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Direct Measurements of Wave-Particle Interactions in the Evolution of the Drift Wave Instability: Application of Space Plasma Instrumentation Wave-Particle Interaction Analyzer

ドリフト波励起過程における波動粒子相互作用の直接計測実験: 宇宙プラズマ計測手法の実験室プラズマへの応用

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We carry out the direct measurement of the evolution of the drift wave instability in laboratory experiments, based on the method proposed in a new instrumentation of Wave-Particle Interaction Analyzer (WPIA) in space plasma. We develop a combination probe, which enables us to measure both wave electric field and ion flow vectors simultaneously at the site of the drift wave enhancement. We present the initial result of our experiment and discuss the feasibility of the proposed method.

1. Introduction

Wave-Particle Interaction Analyzer (WPIA) is a new instrumentation proposed for the direct measurement of wave-particle interactions in space plasma [1-3]. The software-type WPIA will be installed in the upcoming JAXA satellite mission ERG (Exploration of energization of Radiation in Geospace) as a software function running on the onboard CPU of the satellite [4]. The WPIA measures a relative phase angle between the wave electromagnetic field vector ($\boldsymbol{E}$ or $\boldsymbol{B}$) and the velocity vector ($\boldsymbol{v}$) of each energetic electron and then computes physical quantities such an inner product $W=q\boldsymbol{E}\cdot\boldsymbol{v}$, where W is the time variation of the kinetic energy of energetic electrons interaction with plasma waves. The prime target of WPIA on board the ERG satellite is direct measurement of nonlinear wave-particle interactions between energetic electrons and whistler-mode chorus emissions, which play crucial roles in energizing radiation belt electrons in the magnetosphere.

The method of the WPIA can be applied to the measurements of various plasma instabilities. In the present study, so as to apply the WPIA method in laboratory plasma, we developed a combination probe for the WPIA analysis and used it in laboratory experiments of the drift wave mode (~kHz) enhanced through the evolution of the electron temperature gradient driven fluctuations (~MHz) [5]. The experiments were performed in the Q_T-Upgrade machine at Tohoku University.

2. Combination Probe for WPIA Analysis

The developed combination probe consists of two pairs of Langmuir probes and Mach probes, as shown in Figure 1. This probe is designed to measure wave electric field ($\boldsymbol{E}$) and ion current flow ($\boldsymbol{I}$) vectors at the site of the wave enhancement simultaneously. The distance between Langmuir probes is ~3 mm, which is enough short to resolve the wavelength of drift wave mode (~3 cm) excited in the experiments in the present study. The accuracy of the alignment of the developed probe is quantitatively evaluated by conducting reliability tests.

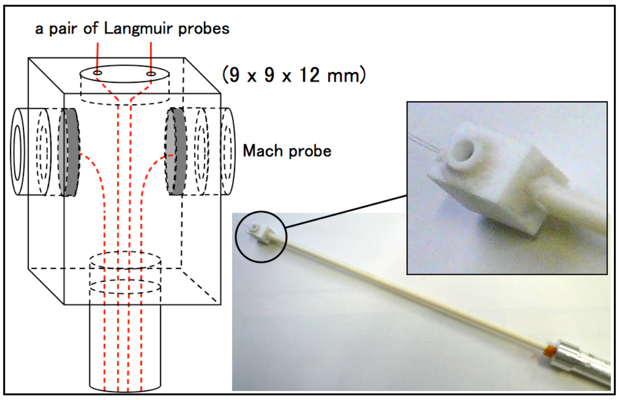

Fig.1. Combination probe used in the present study

3. Results and Discussion

We carried out experiments of the drift wave mode excitation as studied in Moon et al. [5]. By the developed combination probe, we measured three components of ***E*** and ***I*** vectors at the site of the drift mode wave excitation. The results showed that the drift wave mode enhanced in the frequency range ~6 kHz and that ***E*** and ***I*** vectors of the waves have components in both azimuthal and radial directions. The wavelength is estimated to be ~3 cm, consistent with the previous study [5]. We then computed an inner product ***E·I*** of the vectors and investigated its time evolution. Since the obtained value of the inner product fluctuated in time, we applied the method proposed in Katoh et al. [3] for the evaluation of the statistical significance of the measured quantity of the WPIA analysis. By showing details of the measurements, we study the feasibility of the WPIA method and its significance for the study of plasma wave instabilities in laboratory and space plasmas.

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