Progress in fast-ion loss detector project in EAST

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1. Introduction

To achieve a high-temperature and high-density plasma, additional heating by means of energetic ion produced by neutral-beam injection and/or ion cyclotron heating is applied in the middle or large-sized magnetic confinement fusion device. At the institute of plasma physics in China, the EAST will soon be equipped with neutral beam injectors. Therefore, by means of strong neutral beam injections, a study of the loss process of energetic ion due to magnetohydrodynamic (MHD) mode becomes possible. In a fusion device, energetic ions such as fusion-born alpha particles might excite MHD mode such as Alfvén eigenmodes. These instabilities are predicted to cause enhanced energetic-ion transport leading to a localized damage on plasma facing components. Understanding of the interaction of Alfvén eigenmodes and energetic ions through experimental observation in existing devices is necessary to find a way to reduce the energetic-ion loss in a fusion reactor. A scintillator-based fast-ion loss detector (FILD) has been installed on tokamaks such as TFTR [1,2], NSTX [3], JET [4] ASDEX Upgrade [5], DIII-D [6], KSTAR [7], Alcator C-mod [8], and HL-2A [9] and helical devices/stellarators such as CHS [10], Wendelstein7-AS [11], and LHD [12] and used to study the energetic-ion loss process. A FILD in EAST will be a powerful tool for a comprehensive understanding of energetic-ion loss physics in torus devices. This paper describes the progress of FILD project in the EAST.

2. Search a position for FILD

A FILD is a type of a magnetic spectrometer using the magnetic field of magnetic confinement device. The set of apertures is designed to get only an energetic ion. Scintillator emits a light due to the bombardment of an energetic ion. The position of the bright spot gives us the energy (E) and pitch angle (χ) of the energetic ion. The installation position for FILD is searched by means of Lorentz orbit code. The code solves the equation of motion of a charged particle with sixth order Runge-Kutta solver on a static magnetic field condition. The procedure for finding of a position suitable for the FILD is as follows. At first, energetic ions are launched from a candidate position of the FILD head. Second, the trajectory of each ion is followed backward in time using the Lorentz orbit code. Finally, we judge whether the ion can enter the plasma domain without hitting the vacuum vessel. If the energetic ion reaches the plasma region, it means that the lost energetic ion is measured by the FILD. Figure 1 shows the typical energetic-ion orbit calclucated on the MHD equilibrium file of g030707.03800. In this calculation, E and χ of energetic-ion at the FILD position are 75 keV, and 84.3 degrees, respectively. We found that the upper position on an outer port is first choice to detect escaping ions having banana orbit in the case of the experiment with counter-clockwise direction, looking down from the top, of toroidal magnetic field.

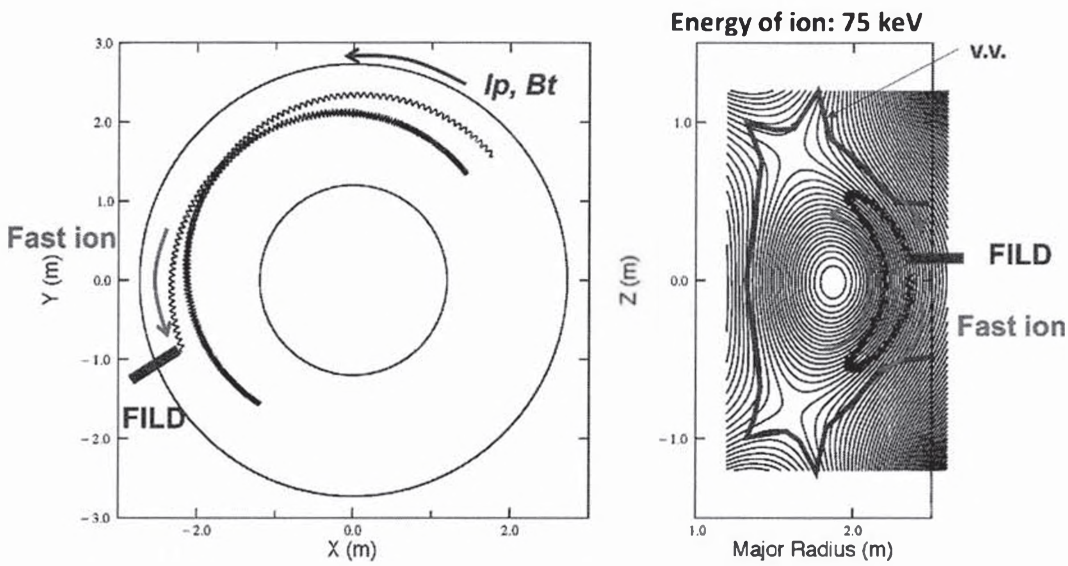

Fig.1 Typical trajectory of energetic ion can be measured by FILD in the EAST.

3. Design of FILD

Figure 2(a) shows the schematic view of the system of a FILD together with J port. The length of the probe is about 3 m, and can move horizontally by 2.5 m by means of servo motor. Note that the distance from the last closed flux surface to the waiting position of the probe head is 2.3 m. Figure 2(b) shows a FILD driving system. Note that the design of supporting structure is changed slightly from that in Fig. 2(a) due to the interference with other diagnostics (Fig. 2(c)). The design of the head is shown in Fig. 3. The width of first aperture and second aperture are 2 mm and 40 mm, respectively. The distance between two apertures is 10 mm. The height of the center of

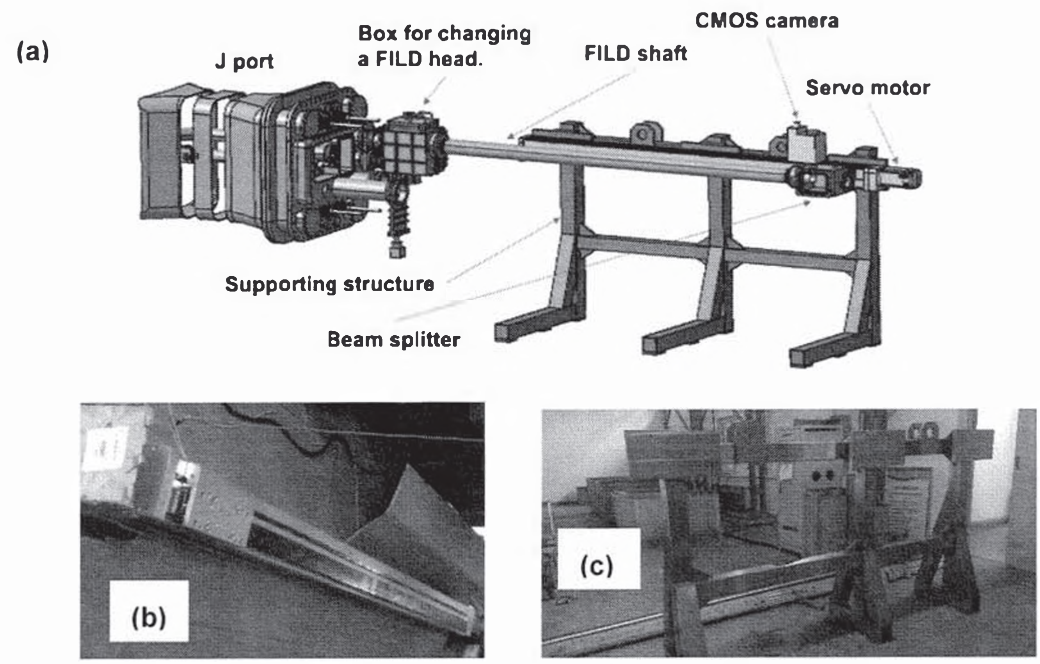

Fig.2 (a) The schematic view of FILD together with J-port. (b) FILD driving system. (c) FILD support structure.

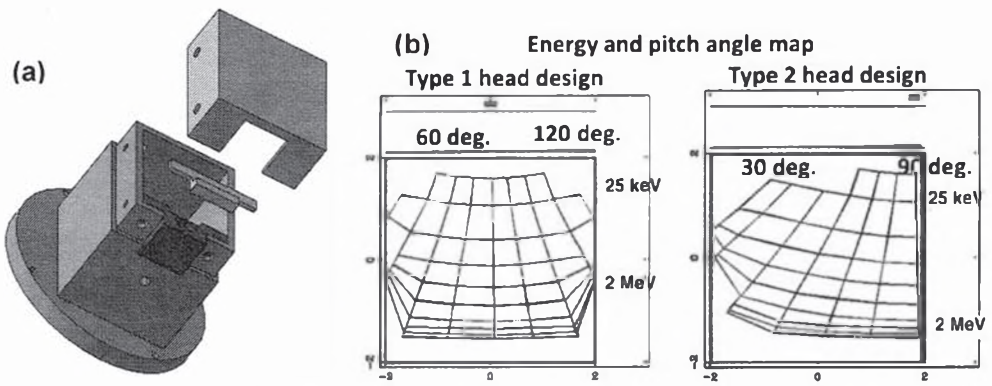

Fig.3 (a) Design of FILD probe head. (b) Energy and pitch angle map of two FILD heads.

these apertures from scintillator screen is 6 mm. The size and position of the aperture and the scintillator is decided according to grid map calculation as shown in Fig. 3 (b). The size of the scintillator is chosen so as to measure deuterons up to 2 MeV. Note that the magnetic field strength on the plasma axis and that on the FILD position are 2.0 T and 1.6 T, respectively. We will prepare two types of heads having different aperture positions. One is to measure energetic ions having χ of 60 degrees to 120 degrees and another is to measure energetic ions having χ of 30 degrees to 90 degrees. The block diagram of an acquisition and a controlling system is shown in Fig. 4. The thermocouple is for measurement of the temperature at the probe head to avoid melting the probe tip. The scintillation image is recorded by photomultiplier (PMT) (H10493, Hamamatsu

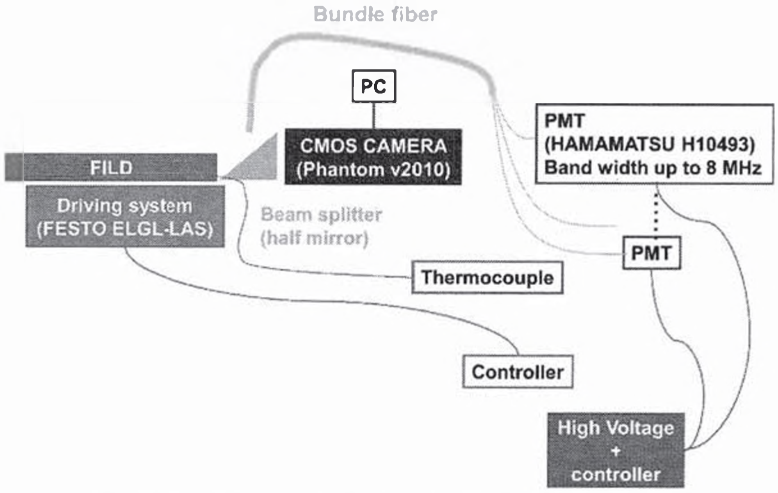

Fig. 4 Data acquisition and control system for FILD

Photonics) and a CMOS camera (v2010, Phantom: up to 22 k frames per second at 1280×800 pixels resolution). We will use 5×5 PMT to follow rapid events associated with energetic-ion-diven MHD instabilities with high-time resolution. The high-speed camera is used to obtain highly resolved energy and pitch-angle pattern on the screen for escaping energetic ions.

4. Summary

Fast-ion loss detector project for EAST is now ongoing as a collaboration between NIFS and ASIPP in the support of A3 foresight program. We chose an upper position on outer port to detect energetic ions escaping from a EAST plasma. Two types of FILD heads have been designed according to energy and pitch-angle grid map calculation. The FILD will be installed on EAST in 2014, being a powerful tool to reveal energetic-ion loss processes in EAST plasmas.

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