

Strong Dependency of Ion Acceleration on Ion Beam Divergency in Magnetized Collisionless Plasma Sheath

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Abstract The ion acceleration inside the collisionless plasma sheath is investigated at the presence of external magnetic field. By using the fluid model, the number and momentum equations of the ions and the Boltzmann and Poisson equations are solved numerically in the case that the ion beam has a small divergency at the plasma sheath boundary. It is shown that the kinetic energy of the ions has a strong dependency to the magnitude of divergency when the magnetic field has a small component parallel to the sheath boundary.

Keywords Plasma sheath · Ion kinetic energy · Fluid model

Introduction

When plasma is in contact with a physical boundary, an ion reach boundary layer appears between the plasma and the boundary [1]. This localized electric field which is called “*sheath*”, confines the electrons in the plasma and accelerates the ions out of the plasma which is due to the fact that the electrons are more mobile species than the positive charged ions. As the positive charged ions are accelerated through the localized electric field inside the sheath, understanding the characteristics of the sheath is one of the oldest problems in plasma physics. The theory of Langmuir probes and the models of divertor plates in tokamaks are some examples which range from child’s law to complex kinetic simulation [2–5]. As finding the ion characteristics

in the plasma sheath is difficult, many numerical methods are used to investigate the sheath dynamics. The analytical models can be found too, in which some assumptions have been made to enable the researchers to describe the sheath analytically [6–12]. As an example, in both numerical and analytical method, it is assumed that there are no components of ion velocity parallel to the sheath edge [10–13]. If the method consists of this parallel component of ion velocity, the sheath dynamics are more complex especially in magnetized plasma sheath.

Recently, the study of the effects of magnetic field and collisions on the sheath characteristics has been generated interest since they can modify the sheath [10–12, 14–16]. It has been shown that the sheath dynamics in the presence of external magnetic field are completely different compared with the absence of magnetic field [12, 17]. However, it is reasonable that for small strength of magnetic field parallel to the sheath edge, the effect of magnetic field can be neglected if the velocity of the ions at the edge of sheath-plasma boundary has no components parallel to the sheath edge. In this paper by using fluid model we have investigated the process of ion acceleration inside the sheath for the case that the ion beam at the sheath edge has divergency. By calculation of the ion kinetic energy versus depth direction, the acceleration of the ions is studied at the presence of an external magnetic field which has a small orientation respect to the depth direction and so the strength of the magnetic field parallel to the sheath edge is small.

Model

In our model we consider the physical boundary as a planar wall. The coordinates of the model and the orientation of the magnetic field are illustrated in Fig. 1.

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