INSTITUTE OF PLASMA PHYSICS

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RESEARCH REPORT

NAGOYA, JAPAN

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Abstract

By using Langmuir probes installed behind limiters, time behaviour of the peripheral plasma in the Reversed Field Pinch (RFP) are investigated. They are strongly affected by the confined RFP plasma and are divided into three phases (the initial phase before setting up the RFP configuration, the current rising phase, and the quiescent phase), which are just the same as those of the confined RFP plasma. Typical behaviour of the peripheral plasma have relations to the pump out phenomena and of the toroidal flux generation.

In plasma confinement devices, measurements of the peripheral plasma using electrostatic probes give important informations for the confined plasma and the plasma-wall interactions. In tokamaks, the profile and the time variation of various parameters of the peripheral plasma such as the electron density, the electron temperature and the magnetic fluctuation level are measured by probes in order to estimate energy and particle loss flux from the confined plasma to the peripheral plasma[1~4]. In Reversed Field Pinch, however, few measurements of the periferal plasma have been carried out[5]. We measured the peripheral plasma by using Langmuir probes installed behind limiters in the RFP, STP-3(M). As the results, it is found that the behaiours of the peripheral plasma are strongly affected by the confined RFP plasma. In this paper, the relations between the behabviour of the peripheral plasma and those of the confined plasma, especially the toroidal flux enhancement and the pump out phenomenon[5] will be described. Experiments are carried out on STP-3(M), in which the vacuum vessel (a/R=0.1m/0.5m) made of a stainless steel was used. Langmuir probes made of a tungsten wire with 1.0 mm of diameter are set up inside the liner as shown in Fig. 1. Probes are usually applied 20 ~ 50 V DC to measure the electron saturation current. For comparing with the density of the peripheral plasma and parameters of the confined RFP plasma, the toroidal flux, the visible light emmited from the plasma and magnetic fluctuations are measured at the same meridional planes. The toroidal magnetic flux loop and magnetic probes are set up onto the liner. The visible light is measured through the vertical port by using spectrometers and an image convertor camera. Those measurements are carried out in four port sections shown in Fig. 1(b). The M.H.D. activities of the RFP plasma are measured by the time derivative of the plasma current. The typical wave form of the electron density of the peripheral plasma estimated from the electron staturation current is shown in Fig. 2, comparing with the time variation of plasma current, the toroidal magnetic field and the continuum radiation. The time behaviour of the density of the peripheral plasma is able to divided into three phases, namely the initial phase before setting up the RFP configuration, the current rising phase (the toroidal flux increasing phase), and the quiescent phase. The behaviour of the confined RFP plasma is also divided into the same three phases[6]. Consequently, the peripheral plasma is strongly affected by the confined plasma.

Before setting up the RFP configuration (Phase I shown in Fig. 2(f)), the electron density of the peripheral plasma has a large and sharp peak. It's peak value is about 3×10^{13} cm^{-3} which corresponds to 16% of the electron density of filling gas (3 mTorr, H_2), and at that time the electron temperature of the peripheral plasma is 15 eV. By comparing with the time history of the continuum radiation shown in Fig. 2(e), it is clearly found that the first peak of the plasma density in periphery corresponds to the first peak of the continuum radiation. As a good confinement is not obtained in this phase, the electron density in periphery has a large value. Just before the setting up RFP configuration, however, the electron density of the peripheral plasma rapidly decreases. At that time, the continuum radiation rapidly decreases, too. Accordingly the first peak of the edge density seems to have a relation to the pump out phenomena. After setting up the RFP configuration, the edge density and the toroidal flux continuously decrease for a little while.

In the current rising phase (Phase II), the toroidal flux increases together with the edge plasma density and the continuum radiation, as shown in Fig. 2. The phenomena of the toroidal flux enhancement propagate in the direction of the electron current flow with velocity of about 1 cm/μs[6,7]. By measurements using Langmuir probes installed in the toroidal direction, it is found that the propagation phenomena of the toroidal flux are accompanied with the increase of the peripheral plasma density. The peripheral plasma density and the toroidal flux have the maximum values at the nearly same time. And then, both the plasma density in periphery and the continuum plasma radiation rapidly decrease to nearly constant values.

In the quiescent phase (Phase III), the peripheral plasma density is about 3×10^{12} cm^{-13}, which corresponds to one-tenth of the peak value in the previous two phases. The rapid and large increase of the peripheral plasma density observed in other two phases does not appear in this quiescent phase. The electron temperature of the peripheral plasma is about 15 ~ 20 eV. Those experimental results show that the good confinement state is obtained in the quiescent phase. The relatively large fluctuations of the peripheral plasma density in the quiescent phase have relations to the increase of the toroidal flux like in the current rising phase. The time histories of the peripheral plasma density and the toroidal flux in the quiescent phase are shown in Fig. 3 comparing with the time derivative of the poloidal magnetic field. The pulsive increase of the peripheral plasma density and of the plasma light correspond to the toroidal flux enhancement. Moreover, this figure shows that beat signals usually appear in the fluctuation of the poloidal magnetic field when the toroidal flux increases. The mechanism of the flux enhancement has been already pointed out that the flux generation is caused by coupling with helical modes having m=0 n=10~13, where m and n are poloidal and toroidal mode numbers, respectively[6]. Those experimental results indicate that the toroidal flux enhancement caused by the mode coupling is accompanied with the pulsive radiation and with increase of the peripheral plasma density. The measurements by using three probes installed in a same meridional plane as shown in Fig. 1, show that the electron densities behind the limiters increase at the same time when the toroidal flux increases. Accordingly increase of the peripheral plasma density caused by nonlinear mode coupling has the poloidal mode number of m=0. Those experimental results seem to indicate that the confined RFP plasma seems to expand uniformly in direction of the minor radius when the toroidal flux increases.

Just before the current termination, any precursor is not observed in signals of Langmuir probe even in planes near the cut of the shell (Port 2, 3), which is consistent with the fact that the outward displacement of the STP-3(M)'s plasma is within several mm in the whole current duration.

By measurements using Langmuir probes behind limiters, the followings are confirmed:

1. The time behaviour of the peripheral plasma density are able to be divided into three phase (initial phase before setting up the RFP configuration, current rising phase, and quiescent phase) just like behaviours of the confined RFP plasma. Those

facts show the behaviours of peripheral plasma are strongly affected by the confined RFP plasma. The electron temperature of the peripheral plasma, however, it is nearly constant value of 15~20 eV.

2. Immediately before setting up RFP configuration, the edge plasma density has a large peak (3×10^{13} cm^{-3}), which seems to have a relation to the pump out phenomena.
3. In the current rising phase, the peripheral density rapidly increases being accompanied with the toroidal flux generation. It has a large peak value (2×10^{13} cm^{-3}) at the time when the average toroidal flux is maximum.
4. In the quiescent phase, the peripheral density is nearly constant (3×10^{12} cm^{-3}). Most of its fluctuations are caused by the toroidal flux generation. Phenomena of the flux enhancement caused by the nonlinear mode coupling accompany with the increase of the peripheral density, whose poloidal mode number is m=0.
5. Before current termination any precursor is not observed in singals of Langmuir probes.

Authors would like to thank to the Director of IPP, Prof. T. Uchida and Prof. T. Amano for helpful discussions. They are also indebted to Prof. K. Akutsu and the leader of C.S. group Prof. A. Mohri for continuous encouragements.

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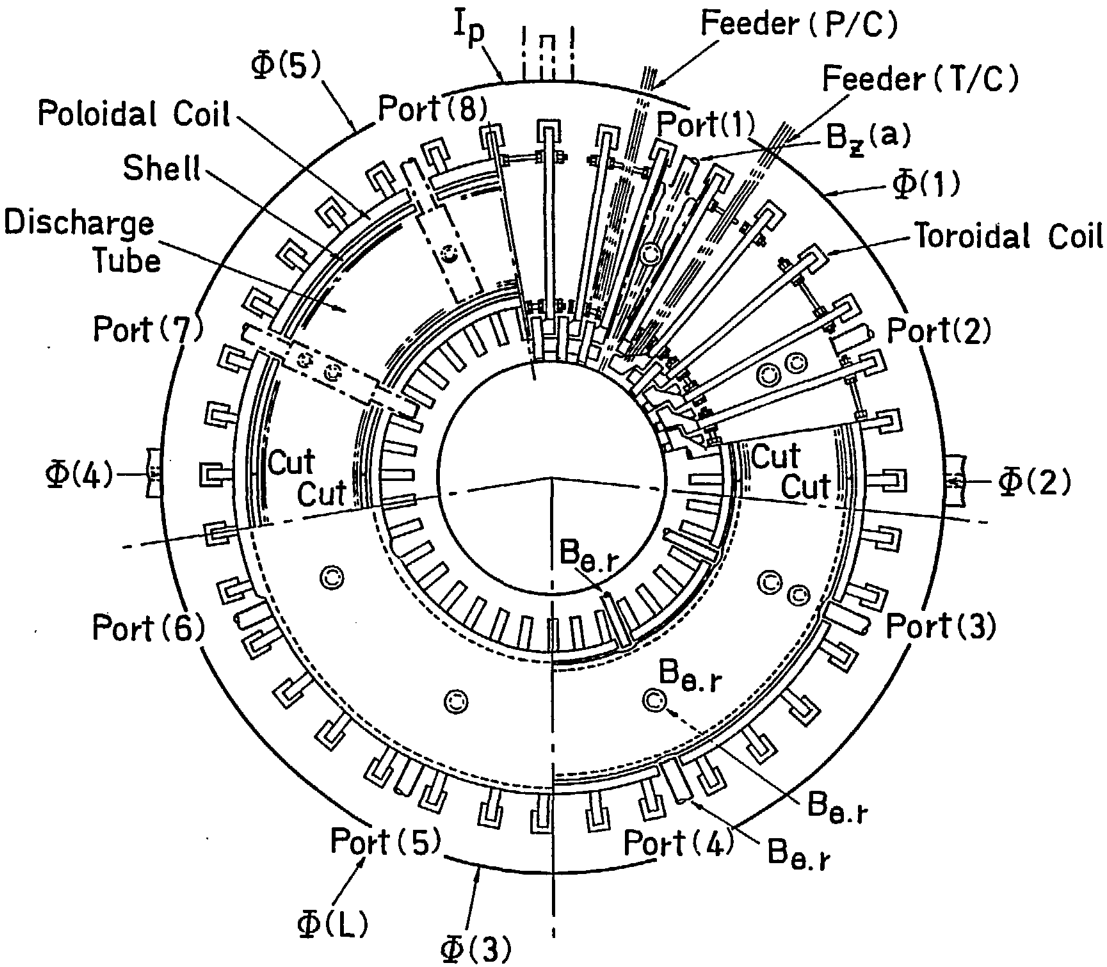
Figure Captions

Fig. 1: (a) Top view of the STP-3(M)'s load assemblies and the arrangement of diagnostic tools; (b) side view showing location of Langmuir probes.

Fig. 2: Time behaviours of electron density of the peripheral plasma comparing with typical parameters of RFP plasma. (a) plasma current; (b) toroidal field at wall; (c) average toroidal field; (d) electron density of edge plasma; (e) continuum radiation; (f) three phases composed of the whole behaviours of the peripheral plasma. Phases I, II and III indicate the initial phase before setting up RFP configuration, the current rising phase and the quiescent phase, respectively.

Fig. 3: The time histories of the peripheral plasma density comparing with the total plasma light, and time derivatives of the toroidal flux ($\dot{\Phi}$) and the poloidal magnetic field ($\dot{B}_p$).



Ip
Feeder (P/C)
Feeder (T/C)
Φ(5)
Port (8)
Port(1)
Bz(a)
Poloidal Coil
Shell
Φ(1)
Discharge Tube
Toroidal Coil
Port (7)
Port(2)
Cut
Cut
Cut
Cut
Φ(4)
Φ(2)
Bθ.r
Port (6)
Port(3)
Bθ.r
Bθ.r
Port (5)
Port (4)
Bθ.r
Φ(L)
Φ(3)

Fig.1 (a)

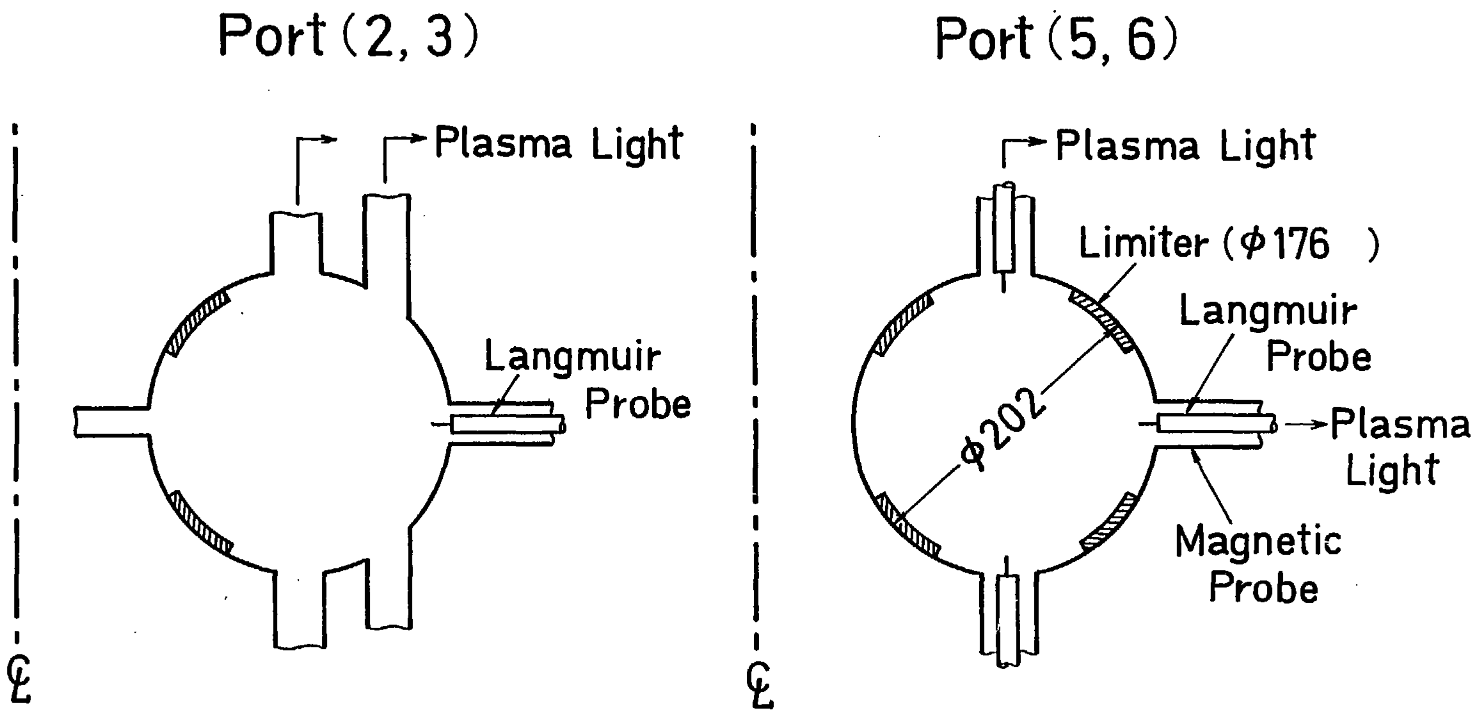
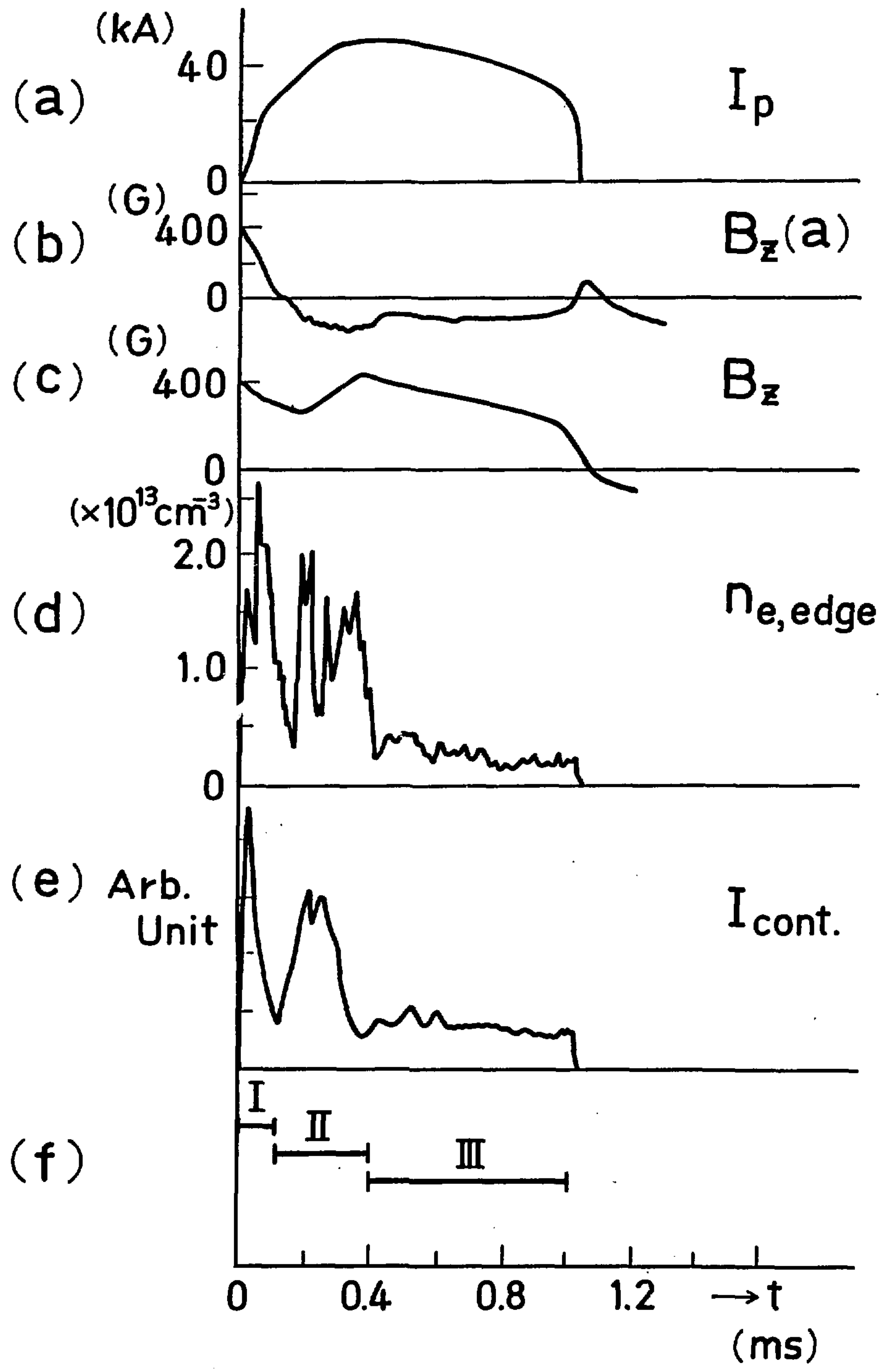

Port (2, 3)
Plasma Light
Langmuir Probe
℄
Port (5, 6)
Plasma Light
Limiter (φ176)
Langmuir Probe
φ202
Plasma Light
Magnetic Probe
℄

Fig.1 (b)



(a)
(kA)
40
0
I_p
(b)
(G)
400
0
$B_z(a)$
(c)
(G)
400
0
B_z
(d)
$(\times 10^{13} cm^{-3})$
2.0
1.0
0
$n_{e,edge}$
(e) Arb. Unit
$I_{cont.}$
(f)
I
II
III
0
0.4
0.8
1.2
→ t
(ms)

Fig.2

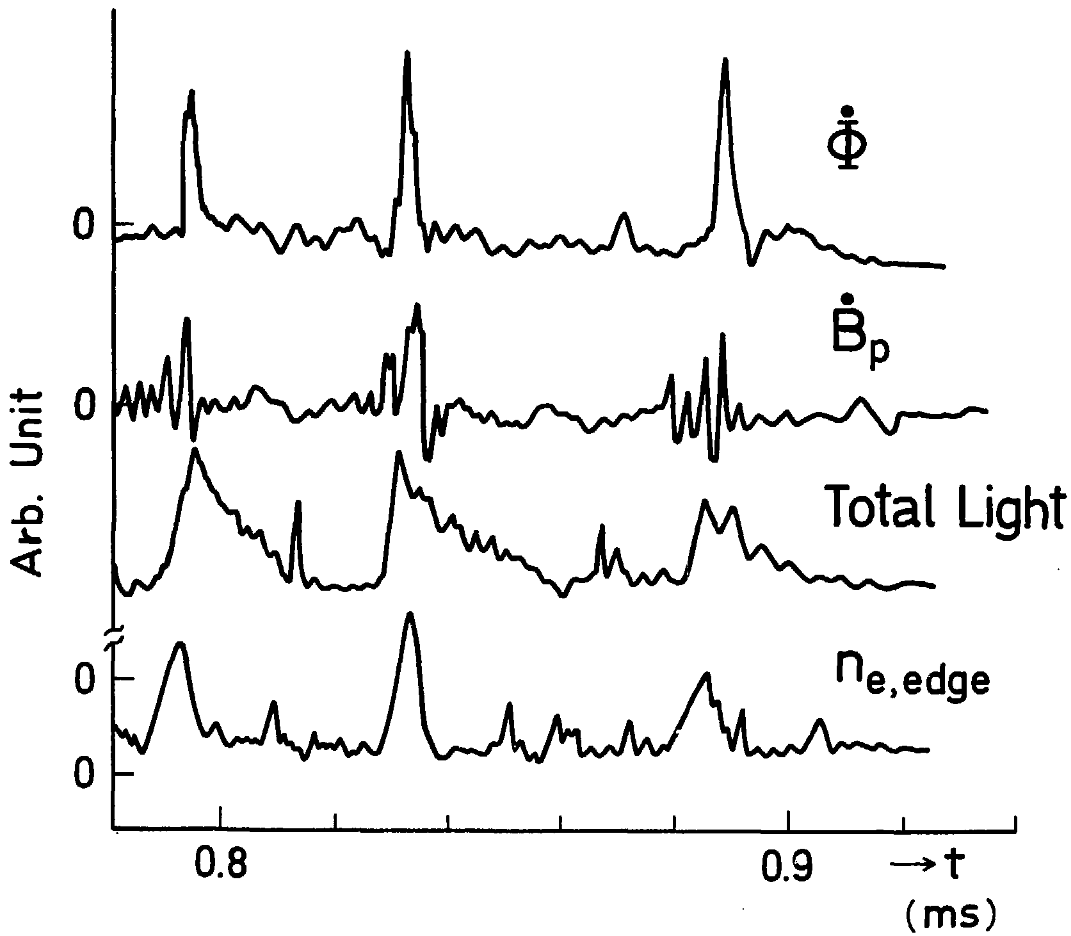


Fig.3