Design of the calibration setup for VUV spectrometers using a calibrated photo-diode detector in the wide range of VUV wavelength

Changrae Seon[1], Boseong Kim[1], Yoo Kwan Kim[2], Younghwa An[1], Jungmin Jo[1], Munseong Cheon[1], Yu Kwon Kim [2], Philippe Bernascolle[3], and Robin Barnsley[4]

[1] *Korea Institute of Fusion Energy, Gwahangno 169-148, Yuseong-gu, Daejeon, Korea*

[2] *Department of Energy Systems Research, Ajou University, 206 Worldcup-ro, Suwon 16499, Korea*

[3]*Bertin Technologies - CS 30495 - 13593 Aix-en-Provence Cedex 3, France13067 St. Paul Lez Durance Cedex, France, 6ITER Organization, Route de Vinon-sur-Verdon, CS 90 046*

[4] *ITER Organization, Cadarache Centre, 13108 Saint-Paul-Lez-Durance, France*

Introduction: The primary role of VUV (vacuum ultra-violet) spectrometers in MCF (magnetic confinement fusion) devices including future tokamak such as ITER is to measure the impurity species in plasmas. To perform the post analysis of the acquired VUV spectra from the line integrated emission, it is necessary to convert the raw data to the calibrated ones. Therefore the absolute intensity calibration of VUV spectrometers has attained its importance. Several methodologies have been reported for the calibration of the VUV spectrometer:

- Calibration directly using pre-calibrated VUV light from the accelerators.
- Calibration using the laboratory scale VUV light source, which is pre-calibrated using pre-calibrated VUV light from the accelerators. [1, 2]
- Calibration using proportional counter and E-beam + target VUV light source with symmetric light emission, so-called Manson-type Source. [3, 4]

The first method requires the transportation of a relatively heavy setup of VUV spectrometer to the accelerator facility, while this method is expected to provide relatively higher accuracy of the calibration curve. The second method has the merit of the lab-scale experiment. However, the VUV light source normally adopts the gas discharge (hollow-cathode or arc discharge), and the stability of the light source is the main cause of the error bar of the calibration curve. The third method using the so-called Manson-type VUV source requires the thin-foil filter set to cut off the visible light and also to select the specific wavelength to be calibrated. However filtering by the thin foil filter set such as Al + Zr filters has the limitation of the available wavelength window. In addition, the handling of these fragile thin foil filters is tricky to perform the experiment in the vacuum condition.

Motivated by these reasons, the new calibration setup with dedicated VUV spectrometer to select specific wavelength was designed in the present study, thanks to the newly available calibrated detector (photo-diode). Figure 1 summarizes the previous study of the calibration experiment using hollow cathode lamp, and the setup of Manson-type VUV source for the references.

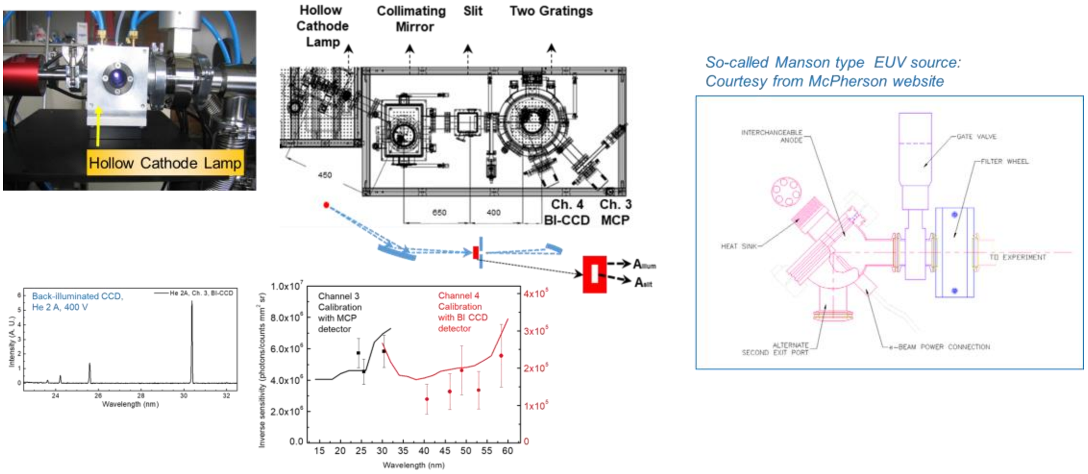

FIG. 1. The calibration from the laboratory experiment using pre-calibrated Hollow Cathode Lamp (1-130 nm, He, Ne, Ar gases, left figure). [1, 2] The Manson-type light source (1 -25 nm) for calibration (right figure). [3, 4]

Calibration Setup Design: In the present study, thanks to the recently developed calibrated Si photodiode detector (VUV Si Detector, calibrated in NIST, McPherson 5 - 1000 nm), the calibration setup was designed including a dedicated VUV spectrometer to select the specific wavelength. Two VUV light sources were employed for this calibration setup in the laboratory scale. A hollow cathode lamp with He, Ne, and Ar gases, which was developed in

Hanover university, is used for the wavelength range from 23 nm to around 130 nm. The other light source multiple anode SXR source (e-beam + target light source), Model 642-1 from McPherson Co. Ltd. is employed for wavelength range of 1 nm ~ 20 nm. The dedicated spectrometer was also designed to select the specific wavelength through aperture, and the Laminar-type Replica Diffraction Gratings for Soft X-ray Region from Shimadzu Co. Ltd. (model #2, #7) was used for these full wavelength ranges of VUV light. By installing the docking system of the pre-calibrated photodiode in the end of the spectrometer beam line, the input photon numbers entering into the new VUV spectrometer to be calibrated can be measured. The new spectrometer to be calibrated is to be connected to the vacuum flange after this photo-diode docking system. As seen in the figure 2, the calibration setup consists of one dedicated VUV spectrometer (gray color) on the rotation stage, which rotation axis is coincident to the spectrometer center.

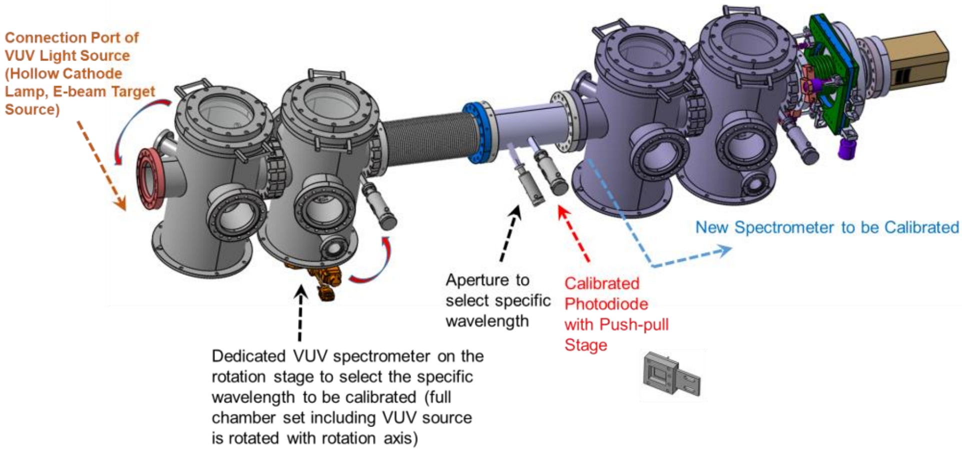

FIG. 2. The calibration setup with dedicated VUV spectrometer and the pre-calibrated VUV photodiode.

Calibration Sequence: There are three main experimental sequences necessary as described in texts of Fig. 3. After the calibration experiments, the inverse sensitivity curve (calibration curve). p^{-1} = Incident_Photons_on_Slit / (Detector_Counts x Spectrometer_Etendue) can be derived. The etendue of the aforementioned formula is the multiplication of the slit area and the solid angle of new spectrometer. In the calibration experiment described here, the solid angle of the VUV light incident on the new spectrometer is to be much smaller than the solid angle of the new spectrometer. Therefore, the solid angle of the incident VUV light defined from the focused image size of VUV light from the sequence #1 is to be used to derive the inverse sensitivity calibration curve.

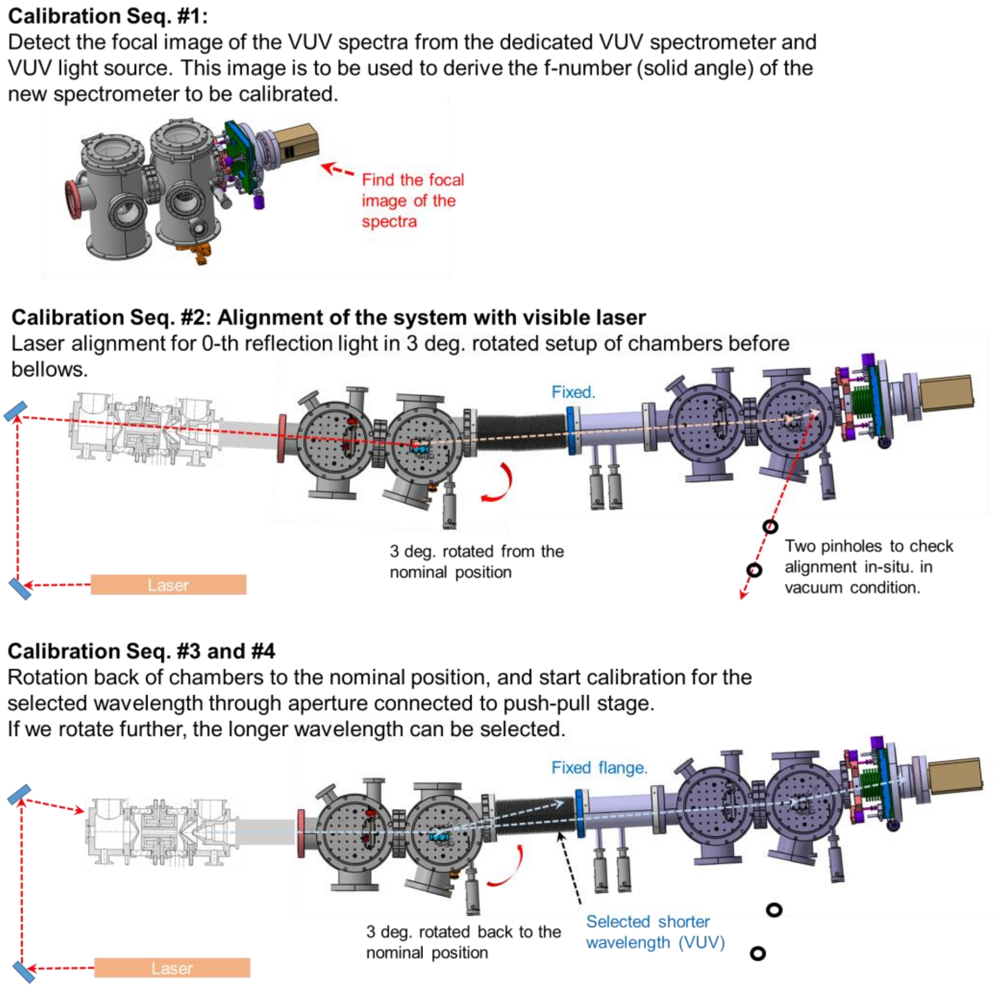

FIG. 3. The calibration experiment sequence

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