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Progress on Preliminary Design of ITER Poloidal Polarimeter
ITERポロイダル偏光計の予備詳細設計の進展

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The authors have developed design of ITER poloidal polarimeter (PoPola). The preliminary design of PoPola is scheduled to be approved in 2015. This study reports progress on preliminary design of PoPola, especially safety design, optical design and mechanical design of in-vessel mirror. Preliminary design needs to show engineering sound design in compliance with applicable French order, standard and codes. This requirement makes PoPola different from existing polarimeters. Knowledge obtained in this study will help us to design diagnostics for DEMO.

1. Introduction

Real-time control and measurement of current profile are necessary to obtain high-performance/steady-state tokamak plasma. In ITER, poloidal polarimeter (PoPola) and motional Stark effect diagnostics will be used to identify a profile of safety factor, q, and a location of flux surface of $q = 1.5,\ 2.0$ and q_{min}. These information will be used for physics study and real-time control of NTM suppression and reverse shear. Japan domestic agency has developed design of PoPola [1-12] and will procure it.

In ITER, there are three kinds of design phase; conceptual design phase, preliminary design phase and final design phase. After the final design is completed, manufacturing will be started. Conceptual design of PoPola was approved on June 2012; and preliminary design is scheduled to be approved in 2015. This study reports progress on preliminary design of PoPola.

Preliminary design needs to show engineering sound design in compliance with applicable standard and codes. PoPola needs to obey several French orders related to nuclear facility because PoPola will penetrate several safety boundaries (i.e. confinement barriers). This requirement makes PoPola different from existing polarimeters. Knowledge obtained in this study will help us to design diagnostics for DEMO.

2. Safety Boundary Concept

Eight kinds of zoning were established in ITER; (1) ventilation, (2) radiological, (3) anti-deflagration, (4) beryllium, (5) magnetic, (6) radiofrequency, (7) fire and (8) waste. PoPola optical transmission lines go from a diagnostic building to neighbor of a vacuum vessel and cross different classes of zoning. Since PoPola makes holes on boundaries between different classes of zoning, PoPola needs to provide additional security. The authors made safety boundary concept prior to launch of preliminary design activity. Fig. 1 shows schematics of the PoPola optical transmission line and the radiological/ventilation/fire boundaries. An air-tight window is installed to make ventilation boundary and to enable a laser beam to pass. The window cannot serve a function of fire boundary because it is difficult to guarantee that the window shall survive even in the fire accident. In order to minimize the total number of windows, the optical transmission line in the gallery has a function of ventilation boundary (i.e. the pipe is air-tight). A flap dumper is installed to make a fire boundary. In an emergency such as fire and liquid-helium leak, the damper will close and serve a function of confinement and fire sector. An additional shielding block is installed around a penetration between tokamak and diagnostic building to make a

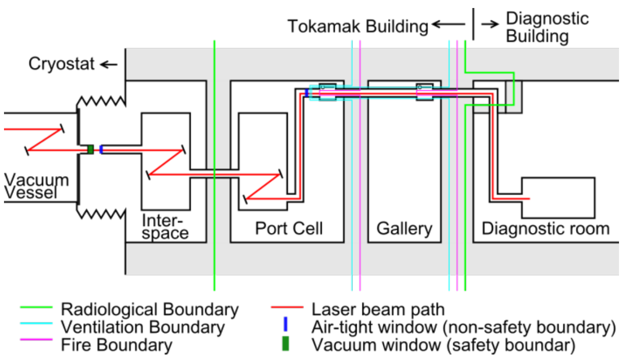

Fig.1. Schematics of the PoPola optical transmission line and the radiological/ventilation/fire boundary

radiological boundary. The additional shielding block is important to protect people in the diagnostic building especially when a remote-controlled transfer of cask containing activated in-vessel components passes through a gallery.

3. Optical Design

As shown in Fig. 1, eight mirrors will be placed in tokamak building. Unlike other polarimeters on existing tokamaks, there are four major difficulties of PoPola design; (1) mirrors in the vacuum vessel cannot be adjusted after the assemble of port plug, (2) maintainability of inter-space components is very limited, (3) vacuum vessel will move by an order of several centimeter owing to thermal expansion, and (4) aperture of vacuum window is not enough large. The authors need to make optical design to maximize reliability under these difficult conditions.

The authors determined which mirror needs to be a steering mirror to transmit a laser beam to a retro-reflector installed in blankets/divertor cassette, evaluated necessary control resolution of the steering mirror, evaluated acceptable installation/manufacturing error of in-vessel components, and confirmed that vignetting at vacuum window is reasonable.

4. Mechanical Design of In-Vessel Mirror

Fig. 2 shows one of viewing chord layout plans of PoPola. Circles in Fig. 2 show locations of in-vessel mirrors. Fig. 2 is a simple schematic, but in-vessel mirrors are located satisfying many

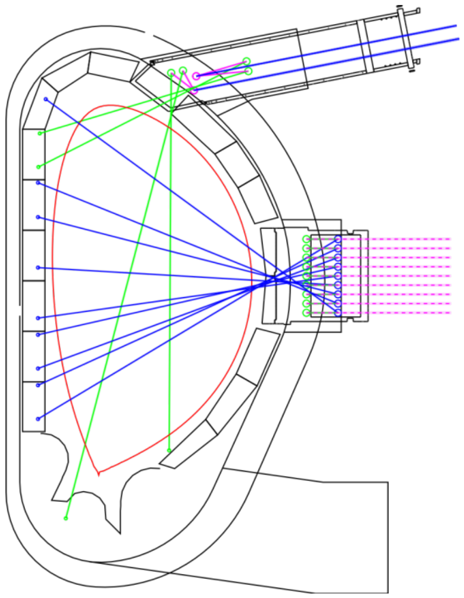

Fig. 2. One of viewing chord layout plans of PoPola. Circles illustrate locations of in-vessel mirrors.

engineering constraints. In this layout, nuclear heat load on mirrors in the equatorial port is less than 50 kW/m^3. A first mirror of the vertical viewing chord receives the highest nuclear heat load of approximately 3.2 MW/m^3. It is challenging to achieve both removal of the high nuclear heating load and small mirror surface deformation.

Tungsten was chosen as mirror material of the first mirror for the reason of high resistance to erosion. Cooling pipe is made of stainless steel. Mirror diameter and thickness is 160 mm and 20 mm, respectively. Temperature, pressure and flow rate of cooling water are 70 ^{o}C, 4 MPa and 100 cc/min, respectively. The authors found that the simple joint of tungsten mirror and stainless steel pipe causes high stress at the joint surface owing to different thermal expansion of tungsten and stainless steel. Evaluated maximal temperature, stress and mirror surface displacement were 173.4 ^{o}C, 882 MPa and 9.3 μm, respectively. The maximal stress is not acceptable. The authors made a new design using tungsten pipe in order to cool tungsten mirror. Results of thermal and structural analysis will be presented in the conference.

References

[1] R. Imazawa *et al.*, International Tokamak Physics Activity Topical Group Meeting on Diagnostics, Oct. 2010, Japan

[2] R. Imazawa *et al.*, Review of Scientific Instruments, 82, 023116-1 - 023116-5 (2011)

[3] R. Imazawa *et al.*, Plasma and Fusion Research, 6, 2402032-1 - 2402032-5 (2011)

[4] M. Ishikawa *et al.*, Fusion Engineering and Design, 86, 1286–1289 (2011)

[5] R. Imazawa *et al.*, Nuclear Fusion, 51, 113022-1 - 113022-8 (2011)

[6] Y. Kawano *et al.*, Proceedings of Plasma Conference 2011 (PLASMA 2011), 22P120-P (2011)

[7] R. Imazawa *et al.*, Plasma Physics and Controlled Fusion, 54, 055005-1 - 055005-7 (2012)

[8] R. Imazawa et al., Proceedings of 24th IAEA Fusion Energy Conference, ITR/P5-38 (2012)

[9] Y. Kawano *et al.*, Proceedings of 24th IAEA Fusion Energy Conference, ITR/P5-35 (2012)

[10] R. Imazawa *et al.*, 55th Annual Meeting of the APS Division of Plasma Physics, TO5.00011, Nov., 2013, USA

[11] R. Imazawa *et al.*, 25th IAEA Fusion Energy Conference, FIP/P7-17, Oct. 2014, Russia

[12] R. Imazawa *et al.*, 41st European Physics Society Conference on Plasma Physics, P5.008, June, 2014, German