# §22. Optical Measurements of Current Sheet Fine Structure in High Guide Field Magnetic Reconnection

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A guide magnetic field $B_g$, which is perpendicular to the reconnection magnetic field $B_{rec}$, often exists in various reconnection situations and becomes dominant in sawtooth crashs or internal reconnection events observed in tokamak discharges. The guide field is considered to bring about some qualitative changes in magnetic reconnection such as spatial profile, energization mechanism, and so on. In this study, we investigate the fine structure of current sheet region in guide field magnetic reconnection by using optical measurements.

The guide field reconnection has also been investigated in numerical simulation studies, in which decoupling between electron and ion motions generates quadrupole guide field component and thus the field amplitude becomes asymmetric with respect to line. In conclusion, charge separation provides in-plane electric field to modify electron and ion flow patterns. On the other hand, the reconnection structure observed in the UTST experiment[1)] was rather line-symmetric, possibly because much higher guide field ratio $B_g / B_{rec}$ ~10 was achieved during spherical tokamak merging events with good controllability and reproducibility.

One of the remarkable features observed in high guide field reconnection experiment was that energetic electrons were efficiently produced near the X point region by the reconnection electric field. The soft X-ray Bremsstrahlung emission from electrons with energy larger than 70 eV measured by Al-filtered surface barrier detectors showed quick increasing trend in the initial phase of plasma merging[2)]. The parallel acceleration is evaluated by the electron's travel length $L_{travel}$ and reconnection electric field $E_{reco}$ near the X point region where negligible in-plane magnetic field exists,

$$L_{travel} = L\,|B|\,/\,|B_{down}| \sim LBg/B_{rec} ,$$

where $L$ is the current sheet half length, $B$ is the total magnetic field near the X point region and $B_{down}$ is the in-plane magnetic field in the downstream region.

The structure in the current sheet region was clearly observed by using ultra-fast camera. We found that localized emission region of carbon impurity line spectrum was formed near the X point when significant parallel acceleration took place. The emission region was highly elongated along the guide field direction and it moved toward the downstream region. In order to investigate this localized emission, we carried out electromagnetic fluctuation measurement together with the fast camera imaging observation.

Figure 1 (a) and (b) show the camera images of the impurity emission region during spherical tokamak merging events in UTST. These two events were in the same experimental conditions and ring-shaped emission regions were formed near the X point region, however, the vertical positions of the X point were slightly different in these two cases. In case (a), the electromagnetic fluctuation probe was inserted inside the bright emission region and significant fluctuations $\delta B_z$ of ~1 MHz frequency range were detected. On the other hand, negligible electromagnetic fluctuations were found in case (b), in which the fluctuation probe located slightly above the emission region.

The observed fluctuations were excited near the X point region and travels toward the downstream region with velocity of ~40 km/s. These features were similar to those of the impurity emission region. These results suggest that the emission region has significant gradient of both pressure and current density, indicating that small plasmoid-like structure was generated in this high guide field reconnection experiment.

In order to investigate the behaviors of magnetic and emission structures quantitatively, we designed a new optical measurement system to evaluate the radial size and travelling velocity of the ring-shaped emission region. Collimator system was fabricated with 20 optical fibers aligned in the radial direction. Adequate lens and interference filter were utilized to focus the emission of carbon impurity line emission on the fiber edges. A photomultiplier array was connected to the other end of the optical fiber bundle to detect the emission. Since the achieved spatial resolution of about 1 cm was shorter than the wavelength of the electromagnetic fluctuation of 2~3 cm, we expect that the temporal evolutions of the radial profiles of emission and current density will be evaluated quantitatively.

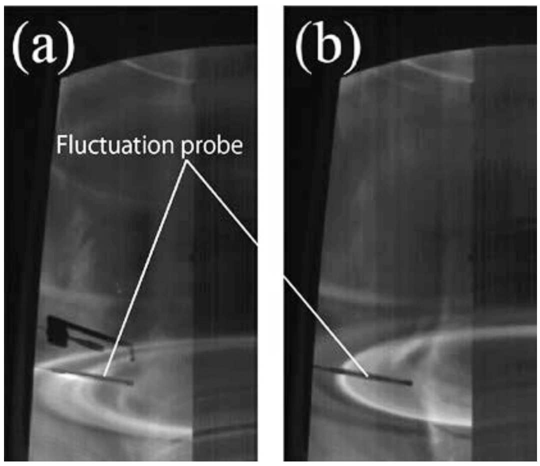


Fig. 1. Fast camera images of carbon impurity line emission.

1) Inomoto, M. et al.: Nucl. Fusion 55, 033013 (2015).
2) Ushiki, T. et al : Plasma and Fusion Res. (in press).