6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

Analytical models to examine non-equilibrium plasmas in laboratory devices

S. K. Karkari[1], S. Das[1], P. Singh[1], Swati[1], Y. Patil[1] and A. Pandey[1]
[1] Institute for Plasma Research, HBNI, Gandhinagar, Gujarat, India 382428
e-mail: skarkari@ipr.res.in

Low temperature, non-equilibrium plasmas ($T_e >> T_i$) have been extensively studied due to its overwhelming applications in fusion research and in wide range of plasma technologies. Its significance arise due to its intrinsic role in plasma surface modifications to the generation of energetic particle beams required for auxiliary plasma heating in fusion devices. The macroscopic plasma parameters in these systems are greatly influenced by the external magnetic field, driving DC/radio-frequency sources and plasma interactions happening with material boundaries. With the invent of modern computers, it has been made possible to track millions of computer particles for simulating these plasma systems, hence producing results that are quite close to original scenario. On the other side, phenomenological models based on intuitive ideas drawn from experimental observations, can provide a faster route to arrive at the underlying physics in a more quantitative scale.

In this paper we exemplify a few cases in which macroscopic behavior of magnetized plasma column in linear devices has been addressed based on phenomenological models. One of the problem examines the nature of radial and axial variation in plasma density and electron temperature in magnetized plasma column, bounded by conducting and insulating boundaries in linear plasma device. It is found that the plasma density and potential exhibits an opposing trend [1] when the endplates were conducting than when it was replaced with an insulator. In the case of insulating end plate the potential and the density across the magnetic field lines are found to be in accordance with the Boltzmann distribution; whereas in the case of a conducting end plate the excess positive ions reaching the radial wall is compensated by electrons flowing along the magnetic field to the grounded end plate. This model has also been applied to explain the radial potential fall behind a macroscopic obstacle introduced inside a non-flowing magnetized plasma column [2].

In one of the experiment, a 13.56 MHz capacitive couple radio-frequency plasma source has been developed, in which a non-uniform electron temperature can be created by introducing an axial magnetic field. An analytical model has been developed for the case of non-uniform electron temperature distribution in the discharge, which relates the plasma potential with the radial plasma density and temperature.

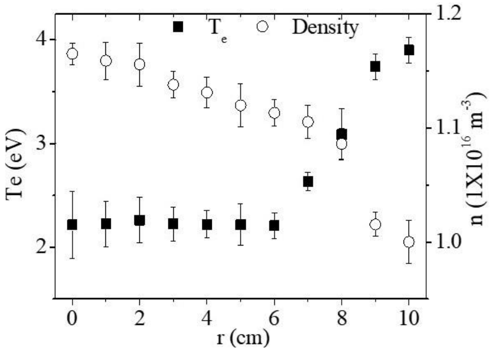

Fig-1: Radial plots of electron temperature and plasma density in 13.56 MHz discharge using cylindrical electrodes and axial magnetic field.

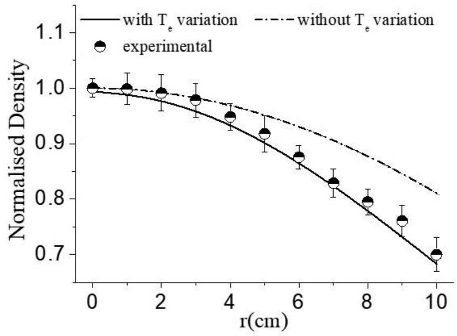

Fig-2: Plot of radial profile of normalised density obtained with (solid line) and without (dashed line) radial temperature variation and compared with experimental density profile (half-filled circles) for discharge at pressure=1 Pa and magnetic field =7.8 mT.

The non-uniform electron temperature model calculates the plasma density which is found to be closely related to experiments than when uniform electron temperature had been considered. The electron temperature is an important plasma parameter in electronegative discharges, as it governs the rate of volume production and losses of negative ions inside the plasma bulk. Therefore the model has been further developed to estimate the electronegativity inside the discharge.

References:

[1] S. Das and S. K. Karkari, Plasma Sources Science and Technology, **28** (7). 075013 (2019)
[2] S. Das and S. K. Karkari, Plasma Sources Sci. Technol. **30**, 055008 (2021)
[3] P. Singh, Swati, S. K. Karkari, J. Phys.D. Appl. Phys. **55** 235201 (2022)