIPP by Japanese SOKENDAI student
**included 6 month stay in NIFS by Chinese USTC student

(S. Morita)

[1] S. Morita, L.Q. Hu, Y.K. Oh, N.Ashikawa, M. Isobe, D. Kato, S. Ohdachi, S. Sakakibara and Y. Todo 13th Asia Pacific Physics Conf., 4-8 Dec. 2016, Brisbane.
[2] L. Zhang, S. Morita, Z. Xu *et al.* Nucl. Mater. Energy (2017) in press.
[3] H.M. Zhang, S. Morita, S.Y. Dai *et al.* Phys. Plasmas **24** (2016) 022510.
[4] Z.J. Wang, T.F. Ming, S. Ohdachi *et al.* Rev. Sci. Instrum. **87** (2016) 11E307.
[5] X.D. Du, K. Toi, S. Ohdachi *et al.* Phys. Rev. Lett. **118** (2017) 125001.
[6] Jungmin Jo, MunSeong Cheon, M. Isobe *et al.* Rev. Sci. Instrum. **87** (2016) 11D828.
[7] J.F. Chang, M. Isobe, K. Ogawa *et al.* Rev. Sci. Instrum. **87** (2016) 11E728.
[8] M. Isobe, Junghee Kim, Yipo Zhang *et al.* Fusion Sci. Tech. **72** (2017) 60.
[9] Y.B. Pei, N. Xiang, Y. Todo *et al.* Phys. Plasmas **24** (2017) 032507.