Observation of Magnetic Fluctuations and Disruption of Magnetospheric Plasma in RT-1

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Abstract. High-beta hot-electron plasma that sustained for more than 1s has been realized in RT-1, a magnetospheric dipole field configuration. High frequency magnetic fluctuations are observed in RT-1 when a large population of energetic electrons is generated by ECH at low neutral gas pressure operation. The fluctuations rotate in the electron curvature drift direction and have no clear phase difference along field lines, and they can cause disruptive loss of plasma. The instability has a strong correlation with the ratio of hot electron component in the plasma, and is stabilized by decreasing the hot electron ratio below approximately 40%.

1. Introduction: Magnetospheric plasma experiment in RT-1 for advanced fusion

The Ring Trap 1 (RT-1) device (Fig.1) [1] is a magnetospheric dipole field configuration constructed for the study of high-beta plasma suitable for burning advanced fuels. As observed in planetary magnetospheres, dipole plasmas can be stable against MHD interchange and ballooning instabilities even in bad curvature regions, due to the effects of field lines compressibility. The use of magnetospheric configurations for advanced fusion [2] was proposed by taking a hint from a natural example of the self-organization of high-beta plasma in the Jovian magnetosphere. Intensive studies on magnetospheric fusion plasmas have been conducted on RT-1 [1], Mini-RT [3], and LDX [4] by using levitated superconducting magnets. In the first series of experiments in RT-1, plasma is generated and maintained by using electron cyclotron resonance heating (ECH). High-beta (local beta~70%) hot-electron plasma has been successfully realized in RT-1 [5] through the optimization of formation conditions including the feedback-controlled levitation of the dipole field magnet [6]. Understanding of the stability limit and fluctuation properties is very important for the stable operation of high-beta plasma confinement in the magnetospheric configuration. Here we report the emergence of magnetic fluctuations and disruptive rapid loss of RT-1 plasma observed in the presence of intense hot electrons. Spatial structures of the magnetic fluctuations and conditions for the stabilization of the disruption are experimentally investigated.

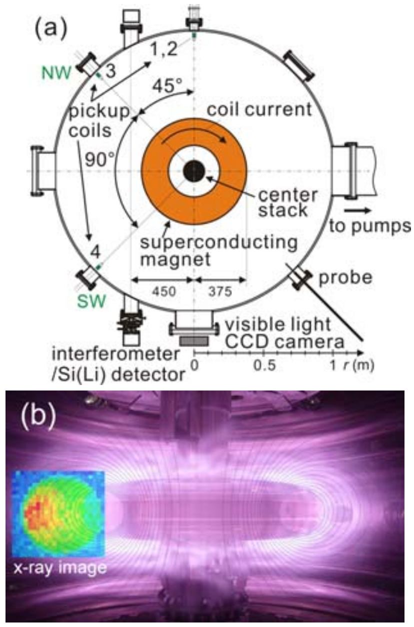

Fig.1 (a) Top view of RT-1 and (b) visible light and x-ray images of hot electron plasma.

2. Experimental Results: Conditions for the stabilization of hot electron plasma in RT-1

In the plasma of RT-1 generated by ECH, measurements with x-ray detectors and edge Langmuir probes showed that electrons have multiple temperature components [5]. The typical temperatures of the hot electron component are 30keV when the dipole field magnet was levitated and 10keV when the magnet was not levitated. Plasma pressure in the present experiments is mainly due to the hot electrons. Because of their small cross sections of collisions with other particles, the hot electrons have longer confinement times. As a result, electron densities observed by the interferometer decrease with different time constants after the stop of microwave injection. The initial rapid decrease is due to the loss of cold electrons of ~10eV, and the second slow decay is due to the effects of long-lived hot electrons. During the slow decay phase, emission of both visible light and x-ray was observed, indicating the ionization of background neutral gas by the trapped hot electrons. By decreasing the neutral gas pressure, very intense hot electrons are generated. In such cases, the plasma sometimes becomes unstable and the excitation of MHz-range magnetic fluctuations was observed.

Figure 2 shows the typical temporal evolution of plasma and the burst of magnetic fluctuation emerged in a slow decay phase after the microwave was turned off. After the stop of microwave power at t=0s, the plasma started to decay. Significant magnetic fluctuations were not observed at this period and the plasma was in a quiet state. The onset of small fluctuation was observed at t=2.35ms, but there was no major change in the decay rate of line averaged electron density n_{ave}. Following the rapid growth of fluctuation amplitude at t=2.58ms, density disruption were observed a t=2.6ms. Typical strength of the fluctuating magnetic field at this point was 10^{-4}T. Measurements with multiple pickup coils showed that the fluctuations propagate in the toroidal direction that agrees with the electron diamagnetic drift direction.

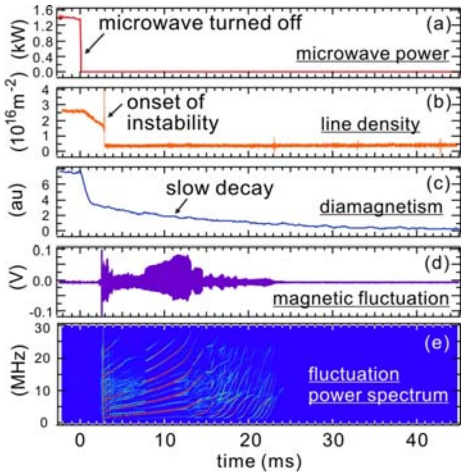

Fig.2 Temporal evolution of fluctuation and disruptive plasma decay.

The emergence of magnetic fluctuations that lead to disruption was observed only when the neutral gas pressure P_n was low and plasma pressure was sufficiently high. Figure 3 plots the line averaged electron density n_{ave} and the diamagnetic signal $\Delta\Psi$ of plasma when the disruption was observed and when not observed. By increasing input microwave power while keeping P_n lower than ~2mPa, drastic increase in the hot electron component was realized, resulting the formation of plasma with low n_{ave} and large $\Delta\Psi$. In these cases, the onset of magnetic fluctuation and sudden density loss were observed in the plasma decay phase. There is a strong correlation between the ratio of hot electrons and the onset of instability. The destructive magnetic fluctuations were observed when the ratio was above ~40%. Kinetic effects due to the intense hot electrons may provide an energy source to induce the disruption, restricting the stability conditions of magnetospheric plasmas. Formation of high-beta plasma [5] is realized by the stabilization of the fluctuations as a result of the reduced ratio of the hot electron component with optimized formation conditions.

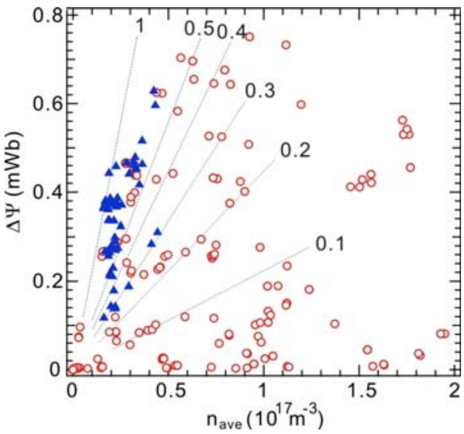

Fig.3 Line density n_{ave} and diamagnetic signal $\Delta\Psi$ when disruptive fluctuations were observed (closed triangles) and not observed (open circles). Dotted lines shows the ratio of hot electrons.

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