Effect of view port degradation on OES system in VEST

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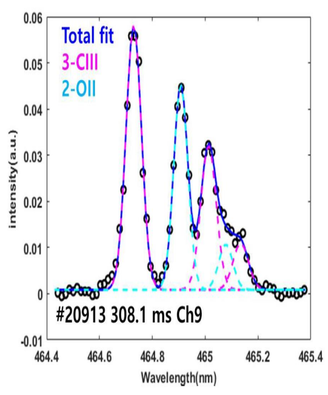
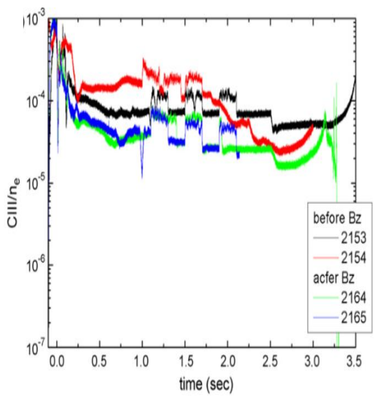
This study investigates the effects of viewport degradation on the Optical Emission Spectroscopy (OES) system within the Versatile Experiment Spherical Torus (VEST), a unique low-aspect ratio tokamak based in Korea. During the process of implementing the Charge Exchange Spectroscopy (CES) system in VEST, we unexpectedly discovered degradation in the viewport, which potentially hampers the accuracy of diagnostic measurements. This degradation, we suspect, could be influenced by boronization, a powerful wall conditioning technique. We conducted an extensive exploration of potential factors such as dust deposition and deposited film that could contribute to viewport degradation. This paper presents a detailed comparison of signals, precise measurements of window transparency, and a discussion on the possible causes. We also propose preventive measures to manage and mitigate this degradation

Introduction



C III lines (464,74 nm) in VEST

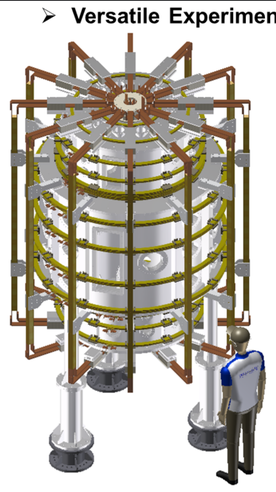


Impurity line emission change in KSTAR before & after boronization

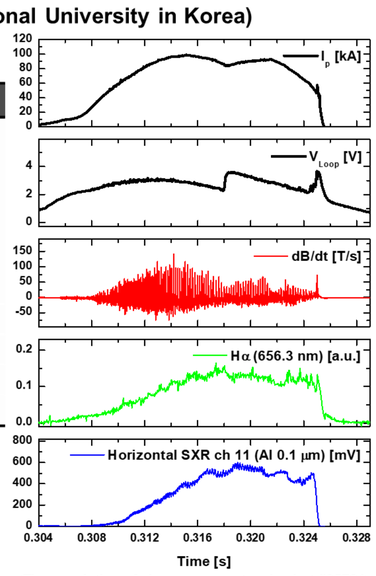
- ✓ **OES system** are widely used for tokamak plasma to **analyze various plasma parameter.**
- ✓ **Ion Doppler spectroscopy system** is used for observing C III lines to **measure ion rotation speed and ion temperature.**
- ✓ It will be necessary to observe the **charge exchange process** when carbon is fully stripped at the plasma core **as VEST plasma performance increases.**
- ✓ **Wall conditioning technique (ex. boronization, gdc)** is crucial factor affecting the plasma performance.
- ✓ **Boronization** can potentially cause **view port degradation making deposited film.**

VEST Ohmic Plasma

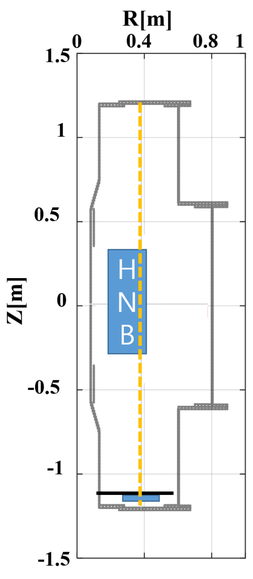
➢ Versatile Experiment Spherical Torus (Seoul National University in Korea)



Parameters	Values
Chamber Radius [m]	Main: 0.8 Upper & Lower: 0.6
Chamber Height [m]	2.4
$B_{t,0}$ [T]	0.18
R [m]	0.4
a [m]	0.3
Aspect Ratio	> 1.3
I_p [kA]	< 170
n_e [m^{-3}]	< 10^{19}
T_e [eV]	< 200



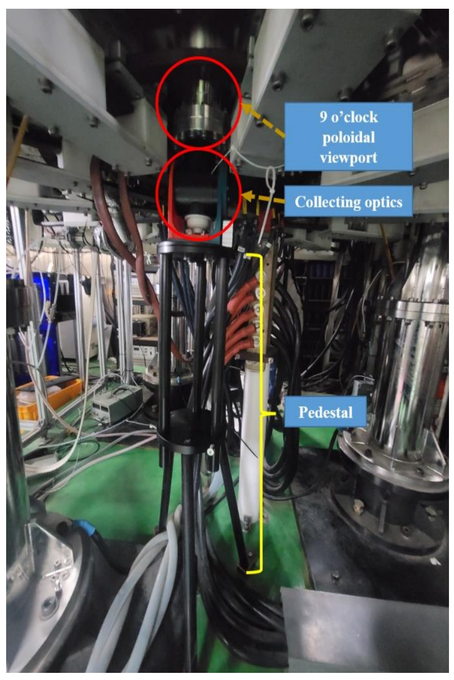
<Time evolution of plasma parameters in shot #35781>



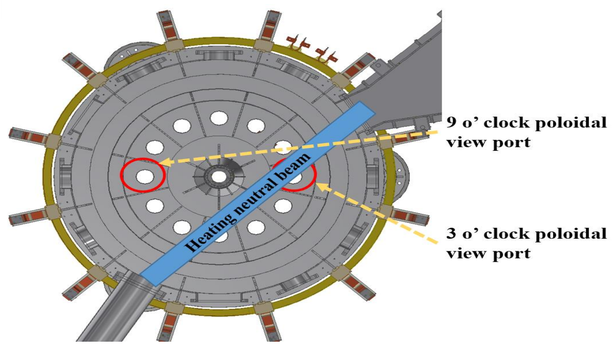
Line-of-sight for 1ch VEST CES system

- ✓ **Initial experiments** are conducted on **VEST ohmic plasma**
  - Ohmic plasma is **pre-ionized** by 8 GHz ECH
  - **Trapped particle configuration (TPC)** by poloidal field (PF) coils is formed for **efficient start-up**

VEST CES system setup



➢ Collecting optics at the 9'o clock poloidal view port



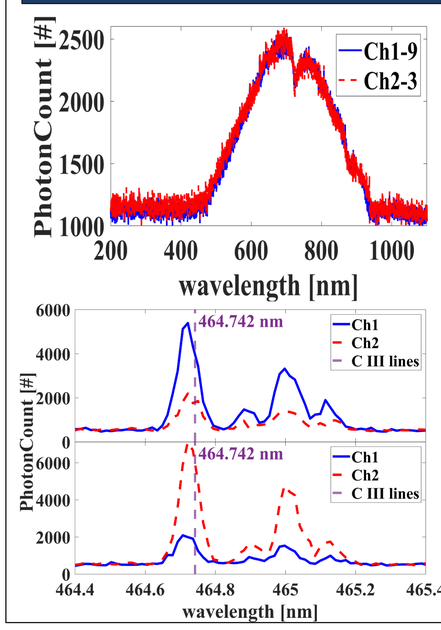
➢ Position of the poloidal view ports for CES system in VEST

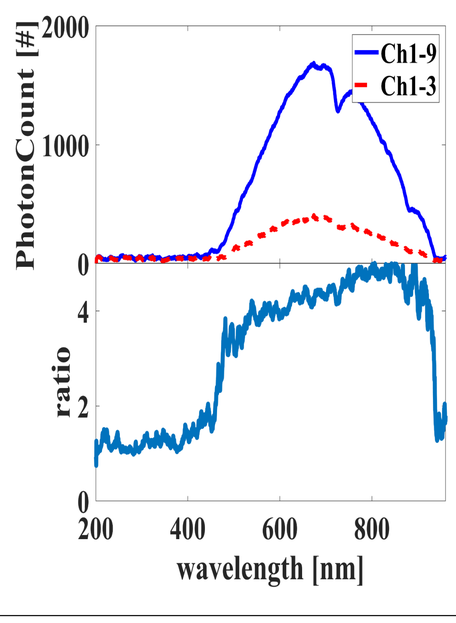
- ✓ **The VEST poloidal CES system** is installed at the bottom of the **3'o clock direction and 9'o clock** direction, respectively.
- ✓ Additionally, since the neutral beam is not modulated, an **active charge exchange signal** can be obtained by measuring a signal including a charge exchange signal in the 3'o clock direction **using toroidal symmetry and subtracting the background signal** measured in the 9'o clock direction.

→ For **obtaining proper CES signal**, it is essential that the **signals without neutral beam are same**.

- ✓ The **viewing dump** is attached using **spectral black-coated foil sheets**.

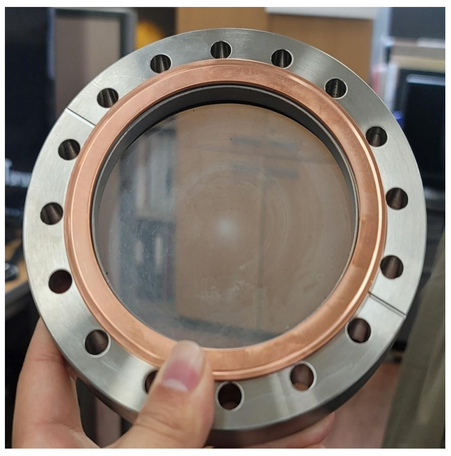
Measurement of optical signal through view port



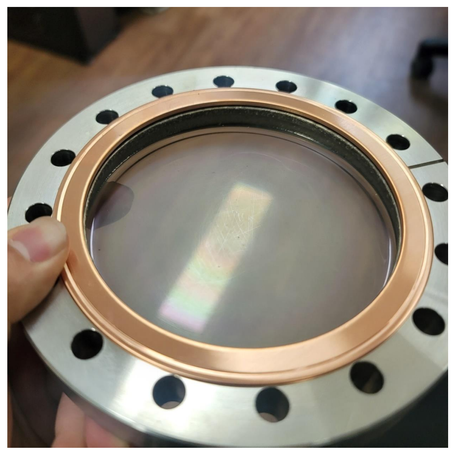


- ✓ **Channel 1** is connected to **9'o clock view port.**
- ✓ **Channel 2** is connected to **3'o clock view port.**
- ✓ **Toroidal symmetry** is compared using **C III lines** in basic Ohmic plasma.
- ✓ **Same optical signals** are measured by connecting each collecting optics to **the same light source.**
- ✓ The signal of 3 o' clock direction is bigger than 9 o' clock. **The CCD channels** are changed. **The same signals appear.**
- ✓ **The signals for the same light source** through each window are different **because of window transparency.**

Causes of view port degradation



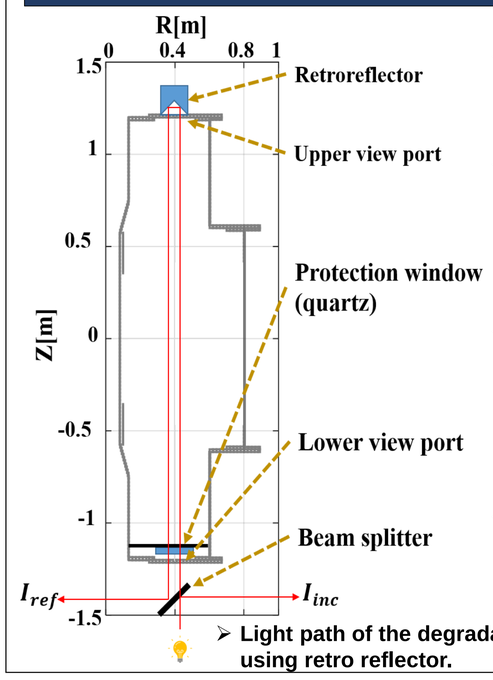
➢ View port covered with dust



➢ View port covered with deposited film

- ✓ The **transparency of view ports may degrade** by **deposition of dust** on the exterior side of window.
- ✓ **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 view port degradation.
- ✓ The carborane vapor flow is not even. as a result, **the deposition of a-C:B/H film** is also irregularly thick.
- ✓ Carborane flux affects the deposition thickness on view port glasses.

Maintenance of view port



➢ Light path of the degradation check method using retro reflector.

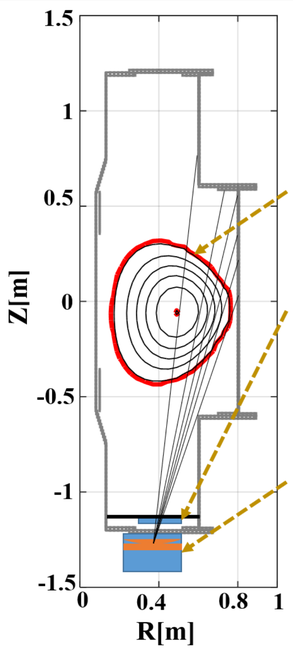
- ✓ **By covering view ports** when not in use, **dust deposition** on exterior side can be stopped or considerably reduced.
- ✓ It is impossible to perfectly prevent **the film caused by the plasma process**, the degradation caused by the film.

→ **Degradation monitoring system** by using a **retro reflector**.

- ✓ The film will be periodically monitored by **sending a laser to the retro reflector**, using it as **a sensor to detect and manage the degradation**.

$$\frac{I_{ref}}{I_{inc}} = \alpha$$

- ✓ When all windows are **clean**, the ratio α = 1, while **dirty windows** will result in the value **approaching 0**.



➢ The location of protection window

- ✓ In the case of the **bottom view port** of the VEST, it has **a very difficult environment to replace.**
- ✓ By configuring a **protection quartz** window in VEST, it is possible to prevent the film from forming on the bottom view port and **make the replacement work much easier.**

Summary & Future Work

➢ Summary

- ✓ **View port degradation** occurred 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.
  - **Only when the light passing through the window** is measured, the signal degradation is confirmed.
- ✓ **Cause of view port degradation**
  - **Dust deposition**
  - **Deposited film** caused by plasma process, boronization, etc.

➢ Future Work

- ✓ **CES view ports** will be replaced. And when not in use, they will be **covered to prevent dust.**
- ✓ To prevent the film, the degradation caused by the film will be periodically monitored **by using retro reflector.**
- ✓ The **additional quartz window** will be adopted by installing it on the inner bottom plate.

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.

Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. 2021M3F7A1084418).

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