FLOW SHEAR EFFECTS ON DRIFT-WAVE AND ION-CYCLOTRON INSTABILITIES IN MAGNETIZED PLASMAS

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ABSTRACT

The external and independent control of parallel and perpendicular flow velocity shears in magnetized plasmas is realized using a modified plasma-synthesis method with segmented plasma sources. Ion flow velocity shears parallel to the magnetic-field lines are observed to destabilize not only the drift-wave but also the ion-cyclotron instabilities depending on the sign and strength of the parallel shear in laboratory experiments. On the other hand, perpendicular ion flow velocity shears are demonstrated to suppress both the drift-wave and the ion-cyclotron instabilities, and furthermore, the suppressions are found to take place independently of the sign of the perpendicular shear.

INTRODUCTION

Sheared plasma flows in magnetized plasmas are very important issues not only in the near-Earth space plasma but also in fusion plasmas. In recent studies, the ion flow velocity shear parallel to the magnetic field lines has been recognized to be the origin of plasma micro-instabilities and turbulences, while the perpendicular flow velocity shear has been believed to regulate micro-instabilities in terms of the decorrelation of turbulences. In order to clarify the mechanisms of excitation and suppression of these instabilities, we claim that the laboratory experiments, where the ion flow velocity shears are externally controlled, are inevitable. Thus, the aim of the present work is to externally and independently control the parallel and perpendicular flow shears in the basic plasma device using a modified plasma-synthesis method with concentrically three-segmented plasma and ion sources [1,2], and to carry out laboratory experiments on low-frequency micro-instabilities excited and suppressed by these flow shears in collisionless magnetized plasmas.

EXPERIMENTAL RESULTS AND DISCUSSION

Experiments are performed in the Q_T-Upgrade machine of Tohoku University. In the case of parallel flow-shear experiments, several kinds of instabilities are found to be excited. One is observed around a density gradient region, and thus, this instability is considered to be the drift-wave instability excited by the shear [3]. The fluctuation amplitude is observed to increase with increasing the shear strength, but the instability is found to be gradually stabilized when the shear strength exceeds a critical value. The experimental results are in good agreement with the dependence of the theoretical growth rate on the shear strength, which is calculated in the kinetic treatment including the effect of the radial density gradient. The other is the ion-cyclotron instability, which is originally excited by applying positive bias potentials to a small disk electrode inserted at the center of a magnetized plasma column. This instability is also enhanced by the shear and is suppressed by the larger shear in the same way as the case of the drift-wave instability.

In the case of perpendicular flow-shear experiments, on the other hand, not only the drift-wave instability which exists in the density-gradient region but also ion-cyclotron instability excited by the small disk electrode is suppressed by only the slight shear of the perpendicular flow velocity independently of the sign of the shear. Particularly for the ion cyclotron instability, the perpendicular shear is found to suppress both of the current-driven type and the potential-driven type instabilities, which can be excited by changing the bias voltage applied to the small disk electrode.

Finally, three-dimensional electrostatic particle simulations are recently performed in order to investigate the effects of ion flow velocity shear in detail. It is found that the parallel ion flow velocity shear can excite these low-frequency instabilities and the excited instabilities are localized at the velocity shear region.

REFERENCES

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