§12. Development of Automatic Optimization System for LHD-HIBP

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A heavy ion beam probe(HIBP) is a unique diagnostic tool for measuring the electrostatic potential, its fluctuations and density fluctuations in high-temperature magnetically confined plasmas directly without perturbing the plasmas. The observation position of HIBP can be selected by changing the probing beam energy and its injection angle. Observable positions of LHD-HIBP are shown in Fig.1. Generally in HIBP, the probing beam energy is fixed and one-dimensional profile is obtained. But two-dimensional measurement is attractive to study detail of transport physics related to magnetic islands and zonal flow structure. As shown in Fig.1, information in two-dimensional region can be obtained by changing the probing beam energy. However, in experiments, the beam energy can not be changed practically because it spends much time to adjust the beam trajectory when the beam energy is changed. The purpose of this study is to develop an automatic trajectory optimization system for reducing time to adjust the beam trajectory, and to measure the two-dimensional electrostatic potential profiles on a ploidal plain.

The deviation from center of beam-transport line is measured by rotating wire called as Beam Profile Monitors(BPM) and there are five BPMs in the beam-transport line of the LHD-HIBP. This deviation is measured in the two directions X,Y-axis by BPM and described here as ΔX and ΔY. ΔX and ΔY are adjusted to 0 by controlling voltage of steerer electrodes and cylindrical deflector, so that the probing beam is transported through the center of beam-transport line.

In this fiscal year, automatic optimization system using a two-dimensional steerer electrodes, BPM4 and BPM5 which are installed in the beam-transport line near a lower vertical diagnostic port of LHD (6.5L) was developed. Detail arrangement of components (steerer, BPMs etc.) in beam-transport line is shown in Ref. 1). The schematic diagram of optimization method is shown in Fig2. The applied voltages on the steerers are calculated by Proportional-Integral-Derivative (PID) algorithm so as to reduce ΔX and ΔY. The experimental result of this optimization is shown in Fig.3. The solid line is the marker signal of BPM, and the peak of this signal indicates that the rotating wire is at the center of beam-transport line. The peak close to 100 ms (300 ms) indicates the center of Y-axis (X-axis) direction. The dashed line indicates the probing beam current intensity measured with wire of BPM. A filled circle indicates the center of gravity of the beam signal in each direction. The beam trajectory optimization is successful if the center of gravity of both direction falls into the allowable range which is ± 10 ms (corresponds to the distance of ± 1.25 mm) from the peak of marker signal. As shown in Fig.3, ΔX and ΔY are large at the both BPMs before optimization. After optimization, ΔX and ΔY in BPM4 are nearly 0. Those in BPM5 are smaller than the initial deviation and falls into the allowable range. The result indicates that the beam trajectory is successfully optimized by this system. In addition to that, the time required for the optimization is shortened to one minute.

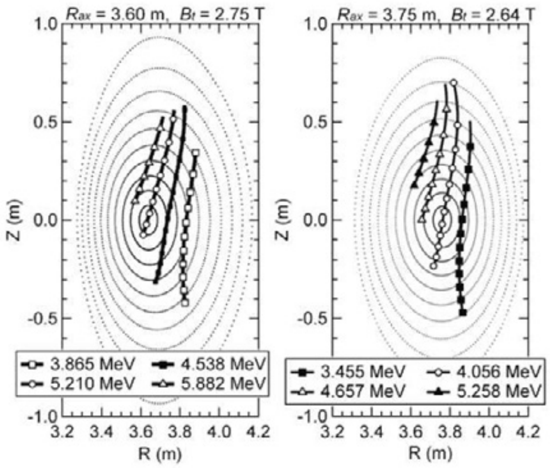

Fig.1. Observable region of LHD-HIBP. Each curve indicates observable region for each probing beam energy. The probing beam is swept by octupole sweepers.

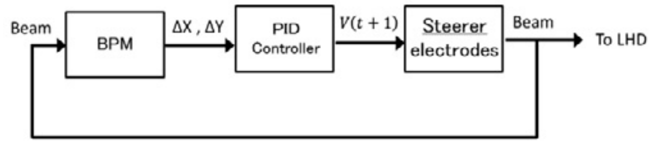

Fig.2. Schematic diagram of automatic optimization system

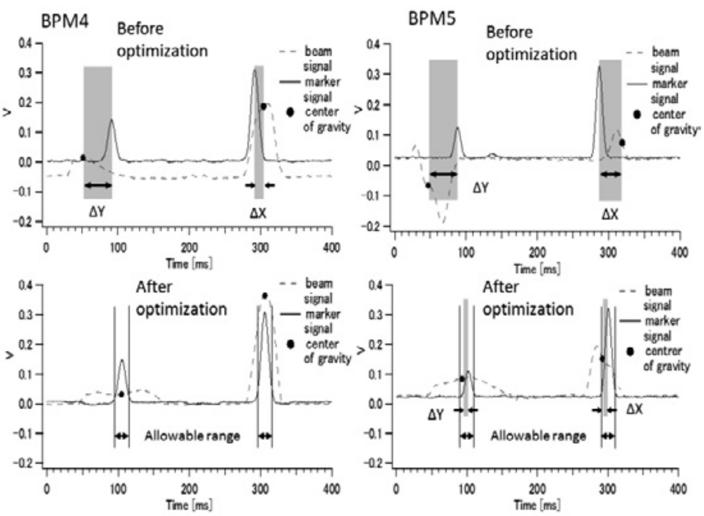

Fig.3. Signals of BPM4 and BPM5. Upper (lower) figures indicate results before (after) the optimization.

1) Ido,T.,Shimizu,A.,Nishiura,M.: Journal of Plasma and Fusion Research Vol86, No9(2010) 507-516