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Effect of view port degradation on OES system in VEST

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1. Introduction

Versatile Experiment Spherical Torus (VEST) is a unique spherical torus and a low-aspect ratio tokamak in Korea [1]. As in other tokamaks, measuring ion temperature and ion rotation speed is one of the important fusion research tasks. The existing VEST spectroscopy system is a passive spectroscopy system that measures the temperature and rotation speed of ion impurities by observing C III lines (464.742 nm) in plasma's light. Ion rotation speed is calculated from the Doppler shift of the spectrum, and ion temperature is determined using the Full Width Half Maximum (FWHM) of the observed spectrum [2]. This system works in the existing VEST system; however, it will be necessary to observe the charge exchange process caused by launching a neutral beam into plasma when Carbon is fully stripped at the plasma core as VEST plasma performance increases.

These systems are called Charge Exchange Spectroscopy (CES), and introduction of these systems into VEST requires several verification processes.

A crucial factor affecting the plasma performance in VEST and other fusion devices is the wall conditioning technique. One such technique is boronization, which involves the deposition of a thin layer of boron-containing compounds on the inner wall surfaces of the tokamak [3]. Boronization is an important process for enhancing plasma performance as it has several benefits, including reducing the impurity influx from the plasma-facing components, suppressing the recycling of fuel particles. Moreover, it can also improve plasma confinement and stability, leading to higher fusion performance. However, boronization can potentially cause degradation in the viewport transparency, affecting the diagnostic measurements in the VEST system.

This paper presents an investigation into the effect of viewport degradation on the OES system in VEST. The focus is on the verification process for introducing the CES system, including the configuration of the poloidal CES system installed in VEST, measurement of the window transparency for measuring the VEST CES signal, comparison of signals, identification of factors affecting the window (dust, coating), and discussion on preventive measures and conclusions.

2. VEST CES system setup

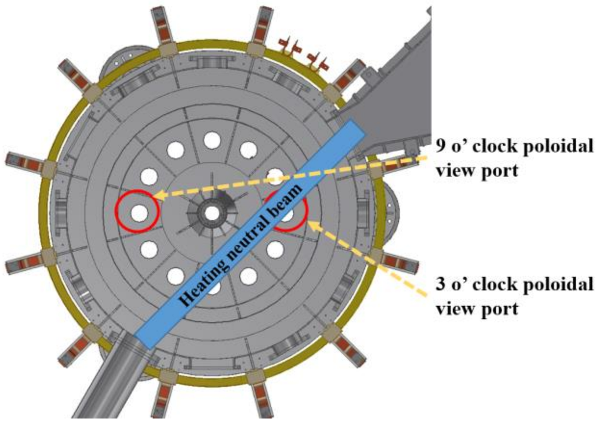

Fig. 1 position of the poloidal view ports for CES

As shown in Fig. 1, the VEST poloidal CES system is installed at the bottom of the 3 o'clock direction and 9 o'clock direction, respectively. To receive the CES signal, the path through which the neutral beam passes must be included as line-of-sight; thus, it is installed in that direction. Additionally, since the neutral beam is not modulated, an active charge exchange signal can be obtained by measuring a signal including a charge exchange signal in the 3 o'clock direction using toroidal symmetry and subtracting the background signal measured in the 9 o'clock direction [4].

Fig. 2 presents the VEST poloidal CES system, composed of a pedestal and collecting lens system. In the lower part of VEST, numerous cables carry currents for PF and TF. Since the collecting lenses are installed close to the lower port, the system is inevitably exposed to strong electromagnetic (EM) forces. In configuring the system, efforts are made to minimize the risk of alignment distortion due to EM forces by avoiding metal materials as much as possible. The viewing dump is attached using spectral black-coated foil sheets, and the CES system is aligned during the recent VEST vacuum breaking procedure.

3. Measurement of optical signal through view port

Before measuring the charge exchange signal using the neutral beam, it is necessary to verify that the two signals satisfy toroidal symmetry.

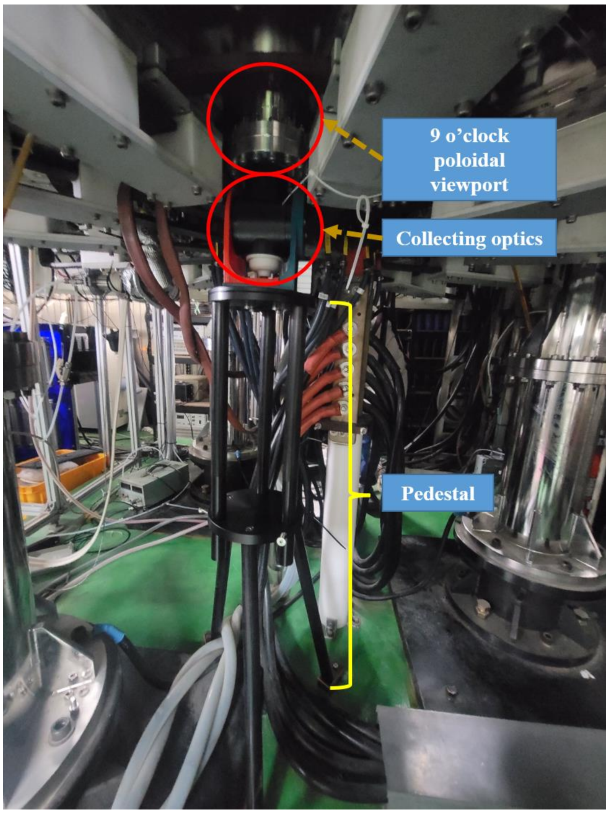

Fig. 2 Collecting optics at the 9'o clock poloidal view port.

Toroidal symmetry is compared using C III lines in basic Ohmic plasma. Fig. 3-a shows that the signal of C III lines in shot #38633 connected to the 3 o'clock direction (dotted lines) is significantly smaller than the signal connected to channel 1 connected to the 9 o'clock direction. To investigate the issue, the CCD channel is changed and measured, as shown in Fig. 3-b. The same phenomenon occurs.

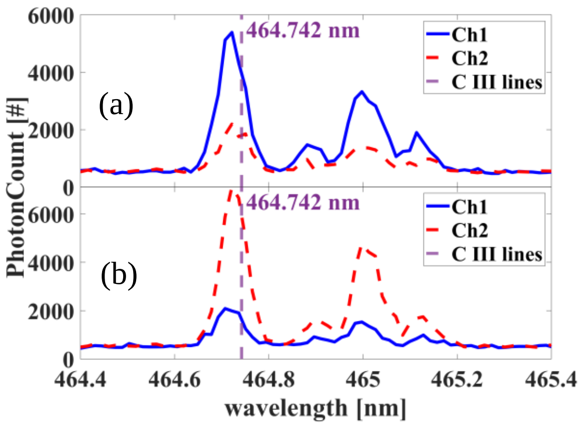

Fig. 3 (a) Signal of Ohmic discharge for shot #38633
(b) Signal of ohmic discharge for shot #38644

Next, the optical signal is measured by connecting each collecting optics to the same light source (halogen lamp) to check for any abnormalities in the fiber. The same number of photon counts is observed through each optical fiber.

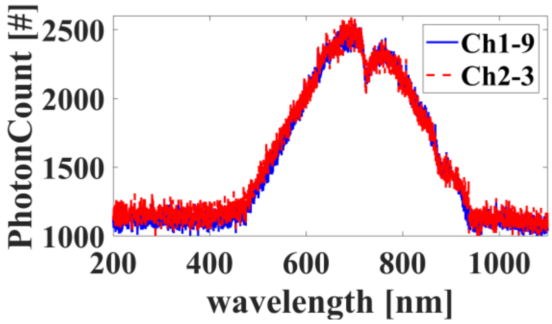

Fig. 4 Signal of Optics fiber for halogen lamp

Finally, the signal for the same light source through each window is measured, as shown in Fig. 5. Based on these results, it is confirmed that there is a difference in window transparency. To investigate this more accurately, the signal measured through the halogen lamp-window-collecting lens-optic fiber is compared.

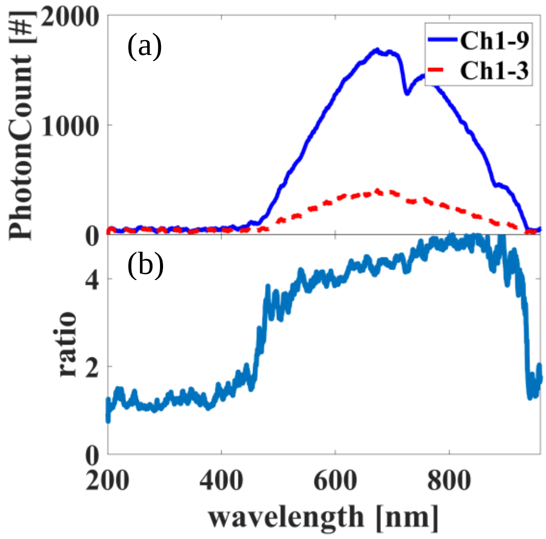

Fig. 5 (a) Signal of each window for halogen lamp
(b) Ratio of signal for 9 'o clock direction window to 3 'o clock direction window.

4. Causes of view port degradation

The transparency of view ports may degrade by deposition of dust on the exterior side of window. Cleaning of the poloidal view ports might often be neglected, as it is not at all easy to access the upper and lower view ports on the VEST. Dust generated from sputtering of wall material during glow discharge cleaning deposits on the vessel wall and onto the inside surface of view ports too. Moreover, sputtering of the graphite limiters in the VEST plasma will form carbon dust also which makes carbide film on the wall and view port.

Specifically, condensation of carborane vapor on the glass during boronization can be an important cause of the deterioration. The carborane vapor flow is not even. As a result, the deposition of a-C:Br/H film is also irregularly thick. Carborane flux affects the deposition thickness on view port glasses at 3 and 9 o'clock. The window which shows the significant decrease of transparency in Fig. 3-1 has been installed at near the path of strong carborane vapor flow indeed.

5. Maintenance of view port

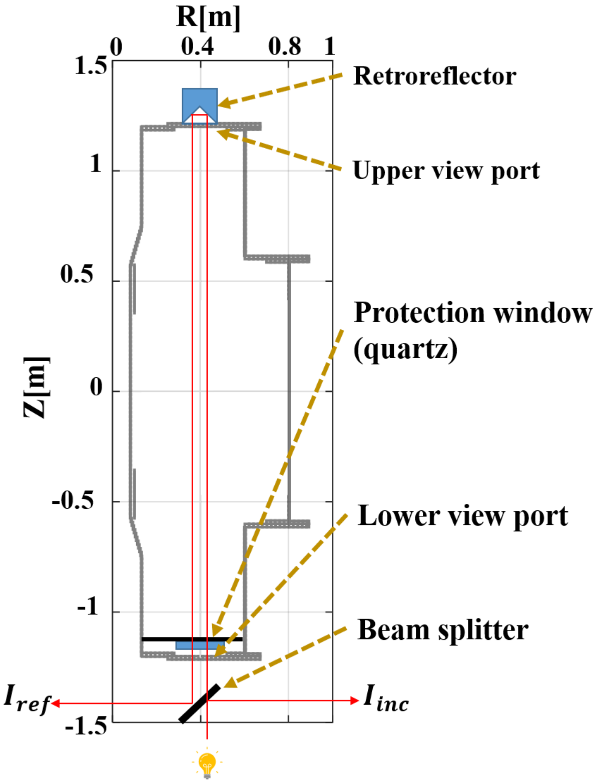

Fig. 6 Light path of the degradation check method using retro reflector.

By covering view ports when not in use, dust deposition on exterior side can be stopped or considerably reduced. A shutter system over window will replace difficult direct access. Deposition of dust generated inside the vessel on the wall and windows, nevertheless, is inevitable and proceeds with discharge. Thus, an alarm is necessary to get the time to replace the window. A transparency probe to check degradation process is useful. Schematic diagram of a trial system is illustrated in Fig. 6. Light from a source is split into two beams on a beam splitter. The reflected beam on the beam splitter enters to a detector to measure incident intensity I_{inc}. The beam passing the beam splitter proceeds through the view ports and then reflects on the retroreflector which is positioned outside of view port. The back-reflected beam travels through the vessel and passes through the lower view port again. Then, it is reflected on the beam splitter and arrives at a second photodetector which gives the reflect intensity I_{ref}. The ratio a between the reflect intensity I_{ref} and the incident intensity I_{inc},

I_{ref} / I_{inc} tells the progress of transparency degradation i.e., opacity. When all widows are clean, the ratio α =1, while dirty windows will result in the value approaching 0. We can choose an appropriate threshold value which corresponds to permissible opacity limit. Measuring α will alert the moment to change view port glass.

In the case of the bottom view port of the VEST, it has a very difficult environment to replace, so by configuring a protection quartz window in VEST as shown in the Fig. 7, it is possible to prevent the coating from forming on the bottom view port and make the replacement work much easier because only the quartz on the plate needs to be replaced.

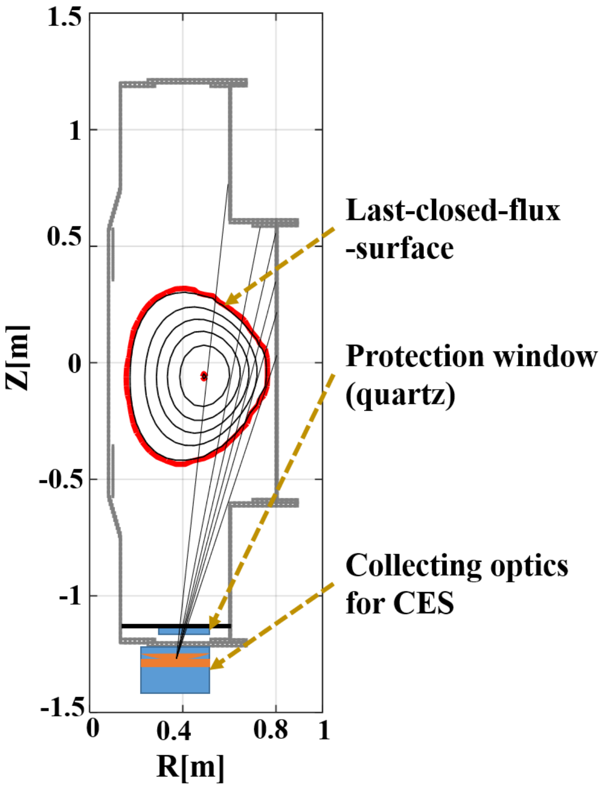

Fig. 7 The location of protection window(quartz)

Conclusion

It is confirmed that degradation occurs in the newly installed VEST CES signal.

To check the cause of this, 1) the signal is checked by changing the channel on the CCD, 2) the halogen lamp signal is measured with each fiber, and 3) the halogen lamp signal through the window is measured.

The same phenomenon occurs when the channel is changed, and the same signal is observed when the fiber test is performed for the same light source. However, when the light passing through the window is measured, the signal degradation is confirmed.

This could be caused by 1) dust deposition and 2) coating caused by plasma process, boronization, etc. The degradation occurred because the view port at the 3 o'clock position is not maintained for an extended period, and it is positioned at the upper 9 o'clock location, which is highly affected by boronization.

In the future, when vacuum breaking is performed, both windows used as CES view ports will be replaced, and when not in use, they will be covered to prevent dust. Since it is impossible to prevent the coating caused by the plasma process, the degradation caused by the coating will be periodically monitored by sending a laser to the retro reflector, using it as a sensor to detect and manage the degradation. In addition, a safer and easier method of replacing only the quartz window will be adopted rather than directly replacing the difficult lower view port by installing an additional quartz window on the inner plate.

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REFERENCES

[1] Chung, K. J., *et al.* "Design features and commissioning of the versatile experiment spherical torus (VEST) at Seoul National University." *Plasma Science and Technology* 15.3 (2013): 244.

[2] Kim, YooSung, *et al.* "Design of combined system of helium charge exchange spectroscopy and hydrogen beam emission spectroscopy in VEST." *Fusion Engineering and Design* 123 (2017): 975-978.

[3] Hong, Suk-Ho, *et al.* "First boronization in KSTAR." *Fusion engineering and design* 85.6 (2010): 946-949.

[4] Isler, R. C. "An overview of charge-exchange spectroscopy as a plasma diagnostic." *Plasma Physics and Controlled Fusion* 36.2 (1994): 171.