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Intensity Calibration of the Liquid-Crystal-Based Tunable Lyot Filter Spectra Camera Using Large White LED Panel
大型白色LEDパネルを用いた液晶リオフィルタスペクトラカメラの感度較正

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In order to apply simple and portable calibration system to the imaging spectroscopy using a tunable Liquid-Crystal-Based Lyot filter, a light-emitting diode (LED) display panel was examined if it can be used as a standard light source having continuum spectrum in visible wavelength region. By comparing with the standard light of the tungsten halogen lamp, the radiance of the LED panel was measured. Then the calibration factor for the intensity and for the intensity ratio was examined.

1. Introduction

In nuclear fusion study, so-called “line intensity ratio method” based on the optical emission spectroscopy (OES) has been applied quite frequently in these one or two decades, in order to measure the plasma parameter. Recently, importance of the imaging diagnostics has been particularly emphasized because the plasma parameter has spatial distribution both along and across the magnetic field. Therefore, in order to apply the intensity ratio method to an imaging spectroscopy, we have developed the tunable Lyot filter spectra camera that can be used with a collisional-radiative model (CR model) [1]. Conventionally, in the calibration of this kind of imaging spectroscopy system, a tungsten halogen lamp and a perfect diffuse reflector plate are used. However, the size and the uniformity of the irradiated surface area of the diffuse reflector can be a problem. This is because the surface area for which the calibration data of the halogen lamp is attached usually limited in a small region. In contrast, the white LED panel has a large surface, which emits continuum spectrum in the visible region for a long time, and is easy in use and less expensive. However, the commercially available LED panels are not intended to be used for optical diagnostics, so that their optical properties have not yet well evaluated. Therefore, in this research, these properties of the LED panel were examined in terms of the applicability as the standard light source for the intensity or intensity ratio measurement in a visible region.

2. White LED flat panel

Required properties for a standard light source are (i) uniformity of irradiance distribution for each wavelength and (ii) small angular dependence of its irradiance. The A3-size LED panel (412 × 228 mm^2 in light-emission surface area), examined in this research, is equipped with the white LEDs at both edges of the acrylic plate. Emitted light from the LED is reflected by dot-shaped white inks, on the back surface of the acrylic plate, which makes the marble pattern. The emission from the surface is non-uniform, due to this marble pattern, so that a milky-white acrylic plate 4 mm thick was used as a diffuse reflector.

The A6-size LED panel (140 × 91 mm^2 in light-emission surface area) was also used for the angular distribution measurement. This panel is equipped with LEDs on one edge and the reflection mirror on the other edge of the acrylic plate.

3. Examination of the LED panel

(A) a low dispersion spectrometer (StellarNet inc. EPP2000C) and (B) a digital camera (Nikon: D90 CMOS detector 4288 × 2848 pixels) attached with the Liquid-Crystal-Based Tunable Lyot Filter (CRi: VariSpec VIS-7-20) were used for the evaluation. The filter has 7 nm FWHM pass band and 12 % transmittance at 550 nm. The wavelength range of the A3 LED panel is 420-750 nm as shown in Fig. 1. While the tunable range of the Lyot filter we use is 400-720 nm, the leak-band, which appears presumably due to the misalignment of the internal optical components, were observed at longer than 548 nm at a specific wavelength setting below 455 nm.

The angular dependence of the irradiance of the A6 LED panel was measured using the system (A). Sweeping the angle between the viewing chord and

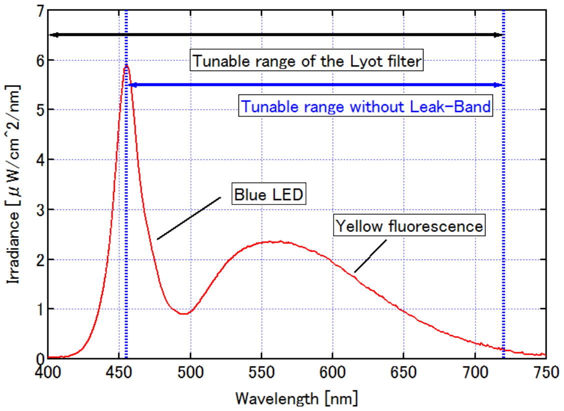

Fig. 1. Wavelength distribution at the center of the A3 LED panel. The tunable range of the Lyot filter is indicated.

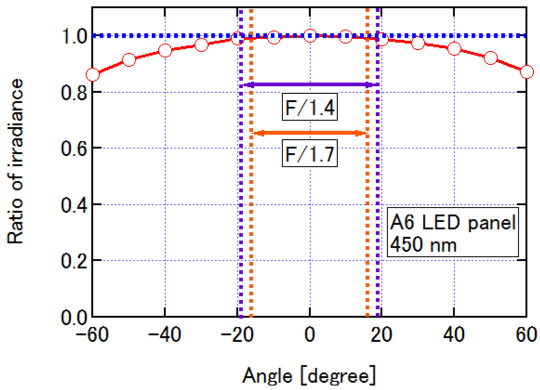

Fig. 2. The angular dependence of the irradiance at the center of the A6 LED panel, normalized to the irradiance for 0 degree. The widths, labeled F/1.4 and F/1.7, are the corresponding to spread angles measured from the optical axis.

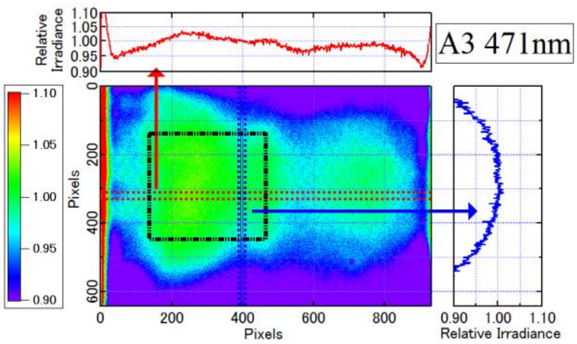

Fig. 3. Spatial distribution of the irradiance for the A3 LED panel surface, normalized to the value at the central region. 1D profiles of the relative irradiance along the horizontal and vertical lines on the image are also appended to the image. The uniformity within ±5 % is observed in the squared area.

the normal direction of the panel surface, the irradiance and the wavelength distribution of the center point of the panel were obtained. This observation shows that, at the angle within ±30

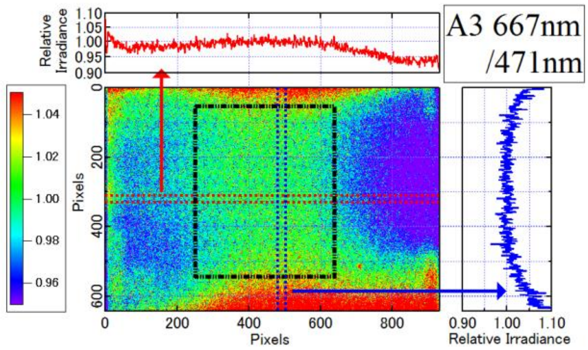

Fig. 4. The ratio of the image of the irradiance tuned to 667nm and that for 471 nm. 1D profiles of the ratio along the horizontal and vertical lines on the image are also appended to the image. The uniformity within ±3 % is observed in the squared area.

degrees, the irradiance is not smaller than 95 % to the irradiance at the 0 degree. It indicates that on the light axis, the bright optical system such as F/1.4-1.7 can be used (Fig.2).

Spatial distribution of the irradiance for the A3 LED panel was examined using the system (B). Considering the spectrum from the helium atom, the pass band of the Lyot filter was set to 471 nm, 501 nm, 587 nm, 667 nm and 691 nm respectively. Figure 3 shows the image for 471 nm obtained using the system (B). The wavelength tuned to 691 nm for the image of the LED panel is slightly shifted from the helium line of 706 nm because sensitivity of the digital camera degrades above 695 nm. The spatial distribution of intensity normalized to that for 471 nm is shown in Fig. 4. The area of approximately 160 × 175 mm^2 exhibits the uniformity within ±3 %. If one applies to the line intensity ratio method, one needs not consider the spatial distribution of the calibration factor over this area.

4. Application to the sensitivity calibration

It has been turned out that the variation of the calibration factor, namely the calibration function, needs to be introduced outside the uniform-ratio area. The calibration function is determined by combining the absolute value of the irradiance at the center of the LED panel, obtained by the system (A), and the images of the irradiance at tuned wavelength.

References

[1] S. Kado, H. Suzuki, Y. Kuwahara, et al.: Plasma Fusion Res., **2** (2007) S1125.