Edge Plasma Behavior During Externally Applied Positive Biasing and Resonant Magnetic Perturbation in IR-T1 Tokamak

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Abstract. Edge plasma behavior during externally applied positive biasing and resonant helical magnetic field (RHF) perturbation in IR-T1 tokamak has been investigated. The experiments have been done in different regimes as electrode and limiter biasing, magnetic perturbation application and both of them. The profiles of radial electron temperature, floating potential, poloidal and toroidal rotation velocity have been measured by using of a movable Langmuir probe and Mach probes in the edge of plasma. Magnetohydrodynamic phenomena based on Mirnov oscillations have been investigated by applying the positive biasing potentials and RHF's. An effect of RHF on magnetohydrodynamics behaviour during positive biasing has been investigated. The results shown that subsequent to the application of a positive bias, an increase in the frequency of poloidal magnetic field fluctuations was observed but after RHF application during L=2 and n=1 (L=poloidal and n=toroidal turn) the m=2 MHD mode oscillations amplified and m=3 mode is suppressed; also by applying L=3 the m=2 mode oscillation has been disappeared. The results analyzed by SVD and wavelet methods. The toroidal velocity changes after a short delay time of about t_d=0.5-1.5ms during RHF application while poloidal velocity changes just after RHF's. The poloidal velocity increased after positive bias during RHF (L=2 mode) application but it decreased after positive biasing during RHF (L=3 mode) regime. Toroidal velocity hasn't considerable change during biasing but its behaviour smoothed after positive bias application. *(The paper still is under revision)*

Keywords: tokamak, MHD activities, plasma rotation, resonant helical magnetic perturbation, electric biasing

1. Introduction

Magnetohydrodynamics (MHD) phenomena in tokamaks are one of the most important topics in tokamak physics. MHD instabilities are considered dangerous phenomena because they may cause destruction of magnetic surfaces and termination of plasma discharge. Mirnov coils directly measure the magnetic field fluctuations associated with rotating magnetic islands. One of the most important problems is the influence of sheared radial electric field on MHD activity and island evolution. Traditional points of view are based on the assumption that the magnetic island rotates in electron diamagnetic drift direction with the rotational frequency ω due to radial electric field E_r and electron pressure gradient. Interest in the edge flows in tokamaks associated with the L-mode (low confinement regime) to H-mode transition has led to recent progress in development of theoretical models for the interpretation of electrostatic probe data for the measurement of plasma ion and electron flows and drifts [1-9]. This paper discusses the relation between the magnetic perturbations and poloidal and toroidal rotation of edge plasma. The effect of a resonant helical magnetic field on magnetohydrodynamics behaviour during positive biasing has been investigated. The RHF in IR-T1 tokamak is an external magnetic field which can improve the plasma confinement. This field is produced by two winding with optimized geometry conductors wound externally around the tokamak torus with a given helicity. The minor radius of these helical windings are 22cm (*L*=2) and 23cm (*L*=3). In the experiments presented here, the current through the helical windings was between 100-400A, which is very low compared with the plasma current itself (25-30kA). The aim of these experiments was to understand the effect of RHF on toroidal and poloidal plasma rotation and suppressing the MHD activities that leading to major disruptions.

2. **Experimental Setup**

The IR-T1 tokamak is a small tokamak with major radius R=45.0cm and minor radius a=12.5cm defined by two full poloidal limiter. A moveable limiter and mushroom electrode made of stainless-steel is located at the equatorial midplane positioned in the r=12.5cm. The biased voltage was restricted to the range of $-350V \le V_{\mathrm{Lim}} \le 350V$. The biasing Limiter and electrode, Mirnov arrays and Mach/Langmuir probes are separated 120° azimuthally from each other. The experiment was performed under ohmically heated hydrogen plasma with toroidal magnetic field B_t=0.7T, plasma current I_p=20-30kA, chord average electron density $\bar{n}_e = (0.3\text{-}1.5)\times 10^{19}\ \mathrm{m}^{-3}$ and plasma discharge duration 20 ms. Fig.1 shows typical Schematic of IR-T1 and of *L*=2/1 and *L*=3/1 RHF winding coil around the chamber.

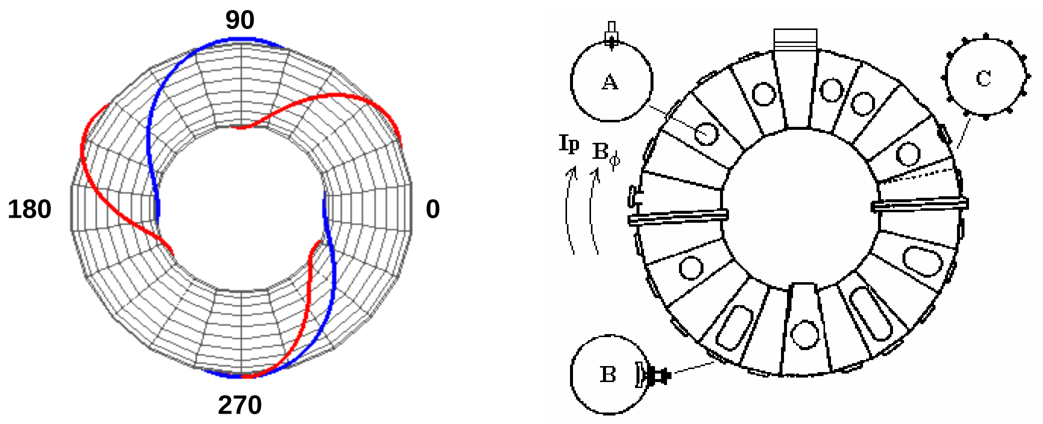

FIG.1. Schematic drawing of IR-T1 (Right), locations of Mirnov coils indicated by (C), limiter/electrode biasing position indicated by (B) and 4-pin Mach probe indicated by (A), and typical schematic of L=2/1 and L=3/1 RHF winding coil around the chamber (Left).

The experiments have been done in different regimes as electrode/Limiter biasing, resonant helical magnetic field (RHF) perturbation application and both of them. In all experiments the biasing applied about 2 ms after RHF application. The results shown that subsequent to the application of a positive bias, an increase in the frequency of poloidal magnetic field fluctuations was observed but during RHF application during *L*=2, n=1 (L=poloidal and n=toroidal turn) the m=2 MHD mode oscillations amplified and m=3 mode suppressed. Also by applying *L*=3, n=1 the m=2 MHD mode oscillations has been disappeared. The reappearance of the MHD activities is led by a kink-like *m*= 1 mode. The toroidal velocity almost changes after a short delay time of about t_d=0.5-1.5ms during RHF application while poloidal velocity changes just after RHF. During RHF application with L=2 mode, the poloidal and toroidal velocity have more fluctuation but after bias application both of them became more smooth. In this case the poloidal velocity increased after positive bias but toroidal velocity hasn't considerable change. When the RHF application is in L=3 mode the poloidal Mach number decreased during positive biasing. The measured Mach number has been shown in Fig.2 and 3 during RHF application and the measured Mach number with bias application has been shown in Fig.4 and 5 during RHF application.

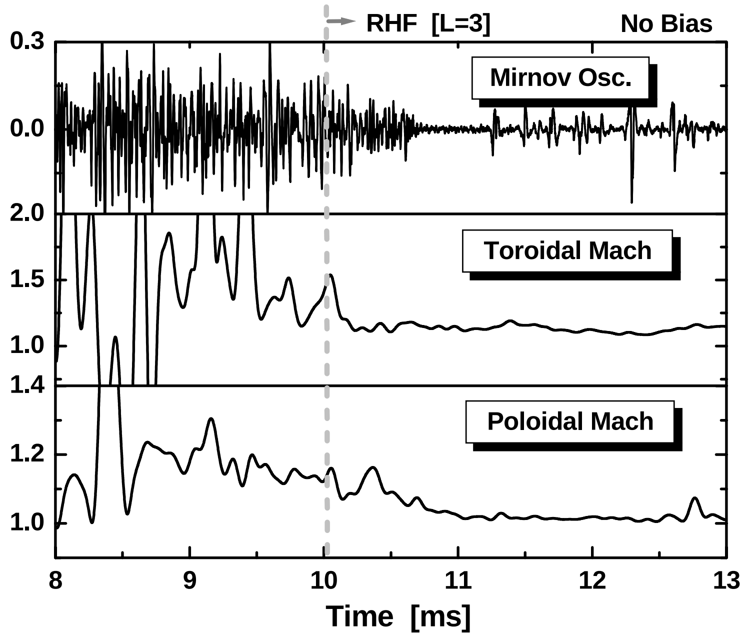

FIG. 2. Time evolution of Mirnov oscillation and poloidal and toroidal Mach number with RHF (L=3) applied in 10 ms and without biasing.

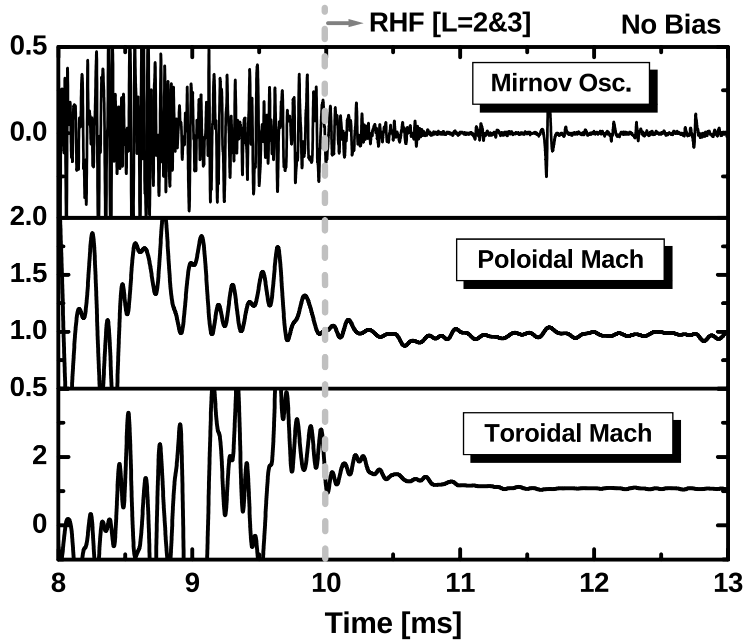

FIG. 3. Time evolution of Mirnov oscillation and poloidal and toroidal Mach number with RHF (L=2&3) applied in 10 ms and without biasing.

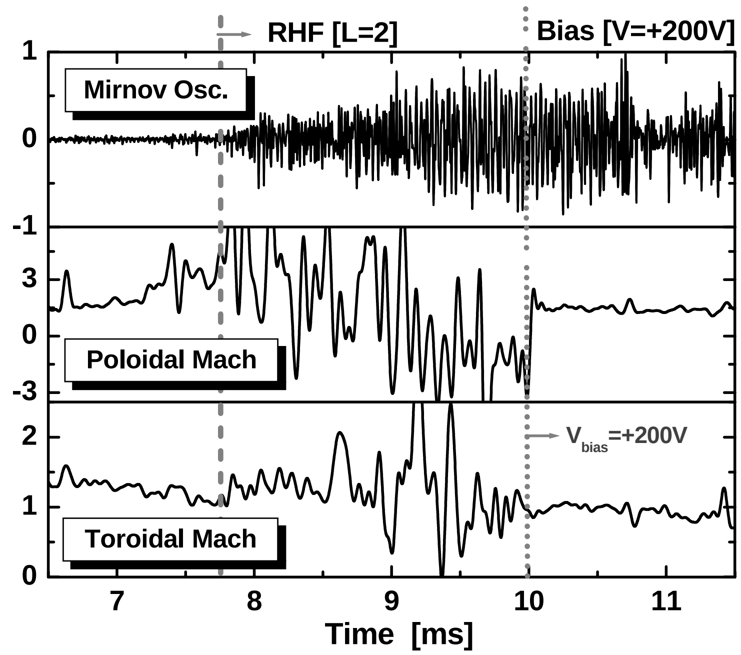

FIG. 4. Time evolution of Mirnov oscillation and Poloidal and toroidal Mach Number With RHF (L=2) applied in 7.8 ms and 200V positive limiter Biasing applied in 10 ms.

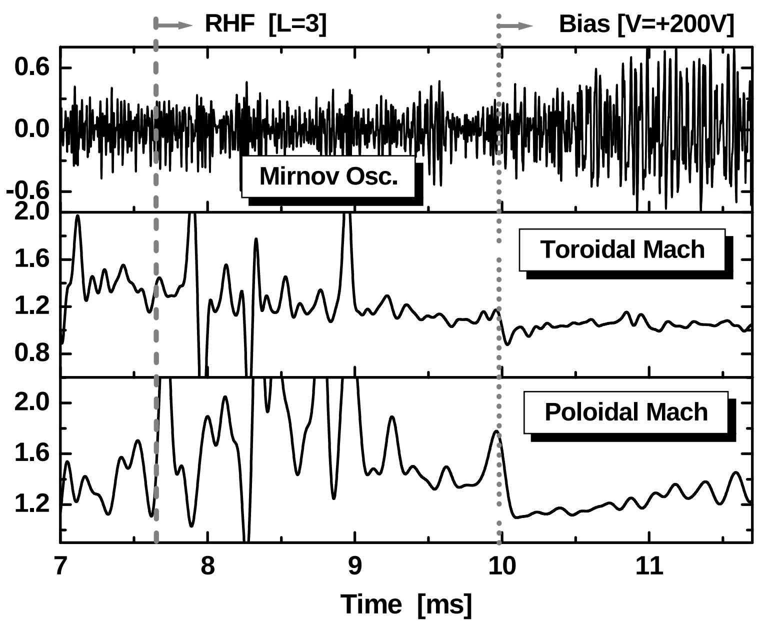

FIG. 5. Time evolution of Mirnov oscillation and Poloidal and toroidal Mach Number With RHF (L=3) applied in 7.7 ms and 200V positive limiter Biasing applied in 10 ms.

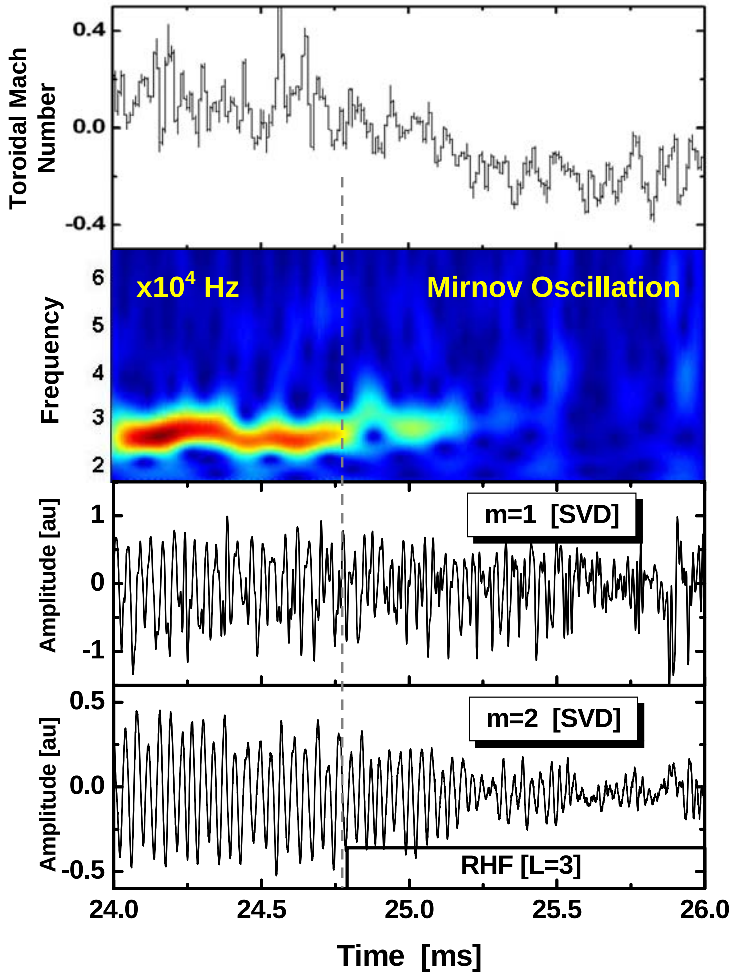

FIG. 6. time evolution of plasma behavior during RHF (*L*=3) application in 24.8 ms. The data from toroidal mach number by 4-pin Mach probe, Wavelet spectrum of Mirnov Coil and SVD (0.5ms time intervals) analyses; top to bottom respectively.

The results analysed by SVD and wavelet methods as shown in Fig.6. The first response of plasma to positive biasing in RHF (L=3 mode) is a decrease of plasma poloidal rotation. During this reduction, in a matter of less than 0.5 ms, the edge electrostatic and magnetic fluctuations are strongly suppressed and the pressure gradient increases. The direction of this rotation usually corresponds to a negative direction of E_r. During positive limiter biasing during RHF application it found a rapid increase in poloidal rotation while in this situation the toroidal rotation became smooth. It could see in Fig.4 that by applying RHF (L=2 mode) the rotation fluctuation increased but after biasing both poloidal and toroidal rotation became smooth. These results show an influence of radial electric field variation on MHD activity, observed similarly in STOR-M [7] and TUMAN-3M [8] tokamaks. Negative biasing and electrode biasing didn't show a clear result in IR-T1.

Conclusions

MHD oscillations in the IR-T1 tokamak have been monitored by discrete poloidal and toroidal Mirnov coil arrays. The wavelet, FFT and SVD techniques have been used to perform time-frequency and spatial-wave number harmonics analyses on the measured MHD fluctuations. Also, the fluctuations have been investigated during resonant helical magnetic field. Significant suppression of MHD fluctuations during the improved confinement phase has been observed. The reappearance of the MHD activities is led by a kink-like m=1 mode. The toroidal velocity changes after a short delay time of about t_d=1-1.5ms during RHF application while poloidal velocity changes just after RHF's. The poloidal velocity increased after positive bias during RHF (L=2) application but it decreased after positive biasing during RHF (L=3) regime. Toroidal velocity hasn't considerable change during biasing but its behaviour smoothed after positive bias application.

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