B-P7 AAPPS-DPP2020

4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Electrical conductivity in a compact dipole plasma device

Ayesha Nanda, and Sudeep Bhattacharjee
Department of Physics, Indian Institute of Technology, Kanpur
e-mail (speaker): ayesha@iitk.ac.in

Investigation on plasma transport properties like electrical conductivity in a magnetized plasma has interested researchers due to the constructive interplay between the collision processes and the external magnetic field. There has been significant theoretical progress on conductivity; and their applications in both laboratory and space plasma have grabbed the attention. It serves as a prerequisite in various laboratory and fusion devices due to its correlation with self-consistent electric field structures and plasma stability[1]. In space, it acts as a conduit between various atmospheric layers. In astrophysical plasma, it influences magnetic field line reconnection resulting in reconnection diffusion[2]. Various pioneering works have been done taking magnetic field along a particular direction[3]. Conductivity in ionosphere has been calculated assuming a plasma sheet surrounding the earth taking angle of dip into account, neglecting normal components of the associated electric field[4] and assuming a unidirectional magnetic field. However, dipole field being the most natural magnetic field configuration in atmosphere is bidirectional.

This work presents a study on the electrical conductivity in a dipolar magnetic field, which is of interest both for laboratory and space plasmas. Laboratory dipole plasma can simulate planetary environments. But in a laboratory dipole plasma, plasma size $\gg$ size of the magnet and thus the conventional approximations of plasma sheet and unidirectional magnetic field may not be proper for a volumetric plasma.

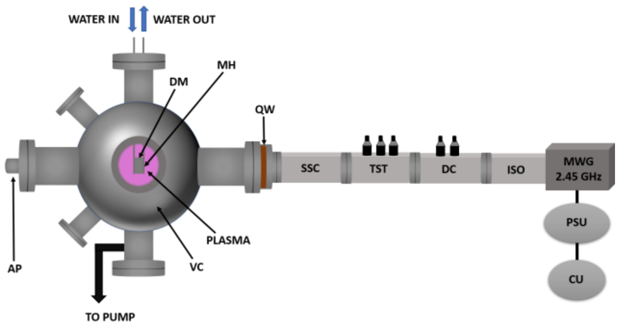

Fig. 1. Schematic of the experimental setup. CU: Control Unit, PSU: Power Supply Unit, MWG: Microwave Generator, ISO: Isolator, DC: Directional Coupler, TST: Triple Stub Tuner, SSC: Straight Section, QW: Quartz Window, MH: Magnet holder, DM: Dipole magnet, VC: Vacuum chamber, AP: Axial port.

A mathematical model for calculating electrical conductivity is formulated by fluid theory approach using the momentum equation considering the superposed velocity due to all possible guiding center drifts. The statistical nature of plasma is preserved by modifying the collision parameter, i.e., electron neutral collision frequency by averaging it over the obtained distribution function[5]. The Ohm's law is derived, from which the conductivity dyad is obtained. The dyad constitutes of Pedersen, Hall and longitudinal terms, with a unique feature of explicit magnetic field dependence on the longitudinal terms, which has not been reported elsewhere.

The schematic of the compact dipole plasma device[6] is shown in Fig. 1. Planar Langmuir probe is employed to obtain plasma parameters at several accessible spatial position (r, θ), and the magnetic field is measured by a gaussmeter. Altogether, these measurements aid in calculating all the components of the conductivity dyad.

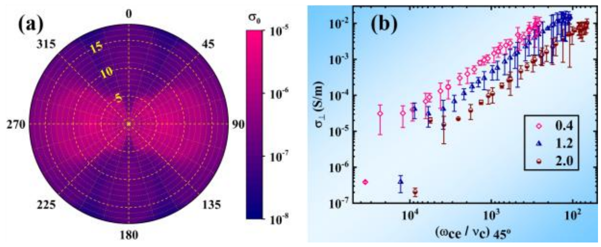

Fig. 2. (a): Polar contour plot of isotropic conductivity at 0.4 mTorr pressure with radial distances (in cm) mentioned on the circumference of the minor circles. (b): Pedersen conductivity variation against the Hall parameter for various pressures (in mTorr): 0.4 (pink), 1.2 (blue), 2.0 (maroon) at a fixed polar angle 45°.

Isotropic conductivity shown in Fig. 2(a) has patterns similar to dipolar magnetic field lines. This is solely due to its dependence on electron density, which varies in similar fashion[7]. Increasing the neutral pressure leads to greater number of collisions and hence reduction in average energy, thereby hindering electron motion. Therefore, a decrement in Pedersen conductivity is observed in Fig. 2(b) with increasing pressure. The variation of Hall and longitudinal conductivity terms along with the detailed study on conductivity in a dipolar magnetic field at various (r, θ) will be presented in the conference.

References

[1] V. Rohansky, Rev. Plasma Phys. **24**, 1-52 (2008).
[2] R. A. Truemann *et al.*, Front. Phys.: Space Phys. **1**, 31 (2013).
[3] P. Porazik *et al.*, Phys. Plasmas **24**, 052121 (2017)
[4] K.I. Maeda, Journal of Atmospheric and Terrestrial Physics **39**, 1041 (1977).
[5] G. G. Lister *et al.*, J. Appl. Phys. **79**, 12 (1996).
[6] A.R. Baitha *et al.*, Plasma Res. Express **1**, 045005 (2019).
[7] A.R. Baitha *et al.*, AIP Advances **10**, 045328 (2020).