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Development of Divertor IR Thermography for ITER
ITERダイバータIRサーモグラフィーの開発

Tatsuo Sugie, Masaki Takeuchi, Masao Ishikawa, Takahiko Shimada, Atsushi Katsunuma[1)], Daisuke Kitazawa[1)], Keisuke Omori[1)] and Kiyoshi Itami
杉江達夫、竹内正樹、石川正男、嶋田恭彦、勝沼淳[1)]、北澤大輔[1)]、大森啓介[1)]、伊丹潔

Naka Fusion Institute, Japan Atomic Energy Agency
801-1, Mukoyama, Naka-shi, Ibaraki 311-0193, Japan
日本原子力研究開発機構　那珂核融合研究所　〒311-0193　茨城県那珂市向山801-1
[1)] Nikon Corporation
12-1, Yurakucho 1-chome, Chiyoda-ku, Tokyo 100-8331, Japan
[1)]株式会社 ニコン　〒100-8331 東京都千代田区有楽町1-12-1

The optics of Divertor IR Thermography has been redesigned within the reduced reservation space. The redesigned optics satisfied the required spatial resolution of 3 mm. The first mirror temperature effect on the detecting signal was evaluated. The effect was less than 5% for the divertor target temperature of lower than around 400ºC if the first mirror temperature was kept below 100ºC and the emissivity less than 0.1. On the other hand, the effect was negligible for the higher target temperature measurement.

1. Introduction

The divertor IR thermography (IRTh) is one of the diagnostic systems procured by Japan for ITER. The IRTh measures distributions of surface temperature and power load on the divertor targets and related baffles with a high spatial resolution of 3 mm and a high time resolution of 2 ms - 0.02 ms for plasma advanced control and physics study. The development of the IRTh has been carried out taking into account ITER harsh environment, such as higher neutron/gamma ray and particle radiations on the components and nuclear heating of the components than those of present devices [1].

2. Design of Divertor IR Thermography (IRTh)

2.1 *Measurement Requirement*

The measurement requirement for the surface temperature T_s and the power load P_L is summarized in Table I.

Table I. Measurement requirement

	Spatial res.	Time res.	Accuracy
T_s (200 - 1000°C)	3 mm	2 ms	0.1
T_s (1000 - 3600°C)	3 mm	0.02 ms	0.1
P_L (0.1-25 MWm^{-2})	3 mm	2 ms	0.1
P_L (0.02-5 GWm^{-2})	3 mm	0.02 ms	0.2

2.2 *Overview of Design*

The IRTh observes outer and inner divertor targets and related baffles from the equatorial port. The distance from the port to each observing area is different and the direction of each line of sight is also different. Therefore, the IRTh has two individual optical systems for outer divertor viewing and for inner divertor viewing. In addition, each optical system has two different detecting systems. One is a 2-colour (3 μm band, 5 mm band) system and another is a spectroscopic (1.5 – 5 μm) system [1]. Figure 1 shows the schematic overview of the IRTh components for one of the individual optical systems.

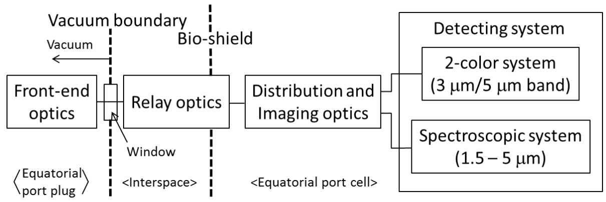

Fig.1. Overview of IRTh components for one of the individual optical systems

2.3 *Status of Optical Design*

Since the reservation space for IRTh in the port plug was reduced, the previous optics [1] has been redesigned satisfying the required spatial resolution and other optical functions. Fig.2 shows the front-end optics in the port plug. The front-end optics for the outer divertor measurement comprise a toroidal first mirror, which allows the IRTh to look tangentially, followed by a cylindrical mirror, two toroidal mirrors, three cylindrical mirrors and two flat mirrors. The front-end optics for the inner divertor measurement comprises a flat first mirror followed by three toroidal mirrors and a cylindrical mirror. The intermediate image of each divertor target is formed around each window and transferred to the distribution and imaging optics, which is installed in the port cell, by the relay optics embedded optical alignment optics in it, and then measured by the detecting system.

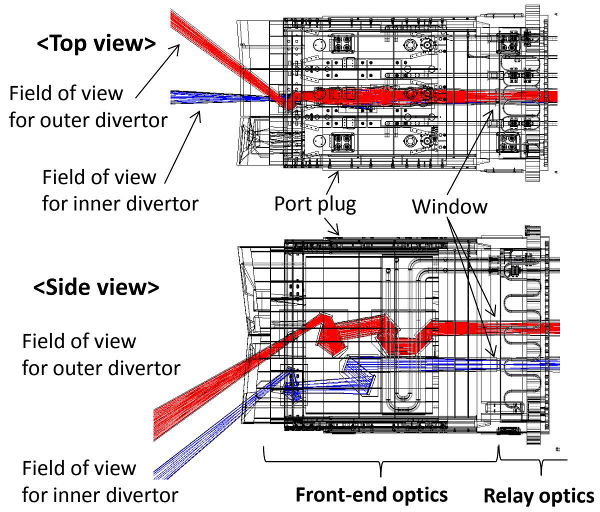

Fig.2. Front-end optics in the port plug

The aperture diameters of around 75 mm were determined in order to satisfy the required spatial resolution of 3 mm considering the diffraction limit. It was confirmed that both inner and outer divertor viewing optical systems including relay optics satisfy the required spatial resolution.

3. First Mirror Temperature Effect

Surface emissivity of the first mirror is expected to be increased due to the particle deposition and/or erosion by particle bombardment, and then the emission from the first mirror surface is increased. The emission is superimposed on the emission from the divertor target to be measured. Therefore, it is important to evaluate the effect of the first mirror temperature on the detecting signals.

The evaluation was carried out for two measurement methods. First one was the method to derive the temperature by measuring the radiation from the divertor target integrated over the wavelength range 1.5 μm - 5.0 μm. Second one was the method to derive the temperature from the ratio between the radiations from different wavelength bands (3 μm band: 2.85 – 3.15 μm and 5 μm band: 4.5 - 5.0 μm), which is called 2-color method.

The relative irradiances on the intermediate image plane (end of the relay optics) originated from the radiation of the divertor target and the first mirror were calculated with optical design software CODE V. The expected irradiances on the intermediate image plane were calculated by multiplying blackbody radiation, emissivities of the surfaces, first mirror reflectivity and the relative irradiances.

For the first method, the effect of the first mirror temperature on the temperature measurements were less than 5% at the divertor target temperature of < 400ºC if the first mirror temperature was kept below 100ºC and the first mirror emissivity less than 0.1. The effect was negligible for the higher target temperature measurement.

For the second method, the effect of the first mirror temperature on the temperature measurements were less than 3% at the divertor target temperature of < 400ºC if the first mirror temperature was kept below 100ºC and the emissivity less than 0.1. The effect was negligible for the higher target temperature measurement.

On the other hand, the effects became large if the emissivity of the first mirror was increased. The detailed results and measures will be discussed in the conference.

4. In-Situ Calibration Method

The transmission of the optics will be measured by using an infrared source (such as a plane heater) mounted behind the shutter located in front of the optics. It is important to know the emissivities of the divertor targets and baffles for the temperature measurement. The emissivities will be measured during ITER baking phase at the divertor temperature of 360 ºC. On the other hand, the new in-situ calibration method using an IR laser has been developed [2, 21pC2-4 in this conference].

5. Works under developing

The neutronics analysis, optical design for optical alignment and calibration, mechanical design, design of control and data processing system for IRTh are under developing. The latest results and the remaining works will be discussed in the conference.

Acknowledgments

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References

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