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Progress in Design Study of ITER Poloidal Polarimeter

ITERポロイダル偏光計測装置の設計検討の進展

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The recent design progress of ITER poloidal polarimeter is presented. As the basis of the design, three guidelines are created. According to these guidelines, a mirror module and a shutter in equatorial port plug have been designed. Candidate polarimetry methods for the primary roles and an approach for back-up / supplementary roles have been indicated along with the guidelines.

1. Introduction

In the ITER project, primary roles of the poloidal polarimeter are current profile measurement (equivalently safety factor (q) profile measurement) at core region of ITER plasmas [1]. In order to fulfill these roles, polarimetry to detect the Faraday effect of far-infrared (FIR) laser beams (wavelength λ~118 μm) is employed [2]. FIR laser beams are launched into the plasma from the equatorial port and the upper port.

Since Japan will procure the poloidal polarimeter, we have conducted the design study for it [3-5]. In this paper, guidelines for the design of the poloidal polarimeter and recent progress in its design study are presented.

2. Design Guidelines for Poloidal Polarimeter

Table 1 summarizes the measurement requirements and diagnostics roles with respect to the poloidal polarimeter [6,7]. As shown in Table 1, the poloidal polarimeter is expected to measure not only the current profile but also other parameters, e.g., line averaged electron density, high frequency instabilities, etc. The real-time plasma control using the data from the poloidal polarimeter is also anticipated. Accordingly, the data provided by the poloidal polarimeter shall be reliable and accurate enough in both physics and control aspects for various kind of parameters. Together with considering the significant displacement and deformation of components of the poloidal polarimeter under harsh nuclear and radiation environment in ITER, design guidelines for the poloidal polarimeter have been created as followings.

(1) Mechanically simple, rigid and stable structure is preferred for components which are installed in vacuum.
(2) Polarimetry methods which are insensitive to displacement and deformation of components are preferred.
(3) Back-up and Supplementary roles are implemented by dedicated sub-systems of the poloidal polarimeter when it is necessary.

Table 1 Measurement requirements and roles with respect to the poloidal polarimeter

Measurement	Parameter	Role	Condition	Range or Coverage	Resolution		Accuracy	Role of Poloidal Polari-meter
					Time or Freq.	Spatial or Wave No.		
Current profile	q(r)	PHY	Physics study	0.5 - 5	10 ms	a/20	10%	P
				5 - 9	10 ms	a/20	0.5	
Current profile	r(q = 1.5,2)/a	AC	NTM Feedback	0.3 - 0.9	10 ms	-	50 mm/a	P
Current profile	r(qmin)/a	AC	Reverse shear control	0.3 - 0.7	1 s	-	50 mm/a	P
Line-averaged electron density	∫ne dl / ∫ dl	BC	Default	1E18 – 4E20 m^{-3}	1 ms	Integral	1%	B
High frequency instabilities (MHD, NTMs, AEs, turbulence)	TAE δN / n, δT/T	PHY	(blank)	5E-6 - 5E-4	30 kHz – 2 MHz	n=10-50	30%	B
Electron density profile	Core ne	AC	r/a < 0.85	3E19 – 3E20 m^{-3}	10 ms	a/30	5%	S
Electron density profile	Edge ne	AC	r/a > 0.85	5E18 – 3E20 m^{-3}	10 ms	5 mm	5%	S
Plasma current	Ip	MP	Default	0 - 1 MA	1 ms	Integral	10 kA	S
				1 - 17.5 MA	1 ms	Integral	1%	S

<Measurement Roles>
MP: Machine Protection, BC: Basic Control, AC: Advanced Control, PHY: Physics Understanding
<Diagnostics Roles>
P (Primary): diagnostic is well suited to the measurement
B (Backup): diagnostic provides similar data to primary, but has some limitations
S (Supplementary): diagnostic validates or calibrates the measurement, but is not complete in itself

3. Mirror Modules in Equatorial Port Plug

Figure 1 shows the side view of the arrangement of plasma facing 1st and 2nd mirrors in the equatorial port plug. According to the design guideline (1), the mirror module in the equatorial port plug has been designed as shown in Fig. 2. There are two specific design features oriented for the mirror module, i.e., i) mirrors are fabricated by direct machining and polishing of mirror block surfaces to eliminate number of components and ii) three blocks are rigidly bolted each other to be a mono-block as the mirror module. By this design, high mechanical stability is expected.

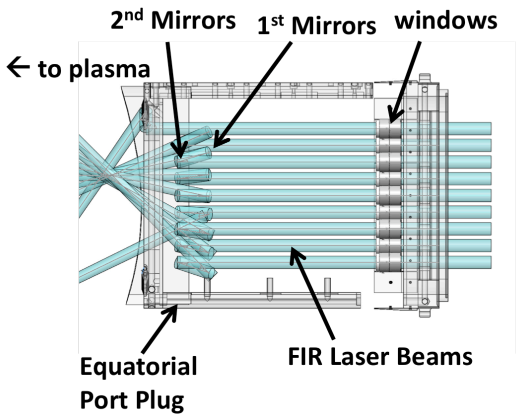

Figure 1 Mirror arrangement in equatorial port plug (side view)

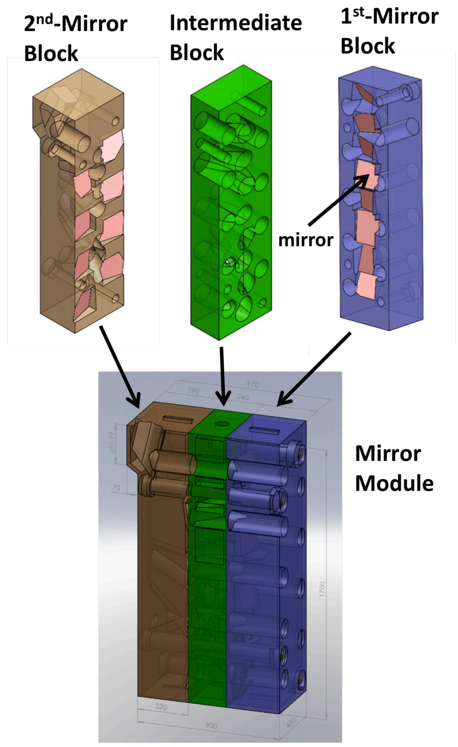

Figure 2 Mirror module in equatorial port plug

4. Shutter in Equatorial Port Plug

An optical shutter system is used to protect 1st and 2nd mirrors against unnecessary impurity deposition and surface sputtering during wall cleaning and plasma operation. However, the shutter is one of the most challenging items to develop since it needs reliable moving components with water-cooling channels. After the investigation of various shutter concepts, present shutter design employs a water cooled shutter panel connected to a spring coil by utilizing of the cooling water tube itself, and the shutter is driven by a reciprocating rod from outside the vacuum. This design provides a relatively simple configuration of the shutter.

5. Methods of polarimetry

According to the guideline (2), polarimetry methods which use interferometric signals are not preferable. Here, two candidates are picked up, i.e., 1) polarimetry by use of photo elastic modulators and 2) polarimetry by use of rotating polarizers or/and wave plates. While the former method needs R&D to demonstrate its feasibility at $\lambda \sim 118$ μm, the latter method is rather conventional and simple method. The latter method will be investigated as the future work.

6. Back-up and Supplementary roles

Candidate polarimetry methods mentioned in the previous section would have limitation for back-up and supplementary roles for electron density measurement, especially in accuracy and temporal resolution. According to the guideline (3), we consider that interferometer sub-system is effective for the back-up and supplementary roles to complement the polarimetery for the primary roles.

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