Electron Density Behavior during Fast Termination Phase of Post-Disruption Runaway Plasma

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Electron density behavior during the fast termination phase of the post-disruption runaway plasma was investigated for the first time. Increases in electron density after the first drop of runaway plasma current were observed. At the second current drop, an increase in electron density with density oscillations having a period of ~1 ms was found. After the second current drop, higher electron density was observed in the case of shorter current decay time.

Keywords:

JT-60U, disruption, runaway electrons, density oscillation, interferometry

It is known that runaway electrons generated at a disruption are quickly exhausted from plasma by low n magnetic fluctuations appearing around q_s as low as 3 or 2 [1,2], where n is the torodial mode number and q_s is the plasma surface safety factor. Hence, fast termination of post-disruption runaway plasma, in which the most of plasma current is driven by runaway electrons, occurs. Here, for further understanding of the termination process, the electron density behavior during the fast termination phase is investigated for the first time. The central line-integrated electron density of the post-disruption runaway plasma in JT-60U operated with outer-touched limiter configuration is measured by a tangential CO_2 laser interferometer [3].

Figure 1 shows waveforms of a post-disruption runaway plasma (E38233) [4]. The disruption at t~11.981 s was induced by impurity (neon) pellet injection. Fast termination begins at t_1~12.1749 s with q_s<3, which is confirmed by the appearance of a sharp spike in the magnetic fluctuation signal (n=1 mode) and a clear drop in the runaway plasma current I_p. The decay time of the plasma current $\tau_{\mathrm{Ip\text{-}decay}}$ defined as $I_p/(-\mathrm{d}I_p/\mathrm{d}t)$ decreases to ~6 ms at t~12.1758 s. The $\tau_{\mathrm{Ip\text{-}decay}}$ is recovered to ~23 ms around t~12.1775 s. Probably new runaway electrons by avalanche generation contribute to that recovery [4]. An increase in the photo-neutron emission rate S_{neut} (time resolution is 1 ms) of around t_1 indicates an increase in number of exhausted runaway electrons, since the photo-neutrons are emitted via photo-nuclear reactions in the first wall and in-vessel components where the runaway electrons hit.

We have observed an increase in the line integrated electron density along the tangential chord $\int n_e \mathrm{d}l^{\mathrm{tang}}$ after t_1. Presumably this is due to an influx of impurities and hydrogen

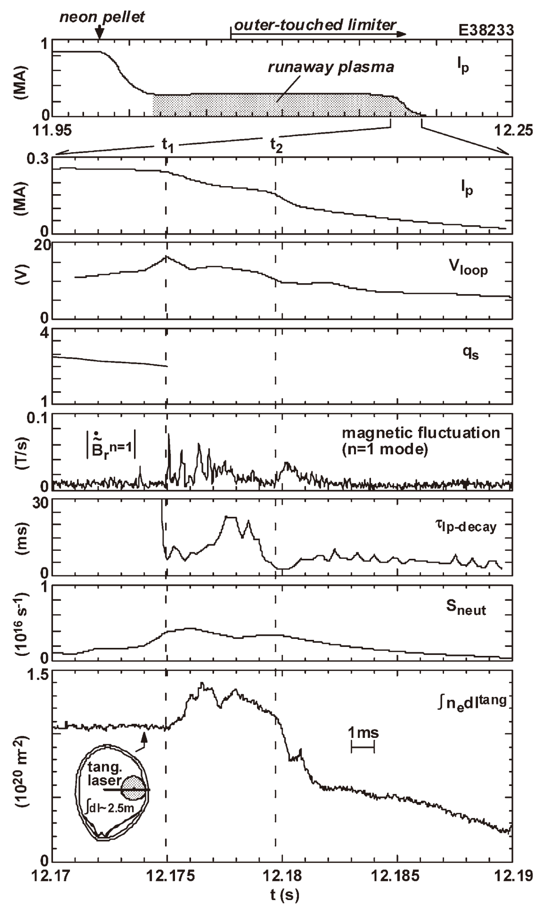

Fig. 1 Waveforms of a post-disruption runaway plasma (shot E38233).

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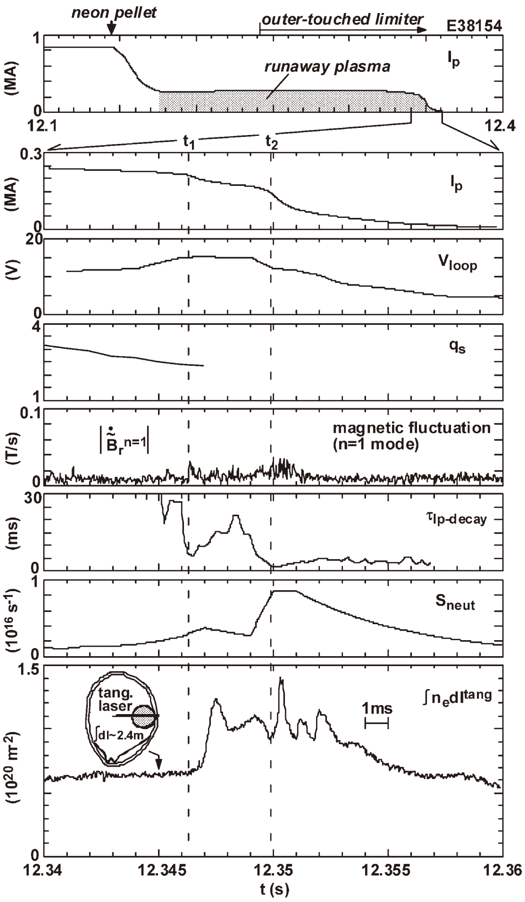

Fig. 2 Waveforms of a post-disruption runaway plasma (shot E38154).

from the first wall. The tangential chord and the plasma shape at ~1 ms before t_1 are shown in the bottom column. While I_p gradually decays from t~12.1784 s, a second clear drop of I_p is observed at t_2~12.1797 s with an increase in the magnetic fluctuation level. Then, the $\tau_{\text{Ip-decay}}$ reaches its shortest value of ~2.7 ms. After a small recovery of $\tau_{\text{Ip-decay}}$ to ~7 ms, the plasma enters the final termination. The change in S_{neut} is not large. The $\int n_e dl^{\text{tang}}$ decreases after t_2 with a small peak seen at t~12.1808 s.

Figure 2 shows waveforms of another post-disruption runaway plasma (E38154), in which the time sequences are very similar to those of E38233. However, the number of exhausted runaway electrons at the second drop seems larger than that in E38233 since the shortest value of $\tau_{\text{Ip-decay}}$ is as small as ~1.5 ms and a significant increase in S_{neut} is observed around t_2. The $\tau_{\text{Ip-decay}}$ is recovered to a smaller value of ~5 ms.

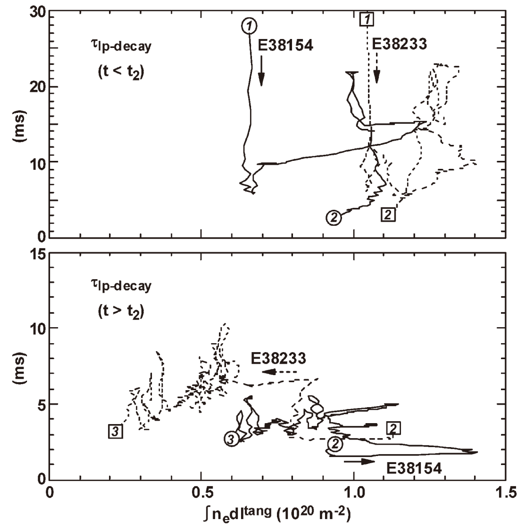

Fig. 3 Time traces of $\tau_{\text{Ip-decay}}$ against $\int n_e dl^{\text{tang}}$.

In this case, after t_2, we observed oscillations of $\int n_e dl^{\text{tang}}$ with a period of ~1 ms. The reason is unclear, but phenomena such as the periodic influx of impurities and hydrogen, "Snake" like activity, and fast oscillation of the plasma column can be considered.

Figure 3 shows time traces of $\tau_{\text{Ip-decay}}$ against $\int n_e dl^{\text{tang}}$ for $t<t_2$ (top column) and $t>t_2$ (bottom column). The time flows in order of the numbers in circles or squares. In the top column, obvious relationships are not recognized between $\tau_{\text{Ip-decay}}$ and $\int n_e dl^{\text{tang}}$. Therefore, changes in $\tau_{\text{Ip-decay}}$ seem to be mainly due to magnetic fluctuations. In the bottom column, $\tau_{\text{Ip-decay}}$ in E38154 appears to remain as a shorter value than that in E38233 even with a similar V_{loop} and magnetic fluctuation level. Therefore, while an increase in electron density is observed in cases where the number of exhausted runaway electrons is larger and $\tau_{\text{Ip-decay}}$ is shorter, quantitative analyses are required to investigate whether the exhaust of runaway electrons is enhanced by the increased electron density.

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