Equilibrium properties of a magnetized plasma behind an insulating obstacle

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Interactions between an external objects and plasma have enormous consequence on the global plasma properties [1]. This ranges from wake creation behind a satellite propelling through stratospheric plasma to the scrape of layer plasma region created in the shadow of a limiter in the edge region of a tokamak, or a void created behind a macroscopic probe inserted in a flowing plasma column. Over the years, the physicists are particularly interested on the equilibrium properties of plasma like, plasma density as well as potential structure inside the wake region, because it influences the dynamics of the neighbouring charge particles around the obstacle [2]. The nature of local plasma parameters inside wake depends on several factors like the external magnetic field, charge-charge or charge-neutral collisions, and flow of plasma. But the most important factor is the nature of the obstacle whether the electrode is an insulator or a conducting body that is immersed inside a magnetized plasma column.

After a research of several years, scientists had concluded that the transport properties of charge particles across magnetic field is quite connected to the nature of interactions between plasma and material electrodes [2,3]. In 1955, Simon et al. proposed that the conducting end plate in a bounded magnetized plasma will be able to short-circuit the excess positive current across the magnetic field by flowing excess negative current through it [4]. It was argued that the short-circuiting phenomena could give rise to higher cross-field diffusion rate comparable with anomalous diffusion by charge fluctuations [4]. Following this, many fundamental research have been carried out in laboratory plasma to unravel the effect of macroscopic object on charged particle transport in magnetized plasma column. A number of analytical models of magnetized plasma column with presence of obstacle have been reported [1,3]. These works are highly system specific and mainly focused on conducting electrode effect. However, it also shows contradictory results based on object material. As the short-circuiting phenomena is absent in case of insulating electrode, therefore we may expect a different variation in radial plasma density and potential than a conducting body [2,3,5]. With regard to the wake region created by such insulating object, an adequate study on charged particle transport across magnetic field behind the obstacle is greatly required which may be applied to a coagulated crystal of dust particles, or a pellet injected in a magnetized plasma during plasma fueling in tokamak, etc.

To investigate the above, an experiment has been designed to study the radial potential and density variation behind a macroscopic object placed inside a non-flowing partially magnetized argon plasma column, created by hot cathode filament and gridded anode inside a linear cylindrical device. Electric probes have introduced inside the shadow of the insulating object and it is showing some interesting effects with increasing the axial magnetic field strength. It is found that the hotter electrons are able to penetrate across the magnetic field lines hence they will be able to reach the shadow region more efficiently and give rise to higher electron temperature behind the insulating obstacle. The transported flux behind the obstructed region consistently increases with increasing the magnetic field strength, which reflects the reduction in radial plasma density and potential gradients. This observation has been explained by a phenomenological model based on particle balance and energy conservation, which considers all the realistic effects in the overall set-up.

References

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