DYNAMICS OF INTERNAL RECONNECTION EVENTS IN VERSATILE EXPERIMENT SPHERICAL TORUS

M. W. Lee[1], Won ik Jeong[2], Soobin Lim[3], Chan-hwi Jeon[2], Jiyun Han[4], Ji Hwan Kim[2], Y. S. Hwang[2], C. Sung[1]*

[1]Korea Advanced Institute of Science and Technology, Daejeon 34141, Republic of Korea
[2]Seoul National University, Seoul 08826, Republic of Korea
[3]Q-beam solution Inc., 160, Daehwa-ro, Daedeok-gu, Daejeon, Republic of Korea.
[4]MIT Plasma Science and Fusion Center, Cambridge, Massachusetts 02139, USA

*Email: choongkisung@kaist.ac.kr

1. EXECUTIVE SUMMARY

We investigate the dynamics of the internal reconnection event (IRE) [1] in the Versatile Experimental Spherical Torus (VEST). Firstly, the dynamics of magnetohydrodynamics (MHD) modes associated with IRE were studied through multichannel soft X-ray (SXR) measurements. The excitation of MHD modes before IRE was reported in several devices [2–4], and it was also predicted by nonlinear MHD simulation on IRE [5]. From previous works, the coupling or overlap of the modes before IRE has been thought to play an important role in the IRE process. In VEST cases, we observed that two coherent modes were excited about 1 ms before IRE at two central frequencies (5 kHz and 8 kHz). By multichannel SXR analyses including two-dimensional tomography, the mode dynamics associated with the IRE process were analyzed. Furthermore, electron temperature (T_e) in the IRE was measured by the two-filter SXR method [6] for the first time, revealing fast T_e evolution on the order of microseconds. The IRE dynamics will be presented in this work will enhance the understanding of the physical mechanism of IRE, which is a unique phenomenon in spherical tokamaks that affects the stability and confinement of the plasmas.

2. MAIN RESULTS

Using SXR measurements, we studied the characteristics of excited modes before IRE bursts. Figure 1(a) shows the plasma current of VEST discharge #44401, which is in a current ramp-down phase that shows frequent IRE bursts in VEST plasmas. Considering the changes in plasma current and core SXR level shown in Figs. 1 (a) and (b), respectively, the start timing of the IRE process is marked as a dashed line (308.44 ms). From a core SXR channel, we observed the onset of fluctuations in a core SXR channel approximately 1 ms before IRE was started. The wavelet spectrum of the SXR channel, shown in Fig. 1(d), reveals two coherent modes with center frequencies of 5 kHz and 8 kHz. As shown in Fig. 1(c), the constructive interference of the two modes was observed near IRE onset time (308.44 ms). Two-dimensional tomography reconstruction shown in Fig. 1(e) also revealed a local increase in the SXR image at the same time. Then, the overall decreases of SXR were observed (308.51 ms), which may be related to thermal quench phase [5]. Next, sudden burst of SXR and current increase happened (308.59 ms). Further analyses including possible correlation between modes and the IRE process will be presented.

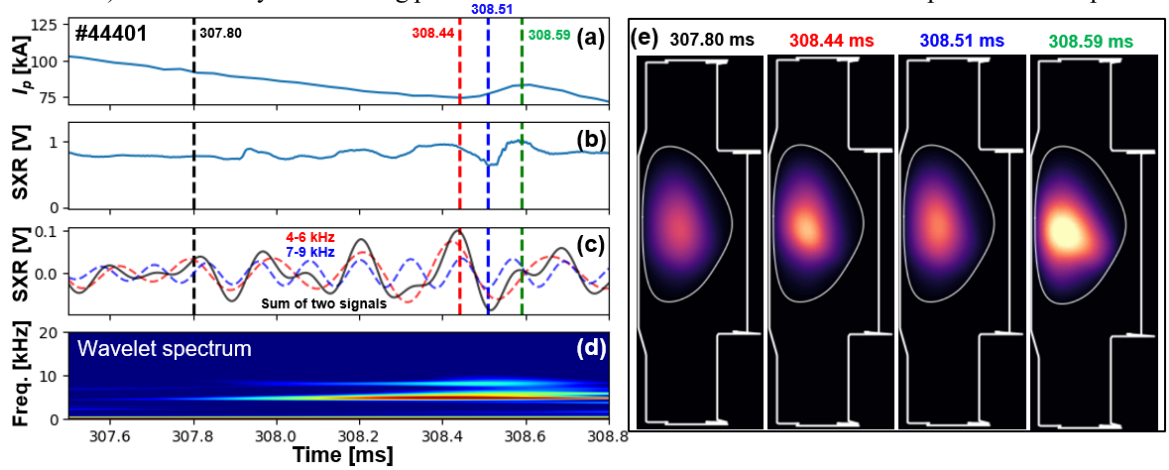

Fig. 1. (a) Plasma current. (b) Soft X-ray from a channel crossing plasma center (R=0.34 m at Z=0). (c) Bandpass-filtered SXR signals at the same channel. (d) Spectrogram of the SXR channel using continuous wavelet transform. (e) SXR images during the IRE process.

Furthermore, we measured electron temperature (T_e) with high temporal resolution using a two-filter SXR system. In previous works [4,5], thermal quench phases at the start of IRE were estimated by using SXR signal that is a convolution of multiple parameters such as electron density (n_e), effective ion charge ($Z_{eff}=\sum_j Z_j^2 n_j/Z_j n_j$, j is ion species), and T_e [6]. As shown in Fig. 2, the measurements of T_e alone in this study could reveal the detailed IRE process. Figure 2(b) is the SXR from a core-crossing channel, and Figure 2(c) is the T_e at the same channel. Figure 2(d) is the T_e from an edge-crossing channel at the high-field side (inboard). The T_e first started to decrease at the core, and a slight increase of plasma current is also shown in similar timing. The T_e decrease at the core lasted until ~308.53 ms. Therefore, the reduced SXR intensity observed in Fig. 1 is attributed to the decreased T_e followed by IRE burst. At the end of the reduction of core T_e, sudden increase in T_e was detected at the edge channel, which could be related to an energy burst in the IRE process. The further analyses on the IRE phases will be followed.

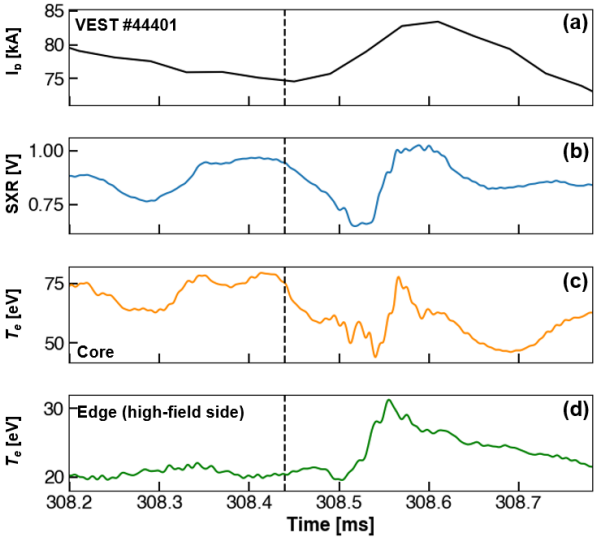

Fig 2. Time series data in the IRE process (a) Plasma current (b) Soft X-ray from a channel crossing plasma center (R=0.34 m at Z=0). (c) Electron temperature from the same SXR sight line (core) estimated using two-filter method. (d) Electron temperature from edge SXR channel (R=0.15 m at Z=0) at high-field side. The dashed lines are plotted at 308.44 ms where T_e started to decrease.

3. CLOSING REMARKS

The dynamics of MHD modes and temporal evolution of T_e in the internal reconnection event are investigated in VEST. The two coherent modes below 10 kHz appeared about 1 ms before IRE, and their amplitude and spatial distribution grew until IRE happened. The evolutions of the modes were studied by a multichannel soft X-ray system. Moreover, IRE process was also investigated with T_e measurements using a two-filter SXR system. The analysis performed in this study will contribute to the understanding of IRE dynamics, which is important to the stability and performance of fusion reactors based on spherical tokamak.

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