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The formation of MHD coherent filament structure and its impact on explosive events in VEST

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One of the most noticeable phenomena during magnetohydrodynamics (MHD) explosive events such as edge localized modes (ELMs) and disruption is a helical emission structure in the outer region. These structures, so-called blobs/filaments, form along magnetic field lines outside the closed magnetic surface and they are intensified on the verge of explosive events. The behavior of filament structures is greatly related to the major loss of stored energy by the explosive events[1, 2], but also deeply related to the MHD instability itself that triggers the events[3]. However, these structure has merely studied as a byproduct of the explosive event, and thus the impact of filament structures on the explosive event has not been studied due to their location at the edge.

In this study, we found the transition of turbulent-like emission structure into a localized MHD coherent structure at the edge, and simultaneously with the increased level of bicoherence between low-frequency MHD modes (<20 kHz) and broadband high-frequency turbulence (>60kHz) at the beginning of the explosive MHD event in Versatile Experiment Spherical Torus (VEST). Furthermore, it is found that the starting point of a thermal quench takes place at the location of the filament structure.

Figure 1 represents sequential internal reconnection events (IRE), which is a minor disruption in spherical tokamak resembling many features with disruption[4,5]. The 3D helical structure of filaments in a visible CCD camera is interpreted using the tracking method of helical structure based on the magnetic reconstruction results[6] and thus converted into a 2D signal in order to directly compare with $\dot{B}_\theta$ signal. It is shown that the signal of filaments is surprisingly consistent with the $\dot{B}_\theta$ signal before IRE. This result can be more easily understood with the sequential images in the right of figure 1 that turbulent-like emission structures at the edge of plasma become a localized emission rotating coherently with MHD modes. Figure 2 illustrates detailed sequences of the thermal quench during IRE. The emission structure that rotates in the opposite direction of MHD modes, which is due to the detachment of filament structures from the flux surface, becomes a reconnection site that leads to the thermal quench. This observation urges a new model for the explosive MHD events that involve filament/blobs in the outer region.

References
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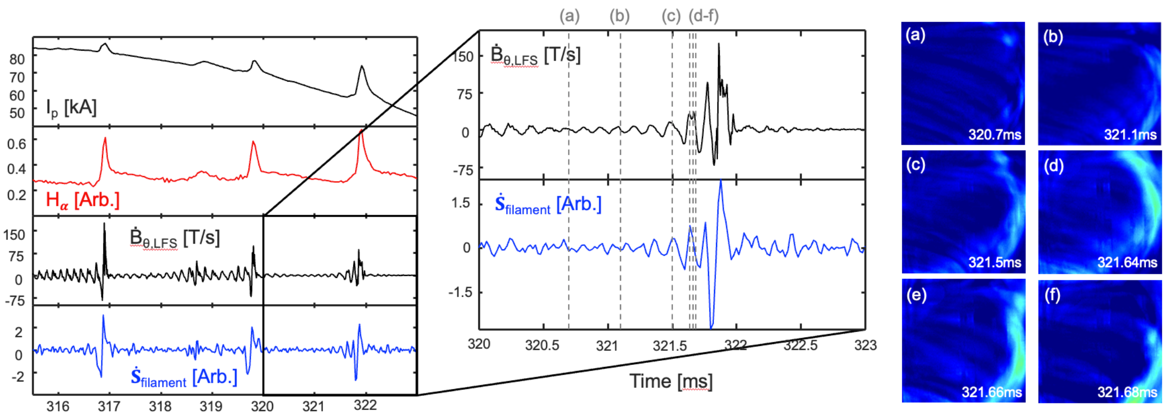

Figure 1. Sequential IREs in VEST with increased $\dot{B}_\theta$ signal and its coherent filament signal (left) and background-subtracted CCD camera images on the low field side in different time steps (right).

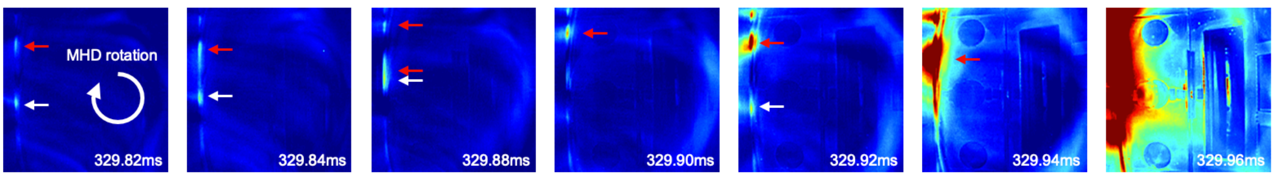

Figure 2. Sequential background-subtracted visible CCD camera images in the beginning of IRE. The rotation of MHD modes due to the plasma rotation is in clockwise direction but the emission structure rotating opposite direction appears, which is due to the detachment of blobs from the last closed flux surface. This emission structure becomes a starting point of thermal quench.