10. International Collaboration

Japan-China Collaboration for Fusion Research (Post-CUP Collaboration)

I. Post-CUP collaboration

The post-CUP collaboration is motivated by collaboration on fusion research with institutes and universities in China including Southwestern Institute of Physics (SWIP). Collaborations with Institute of Plasma Physics Chinese Academy of Science (ASIPP), University of Science and Technology of China (USTC) and Huazhong University of Science and Technology (HUST) are basically included in the A3 Foresight Program financed by the Japan Society for the Promotion of Science (JSPS). The Post-CUP collaboration is carried out for both studies on plasma physics and fusion engineering, while the A3 program is carried out only for the plasma physics.

II. Activities of collaboration in FY 2016

In 2016 FY 9 scientists visited SWIP including young scientists and graduate students. Two scientists visited Fudan University and Dalian University of Technology individually. 11 scientists visited NIFS from SWIP including visitors of graduate students from USTC based on Sakura Science Program. Three seminars were also taken place in China as the Post-CUP collaboration;

1. China-Japan-Korea Joint Seminar on Atomic and Molecular Processes in Plasmas (AMPP2016) hosted by SWIP, 26-28 July 2016, Chengdu, China (42 oral presentations)
2. China-Japan Symposium on Materials for Advanced Energy Systems and Fission & Fusion Engineering (CJS-13) hosted by Institute of Nuclear Energy Safety Technology (INEST), 26-29 September 2016, Hefei, China (270 participants)
3. China-Japan Collaborative workshop on Stability and Transport of Edge Plasmas hosted by ASIPP, 3-4 March 2017, Fuzhou, China (25 oral presentations including 13 graduate and post-doctoral students and 5 young scientists)

Some of results on the Post-CUP collaboration in 2016 FY are described in the following.

The effect of ECRH on the impurity transport has been investigated with ECRH power deposition in HL-2A [1,2]. When the ECRH power deposits inside the sawtooth inversion radius an inverse sawtooth oscillation combined with a long-lasting m/n = 1/1 mode is observed with a sudden negative jump in the central soft x-ray chord. Aluminum is then injected into discharges with inner- and outer-deposited ECRH using laser blow-off (LBO) method. Temporal behaviors of the SXR signals are analyzed with one-dimensional impurity transport code. The result shows that the radial transport of the Al ions is strongly enhanced by the inner-deposited ECRH. The simulation also indicates that the centrally peaked Al profile appeared in the outer-deposited ECRH can be effectively flattened by the inner-deposited ECRH.

The iron impurity density in the central column of LHD plasmas with a hollow electron density profile is found to be much smaller than those with a peaked density profile based on the radial density profile measurement of iron ions in several ionization stages [3]. The iron impurity transport has been studied with the help of a one-dimensional simulation code. The radial structure of convective velocity suggests that an impurity transport barrier is formed by a strong density gradient effect on the impurity convection near the edge region of LHD plasmas with a hollow electron density profile.

A collisional-radiative (CR) model is developed to analyze magnetic dipole (M1) lines emitted by W^{q+} ions in the ground state ($4d^{10}4f^k$) [4]. Proton collision effects on the M1 line intensity are theoretically investigated with the CR model. The result suggests that the proton collision facilitates a significant radiative decay of the sub-valence excited configuration ($4d^9 4f^{k+1}$) to the ground state. It leads to an enhancement of the M1 line intensity. The ion density of W^{27+} ions is successfully obtained in LHD plasmas based on the present modeling.

The transport properties and line emissions of carbon impurity in the stochastic layer of LHD are studied with 3D edge transport code EMC3-EIRENE [5,6]. The modeling has revealed that the impurity perpendicular transport coefficient (D_{imp}) and the first wall source play important roles, while changes to the ion thermal and the friction forces are rather irrelevant. The analysis indicates that D_{imp} might be larger than that of background plasma by a few factors and also that there probably exists a substantial amount of first wall impurity source.

[1] Z.Y. Cui, K. Zhang, S. Morita, X.Q. Ji, *et al.*, “Study of impurity transport in the HL-2A ECRH plasmas with MHD instabilities”, 26th IAEA Fusion Energy Conference, 17-22 October 2016, Kyoto (Japan), EX/P7-21 (2016).

[2] X.R. Duan, Y. Liu, M. Xu, L.W. Yan, Y. Xu, M. Isobe, S. Morita *et al.*, to be published in Nucl. Fusion **57** (2017).

[3] X.L. Huang, S. Morita, T. Oishi, *et al.*, “Formation of impurity transport barrier in LHD plasmas with hollow density profile”, 26th IAEA Fusion Energy Conference, 17-22 October 2016, Kyoto (Japan), EX/P8-5 (2016).

[4] D. Kato, K. Fujii, M. Goto, T. Oishi, X.-B. Ding, C.-Z. Dong, S. Morita, *et al.*, “Collisional-radiative models for ground-state M1 line emission of highly charged tungsten ions in the LHD”, NIFS-PROC-103 (2017) 17-21.

[5] S. Dai, M. Kobayashi, G. Kawamura, S. Morita, T. Oishi, *et al.*, Contrib. Plasma Phys. **56** (2016) 628.

[6] S. Dai, M. Kobayashi, G. Kawamura, S. Morita, H.M. Zhang *et al.*, Nucl. Fusion **56** (2016) 066005.

(S. Morita)

Fig. 1 China-Japan Collaborative workshop on Stability and Transport of Edge Plasmas (Fuzhou, China, 3-4 March 2017)