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Conditional averaging measurement of spatiotemporal parameter dynamics during cross-field recombining-plasma ejection events

Hirohiko Tanaka[1], Shin Kajita[2], and Noriyasu Ohno[1]
[1] Graduate School of Engineering, Nagoya University,
[2] Institute of Materials and Systems for Sustainability, Nagoya University
h-tanaka@ees.nagoya-u.ac.jp

Plasma detachment is an effective solution for reducing the heat load on the divertor target in future fusion devices. In low-temperature detached plasmas, due to plasma-gas interactions and volume-recombination processes, plasma parameters significantly change along the magnetic field. Moreover, non-diffusive cross-field transport enhanced in the detached divertor condition was reported in several magnetic confinement devices. In the linear device NAGDIS-II, there are several findings in previous studies: the radial ejection events, which mainly have the azimuthal mode number of $m = 1$ [1], are enhanced near the highly volume-recombining region (hereafter called "recombination front") [2] and are related to the fluctuation with $m = 0$ in the plasma column [3]. Although some dynamics of the plasma structure has been revealed, the enhancement mechanism is still unknown.

To clarify its mechanism, this study aimed to reveal spatiotemporal behavior of plasma parameters (electron density n_e, electron temperature T_e, and plasma (space) potential V_s) during the plasma ejection events around the recombination front in NAGDIS-II [4]. To achieve multipoint and high-temporal-resolution measurement, we applied the conditional averaging (CA) technique to dataset of fluctuations obtained by the two-dimensional movable multi-pin Langmuir probe (2D probe) and a single Langmuir probe (reference probe).

The reference probe measured the ion saturation current (I_{ref}) at the fixed position radially far from the plasma column (radius of r = 23 mm) to detect the radial ejection events. On the other hand, the measuring position of the 2D probe was changed in radial and axial directions naer the recombination front which equips strong line emissions from highly excited states. In each position, 50 sets of 1-s time series of double-probe current (I_p), double-probe voltage (V_p), and floating potential (V_f) were simultaneously acquired by the 2D probe in addition to I_{ref} by the reference probe in a steady-state helium discharge. The double probe is known as the reliable measurement method even in detached plasmas with $T_e < 1$ eV [5].

By setting a threshold for low-passed I_{ref}, radial-ejection timing for each event was identified as $\tau = 0$, and measured signals were collected and then averaged from $\tau = -500$ to 500 µs every 1 µs. As a result, time series of n_e and T_e estimated from I_p-V_p characteristic and V_f were obtained. Moreover, V_s was also estimated as $V_s \sim V_f + 3.7T_e$ [2]. After that, to reduce noise component over 100 kHz, a simple moving average with a sliding window of 10 µs was applied.

Figure 1 shows spatiotemporal dynamics of plasma parameters as functions of r and τ, where the axial position corresponds to the recombination front. Radially elongated structure of n_e is clearly seen around $\tau \sim 0$. Additionally, before the plasma ejection, n_e, T_e, and V_s in the plasma column increases/decreases/increases, respectively, with longer time period. After that, these parameters fluctuated in opposite signs. These low-frequency components have $m = 0$. Considering the phase relationship of fluctuations, the radial transport seems to suppress the axial movement of the volume-recombining region in the plasma column. The neutral flow effect is thought to be a candidate of driving force of the radial transport [4].

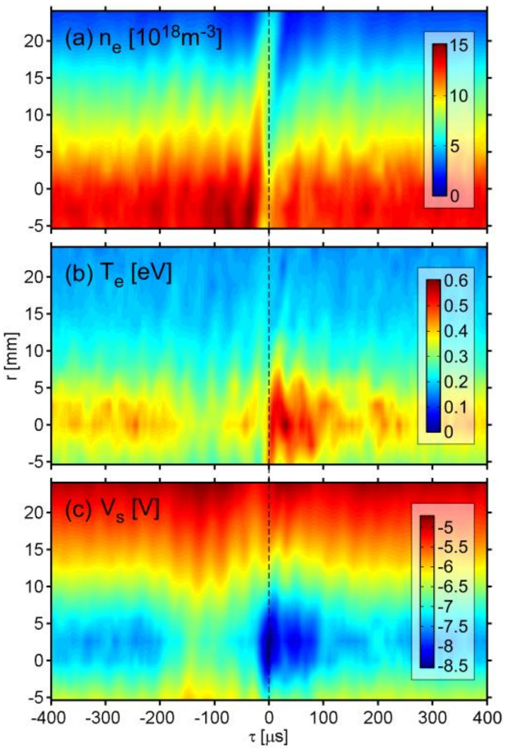

Figure 1 Spatiotemporal evolutions of (a) n_e, (b) T_e, and (c) V_s near the recombination front.

References

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