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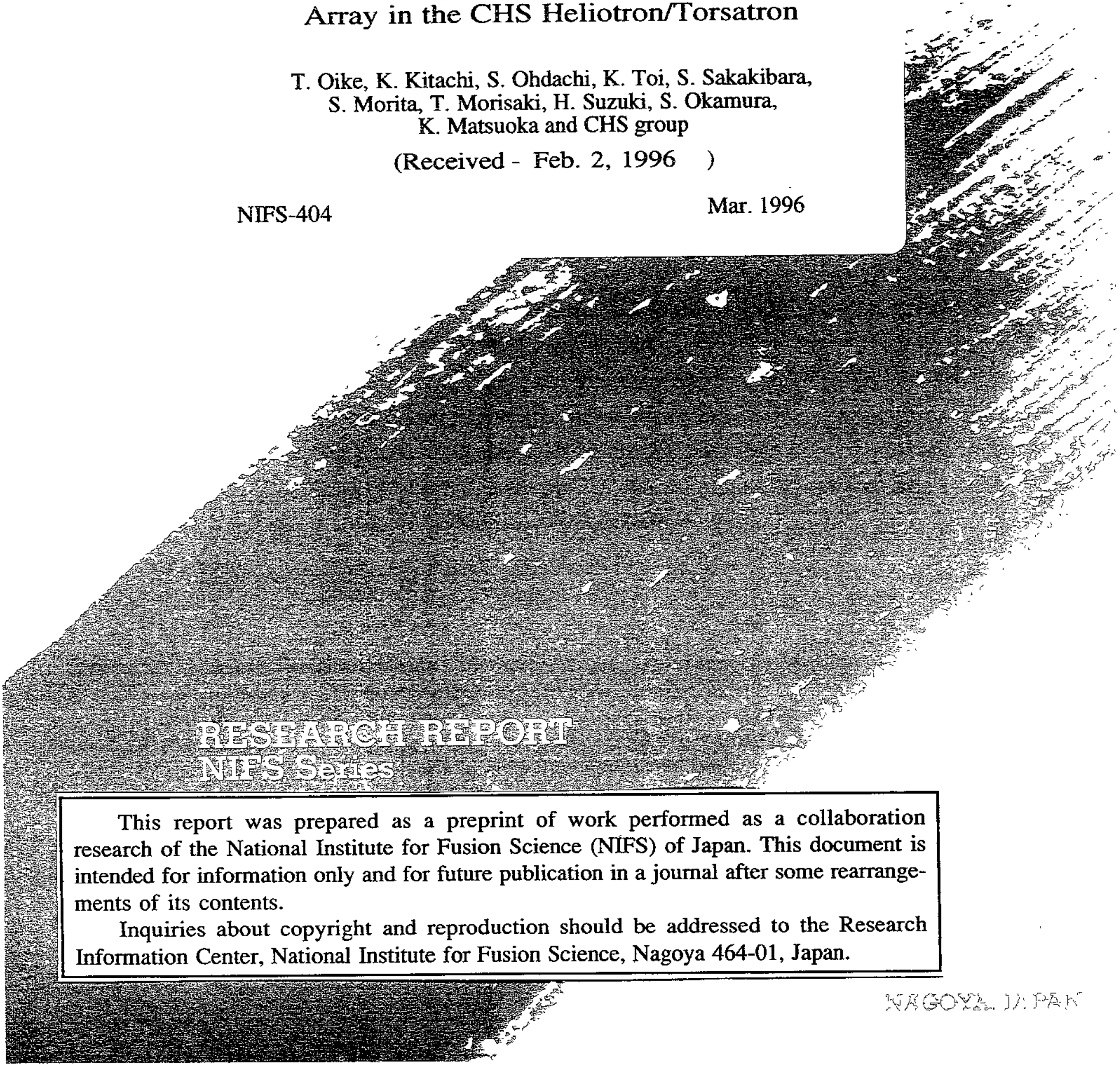

RESEARCH REPORT
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MEASUREMENT OF MAGNETIC FIELD FLUCTUATIONS NEAR PLASMA EDGE WITH MOVABLE MAGNETIC PROBE ARRAY IN THE CHS HELIOTRON/TORSATRON

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ABSTRACT

Magnetic fluctuations are measured with a newly developed movable probe array in the region from scrape-off layer to just inside the last closed flux surface of neutral beam heated plasmas in CHS. Radial profiles of magnetic fluctuation amplitude and their correlation length are derived for low frequency (< 40 kHz) coherent components having low mode number and relatively high frequency (> 60 kHz) incoherent ones. The former components are inferred to be an ideal interchange mode excited in the plasma interior and has a large radial correlation length $L_r \geq \langle a \rangle$ (averaged minor radius). The latter of which instability is not yet identified has relatively short correlation length $L_r \sim \langle a \rangle/7$.

Keywords: Heliotron/Torsatron, Magnetic Fluctuations, Movable Magnetic Probe Array,
Correlation Length, Interchange Mode

I. INTRODUCTION

Heliotron/torsatron configuration has recently been received much interest as same as stellarator configuration, from a point of view of steady state operation. However, the plasma confined in the heliotron/torsatron configuration may suffer from ideal interchange modes, depending on combination of magnetic hill and magnetic shear [1]. Moreover, resistive interchange mode may be always unstable in the plasma edge because of magnetic hill there [1]. These instabilities can degrade considerably the plasma confinement. In CHS, which is a low aspect ratio heliotron/torsatron device with the major radius R~1m and averaged minor radius <a>~0.17 m [2]. The rotational transform profile is modified with a net plasma current to study the instabilities and the effects on plasma confinement [3, 4, 5, 6]. In these experiments magnetic fluctuations are measured with only Mirnov coils located on inner surface of the vacuum vessel. We have developed a movable magnetic probe array to study magnetic fluctuations in the region from scrape-off layer to just inside the last closed flux surface and correlation with electrostatic fluctuations.

II. EXPERIMENTAL SETUP

The movable magnetic probe array is installed on the top of the CHS vacuum vessel as shown in Fig.1. The magnetic probes are set inside the stainless steel (SUS) pipe of 13mm diameter and 1mm thickness which is electrically insulated from the vacuum vessel. For protection from plasma bombardment the top of SUS pipe is covered with a cap of carbon-carbon composite with 20% boron, of which size is 30mm diameter and 30mm length. The probe array consist of fourteen probes: seven probes 'θ1~7' for the measurement of poloidal field component and the other seven ones 'R1~7' for radial field component . The magnetic probe installed closest to the plasma can be inserted up to ~130mm height from the equatorial plane of the plasma, which corresponds to the ratio of averaged radial position to the minor plasma radius r /<a>~0.5. In the present experiments, the probe array was inserted up to r/<a>~0.8, but no serious effect on plasma performance is observed.

III. EXPERIMENTAL RESULTS

Figure 2 shows time evolutions of magnetic fluctuations detected with the magnetic probe array and ion saturation current I_{is} detected with a Langmuir probe, in a neutral beam heated deuterium plasma with about 30kA plasma current I_p. In this discharge, the rotational transform at LCFS is increased from ~0.9 in the vacuum field to ~1.1 at I_p~30kA. The rotational transform at the center is also increased from ~0.3 (in the vacuum) to ~0.7 if the toroidal current density profile is assumed to be parabolic. The probe $\theta 1$ is inserted at ~256mm, and the probe R1 at ~252mm,where LCFS corresponds to Z~280mm. These signals considerably change with the increase in I_p. Figure 3(a) shows auto power spectrum of the probe $\theta 1$ ($P[\theta 1(f)]$) and I_{is} ($P[I_{is}(f)]$) near the peak of I_p (120~125ms), where the data sample time is 2ms. Auto power spectrum of the probe $\theta 1$ has obvious coherent peaks marked as ① and ②. Squared coherence of the $\theta 1$ signal with three other signals, probes $\theta 2$, $\theta 5$, and I_{is}, $\gamma^2(f)$ are calculated as shown in Fig. 3(b). The coherence between $\theta 1$ and $\theta 2$ of which radial separation is 7mm is very high in the frequency range less than 100kHz. We recognize obvious peaks of $\gamma^2 \sim 1$ in the low frequency range (<40kHz), but there is no obvious peaks in the range of f>60kHz. Auto power spectrum of I_{is} exhibits strong turbulent nature and coherence with the $\theta 1$ signal is fairly low. Figure 4 shows radial profile of magnetic fluctuation amplitude measured by the probes $\theta 1$, 2, 3, 5 and 7. The profiles are obtained for two coherent peaks (① and ②) and incoherent components (③) assigned in Fig.3. It is important to investigate the relation between the mode number determined Mirnov coil arrays and the radial variation of the component. The amplitude of incoherent components decays rapidly toward outside the plasma. Figure 5 shows coherence $\gamma(f)$ of the $\theta 1$ signal with signals $\theta 2$, 3, 5 and 7 as a function of the radial separation of these probes, for the frequency ranges ①, ② and ③ in Fig.3. From Fig.5, the coherent components have a large radial correlation length $L_r \geq \langle a \rangle$ (minor radius). The correlation length L_r of the incoherent one is about $L_r \sim \langle a \rangle /7$.

Ⅳ. SUMMARY

In neutral beam heated plasmas of CHS , characteristics of magnetic fluctuations in the region from scrape off layer to just inside LCFS are investigated with a newly developed movable magnetic probe array without any deteriorating effect on plasma performance. From the coherence analysis, low frequency coherent fluctuations have large radial correlation length ($L_r \sim \langle a \rangle$). Radial variation of the fluctuation amplitude suggests they have low mode number. The fluctuations are inferred to be an ideal interchange mode excited in plasma interior. Incoherent components in relatively high frequency have small correlation length of $L_r \sim \langle a \rangle /7$. It is required to identify the instabilities generate the incoherent fluctuations and to elucidate relationship between the incoherent fluctuations and plasma transport.

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Figure captions

Figure 1 Schematic drawing of the movable magnetic probe array installed in CHS. The calculated magnetic surface in the present experiments is also shown.

Figure 2 Time evolution of magnetic fluctuations detected with the movable magnetic probe array, and ion saturation current I_{is} detected with a Langmuir probe, in the neutral beam heated plasma. The plasma current I_p is increased up to ~30kA by an inductive electric field, at the toroidal field B_t~1.2T, where absorbed NBI power P_{NBI}~ 450kW and electric temperature at the center T_{e0}~400eV.

Figure 3 (a) Auto power spectrum of the probe θ1 (P[θ1(f)]) and ion saturation current I_{is} (P[I_{is}(f)]) near the peak of the plasma current (120~125ms) in the shot of Fig. 2.

(b) Squared coherence $\gamma^2(f)$ of the probe signal θ1 with three signals θ2, θ5, and I_{is}. The frequency ranges marked ①, ② and ③ correspond to 12~17kHz, 30~35kHz, and 70~75kHz, respectively.

Figure 4 Radial profiles of magnetic fluctuation amplitudes measured by probes θ1, θ2, θ3, θ5 and θ7 for the three frequency ranges ①, ② and ③.

Figure 5 Coherence γ of the θ1 signal with θ2, θ3, θ5 and θ7 signals at various frequency ranges as a function of the radial (or vertical) separation of these probes.

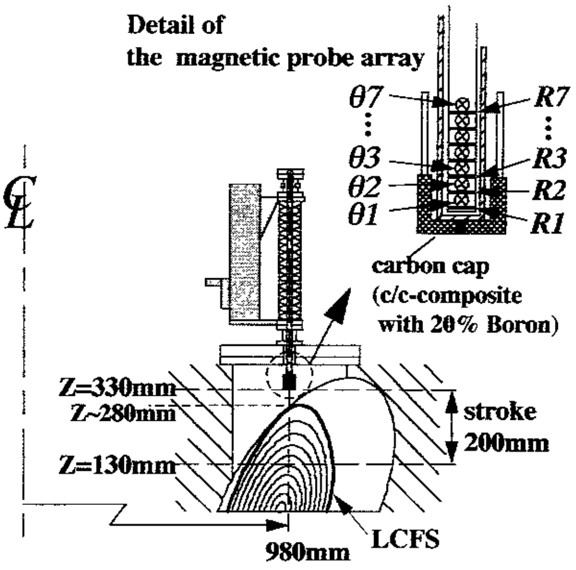

Fig.1 T.Oike et al.

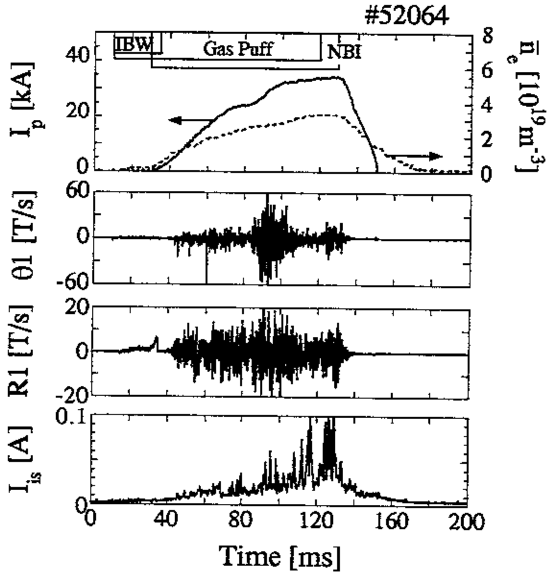

Fig.2 T.Oike et al.

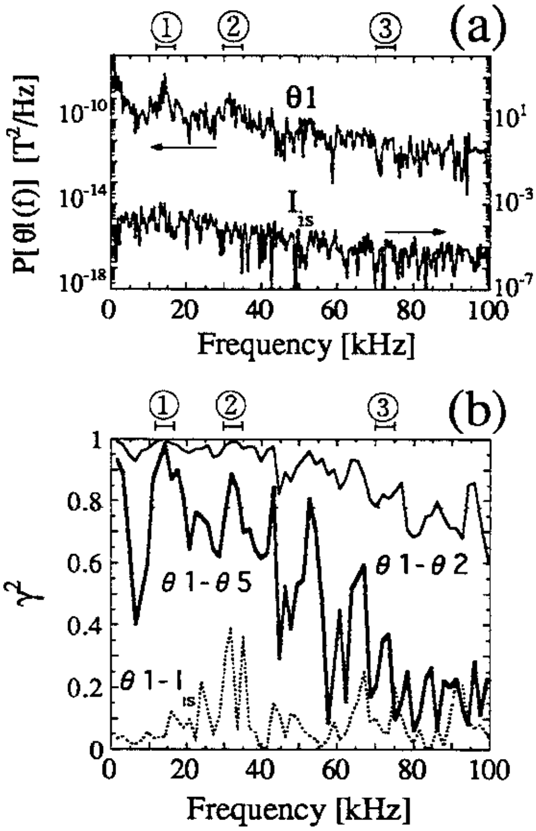

Fig.3 (a),(b)   T.Oike et al

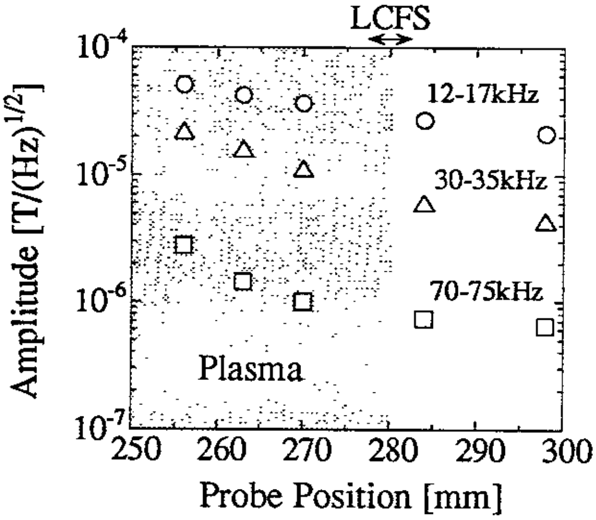

Fig.4 T.Oike et al.

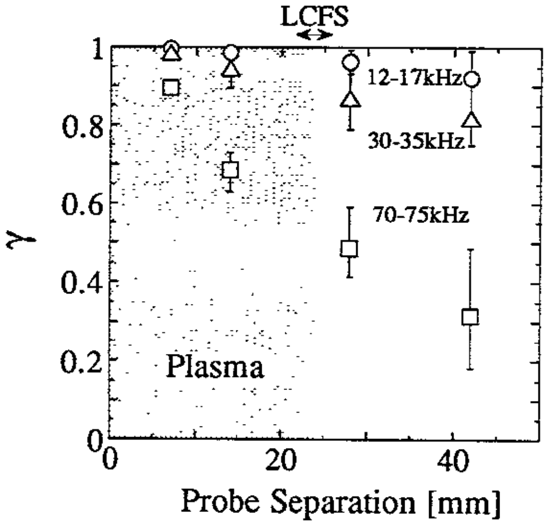

Fig.5 T.Oike et al.

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