EDGE BIASING OF SINP-TOKAMAK PLASMA IN HIGH-q REGIME

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Abstract

In SINP-TOKAMAK [an iron-core device having major radius = 30 cm, minor radius = 7.5 cm and B(toroidal) = 2 Tesla(maximum)] both high/normal q and very low q (VLQ) regimes can be achieved. Recently in this machine fast edge biasing experiment in the later regime revealed a change in plasma current profile at edge region leading to better confinement and longer duration of plasma current. The continuation of the same experiment is done in high/normal q regime. For this purpose, as before, a tungsten electrode assembly with 6 mm diameter rod, biased by a pulsed power supply, is introduced in the edge of the plasma. Preliminary analysis of data reveals similar observations even in this high-q regime, namely, the current profile modification obtained by biasing has more pronounced effects compared to those in the very low q regime experiment. The current duration increases from about 9 msec to about 13 msec, i.e. by more 40%. Under certain conditions the peak plasma current sometimes increases. The electrode current drawn in this regime is comparatively much lower than that in the VLQ case, but this is as expected since toroidal magnetic field is much higher in this regime. Lowering of H_α signal and loop voltage is also observed which indicates better confinement.

1. Introduction

The transition from the low confinement mode to high confinement mode has been observed in various tokamak operations. But the physics of the transition does not seem to be same for all the tokamaks where this event has been observed. Different types of theoretical model have been developed to explain this phenomenon. There is substantial support for the model of the sheared radial electric field which causes the suppression of turbulence as an element of the L-H transition [1-5]. On the other hand, several experiments [6-10] and theories support toroidal current density profile modification in the L-H transition [11-13].

Several plasma edge biasing experiments have been done to simulate radial electric field. In general ExB shear is increased to cause better confinement in the H-mode by improving radial electric field (E_r) in edge biasing experiment [14-15]. These E_r profile modification experiments leading to a better plasma confinement have been done mostly for the normal q_a discharges (q_a is the safety factor at the edge ; $q_a > 3$). On the other hand, in few experiments, modification of the j_ϕ (current density in the toroidal direction) profile has been observed after applying the bias voltage at the plasma edge [16]. And plasma edge biasing experiment in SINP-TOKAMAK in low q regime is one of them. There the j_ϕ-profile modification resulted in better energy confinement. But as far as our knowledge goes the j_ϕ-profile modification at high q regime by applying bias voltage is not done yet. In SINP-TOKAMAK we have carried out such an experiment. After applying the bias voltage at the edge of plasma it is observed that the plasma current duration extended, the H_α intensity level decreased, the loop voltage dropped and other effects were observed, all of which will be discussed in section 3. Section 2 describes the experimental setup first.

2. Experimental Setup:

The SINP-TOKAMAK is a small iron-core machine having circular cross-section with R=0.30m & a=0.075m. In this tokamak normal duration of the plasma discharge is ~ 2 to 3 milliseconds. But using extra capacitor bank discharge duration can be extended nearly 10 times without any external disturbance (such as probe insertion). In the present experiment extra capacitor bank is used for longer plasma discharge duration (10-15 msec) in high q regime. (I_P= 18 - 22 kA, B_T=1.2 T, q_a= 6 to 7). To bias the plasma edge a cylindrical shaped highly purified tungsten rod of 6 mm diameter is inserted from a top port. It is hold by a ceramic tube which is attached in a two bellow system. Total arrangement for holding the tungsten electrode is made in such a way that exposed length of the electrode can be varied and also electrode can be moved spatially at a fixed exposed length. Voltage is applied through this electrode to the plasma edge by a SCR controlled fast switching high voltage power supply (switching speed is the order of microsecond). A trigger circuit is also

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developed to switch the SCR. In addition, voltage can be applied at different times using time delay in the trigger circuit of plasma duration.

3. Results & Discussions:

In this experiment negative voltage, w.r.t. vacuum vessel (to which limiter is connected), is applied through the electrode (placed 90^0 toroidally away from limiter) in the plasma edge at high-q regime of the SINP-TOKAMAK. The position of the electrode tip is at 6.7 cm from the plasma centre and exposed length of the electrode is 0.5 cm. Biasing voltage is gradually increased from -50V to -160V. It is observed that duration of the plasma current is increased gradually and after reaching a maximum increment it begins to decrease gradually. The maximum increment of the plasma current duration is nearly 2 msec. The enhancement of the plasma current duration is shown in Fig.1(a). The loop voltage which decreases slightly is shown in the Fig.1 (b). And in Fig.1(c) the current drawn by the electrode is presented. It is interesting to observe that during biasing the electrode current is small.

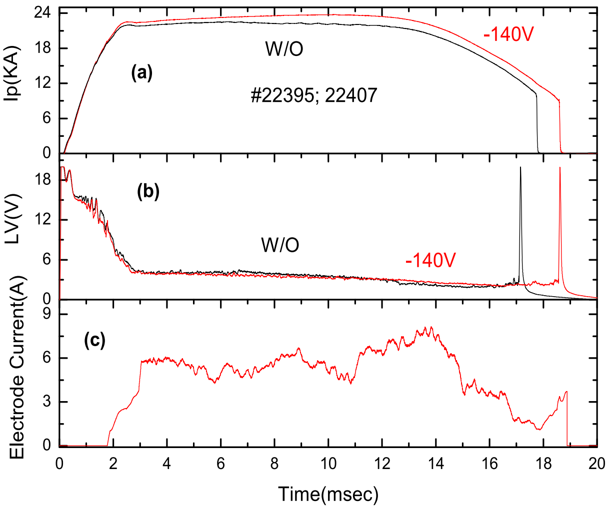

Fig1: Temporal evolution of (a) I_P, (b) Loop voltage for plasma discharges for with & without bias and (c) electrode current

Radially integrated intensity of the H_α signal is observed along the central chord by the spectroscopic arrangement in the presence of bias and without bias. It is observed that at the time of onset of the biasing voltage intensity of the H_α signal is decreased in comparison to without bias case (Fig. 2).

To investigate further a Langmuir probe array and a magnetic probe array set up are used. In Langmuir probe array three probes are there at 3 radial positions. The centre to centre distance of successive probes is 5 mm. Length of the probe is 2 mm & diameter is 0.5 mm. Radial positions of the probes are at 73 mm, 68 mm & 63 mm from the plasma centre. In this experiment floating

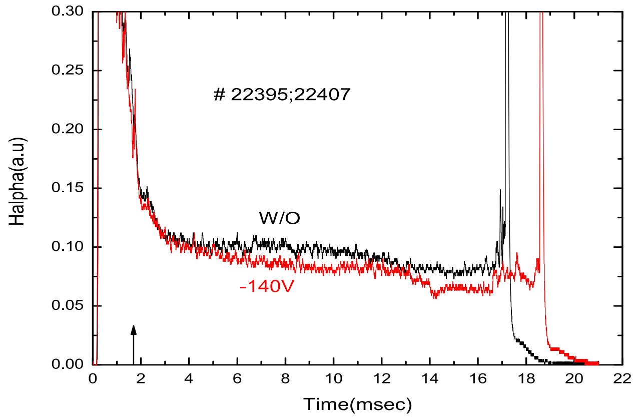

Fig 2: Temporal evolution of H_α-emission for plasma discharges with (arrow position) & without bias voltage.

potential of the plasma has been measured with and without bias. It is observed that floating potential is measured by the outer two probes do not change remarkably in the presence of biasing in comparison to those without bias. But floating potential measured by the inner probe (position at 63 mm) is increased negatively with the onset of the biasing voltage. But this change is remained nearly 2 to 3 milliseconds. After this time duration floating potentials of the plasma with & without bias have no difference as is shown in Fig. 3.

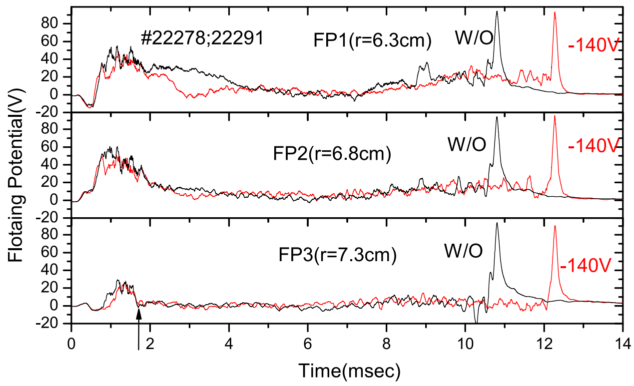

Fig 3: Temporal evolution of Floating potential in plasma discharge with (arrow position)) & without bias.

Internal magnetic field in the poloidal direction was measured by a magnetic probe array set up, which consists of three magnetic probes located radially. Centre to centre distance of successive magnetic probes is 8 mm and cross section of each probe is 5mm x 1mm. Radial positions of the three probes are at 80 mm, 72 mm, 64 mm from the plasma centre. This array is used to observe the change of poloidal magnetic field (B_p), hence the toroidal current density (j_φ) profile modification with biasing. Magnetic probe results are shown in Fig.4. It is observed that inner magnetic probe signal is significantly increased almost instantly with the application of the bias voltage.

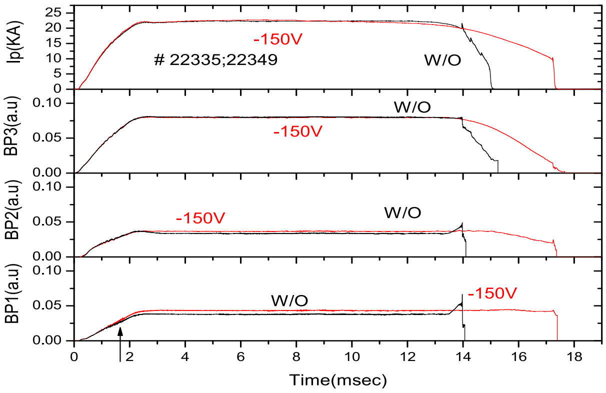

Fig4: Temporal variation of B_p with plasma discharge in three radial locations with (arrow position) and without bias. Top curve shows plasma current.

To observe the change of electron density and electron temperature a triple-Langmuir probe is inserted at 69 mm from the plasma centre. The plasma density is seen to decrease initially, but increases few milliseconds later after onset of biasing voltage. It is shown in Fig. 5.

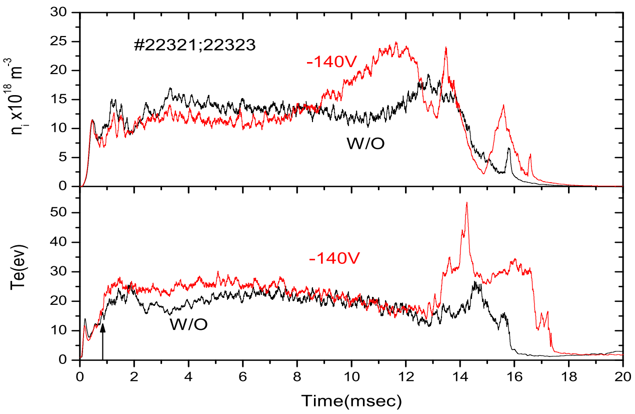

Fig 5: Temporal evolution of electron density and electron temperature of plasma discharges with (arrow position) and without bias.

To see any change in the steepness of the density gradient because of electrode biasing at the edge of the plasma spatial profile of the plasma density has been taken by double Langmuir probe at the steady plasma current region up to 12 millimeter inside from the plasma edge. It has been observed that steepness is increased due to the effect of electrode biasing as is shown in Fig. 6.

Increase of the plasma current duration, decrease of the intensity level of the H_α, increase of the ion density and

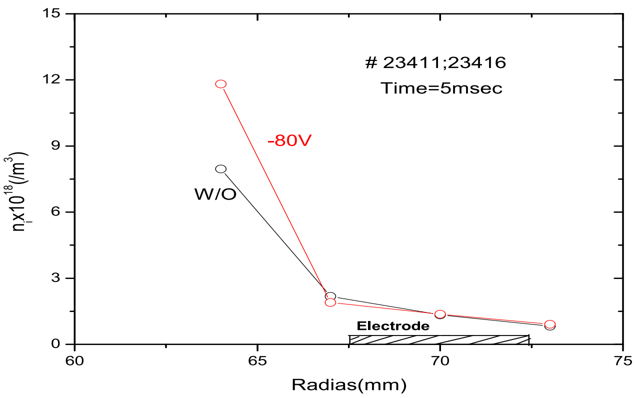

Fig 6: Spatial profile of the plasma density with and without bias up to 12 millimeter inside from the plasma edge.

electron temperature indicates an improved plasma confinement. Modification of the electric field in radial direction for the small duration and toroidal current profile changes both may be the cause of the transition to the improved confinement. But to search for exact reason of the transition deep physical insight is needed and in progress.

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