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Intermittent Electron Flux in an ECR Plasma (I) : 2D Profile Measurement
ECRプラズマ中の間欠的電子流束(I)：二次元分布計測

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Spontaneous generation of intermittent high-energy electron fluxes has been observed in a linear electron-cyclotron-resonance (ECR) plasma. In order to investigate the spatial distribution of electron flux and the spatial point of occurrence, we developed a wire-grid probe with independent 16 electrodes. The wire-grid probe successfully reconstructed two-dimensional distribution of the high-energy electrons. It was found that the high-energy electron fluxes have a typical size of 20-50 mm in diameter and are generated at various spatial positions in a seemingly random manner.

1. Introduction

Intermittent phenomena are ubiquitous both in laboratory and in astrophysical environment. Intermittent particle transport called "blob" has been observed in many magnetically confined plasmas [1] and intermittent explosive energy release takes places in the solar flare events [2].

Recently, spontaneous generation of intermittent high-energy electron fluxes, or electron currents, has been observed in a linear electron-cyclotron-resonance (ECR) plasma. The electron fluxes have a typical duration of 10 μs and are generated on the whole plasma cross-section. Because of intrinsic intermittency of the phenomenon, measurements with a few probes do not provide valuable information on the spatial distribution of the electron flux. To obtain the definitive information, we have developed a wire-grid probe (WGP) capable of reconstructing two-dimensional distribution of the high-energy electrons, and determined the points of occurrence.

2. Necessity of Two-dimensional Measurement

We utilize the floating potential (V_f) as a signal of existence of the intermittent high-energy electron flux, since the existence of high-energy electrons strongly changes V_f of the probe. Figure 1 shows the simultaneous measurement of V_f fluctuations with two Langmuir probes located at 20 mm apart each other. As seen in the figure, some of the spikes are coincidently observed with two probes and other spikes are detected by a single probe. This result is attributable to the fact that the high-energy electrons have finite spatial extent, and when they

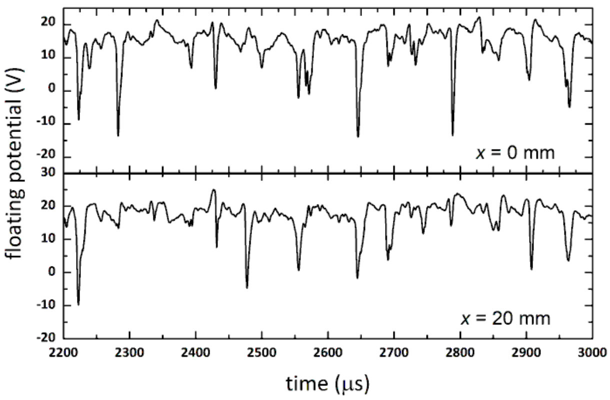

Fig.1. Floating potential fluctuations measured by two LPs located at x=0 mm and x=20 mm.

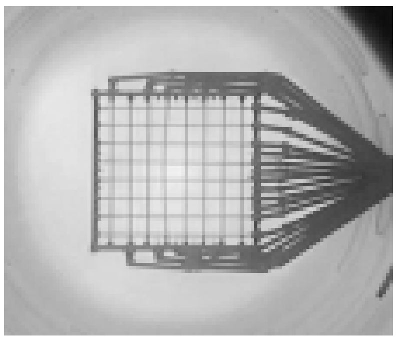

Fig.2. TheWGP in the HYPER-I device.

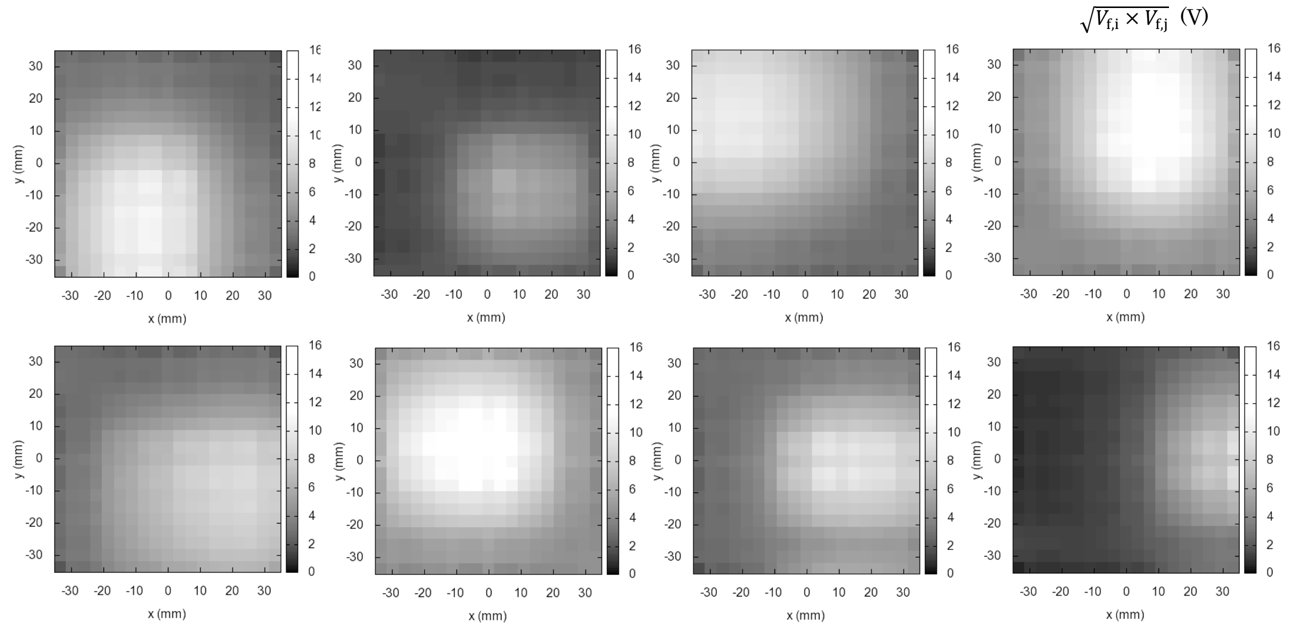

Fig.3. Two-dimensional profiles (intensity maps) of the intermittent high-energy electron fluxes.

flow into the two probes, the coincident observation of negative spikes happens. The detection by a single probe indicates that the electron fluxes are generated in various positions. These experimental facts strongly suggest that two-dimensional measurement of high-energy electrons is needed.

3. Experimental Setup

The experiment has been carried out using the high density plasma experiment (HYPER-I) device [3] at the National Institute for Fusion Science. HYPER-I is a cylindrical plasma device with 0.3 m in inner diameter and 2.0 m in axial length. A helium plasma is generated by ECR heating with a 2.45 GHz microwave. The input microwave power and the gas pressure were fixed at 20 kW and 1.5 mTorr, respectively. The typical electron density and temperature are 10^{17} m^{-3} and 10 eV, respectively.

The WGP consists of eight horizontal and eight vertical electrically insulated tungsten wires with a diameter of 0.7 mm and has 64 lattice points, as shown in Fig. 2. Each wire is separated from the adjacent wire with the distance of 10 mm. The WGP measures 16 time-series of V_{f} fluctuation to reconstruct the intensity map of the electron flux with 64 lattice points.

4. Experimental Results

Floating potential is proportional to the electron temperature and has positive correlation to the imbalance between the ion and electron flux [4]. Therefore, the intensities of electron fluxes at 64 lattice points may be evaluated as

$$\Gamma_{\mathrm{e,ij}} \propto \sqrt{\tilde{V}_{\mathrm{f,i}} \times \tilde{V}_{\mathrm{f,j}}}\,, \tag{1}$$

The quantity $\sqrt{\tilde{V}_{\mathrm{f,i}} \times \tilde{V}_{\mathrm{f,j}}}$ has a positive correlation to the variation of the electron fluxes and the symbols i ($\mathrm{i} = 1, 2, \cdots, 8$) and j ($\mathrm{j} = 1, 2, \cdots, 8$) indicate the electrode numbers of horizontal and vertical wires, respectively.

The two-dimensional profiles (intensity maps) of the intermittent high-energy electron fluxes are shown in Fig. 3, where the origin $(x, y) = (0, 0)$ corresponds to the center of the device. The reconstructed profiles of the electron fluxes exhibit finite spatial extent with a circular cross-section. From 80 samples of such profiles, it is found that the electron fluxes have a typical size of 20-50 mm in diameter. In addition, the fluxes are generated at various positions with various intensities in a seemingly random manner.

In conclusion, the newly developed WGP successfully reconstructed two-dimensional profiles of the electron fluxes and determined the points of occurrence. The random nature of the phenomenon requires a statistical approach to investigate the entire picture of this event.

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