Seminar

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Institute for Plasma Research

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Title: Control of edge and Scrape-off layer Tokamak plasma Turbulence

Speaker: Mr. Vijay Shankar
Institute for Plasma Research, Gandhinagar

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Abstract

The plasma in the edge and scrape-off layer (SOL) regions of a tokamak is highly turbulent mainly due to the excitation of the interchange instability. This instability occurs as the directions of centrifugal force due to the rapid toroidal plasma motion and the density/pressure gradient are in opposing directions. The plasma turbulence gives rise to some coherent nonlinear density structures called "blobs" and these blobs are responsible for the anomalous transport of the plasma. Therefore, the control of anomalous transport and these instabilities are necessary for the stable/safe operation of tokamaks. Various processes have been used to control these instabilities in the past. In this work, we investigate the control of turbulence from the perspective of the blob birth generation mechanisms, and by applying an external bias (electrode biasing) in the edge region.

The formation of a blob in the edge and SOL regions of a tokamak plasma normally takes place when a radially elongated density streamer structure breaks due to differential stretchings in the radial and poloidal directions. Such a phenomenon has been extensively studied in the past in the edge-to-SOL transition region using 2D (two-dimensional) model equations. In this work, we have examined the blob formation mechanism in the SOL and far SOL region of a tokamak plasma using a 3D (three-dimensional) model theoretically as well as numerically. The blob formation mechanism is found to be quite different from those in the edge-to-SOL transition region where the poloidal gradient of the poloidal electric field (PGPEF) is playing an important role which is not considered in the earlier works. We have derived a heuristic condition for such a plasma blob formation theoretically. Blob formation takes place when the amount of shear exceeds the non-linear growth rate (γ_n) of the basic interchange instability within the radially elongated streamer region. From 3D simulational data, it has been observed that the cross-correlation between PGPEF and γ_n is higher than the cross-correlation between other shears and γ_n. These correlations indicate that γ_n and these shears are not independent phenomena, they may be connected by a blob formation. In this work, the blob formation has been investigated in terms of a criterion using a large number of blob formations. It is found that if the contribution of PGPEF is removed, the blob formation criterion does not satisfy or marginally satisfy. PGPEF is also related to the plasma blob rotation during and after the blob formation. This indicates the importance of PGPEF in this work.

Electrode biasing in the tokamak boundary region is an important topic as it can control particle recycling, exhausts, confinement time, and heat loads on the limiter/divertor plates. Here, in this work, we have investigated some of the above effects theoretically and also numerically. A linear analysis of a set of model fluid equations shows that biasing stabilizes the small k_y modes. Positive biasing is found to lead to a larger increment in plasma density and temperature as compared to negative biasing. It is further observed that cross-correlation between density and poloidal electric field at different radial positions decreases for positive biasing and in the case of negative biasing it is almost similar to that of no (w/o) biasing. Plasma density and poloidal electric field fluctuations have been investigated which show that the density fluctuations increase (decrease) for positive (negative) biasing but the radially outward flux for these biasing cases always decreases mainly due to the decrease of cross-correlation between density and poloidal electric field fluctuations. The concomitant modifications in the radial transport and power spectra are also analyzed. Non-linear analysis shows that a positive bias shifts the peak of the k_y-spectra towards a lower k_y value in the edge region. The heat and particle fluxes in the edge region are seen to increase with the radial electric field shear in the region where a flow reversal takes place. Elsewhere, the fluxes decrease with an increase in the shear. The heat and particle loads per unit time on the limiter/divertor material plates decrease with the biasing voltages in comparison to those w/o biasing, but the load intensities increase. It is found that the blob fraction decreases with the radial electric field shear but at lower radial positions around the biasing region it increases from -16 volts to +64 volts.