S14-5

Evaluation of diagnostics and future development subjects
計測器の総合評価と今後の開発課題

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Candidates of diagnostics on a DEMO reactor such as magnetics and an interferometer/polarimeter are listed up from requirements of plasma start-up and steady state operation scenarios. Due to the higher radiation, the higher temperature and the limited access than present devices, there are challenges to be overcame. In this presentation, challenges of each candidate are clarified and the life time, and limitation are estimated quantitatively and qualitatively.

1. Introduction

In S14-4, necessary plasma parameters for burning plasma control and candidates of diagnostics on a DEMO reactor are shown: magnetics, interferometer/polarimeter, microwave diagnostics, Thomson scattering measurement, spectroscopy and neutron diagnostic. Due to a harsh environment, such as high radiation level and high temperature, in the DEMO reactor, the life time of the diagnostics and resolutions will be limited. In order to make diagnostic set which satisfies the requirements of the reactor operation, it is important to clarify challenges in the present diagnostic techniques and to start the developments.

Table 1: Radiation levels in locations of diagnostic components

Region	Location	Fast neutron flux ($cm^{-2}s^{-1}$)	γ-ray flux (MGy/h)
Zone A	Behind brancket	2×10^{13}	0.5
Zone B	Behind high-temperature shield	5×10^{10}	0.001
Zone C	Behind low-temperature shield	3×10^{9}	0.0001

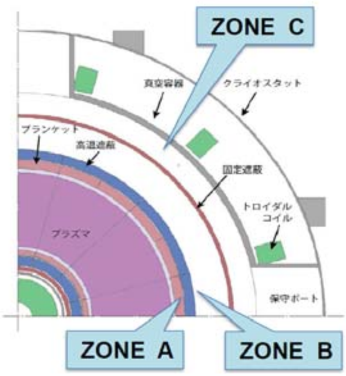

Fig. 1: Horizontal cross section of Slim-CS [2]

For discussions of radiation effects on diagnostic components, the reactor design and the radiation level of Slim-CS [1] are used as an example of those in the DEMO reactor. The locations where diagnostic components will be installed are divided into three regions as shown in Table 1 and Fig. 1.

2. Magnetics

The radiation causes a temporal or permanent degradation of the insulation performance of the ceramic (RIC, RIED) and induces the electromotive force (RIEMF, TIEMF) in magnetics. They determine the life time and resolutions. As for the radiation induced conductivity (RIC), the database of irradiation experiments [3] shows the induced conductivity is at an acceptable level in the Zone A. For suppression of the radiation induced electrical degradation (RIED), magnetics in ITER are designed, following the guideline that the radiation flux is smaller than 100 Gy/s [4]. The flux in Zone A is slightly higher (140 Gy/s) than the guideline, the RIED may occur earlier than ITER. Supposing that the size of a flux loop in the DEMO reactor is comparable to that in ITER, the expected thermoelectric electromotive force (TIEMF) is about 1 mV, is not negligible level. The neutron irradiation test of the Hall sensor, which is an alternative sensor of the magnetic field, shows a life time of about three years behind the brancket (Zone B). Further reduction of the radiation level to extend the life time longer than that of the brancket replacement interval and estimation of the signal to noise ratio at the isolated position from a plasma are necessary. Since these radiation effects strongly depend on the insulation and conductor materials, the developments of materials with the small radiation effect are also necessary. To that end, the operation of the irradiation facility with sufficient flux and irradiation area is indispensable.

3. Laser/Microwave diagnostics

3.1. Interferometer/Polarimeter

The optimum wavelength of the probe light is at the infrared or near infrared region in the DEMO reactor. The candidates of the window are quartz and sapphire for near infrared laser light. Locations of the window will be Zone C and the reflectivity of the sapphire is expected to be reduced by 10% for about one year. Since the labyrinth structure can reduce the radiation level by one order, the life time of the window will be able to extend up to about ten years.

The first mirrors will be installed in Zone A. Although past irradiation tests of metallic mirrors showed no degradation, the total fluence corresponded to less than 100-days' fluence in Zone A. Hence the further irradiation test is necessary for conformation of performance of the first mirror. The other mirror issue is erosion, impurity deposition and helium bubbles. Since they are also severe problems in ITER, suppression method, such as fin-shaped protection [5], and cleaning method will be examined on ITER.

The density resolution required from a helical reactor FFHR-d1 is 10^{17} m^{-3} to suppress variations of the fusion output [6]. The present two-color interferometer cannot realize the quite high resolution. The dispersion interferometer has higher density resolution [7] and is one of the candidates. Even so, the density is underestimated by about 10% due to the relativistic effect. Correction with the temperature profile will be necessary.

3.2. Thomson scattering measurement

The spectrum of the scattered light (the incident light: 1064 nm) broaden down to 200 nm for an electron temperature of 40 keV. Since the transmission degradation of the window and the optical fiber become more significant for shorter wavelength, the upper limit of the neutron and γ-ray fluences will be lower than that for the interferometer/polarimeter. A neutron fluence of 1×10^{16} n/cm^2 reduces the transmissivity of a quartz window by 10% at 300 nm. The fluence corresponds to only 0.1 year's irradiation in Zone C. The reduction of the radiation level about two orders is indispensable: shielding and labyrinth duct structure. In addition, the degradation is significant for shorter wavelength than 500 nm, where the wavelength broaden. Hence the detected spectrum of the scattered light will change gradually and then the frequency of the calibration should be considered. The issues of the first mirror are similar to and more significant than those for the interferometer /polarimeter.

3.3. Reflectometer, ECE

Microwave diagnostics are relatively robust in the DEMO reactor because a waveguide and a first mirror/horn are not affected so much by the radiation. Hence, it can be used as reliable diagnostics of a plasma edge, alternative to the magnetics [8]. On the other hand, relativistic effect causes underestimation of the density for the reflectometer and limitation of the measurable region to the edge for ECE (due to downshift of the radiation frequency). As an edge measurement, they will be reliable diagnostics in the DEMO.

4. Neutron diagnostics

A microfission chamber has a wide dynamic range, the high resolution and the fast response. For conversion of the local neutron yield to the fusion output, a calibration experiment is necessary. However, present neutron sources are too weak to calibrate the fission chambers with a sufficient signal to noise ratio even in ITER. Several calibration methods are proposed [9, 10] and will be examined in ITER.

5. Discussion and summary

In this presentation, challenges of each diagnostic on ITER are shown. Irradiation tests of components are still necessary for most of diagnostics. However, irradiation facilities in Japan are limited now. Re-start of a fission reactor for irradiation tests such as JMTR is desired.

The relativistic effect will be more significant in ITER and DEMO than present devices. The underestimation of the density and limitation of the measurable area of the temperature cannot be negligible. The calibration method or good approximations should be established through ITER experiments.

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