26th EPS Conf. on Contr. Fusion and Plasma Physics, Maastricht, 14 - 18 June 1999 ECA Vol.23J (1999) 461 - 464

Improvement and Longer Operation of Potential Confinement in the GAMMA 10 Tandem Mirror

K.Yatsu, T.Cho, M.Hirata, H.Hojo, M.Ichimura, K.Ishii, A.Itakura, I.Katanuma, J.Kohagura, A.Mase, Y.Nakashima, T.Saito, T.Tamano, Y.Tatematsu, M.Yoshikawa

Plasma Research Center, University of Tsukuba, Tsukuba, Ibaraki 305-8577, Japan

Abstract

The central-cell density and diamagnetism have been doubled by a potential confinement. The duration of potential confinement has been extended from 50 ms to 75 ms, and a longer sustainment of potential confinement is understudy. A second microwave pulse is applied in addition to the first one for further improvement and/or longer sustainment of potential confinement.

Introduction

A potential confinement is successfully attained in the GAMMA 10 tandem mirror. The central-cell density and diamagnetism have been doubled [1]. The improvement of potential confinement was attained by axisymmetrization of heating patterns of ECRH(electron cyclotron resonance heating) for potential formation and ICRF (ion cyclotron range of frequency) heating [2]. Conducting plates installed at the anchor transition regions also contributed to the improved confinement.[3].

The duration of the potential confinement was increased from 50 ms to 75 ms as a step to investigate a quasi-steady state operation. A 115% increase of the density and diamagnetism by potential confinement was sustained during 75 ms. The duration was limited by a gyrotron power supply and was extended recently to 100 ms. An experiment to apply a second ECRH pulse started in order to raise the confining potential and also to extend a duration of potential confinement.

Potential Confinement in GAMMA 10

The GAMMA 10 tandem mirror consists of a central cell, two anchor cells, and two plug-barrier cells. The axisymmetric field in the central cell is connected to the minimum-B field in the anchor cell and then recircularized to connect to the axisymmetric field in the plug-barrier cell. Regions between the axisymmetric field and minimum-B field are mentioned as transition regions. The length of the central cell, anchor cell and plug-barrier cell are 6.0 m, 4.76 m and

2.48 m, respectively, and the magnetic field strength at the midplane of each cell are 4 kG, 6.1 kG and 5 kG, respectively.

Plasma densities are measured with microwave interferometers at several locations along GAMMA 10. End loss currents and ion energy spectra at the ends are measured with end loss ion energy analyzers (ELA) [4]. Plasma potentials in the central cell and in the barrier region are measured with heavy ion beam probes. The ion temperature is determined from the data using a charge-exchange neutral-particle energy analyzer together with the diamagnetic signal. The electron temperature is obtained from x-ray diagnostics.

The ICRF heating in the central cell and anchor cells with gas puffing in the central cell sustains a hot ion plasma with an ion temperature and plasma density of about 4 keV and 2 $\times 10^{12}$ cm^{-3}, respectively. The FWHM of the central-cell density profile was 18 cm. An ion confining potential is produced by applying fundamental ECRH in the plug-barrier cell at a position outer to the midplane with a gradient of the magnetic field strength. Some radial losses were observed in anchor transition region and/or plug-barrier cell. The radial loss is considered to be caused by irregular electric fields probably occurring when ECRH is applied to the ICRF sustained plasma. The conducting plates were installed adjacent to the surface of the plasma at both sides of a flat shaped magnetic flux tube at the anchor transition regions. The conducting plates consist of four plates at one side and are arranged along field lines. The conducting plates are intended to fix the potential at the plasma boundary. The central-cell density and diamagnetism increased 100% as shown in Fig.1 by formation of a confining potential with 140 kW ECRH power in each plug-barrier cell. The plasma density and ion temperature on the axis were 2.7 $\times 10^{12}$ cm^{-3} and 4.5 keV, respectively. The conducting plates contributed to attain this confinement improvement. The

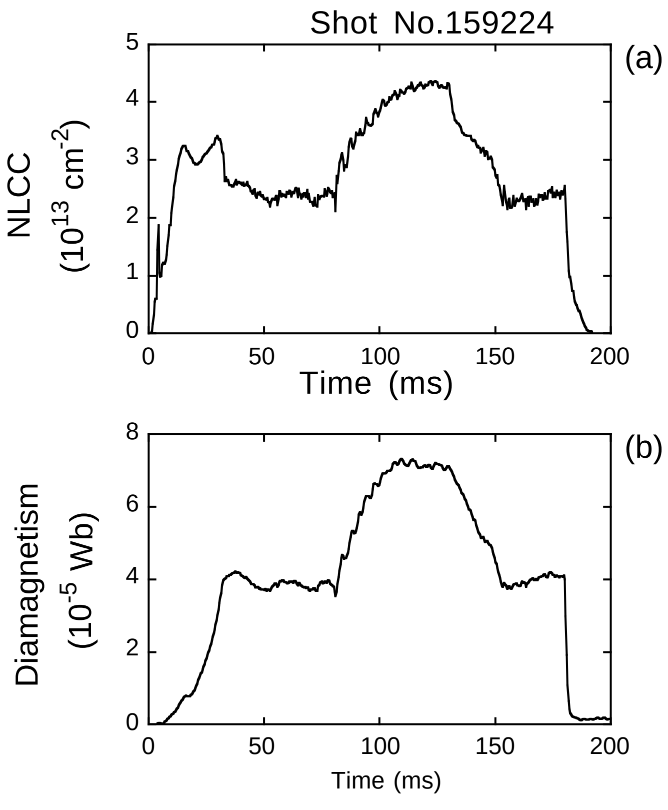

Figure 1 Central cell line density (a) and diamagnetic signal (b) for a shot when they are doubled by formation of a plug potential at ECRH power of 140 kW in each plug region.

conducting plates can be grounded or floated. A large density increase was observed when they were floated. The floating potentials were about 400 V at the transition region of central-cell side and about 100 V at the transition region of plug-barrier side.

Improvement and Longer Operation of Potential Confinement

The duration of the potential confinement was increased from 50 ms to 75 ms. A 100% increase of the density and diamagnetism by potential confinement was sustained during 75 ms. However, the confining potential tends to decrease with the increase in the plasma density during potential confinement. An experiment to apply a second ECRH pulse started in order to raise the confining potential and also to study the effect of multi-beam microwave heating at the plug region. The multi-beam heating will be an important problem in a future tandem mirror reactor, in which several gyrotrons will be used at one plug region for the production of a high confining potential. Figure 2 shows the central-cell density and diamagnetic signal of a shot when 115% density increase was sustained for 75 ms. In this shot, a second ECRH pulse was applied for 30 ms at the last part of the first ECRH and the confining potential increased about 20%. Although, changes in the density and diamagnetism are not appreciable in Fig.2, increases in density and/or diamagnetism are observed in anther shots. An effect of a second ECRH on increase in density and/or diamagnetism depends on experimental conditions. The injection angle of the second microwave pulse is smaller than that of the first one due to structural constraint. Since the microwave is launched with a linearly polarized wave, the absorption coefficient is smaller for the second ECRH due to the smaller injection angle. Another usage of the second ECRH is to use it in series with the first one. By using this way, a 130 ms

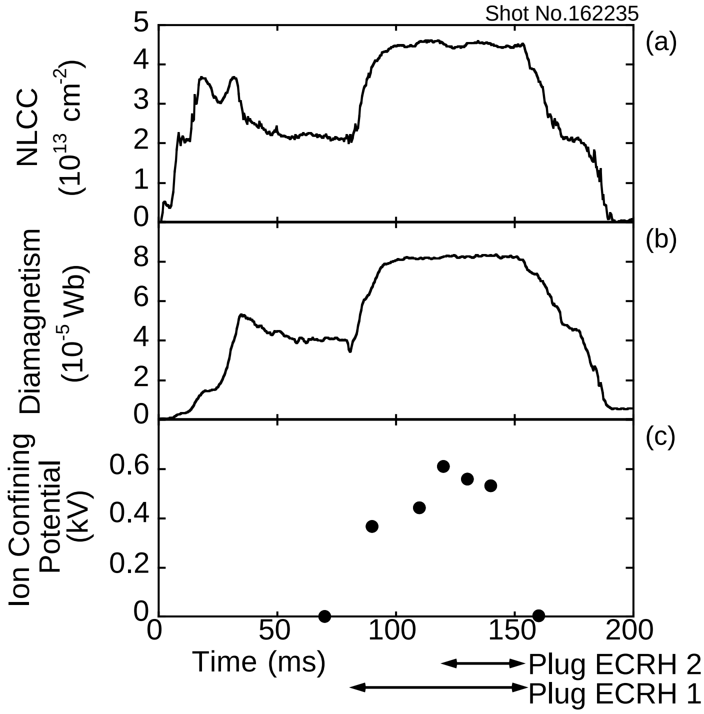

Figure 2 Central cell line density (a), diamagnetic signal (b) and ion confining potential for a shot with ECRH duration of 75 ms. The central cell density increased 115% and is sustained 75 ms. The ion confining potential increased 20% by second ECRH.

potential confinement was sustained with density increase of 30%. The density increase is expected to become larger with progress of experi-ments.

Figure 3 shows density increment by potential confinement and confining potential, in which data indicated by filled symbols are obtained after IAEA Conference in Yokohama for shots with pulse length of 75 ms. A steady develop-ment is observed in confinement and longer sustainment.

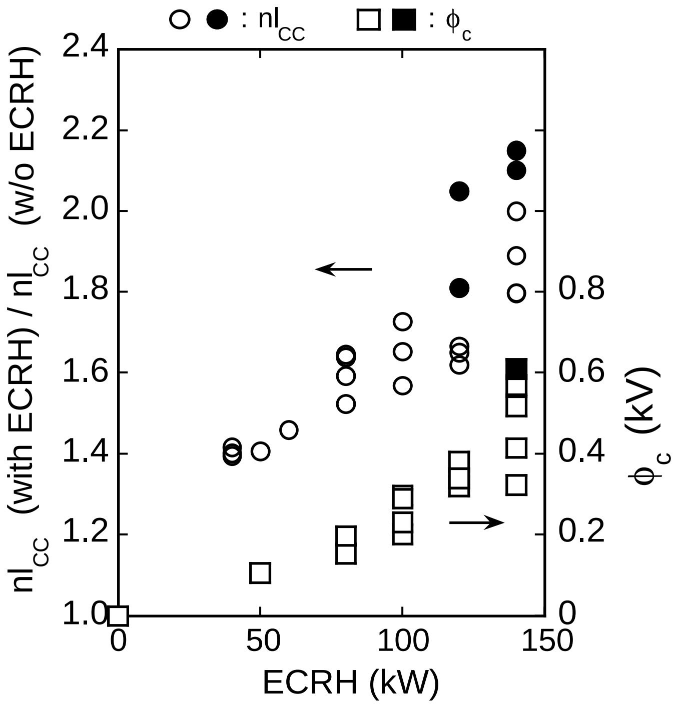

Figure 3 Increment of the central-cell line density and the confining potential as a function of the ECRH power in each plug region. Data indicated by filled symbols are obtained after IAEA Conference in Yokohama.

Summary

Experiments have been carried out for further improvement of confinement and longer sustainment of potential confine-ment. A density increment of 115% is attained with ECRH pulse duration of 75 ms. Experiments are underway with promising results in increasing and/or sustaining potential confinement.

References

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