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Recent Development of the Plasma Diagnostics for JT-60SA
JT-60SAにおける計測開発の現状

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Recent design activities of the plasma diagnostic systems for JT-60SA are presented. Toward finalizations of the cryostat design and arrangements of all the systems in the JT-60SA torus hall, design study of the port plug and arrangement of diagnostic around the cryostat port have progressed significantly. Divertor Langmuir probes are manufactured in FY2011. In addition to the diagnostic systems which have been already defined, advanced diagnostics are studied.

1. Introduction

Plasma diagnostic systems in JT-60SA[1] measure accurate profiles of main plasma and divertor plasma parameters and to provide real-time data to the plasma control system in order to self-regulating high β_N plasmas in steady state [2]. The plasma diagnostic systems in JT-60SA has been classified into three categories, such as the diagnostic systems for “Machine Protection and Operation”, the diagnostic systems for “Fundamental Parameter Measurement” and the diagnostic systems for “Physics Understanding”. This paper presents the recent progress of the design activity of the plasma diagnostic systems for JT-60SA.

2. Port Plug Design Activity

Toward finalizations of the cryostat design and arrangements of all the systems in the JT-60SA torus hall, design study of the port plug and arrangement of diagnostic around the cryostat port have progressed significantly. Since port plug structure for optical diagnostics in JT-60SA is long and large, the port plug design must take into account of installation and maintenance by machines in limited space around the cryostat port.

Use of the P2 horizontal port section is shown in Fig. 1, as a typical case of the sharing space among the plasma diagnostics and in-vessel components. Please note that tiles which cover the stabilizing plate and RWM coils are not drawn in this figure. Since distance from the plasma edge to the vacuum boundary of the cryostat port is ~ 3m, front-end components of optical diagnostics are enclosed in port plugs. Collection optics of Thomson scattering measurement and back ground light optics of CXRS (charge exchange recombination spectroscopy) are enclosed in the P2 port plug. Vacuum windows in the P2 port plug are placed behind the stabilizing plate and then the front-optics for Thomson scattering system and CXRS system view the plasma through an aperture of the stabilizing plate and RWM (resistive wall mode) coil. Arrangement of vacuum windows in this port plug is designed in combination with toroidal width of the aperture, so that necessary field of view is possible through aperture of the stabilizing plate. Lower part of this horizontal port duct is used by current feeders for RWM coils and EFC (error field correction) coils.

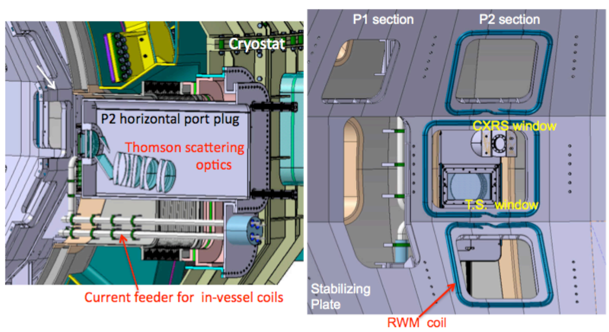

Fig. 1
Cut-away and front view of the P2 horizontal port.

Design activity of shutters for vacuum windows is also progressed, recently. Head of the P2 port plug is shown in Fig. 2. Diameter of the vacuum window is as large as 40 cm and a shutter, which must withstand electro magnetic forces due to the plasma disruptions and heat flux from the plasmas, is designed to be driven mechanically by wires.

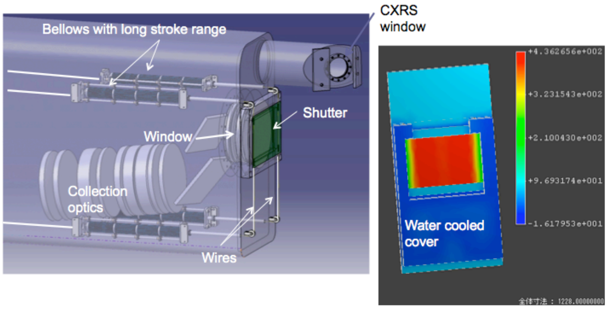

Fig. 2 Design of shutter in the P2 horizontal port plug for Thomson scattering measurement.

3. Divertor Langmuir Probes

Divertor Langmuir probes are very useful diagnostics in order to identify diveror configurations and to compare with equilibrium by the magnetic measurement in the initial phase of the JT-60SA experiment. Langmuir probe tips are placed between target tiles and distributed in the divertor cassette, as shown in Fig 3. Four sets of 40 probes are installed at the different toroidal locations.

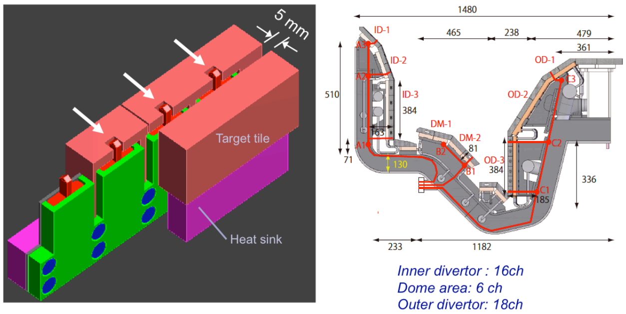

Fig. 3
Langmuir probes installed in the divertor target.
Arrow shows direction of the plasma flow.

Tips of the probe are roof like shape and made of CFC. The surface area which collects the current from plasmas is ~6 mm^2. The connectors made of nickel are brazed at the bottom of the collectors to which the MI cables are connected. It is expected that these target probes withstand the heat flux of 1 MW/m^2 for 100 s or 10 MW/m^2 for 5 s. Those probe tips will be manufactured in FY2011.

The divertor Langmuir probes is also used to measure plasma parameters in divertor region, such as, electron density (n_e), electron temperature (T_e), floating potential (V_f) and ion saturation current (I_{sat}). These plasma parameters are essential to produce and to control the partially detached divertor plasmas. Studies of plasma-material interaction, such as erosion and deposition of wall materials and retention and recycling of fuel particles, also require this diagnostic system.

4. Optics for Visible/IR First wall TV system

The Visible/IR First wall TV system must provide a wide-angle view in both visible and infrared range of wavelength on both the main chamber and divertor area. This diagnostic is essential for safe operation with real time protection during the higher input power (NBI+ECRF) heating. The 3-Dimensinal effect of ELM interaction on the JT-60SA main chamber is also attractive for physics studies.

A new idea for the front end optics of the periscope is being proposed. In the new design, no aspheric mirror are used as the conventional design, such as that used in JET. Two set of spherical mirrors (plus two flat mirrors), instead of a aspheric mirror, makes it possible to reduce a tolerance for manufacture/installation. Another advantage is a blind spot in the field of view, inherent in the conventional optical design, can be avoided. R&D of the periscope applying the new optical design is planned.

4. Advanced diagnostics

In addition to the diagnostic systems which have been defined in WBS system, the several plasma diagnostic systems which have advanced features are being studied.

A crystal spectrometer is under consideration for installation at the P10 horizontal port, which is shared with the VUV spectrometer and the neutron profile monitor as shown in Fig.4. The primary purpose of this spectrometer is to measure the ion temperature at the plasma center in high density discharges such as Scenario 2 (electron temperature 8 keV and electron density 1x10^{20} m^{-3}), instead of the CXRS system because the neutral beam will not penetrate into the plasma core. As a diagnostic gas, krypton is found to be a choice because a steady-state impurity transport analysis indicated that full striped argon is dominant at the plasma center, resulting in no line emission and that neon-like xenon exists at the plasma center in a limited electron temperature range between 5 and 9 keV, resuling in limitation of the ion temperature measurement. In order to measure the Doppler broadening of Kr XXXV (1s^2 $^1S_0$ – 1s2p $^1P_1$: l = 0.09455 nm), a Johann type crystal spectrometer with a Rowland circle diameter of 3 m is under consideration.

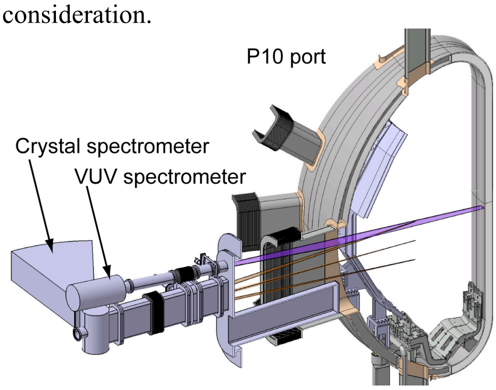

Fig. 4
Viewing chords of the VUV and crystal spectrometers

References

[1] S. Ishida et al., Proc. of the 23rd Fusion Energy Conf., 2010, OV/P-4.

[2] Y. Kamada et al., Journal of Plasma and Fusion Research SERIES Vol. 9 (2010) 641.