Control of a Pressure Driven m=1 Mode in a Low Shear LHCD Plasma by ECH in the WT-3 Tokamak

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Abstract. A large amplitude m=1 mode is excited by LHCD in the WT-3 tokamak (a=20cm, R=65cm, Bt≦1.75T). The mode excitation is accompanied with decrease of the magnetic shear near the q=1 surface and peaking of the soft X-ray (SX) emissivity profile, suggesting that the mode is a pressure driven mode. The mode is suppressed by ECH near the q=1 surface, while enhanced by ECH near the plasma center. The mode stabilization is accompanied with a local enhancement of the SX emissivity near the q=1 surface.

1. Introduction

In the recent decade, electron cyclotron heating (ECH) and current drive (ECCD) has been found to suppress MHD activities effectively in many tokamaks. The sawtooth oscillations were suppressed by ECH on the q=1 surface [1] as well as ECCD on the magnetic axis [2]. The m=2 tearing mode was also suppressed by ECH on the q=2 surface [3,4]. Direct ECH on the O-point of the m=2 mode was effective to avoid a major disruption [5]. ECCD was effective to suppress the neoclassical tearing mode [6]. In these experiments, suppression was ascribed to the local current modification by ECH/ECCD. In this paper we present an experimental result which shows that a pressure driven m=1 mode excited by lower hybrid current drive (LHCD) is suppressed by local pressure profile modification by ECH.

2. Excitation of m=1 mode by LHCD

Ohmically heated (OH) plasmas with the safety factor of q_L=3 at the limiter, the plasma current of Ip=150 kA, and the line averaged electron density of $\overline{n_e} \simeq 0.7 \times 10^{13}$ cm^{-3}, are used for a target plasma, where a stationary excited tearing mode in the form of coupled m=1/n=1 and m=2/n=1 mode [4] and a weak sawtooth oscillation are observed on the SX signals as shown in Fig.1(a). Here, Isx(r/a) is reconstructed by the SX computerized tomography (CT) and indicates the local SX emissivity at the normalized radius, r/a, on the mid-plane of the plasma column. By application of LHCD power (2GHz, 100kW), the loop voltage decreases from V_L=2.4 to 1.0 V, indicating that over half of the plasma current is replaced by LH driven current. In accordance with the decrease of V_L, the SX amplitude of the m=1,2 mode and sawtooth osccilations decreases and then a relatively quiescent phase continues as shown in Fig.1(a). Following this, a new m=1/n=1 mode suddenly appears at t=59 msec. This LHCD m=1 mode quickly grows and saturates in one period of oscillation.

Although Isx signals looks quiescent during the time t=54-58 msec in Fig.1(a), a weak double m=1 mode is actually observed on SX CT images of enhanced scale as shown in

Fig.2(II). The temporal evolution of of the peak radial position and the full width at the half maximum of the m=1 mode structure on $\tilde{\mathrm{I}}$sx=Isx-$\bar{\mathrm{I}}$sx profile is analyzed by CT as shown in Fig.2 and plotted in Fig.1(b). Here, over bar on Isx denotes the time averaging over 1 ms. The peak radius of the outer mode of the double mode is in the range of r/a=0.3-0.4. and nearly equal to those of OH and LHCD m=1 modes. The appearance of the weak double m=1 mode indicates that the magnetic shear becomes weak around and inside the q=1 surface before appearance of the LHCD m=1 mode.

In Fig.1(c) is plotted the temporal evolution of the SX profile integral as a measure of poloidal beta inside the q=1 surface, by assuming that $\bar{\mathrm{I}}$sx(r/a) is proportional to the local plasma pressure. The integral increases before appearance of the LHCD m=1 mode as the amplitude of the OH m=1 mode decreases by LHCD and is saturated after appearance of the LHCD m=1 mode, suggesting that the LHCD mode is a pressure driven mode under a weak magnetic shear. Furthermore, a crescent-shaped mode structure appears on the SX CT image of the LHCD m=1 mode as shown in Fig.3, suggesting that the mode is a quasi-interchange type driven by pressure gradient in the low shear field [7].

3. Control of m=1 mode by ECH

The ECH power (89GHz,100kW) is injected from the low field side perpendicularly to the toroidal field in X-mode and is absorbed at the second harmonic ECR layer ($R_{\omega=2\Omega e}$). As shown in Figs.1(a) and (c), the mode is suppressed quickly (∼0.5 msec) after ECH on, in accordance with the quick decrease of the SX profile integral. In this case, the ECR layer is located at r/a=-0.34 and the SX intensity increases at the ECR layer as well as at the plasma center. The hard X-ray emission does not change, indicating that ECH power is primarily deposited to the bulk electrons and not to the LHCD fast electrons. The ray tracing calculation shows that the single pass absorption of the EC wave by the bulk electrons is more than 50% under the present experimental conditions.

The location of the ECR layer is scanned by changing both Bt and Ip with keeping q_L constant. The complete suppression is obtained when the ECR layer is located in the range of r/a= -0.27∼-0.40 as shown in Fig.4, where the local enhancement of Isx near the q=1 surface is always observed as shown in Fig.5(b). When the ECR layer is positioned near the plasma center, the SX mode amplitude is enhanced by ∼30% and the SX profile becomes more peaked as shown in Fig.5(c). In the case of r/a≦-0.45, there is no suppression at all and the SX profile does not change as shown in Fig.5(a).

The result that the LHCD m=1 mode is not a resistive instability but a pressure driven one seems to appear in the following characters on the suppression by ECH. First, the width of the ECR layer effective for the complete suppression is much wider in the present case (Δr/a=0.13) compared with the previous ECH experiments of sawtooth suppression (Δr/a=0.03)[1] and the tearing mode suppression (Δr/a=0.04)[4]. Second, the time needed for the complete suppression after ECH on is in the range of t=0.4-0.75 msec, which is much faster than the resistive current diffusion time for the case of the tearing modes in the OH plasma (∼2msec) [4], and depends only weakly on the location of the ECR layer. These results suggest that mode stabilization is ascribed to the local pressure profile modification near the q=1 surface.

4. Summary

A pressure driven m=1 mode is excited by LHCD, which flattens the current profile and increases the plasma pressure inside the q=1 surface. The mode is controlled by the local modification of the pressure profile by ECH near the q=1 surface.

References

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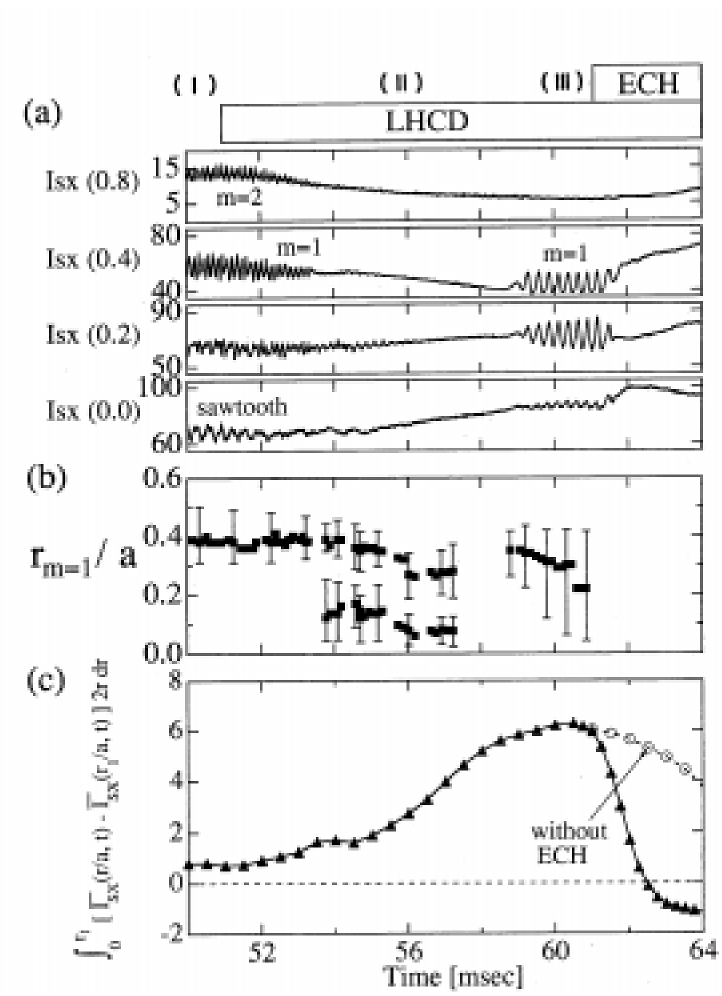

Figure 1: *Time evolution of (a) m=1 mode, (b) m=1 peak radius and (c) SX profile integral.*

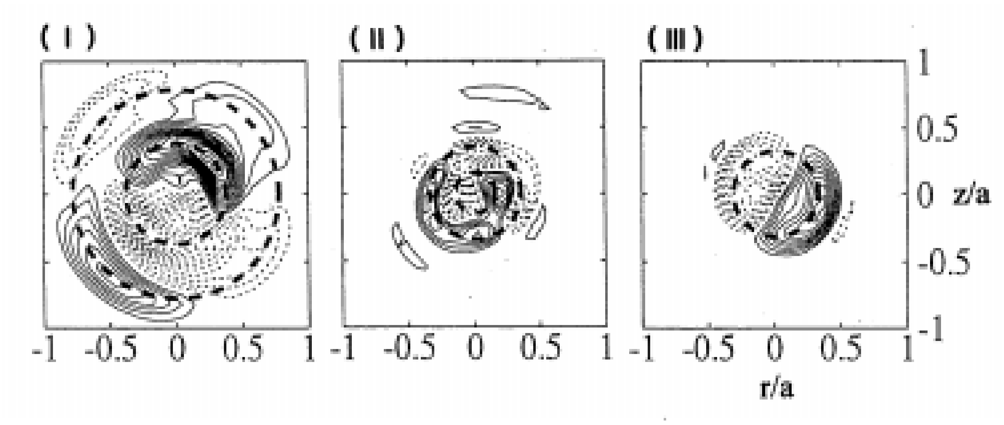

Figure 2: *SX CT images of m=1 modes ($\tilde{I}sx$) at the time (I), (II) and (III) in Fig.1. The contour scale is enhanced twice in (I), ten times in (II) compared with (III).*

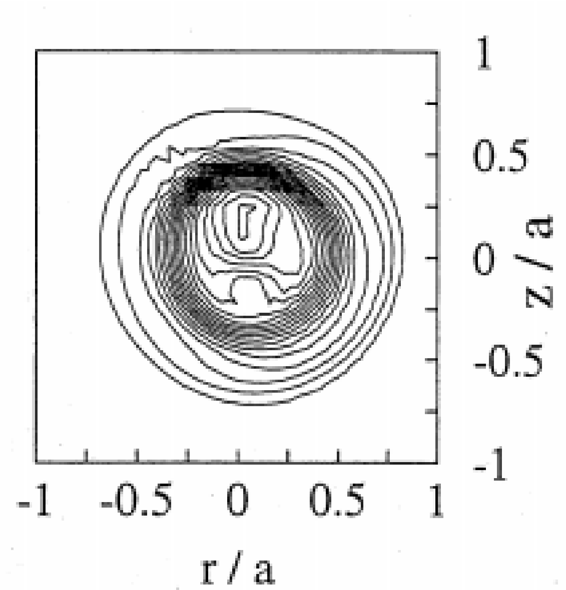

Figure 3: *SX CT image of the LHCD plasma at t=63.4 msec.*

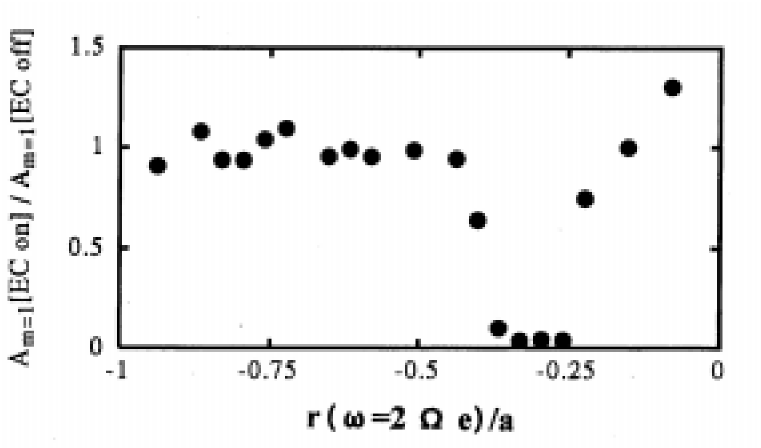

Figure 4: *The ratio of the SX m=1 amplitude with ECH to that without ECH versus the location of the second harmonic ECR layer.*

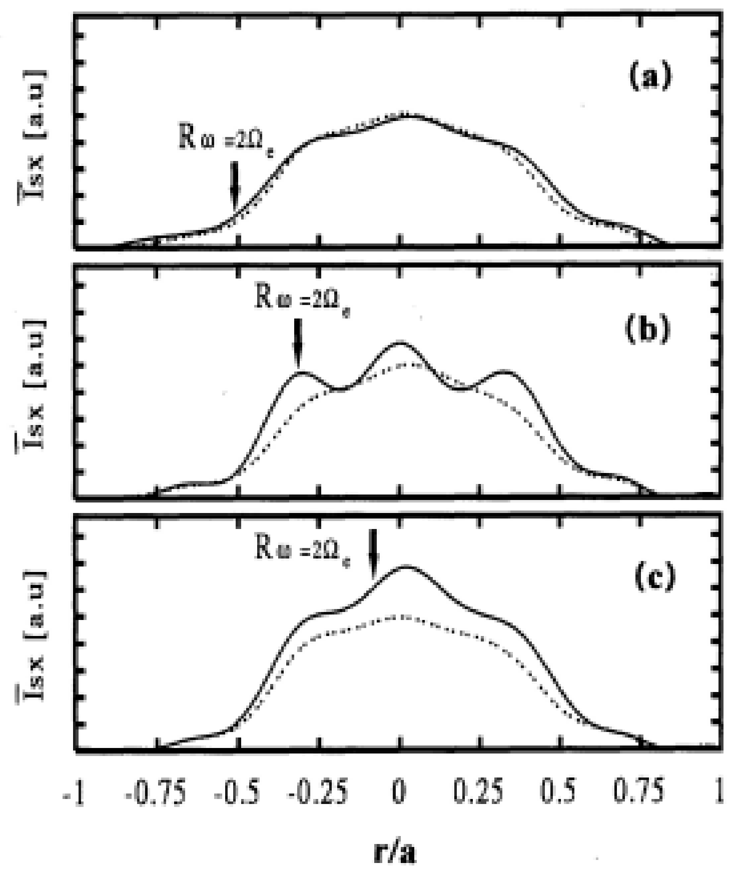

Figure 5: *The time averaged SX profile before (dotted line) and after ECH (solid line) for various locations of the ECR layer.*