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# Magnetic Field Configuration Dependence of Density in Hydrogen Helicon Plasma

## ダイバータプラズマ模擬装置DT-ALPHAにおける水素ヘリコンプラズマ密度の磁場配位依存性

Takuya Takahashi, Takatsugu Miura, Atsushi Okamoto, Hiroyuki Takahashi and Sumio Kitajima
高橋拓也, 三浦隆嗣, 岡本敦, 高橋宏幸, 北島純男

*Department of Quantum Science and Energy Engineering, Tohoku University, 6-6-01-2 Aobayama, Sendai 980-8579, Japan*
東北大院工 〒980-8579 仙台市青葉区荒巻字青葉6-6-01-2

Hydrogen plasma is produced in a linear divertor simulator DT-ALPHA with various converging magnetic field. When a frequency for plasma production is nearly equal or smaller than lower hybrid resonance frequency at the upstream end of antenna, hydrogen plasma density increases by a factor of 3.

### 1. Introduction

One of the most important issues in magnetic confinement fusion reactors is reduction heat and particle loads on the divertor plates. To reduce these loads, detached plasma operation that is achieved by enhancing volumetric recombination processes in front of diveror plate has been proposed. In this operation, charged particles that have flowed into the divertor are neutralized and heat loads spread around.

In the high confinement mode (H mode) regime, the pulsed energetic particle fluxes are induced by Edge Localized Modes (ELMs). Collapse of recombining plasma caused by these fluxes was concerned. Therefore, it is important to investigate the effect of energetic particles on steady state recombining plasma. In divertor plasma simulator DT-ALPHA, we are planning to inject a high-energy ion beam to a hydrogen recombining plasma.

In order to enhance recombination processes, high density plasma is required. The helicon discharge[1] is known as a high density plasma production method. However, the reported cases using hydrogen are less than other gas species, and it is known that the density of hydrogen helicon plasma can reach one order of magnitude lower than the others[2]. Helicon plasmas have been produced in uniform magnetic field for theoretical analysis[3] and in diverging magnetic field for applications[4]. In converging magnetic field, high density helicon plasma was produced[5,6]. Therefore, in the present study, we tried to produce high density hydrogen helicon plasma by adjusting magnetic field configuration.

### 2. Experimental Setup

Experiments were performed using the DT-ALPHA device in Tohoku University, where plasma was produced by 13.56 MHz radio-frequency (RF) discharge[7,8]. Schematic is shown in Fig. 1. An antenna is wound around a quartz tube of 36 mm in inner diameter, 0.5 m in length. So called Nagoya type-Ⅲ or Boswell type antenna is adopted, the length of which is 0.15 m. Typical RF power is 300 W in the present experiment. The plasma is terminated by two end-plates.

Equally spaced ten magnetic field coils, intervals of which are 0.15 m, are connected to five independently controlled power supplies. Typical magnetic field configuration is shown in Fig. 2(a). While up to 0.2 T of magnetic field is applied in a down stream region, where recombining processes will be investigated, magnetic field strength in the RF antenna region is varied in a range of 0.01-0.07 T. Emission intensity of hydrogen atoms ($H_\beta$) is measured between the quartz tube and the first orifice ($z$ = 1.1 m).

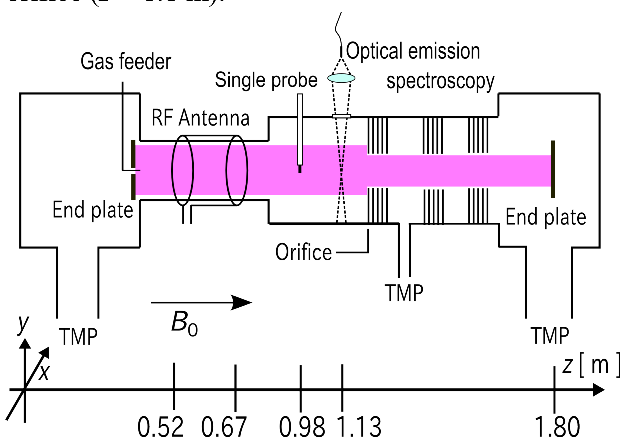


Fig. 1. A schematic of the DT-ALPHA device.

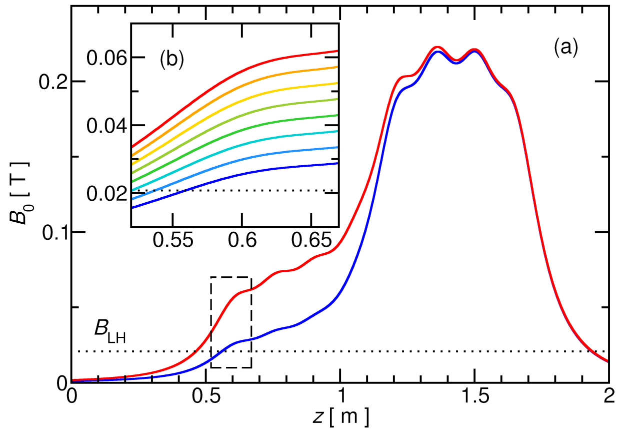


Fig. 2. Magnetic field configuration. (a) overall view, (b) expanded view of antenna region. Dotted line corresponds to the field when RF frequency matches the lower hybrid resonance frequency.

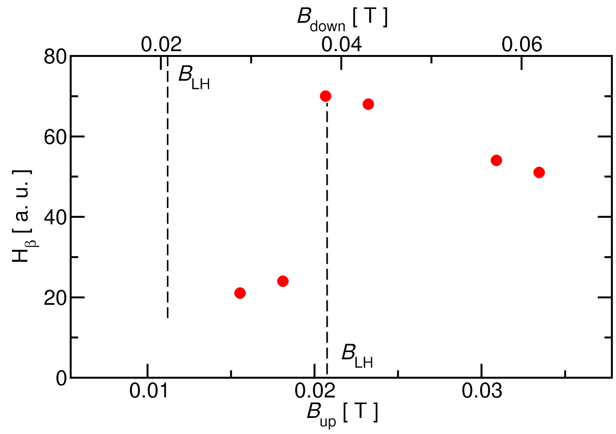


Fig. 3. Dependence of $H_\beta$ on magnetic field strength at both antenna ends. Two dashed lines correspond to hydrogen lower hybrid resonance at upstream antenna end ($B_{up} = B_{LH}$, right) and downstream antenna end ($B_{down} = B_{LH}$, left).

## 3. Experiment

Fig. 3 shows an experimental result on hydrogen atom emission intensity when magnetic field is changed as Fig. 2. When plasma density is sufficiently larger, hydrogen lower hybrid frequency can approximated as

$$\omega_{LH-HD} \approx (\omega_{ci}\,\omega_{ce})^{\frac{1}{2}} \quad (1)$$

where $\omega_{ci}$ and $\omega_{ce}$ are ion cyclotron frequency and electron cyclotron frequency respectively. When the RF frequency $\omega_{RF}$ matches to the lower hybrid frequency. the corresponding magnetic field $B_{LH}$ is expressed as follows:

$$B_{LH} = \frac{\sqrt{mM}}{e}\,\omega_{RF} \quad (2)$$

The range of the magnetic field in the RF antenna region (Fig. 2(b)) contains the condition, in which the RF frequency matches the lower hybrid resonance frequency for hydrogen ($B_{LH}$ ~ 0.021 T, dotted line in Fig. 2).

When magnetic field strength at antenna upstream region is nearly equal or slightly larger than that matches to lower hybrid resonance frequency, i.e. RF frequency is nearly equal or smaller than lower hybrid frequency, $H_\beta$ emission intensity increases by a factor of 3. In larger magnetic field region, $H_\beta$ emission intensity gradually decrease with magnetic field. Discussion in detail and experimental result of Langmuir probe will be reported in conference.

## 4. Summary

Dependence of hydrogen plasma produced in DT-ALPHA on magnetic field configuration was investigated. When RF frequency is nearly equal or smaller than lower hybrid resonance frequency at upstream antenna region, hydrogen plasma density increases by a factor of 3.


## Acknowledgements

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