22P097-P

Design of IR thermography for divertor in ITER
ITERダイバータ用IRサーモグラフィーの設計

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The conceptual design and physical investigations of the IR thermography for divertor in ITER have started. For the temperature measurements of the divertor plates, this diagnostic has a two color (wave length λ = 3, 5 μm) system and a spectroscopic system which has the measurement performance with 30 wavelength points in 1-5 μm and 100 spatial points for each wave length. From equatorial port, it observes the nearest inner divertor plate and 9.9 m away outer divertor plate. In this study, a fundamental system is introduced and physical investigations such as the effect of diffraction due to the size of the optical aperture and the emission intensity from divertor plates has been performed.

1. Background and Objective

The IR thermography for divertor [1] is one of the diagnostics which Japan is charge of development. In this study, the conceptual design and physical investigations of the IR thermography have been performed to meet the requirement for ITER.

The objective of this diagnostics is a measurement of the profiles of surface temperature and thermal power load on the inner and outer divertor plates and a part of (30 %) baffles. A spectroscopic measurement in an IR range of the emission light from the divertor plates and baffles are performed. For advanced control and physics studies, the IR thermography for divetor has a role of the measurement with higher time and spatial resolution than those of other temperature diagnostics such as VIS/IR cameras and thermocouples.

2. Specifications and system of IR thermography for divertor

Table 1 shows the measurement requirements of the profiles of temperature and power load on divertor plates. The surface temperature measurement is required in a wide range of 200-3600 °C with different time resolution (2 ms, 0.02 ms), and precisive spatial resolution (3 mm). The power load on divertor plates is calculated from the surface temperature, side temperature of divertor plates measured by thermocouples, temperature of cooling system, thermal conductivity and so on.

For an achievement of the requirements, two independent optical systems will be builded up. One is a two color (wave length λ = 3, 5 μm) system. This system has 2 detectors and the temperature is derived from the ratio of each emission light. The other one is a spectroscopic system. This system is constituted of a spectrometer and a detector, which has the measurement performance with 30 wavelength points in 1-5 μm and 100 spatial points for each wave length.

Figure 1 shows the field of view of the IR thermography for divertor. The optical system will be installed in a port plug at an equatorial port. Both the nearest inner divertor plate and a 9.9 m away outer divertor plate are observed. In these regions, it is possible to observe the divertor plate from the bottom to the top. The emission light is transmitted from the front-end optics to the spectrometer and the detector thorough the relay optics. A molybdenn first mirror is used and there are some optical labyrinths for neutron shielding. Two vacuum windows made of sapphire are used. The sapphire has a preferable transmission rate in 1-5 μm and a robust characteristic against the radiation by neutrons (~10^{19}-10^{20} n / cm^2).

Table 1. The measurement requirements of the profiles of temperature and power load on divertor plates.

Parameter	Range	Time resolution	Spatial resolution	Accuracy
Surface temperature	200-1000 ℃	2 ms	3 mm	10 %
	1000-3600 ℃	0.02 ms	3 mm	10 %
Power load (default)	0.1-25 MW/m^2	2 ms	3 mm	10 %
Power load (disruption)	0.02-5 GW/m^2	0.02 ms	3 mm	20 %

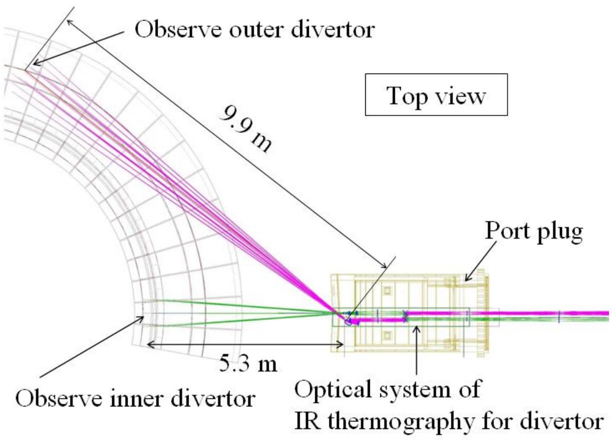

Fig.1. The field of view of the measurement area of the IR thrmography for divertor.

3. Effect of diffraction due to the aperture of the optical system

It is generally known that a circle-like diffraction pattern arises in the case of observation with a circle aperture. The following equation gives the limit of resolution of optics for the Fraunhofer diffraction.

$$\Delta y = 1.22\, L\lambda / d$$

where, Δy is a spatial resolution on the observation area, L is a distance from the aperture to observed area and d is a diameter of the aperture. To meet the spatial resolution (3 mm), the aperture diameters of d > 20 mm, d > 10 mm are needed for the measurements of outer divertor and inner divertor, respectively.

4. Evaluation of the emission intensity from the divertor plate

The emission intensity is calculated by Planck's equation for the blackbody emission. Figure 2 shows temperature dependence of the emission intensity which enters into the aperture from the inner divertor plate in λ = 1, 3, 5 μm with 10 % band width and the ratio of the emission. In this case, the observed area on divertor plate is 9 mm^2 and the aperture diameter is 60 mm, which has enough emission intensity and good spatial resolution Δy < 0.54 mm in λ = 1-5 μm. It has a tendency for emission intensity to decrease as temperature decreases. Though the emission intensity decays (~10^{-2}-10^{-3}) by the reflection and transmission of mirrors and lenses, it will be enough to measure by a detector. An estimated bremsstrahlung light may affect only under low temperature (~250 °C). This is one of the issues of the measurement. In the case of the ratio of photons of Ph (λ = 3 μm) / Ph (λ = 5 μm), it can measure the temperature under 1000 °C unlike other two ratios. Therefore, this ratio will be used in the 2 color temperature measurement.

5. Other physical investigations and issues

The observed divertor plates and baffles have 3-dimensional structure and lean to the field of view. Therefore, smaller spatial resolution of < 3 mm is required. Furthermore, the spatial resolution of the temperature derived from the observed emissions is expected to be worse than 3 mm because of the nonlinearity between temperature and emission light. If the size of the optical aperture is larger, the spatial resolution becomes better in principle. It is also important to consider the focal depth of lens in optical system for realize a precise spatial resolution. The optimum optical system and the detector are being investigated now. For a degradation of optics and a deposition of impurities and erosion of divertor plates which change the emissivity, a calibration system and shutter is needed. The effect of neutron flux should be considered in selecting the optical material.

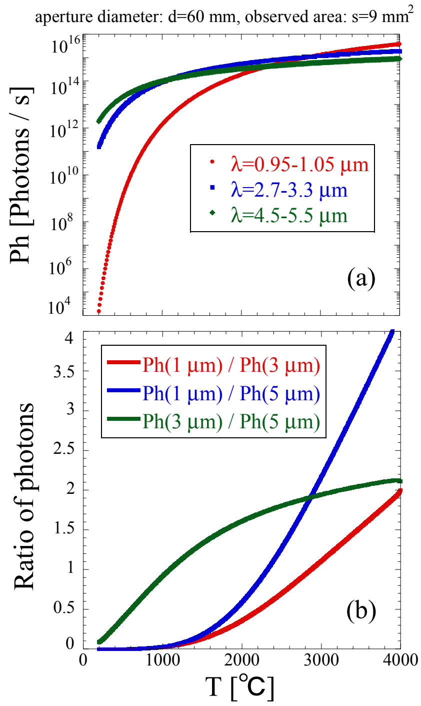

Fig.2. (a) Temperature dependence of the emission intensity which enters into the aperture from the inner divertor plate in λ = 1, 3, 5 mm with 10 % band width and (b) the ratios of the emission.

Reference

[1] A.J.H. Donne *et al.*, Nucl. Fusion **47** (2007) S337-S384.

Disclaimer: The views and opinions expressed herein do not necessarily reflect those of the ITER organization.