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EFFECT OF EDGE-LOCALIZED MODE SIMULATION ON DETACHED PLASMA IN THE DIVERTOR SIMULATION EXPERIMENTAL MODULE OF GAMMA 10/PDX

M. YOSHIKAWA[1], J. KOHAGURA[1], N. EZUMI[1], T. KARIYA[1], R. MINAMI[1], T. NUMAKURA[1], M. HIRATA[1], S. TOGO[1], M. SAKAMOTO[1], K. EMOTO[2], Y. SHIMA[1], T. OKAMOTO[1], S. TAKAHASHI[1], Y. NAKASHIMA[1], T. MINAMI[1], S. KOBAYASHI[3], D. KUWAHARA[4], H.V.D, MEIDEN[5]

[1]PRC, Univ. Tsukuba, [2]NIFS, [3]IAE, Kyoto Univ., [4]Chubu Univ., [5]DIFFER

yosikawa@prc.tsukuba.ac.jp

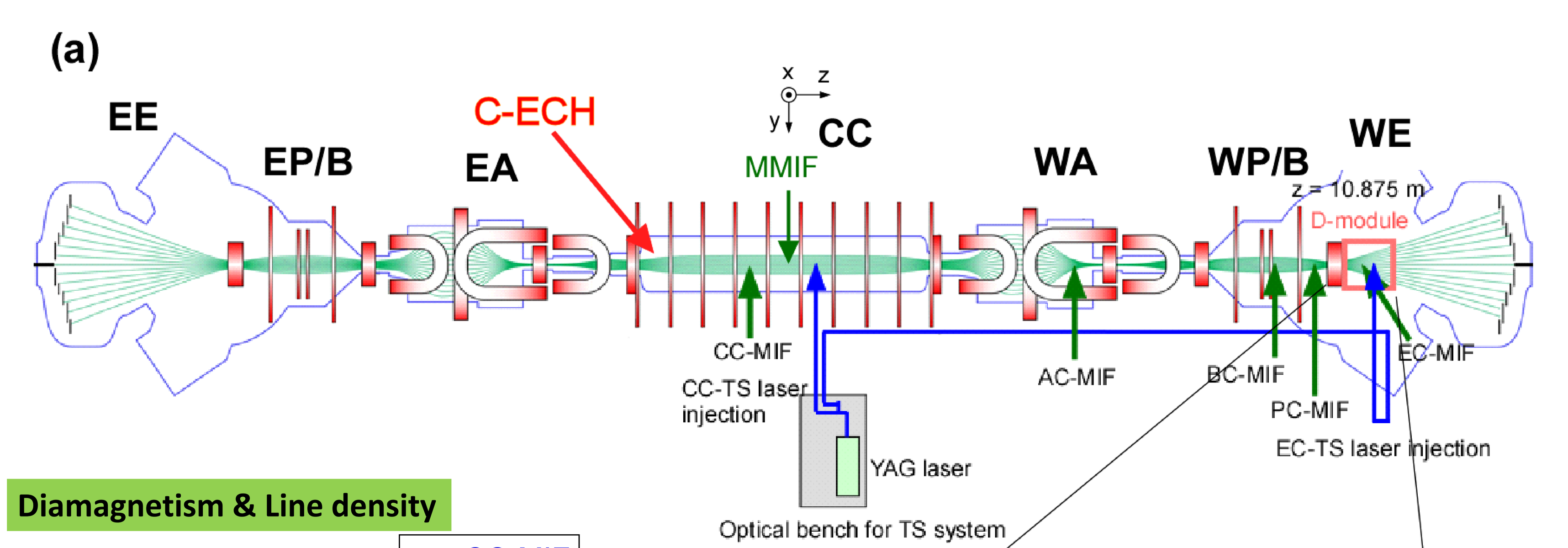
ABSTRACT

- Experiments were conducted in the divertor simulation experimental module (D-module) of GAMMA 10/PDX to investigate the dynamic behavior of detached plasma under intermittent high-density and high-temperature particle fluxes.
- A double-pulse electron cyclotron heating (ECH) scheme was employed to emulate edge-localized mode (ELM)-like transient loading conditions.
- The experiments revealed that intermittent particle fluxes induced transitions between detachment and reattachment phases.
- Time-resolved diagnostics captured changes in electron temperature, density, and emission profiles, providing insight into the recovery mechanisms of detached plasma under transient conditions.
- These results contribute to the understanding of divertor plasma dynamics and support the development of advanced control strategies for future fusion reactors.

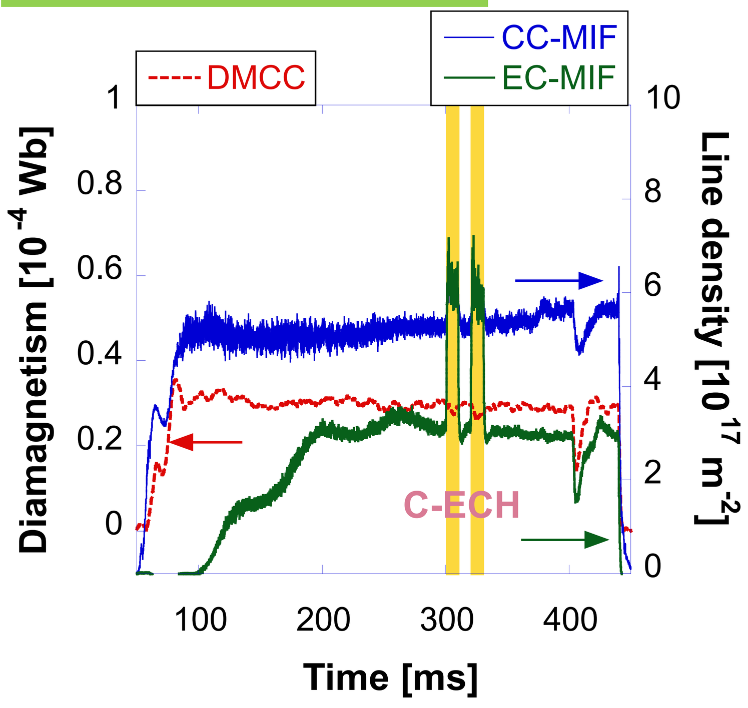
INTRODUCTION

- In high performance fusion plasmas, particularly in H-mode tokamak operations, the occurrence of edge-localized modes (ELMs) introduces transient bursts of heat and particles that can strongly influence the detached plasma state.
- To further investigate detachment dynamics under high heat flux conditions (>20 MW/m²), a divertor simulation experimental module (D-module) was installed in the end cell (EC) of the GAMMA 10/PDX tandem mirror device. GAMMA 10/PDX confines plasma in the central cell (CC), with plasma escaping toward the EC and entering the D-module.
- Previous experiments in GAMMA 10/PDX have demonstrated that sudden increases in particle flux—mimicking ELM-like events—can alter the state of detached plasma. However, these studies employed single-pulse operations of electron cyclotron heating (ECH) to increase core plasma density and temperature.
- In the present study, we introduce a double-pulse ECH scheme to simulate intermittent high-density and high-temperature fluxes into the D-module. This approach enables a more realistic emulation of ELM-like conditions and allows us to examine the dynamic response of detached plasma to transient particle loading.
- By analyzing the behavior of the divertor simulation plasma under these conditions, we aim to clarify the mechanisms governing detachment recovery and reattachment, contributing to the broader understanding of divertor physics in fusion devices.

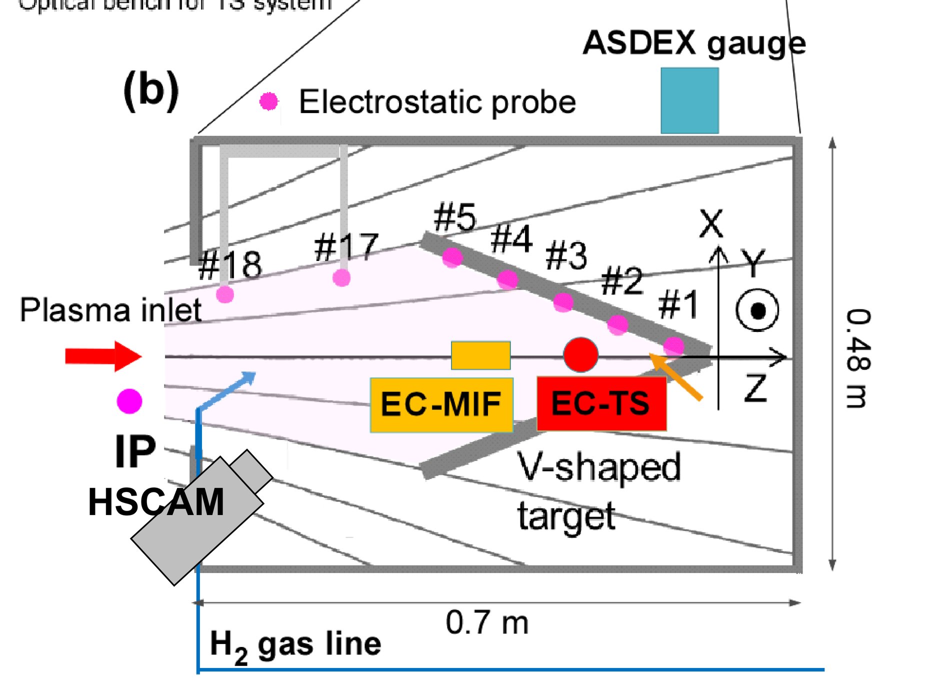
GAMMA 10/PDX AND D-MODULE



Diamagnetism & Line density



Time evolutions of diamagnetisms (red detted line) and line densities of CC and EC (blue line and green line) with double-pulse C-ECH injections in the CC.



Schematics of the experimental setup of GAMMA 10/PDX (a) and the divertor simulation experimental module (b).

It is clearly confirmed that the electron line densities increased in both the CC and EC regions, while diamagnetism slightly decreased during the double-pulse C-ECH injection.

ACKNOWLEDGEMENTS

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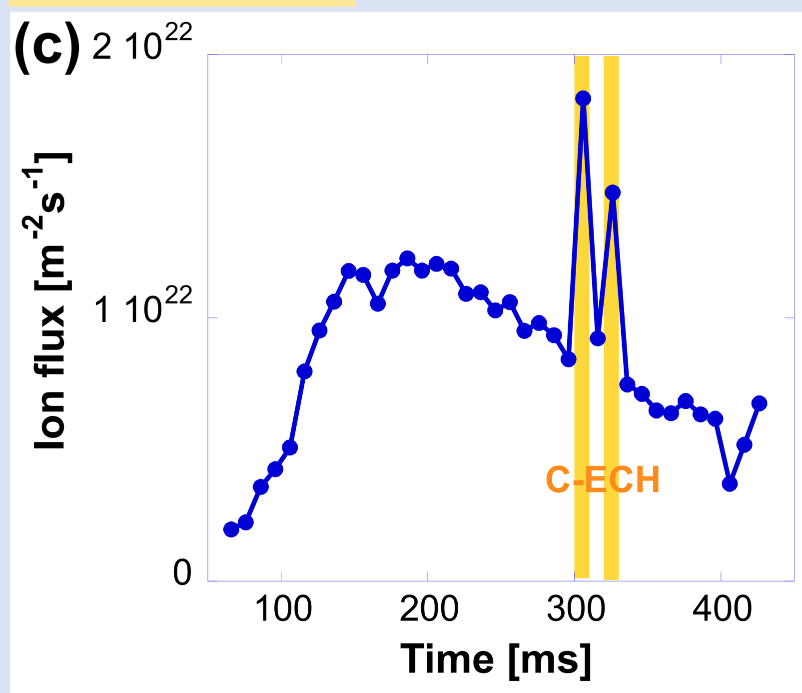
DETACHED PLASMA EXPERIMENTS WITH INTERMITTENT PARTICLE FLUX

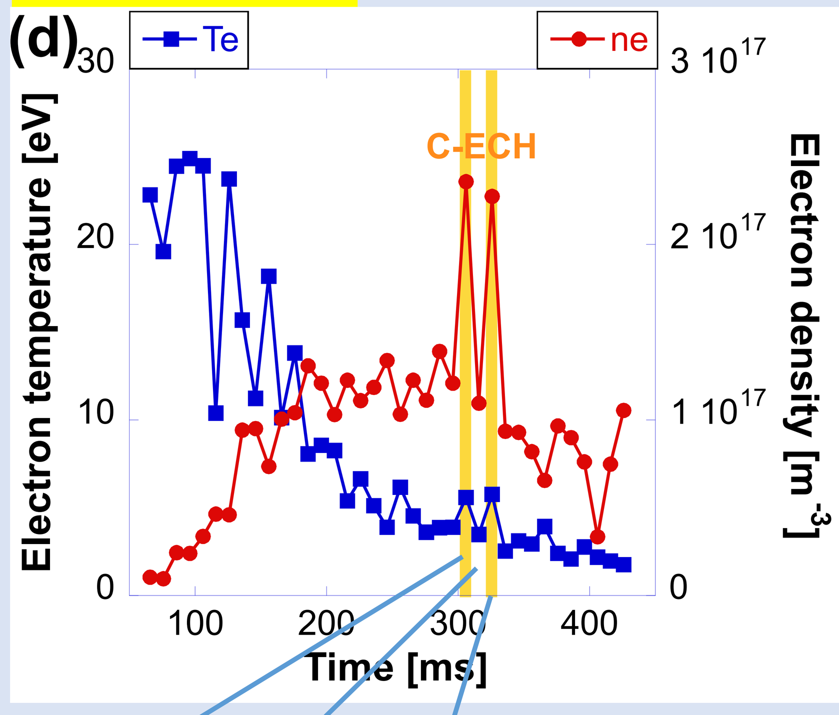
- The hydrogen plasma is produced and heated by ion cyclotron range of frequency wave from t = 51 to 440 ms, with additional hydrogen gas puffing for radiator gas in D-module from t = 50 to 450 ms at a pressure of 1200 mbar for the detached plasma experiment. C-ECH is injected at t = 300-310, and 320-330 ms in double pulse with a power of 130 kW.
- Figure (c) and (d) show the time evolution of ion flux, electron temperature and density, respectively, with the double pulse C-ECH injection periods indicated by yellow hatch.
- The electron densities and temperatures with and without C-ECH are approximately 6 eV and 2.3 × 10^{17} m^{-3}, and 3 eV and 1.2 × 10^{17} m^{-3}, respectively, in D-module.

Ion flux in D-module



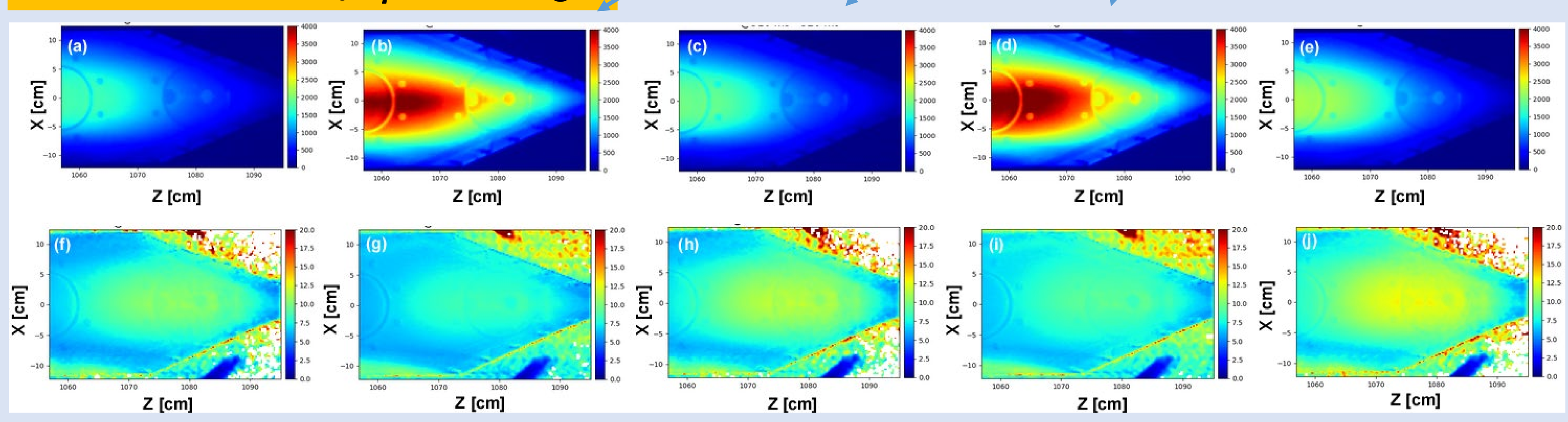
Time evolutions of ion flux in D-module at ESP #3.

Te & ne in D-module



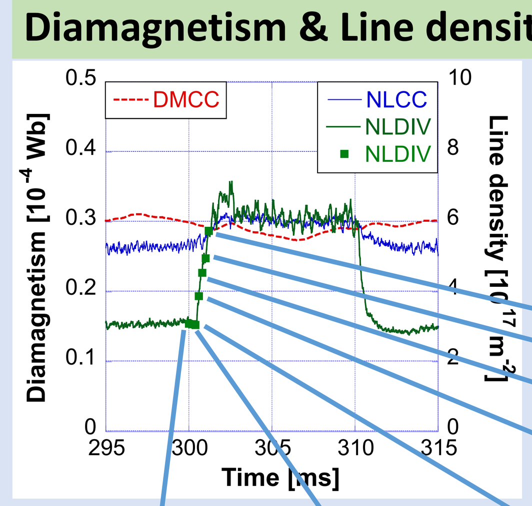
Time evolutions of electron temperatures (blue squares) and densities (red circles) in D-module obtained by ESP #3.

Hα emission and Hα/Hβ ratio images



Hα and Hα/Hβ intensity ratio images at t = 290-300 ms (a) and (f), 300-310 ms (b) and (g), 310-320 ms (c) and (h), 320-330 ms (d) and (i), and 330-340 ms (e) and (j), respectively, measured by HSCAM.

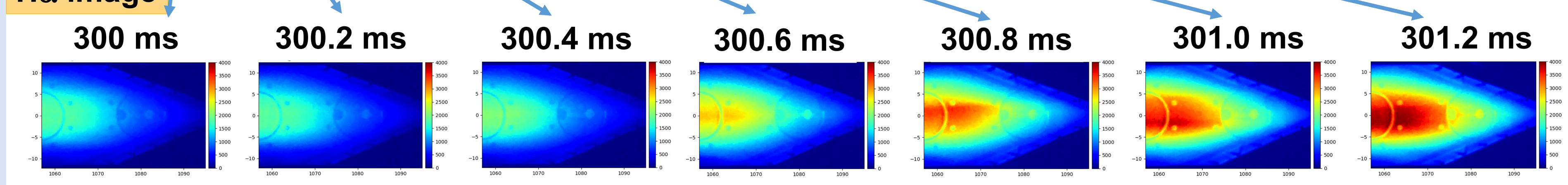
Diamagnetism & Line density



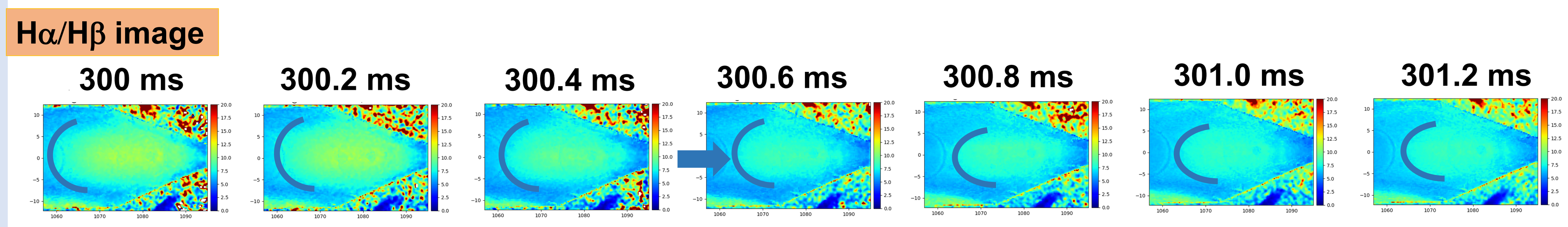
Time-expanded view of the diamagnetism, NLCC, and NLDIV.

The dynamic transition from detached to attached plasma was observed using HSCAM.

Hα image



Hα/Hβ image



Due to the increased particle flux from upstream, the density within the D-module rises, causing the recombination front to gradually shift downstream. A reduction is observed both in the radial extent of the molecular activated recombination region and in the overall amount of recombination.

The increase in ion flux and electron density with C-ECH injection indicates that the higher temperature electron flux increased plasma ionization, leading to a total increase in ion flux in the D-module. The intermittent higher electron density and temperature condition of the core plasma affects the D-module detached plasma condition, transitioning it to an attached plasma state during the C-ECH injection periods.

SUMMARY

Double-pulse injection of slightly elevated electron temperature and density fluxes enhances ionization and increases ion flux in the D-module, triggering intermittent transitions from detached to attached plasma states during C-ECH periods.