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

I. Post-CUP collaboration

The post-CUP collaboration is motivated by collaboration with Southwestern Institute of Physics (SWIP), institutes and universities in China for fusion research. The SWIP is now operating HL-2A tokamak and starts to construct HL-2M tokamak, of which the first operation is expected at the end of 2017, for further fusion studies. Collaboration 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), of which the institutions are operating EAST tokamak, J-TEXT tokamak and KTX reversed Field pinch devices. The Post-CUP collaboration is carried out for both the studies on plasma physics and fusion engineering, while the A3 program is carried out only for plasma physics required for steady state sustainment of fusion plasmas.

II. Activities of collaboration in FY 2015

In 2015 FY 11 scientists visited at SWIP including young scientists and graduate students. Some of the results are described in the following.

Impurity transport in the scrape-off layer (SOL) has been studied in ohmically heated discharges of the HL-2A tokamak based on space-resolved vacuum ultraviolet spectroscopy [1]. The vertical profile from the plasma center to the lower X-point of carbon emissions of CIII (977 Å: $2s^2\ ^1S_0$-$2s2p\ ^1P_1$) and CIV (1548 Å: $2s\ ^2S$-$2p\ ^2P$) as well as the ratio of CIV to CIII were measured to investigate the edge impurity transport with relation to impurity source locations and sputtering characteristics. The experimental result shows that the impurity profile in the SOL has been clearly changed against different source locations. The emission of CIII and CIV from the mid-plane is stronger than that from the X-point when the impurity source is located at the divertor plate. The profile becomes flat as a result. When the impurity source changes to the dome source, the profile clearly changes to a slightly peaked one, indicating the edge carbon emission at the X-point is stronger than the mid-plane. The change to the limiter source makes the profile further peaked by increasing the carbon emission at the X-point. In the case of the dome impurity source, the intensity of CIII/n_e and CIV/n_e, normalized to line-averaged electron density, ne, decreases with n_e at low n_e ($n_e \le 2.6\times10^{13}$cm^{-3}) and becomes saturated at high ne ($n_e > 2.6\times10^{13}$cm^{-3}). In contrast, the ratio of CIV to CIII increases with n_e at low n_e and starts to decrease at high n_e. A numerical simulation with 3D edge plasma transport code, EMC3-EIRENE, suggests that a poloidal asymmetry in the impurity flow profile and an enhanced physical sputtering play an important role in the edge impurity distribution.

Characteristics of fast-ion losses induced by various magnetohydrodynamic (MHD) instabilities such as tearing mode (TM), long-lived mode (LLM) and sawtooth crash have been observed and experimentally investigated in the HL-2A tokamak [2]. To study fast ion losses, a new scintillator-based lost-fast ion probe has been developed and used, and an increment of the fast-ion loss rate as the MHD amplitude increase has been measured. Compared with TM and LLM, the fast-ion losses induced by sawtooth crash have a broad range in energy and pitch angle. There may be some interactions between fast ions and magnetic disturbance, which cause the losses with a wide range of energy and pitch angle. During disruptions, the total neutron emission rate drops by ~90% as a result of the strong fast-ion losses. The possible reasons for this phenomenon are the strong magnetic perturbations and the drastic change of the fast-ion transport. In addition, the clear experimental evidence of drastic losses of fast ions during disruptions has been obtained.

A simulation and decomposed each individual term in the transition matrix level are performed [3] and it is found that the Breit interaction is dominant when the leading term contribution of the two-electron Coulomb interaction is vanished. Based on this mechanism, it is explained why the dielectronic capture strength to $1s2s^2P_{1/2}J_d$=1 state is much stronger than the one to $1s2sP^2{}_{1/2}J_d$=1 as well as why the Breit interaction plays a dominant role in the anisotropic parameters. The present result may guide to search some physical processes in which the Breit interaction is dominant by simply analyzing the coupling coefficients for a given isoelectronic sequence.

The nonlinear evolution of the Kelvin-Helmholtz (KH) instability driven by a radially antisymmetric shear flow in the double current sheet configuration has been numerically investigated based on a reduced magnetohydrodynamic model [4]. Simulations reveal different nonlinear fate of the KH instability depending on the amplitude of the shear flow, which restricts the strength of the KH instability. For strong shear flows far above the KH instability threshold, the linear electrostatic-type KH instability saturates and achieves a vortex flow dominated quasi-steady state of the electromagnetic (EM) KH turbulence with large-amplitude zonal flows as well as zonal fields.

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