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Pitch Angle Dependence of Fast Electrons Energy Spectra Measured with a Soft X-Ray Pulse Height Analyzer in Heliotron J

ヘリオトロンJにおける軟X線波高分析による高速電子エネルギー分布のピッチ角依存性計測

Yoshinobu Wada[1], Hiroyuki Okada[2], Kazunobu Nagasaki[2], Satoshi Yamamoto[2], Tohru Mizuuchi[2], Takashi Minami[2], Shinji Kobayashi[2], Shinsuke Ohshima[3], Kiyofumi Mukai[1], Hyunyong Lee[1], Linge Zang [1], Watada Hiroto[1], Arai Shohei[1], Kagawa Tasuku[1], Kousji Mizuno[1], Takayuki Minami[1], Hiroaki Yashiro[1], Yuji Nakamura[1], Kiyoshi Hanatani[2], Shigeru Konoshima[2] and Fumimichi Sano[2]

和田善信 [1], 岡田浩之 [2], 長崎百伸 [2], 山本　聡 [2], 水内　亨 [2], 南　貴司 [2], 小林進二 [2], 大島慎介 [3], 向井清史 [1], H.Y. Lee[1], L. Zang[1], 和多田泰士 [1], 荒井翔平 [1], 香川　輔 [1], 水野浩志 [1], 南　貴之 [1], 八代浩彰 [1], 中村祐司 [1], 花谷　清 [2], 木島　滋 [2], 佐野史道 [2]

[1]*Graduate School of Energy Science, Kyoto University, Gokasho, Uji, 611-0011, Japan*
京都大学エネルギー科学研究科　〒611-0011　京都府宇治市五ヶ庄
[2]*Institute of Advanced Energy, Kyoto University, Gokasho, Uji, 611-0011, Japan*
京都大学エネルギー理工学研究所　〒611-0011　京都府宇治市五ヶ庄
[3]*Pioneering Research Unit for Next Generation, Kyoto University, Gokasho, Uji, 611-0011, Japan*
京都大学次世代開拓ユニット　〒611-0011　京都府宇治市五ヶ庄

A soft x-ray Pulse Height Analyzer (PHA) is installed in Heliotron J for the measurement of fast-electron energy spectrum at various pitch angles. The detector can be tilted in the range from -10° to 10° horizontally and from -3° to 7° vertically. The main purpose of the study is to confirm experimentally the change of fast-electron spectra expected in the electron cyclotron current drive (ECCD) phase. In this paper, we report the change in fast-electron energy spectrum of ECH only phase in pitch angle scan.

1. Introduction

Measurement of energy spectra in soft X-ray region can give us useful information about line impurities species, bulk electron temperature and electron loss region in the velocity space. In addition, the effect of fast electrons on the toroidal current can be evaluated from the signals in the parallel and anti-parallel directions.

A new movable PHA system has been installed in Heliotron J [1, 2] in order to measure the pitch angle dependence of the electron energy spectrum. In this paper, we report a preliminary result of pitch angle scan experiment performed to examine the change in energy spectrum, especially in ECCD experiment.

2. PHA System in Heliotron J

Figure 1 illustrates the arrangement of the PHA system in Heliotron J. This system can tilt its sight line horizontally from -10° to 10°. This range is equivalent to the pitch angle, φ, from 98° to 126° in the standard configuration of Heliotron J. The observing area can be controlled by using perpendicular and horizontal slits. The sensitivity range of a silicon detector in the PHA system is from 0.5 to 30 keV. The energy resolution is 0.10 - 0.25 keV.

The maximum rate of the shaping amplifier is about 80×10^3 counts/s. This system has four Be filters of which thickness are 30 μm, 70 μm, 150 μm and 300 μm to control minimum detectable energy. The values of photon energy for the transparency greater than 80% are 2.5 keV for the 30 μm filter, 3.2 keV for 70 μm filter, 4 keV for 150 μm filter and 5keV for 300 μm filter.

Figure 2 shows arrangement of PHA system in the poloidal cross-section. The angle of the sight line can be changed perpendicularly from -3° to 7°. These values correspond to the range in normalized radius from 0 to 0.35. By using this tilting system the observed pitch angle can be changed toroidally with keeping the condition that the sight line crosses the magnetic axis.

3. Experiments and Discussions

Figure 3 shows the line averaged electron

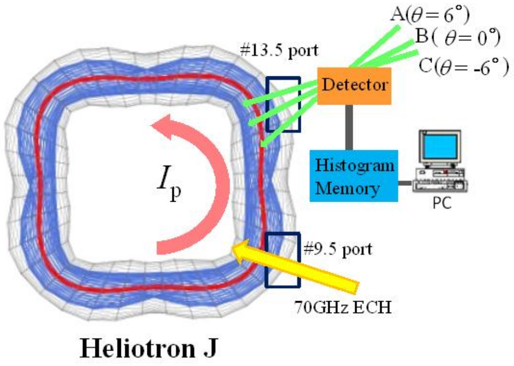

Fig.1 Arrangement of the PHA system

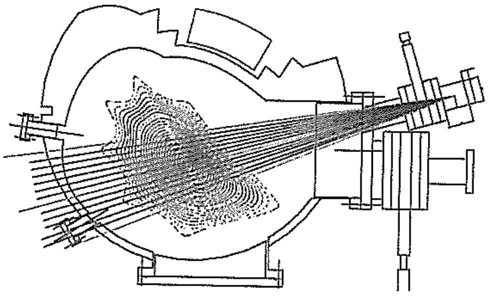

Fig.2 Projection of the sight line of PHA system on the poloidal cross-section

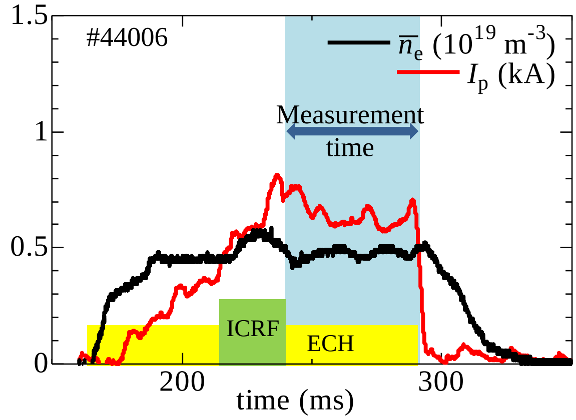

Fig.3 Measurement plasma parameter and injection parameter

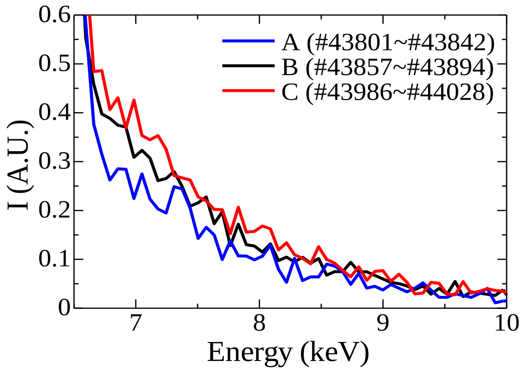

Fig.4 Measurement of energy spectra of soft X-ray by PHA system

density, $\overline{n}_e$, and the non-inductive plasma toroidal current, I_p. A plasma is generated and sustained by 70-GHz ECH ($N_{//}$ = 0.35) in the high bumpy configuration [3]. The average magnetic field strength is 1.36 T. The ECH pulse is injected from 165 ms to 285 ms, and its injection power is about 250 kW. In addition, ICRF [4] is injected from 220 ms to 240 ms in this particular set of discharges. The electron density is about 0.5×10^{19} m^{-3}. The total plasma current flows in the counter-clockwise direction in Fig.1. The current gradually increases up to 0.8 kA in the first half period of the discharge and is almost constant in the second half of the discharge. The energy spectra are observed for three different pitch angles keeping on-axis condition. The selected sight lines are indicated as A, B and C in Fig.1. The pitch angles are 119° for A, 110° for B, and 101° for C.

Figure 4 shows the observed energy spectra for the three cases. The measurement time interval of the PHA is from 240 ms to 290 ms. It is observed that the photon counts in the energy range 7-10 keV is decreased as changing the pitch angle from φ = 101° to 119°, while there is no clear difference at low-energy (< 6.5 keV) photon counts and high-energy (> 9 keV) photon counts. The result of the observation is consistent with the toroidal current direction if the fast electrons in the range of 7-10 keV carry the plasma current. For the next step, we will try to make observation of PHA signals for the plasmas where the toroidal plasma current by ECCD flows much larger, for example, in low bumpy configurations [3].

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