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DESIGN AND DEVELOPMENT OF ITER VUV SPECTROMETERS WITH PROTOTYPE TESTING

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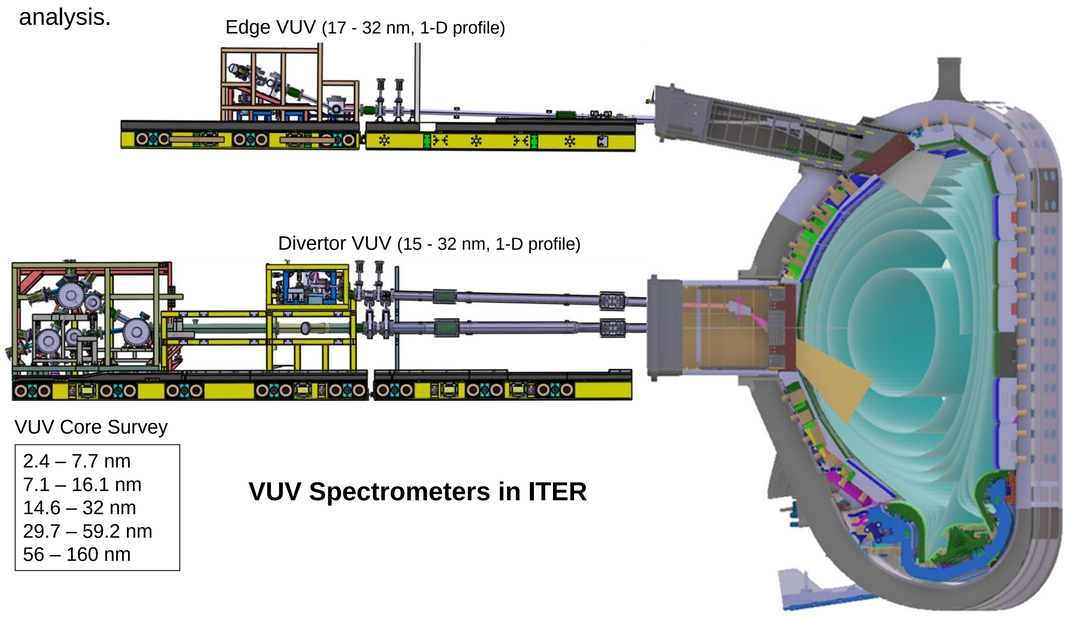
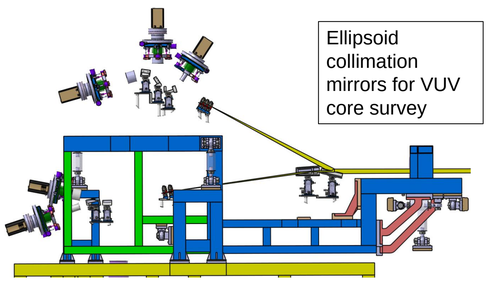
Abstract

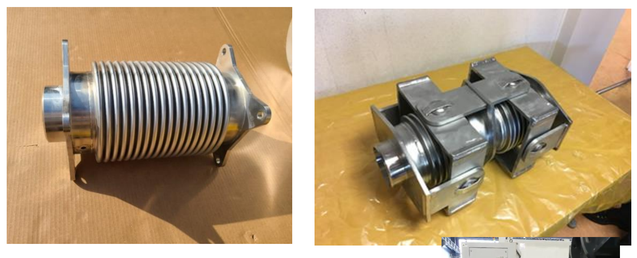
Development of ITER (nuclear facility, INB-174) VUV spectrometers are in the final design stage, and the manufacturing has partially been started from the in-port-plug components. From the study with various mock-ups and prototypes, the design of ITER VUV spectrometer could be verified to proceed the development and procurement to the next stage. Especially, the prototype divertor VUV spectrometer installed at KSTAR was modified in the year of 2023 to accommodate the design update of ITER divertor VUV spectrometer replacing the collimation mirror with the space-resolved slit, and the initial data could be obtained with this spectrometer at KSTAR with upgraded tungsten divertor. By employing the space-resolved slit, 1-D profile of impurity emission lines in the wavelength range of 5 nm – 18 nm including tungsten lines could be observed showing the shape different from the Oxygen line. The real size mock-up for the field mirror box was manufactured and tested to check the manufacturability and also to assess the remote handling maintenance scenario. In addition, a set of bellows as safety important components was manufactured to check the design value of the allowed operation cycles derived from the structural analysis.



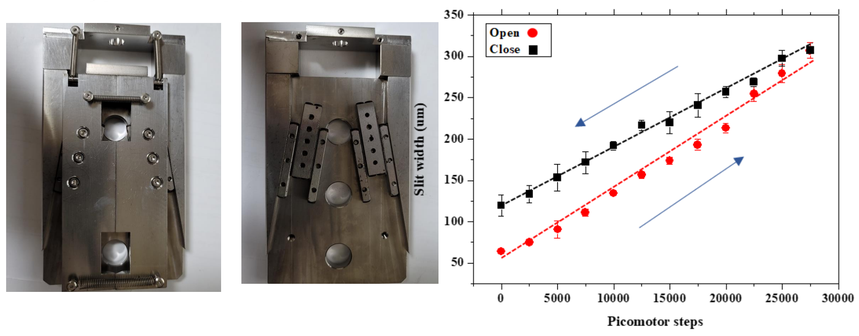
VUV Spectrometers in ITER



Prototype double-wall bellows (~1200 cycle design value were tested)

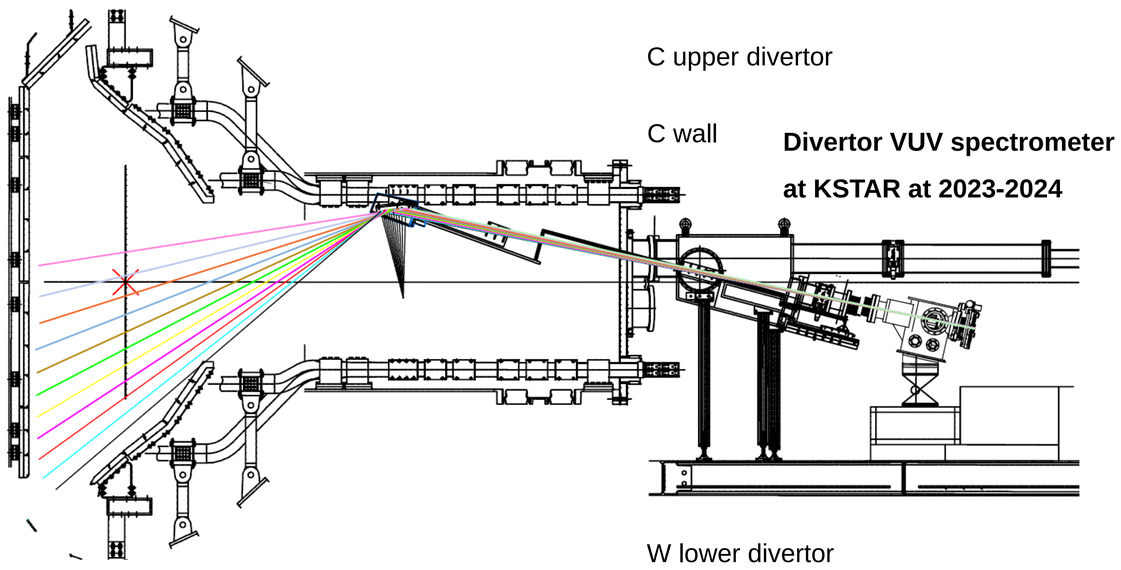


Prototype slit with pico-motor actuation



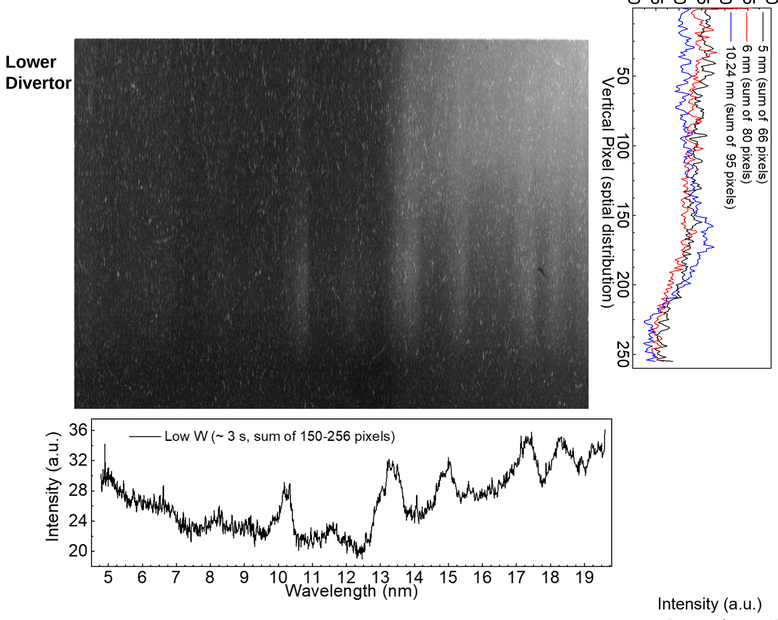
KSTAR Divertor VUV spectrometer

- This divertor VUV spectrometer was upgraded in the years of 2021-2023 to accommodate the design update of ITER divertor VUV spectrometer replacing collimation mirror with the space-resolved slit due to the lack of space in ITER port cell. (Fig. 2)
- As the first data, the acquired spectrum from the campaign of 2023-2024 for the shot #33372 is shown in Figure 3. Tungsten quasi-continuum emission lines of 5 – 7 nm could be observed originated from the tungsten divertor of KSTAR installed replacing carbon divertor in the year of 2023. By employing the space-resolved slit, 1-D profile of impurity emission lines for the wavelength range of 5 – 18 nm could be observed.

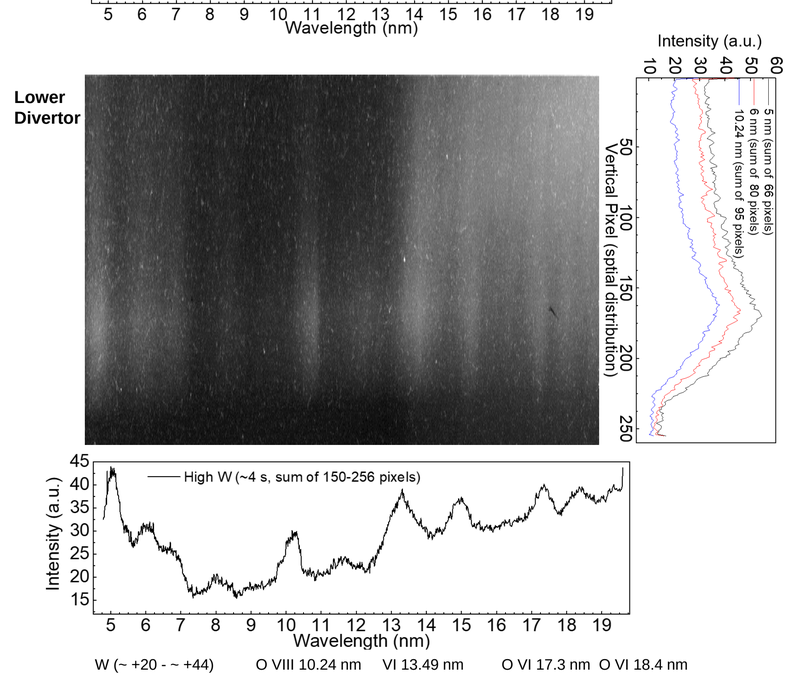


Divertor VUV spectrometer at KSTAR at 2023-2024

VUV spectra for the shot #33372



- At discharge time around 3 s, relatively lower tungsten emission.
- The wavelength was calibrated by the 3rd order polynomial fit for identified lines.
- Stray visible light in upper right coner needs to be blocked and S/N needs to be improved as future work.

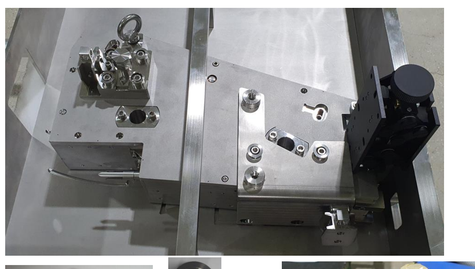


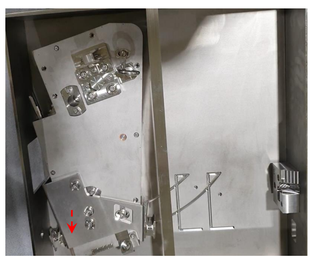
- At discharge time around 4 s, relatively higher tungsten, an array of unresolved lines (4.5 – 7.5 nm) was measured.
- Upper part of CCD image corresponds to the line-integrated emission from lower divertor region.
- Different 1-D profiles between W (~ +20 - ~ +44) and O VIII emission lines could be identified.

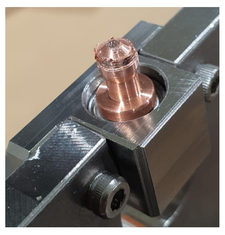
- The mirror reflectivity (Au coated, roughness ~3 nm r.m.s., ~ 16 deg. grazing angle) should be multiplied to derive the line integrated emission intensity from the impurity species, and this reflectivity is orders of magnitude higher in the line of sight through the plasma core region compared to that of the divertor region. This reflectivity difference become much higher in the lower wavelength region [8].
- Therefore, **the tungsten emission in the divertor region is orders of magnitude higher** than that of the plasma core region, while this difference of spatial distribution for **O VIII 10.24 nm line is much smaller**.

Field mirror box mock-up

- A mock-up for the field mirror box with shutter for divertor VUV spectrometer was manufactured as shown in Fig. 5.
- To check the remote handling scenario for the replacement of the mirror box, the dynamic movement of this box on the base plate was tested.
- From the test, it was found that a remote handling tool such as a **lab-jack is necessary for disengagement** of the mirror box because the friction on the connection area of the dowel and guide pins are not negligible. Two guiding rollers with ball bearings are attached to the remote handling adaptor for guiding motion on the channels on the base plate.
- Two **CuCrZr bushing blocks** are designed for smooth rotation of the shutter rod located on the channel hole of the structure. (Shrink fit between CuCrZr bushing ring and Stainless Steel ring → After that, thread connection and orbital welding)







Guiding rollers with ball bearings. (two)

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(2) The views and opinions expressed herein do not necessarily reflect those of the ITER Organization