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High Energy Electron Measurement in Tokamak Merging Experiments

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Our multi-view soft X-ray imaging system detected high-energy electrons generated by magnetic reconnection between two merging tokamak plasmas in the experimental device TS-6. The soft X-ray emission was measured over a wide area including the X-point of the reconnection and the downstream region. Magnetic reconnection occurring during the merging tokamaks is unsteady, with parameters varying over time. The spatial distribution of soft X-ray emission also underwent significant changes as the magnetic reconnection progressed.

Application of magnetic reconnection for the merging startup of spherical tokamak plasmas has been studied in TS-6, UTST, MAST, and ST-40 [1]. In the merging startup, electron acceleration by reconnection electric field occurs before the high-power ion heating. Therefore, measuring the spatial distribution of accelerated electrons and their energies becomes very important for understanding the energy conversion of magnetic reconnection. To measure the 2D profile of the Bremsstrahlung emission from high-energy electrons, we installed the multi-view soft X-ray imaging system composed of a high-speed camera, four imaging fiber bundles, and four built-in microchannel plates, each equipped with a pair of pinholes and optical filters: 1 μm aluminum film, 2.5 μm aluminum film, 1 μm mylar film and 2 μm mylar film for soft X-ray photons whose energies are >20eV, >50eV, >100eV and >200eV, respectively. The system simultaneously measures the line-integrated images of soft X-ray emissions from which the R-Z contours of soft X-ray local emission are reconstructed using the minimum Fisher information method [2].

Figure 1 illustrates the time evolution of the soft X-ray emission. This time evolution indicates that the high-energy electrons first appear over a wide area from the X-point of the reconnection to the downstream area (a, b) and then localize at the X-point (d-f). In the low-energy band images (a, b), the soft X-ray emission extended obliquely from the vicinity of the X-point toward the downstream region, which is interpreted as the detection of electron outflow forming a negative potential structure. Although magnetic reconnection was ongoing, the soft X-ray emission near the X-point diminished (g-i). A simultaneous decrease in electron density was also observed in this region, implying that the reduction in density may have contributed to the decay of the emission.

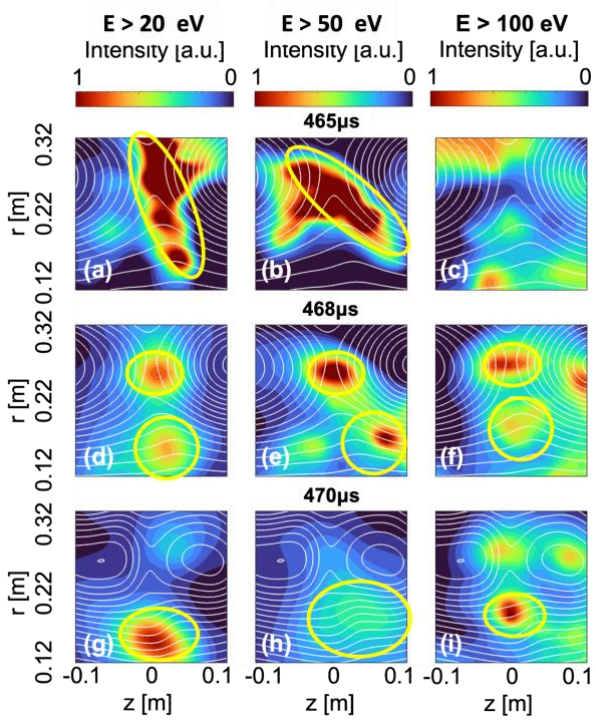

Figure 1. Z-R contours of 2D soft X-ray emission (color) with poloidal flux surfaces (white lines)

References

[1] Y. Ono et al., Fusion Energy 2023 (London, UK, 16-21, October) IAC/1707, (2023).
[2] Anton M. et al., Plasma Phys. Control. Fusion (1996).