Design of a new charge exchange spectroscopy system in VEST

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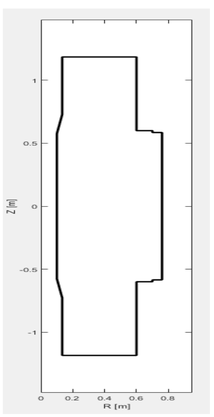
1. Introduction

1.1. Introduction to VEST (Versatile Experiment Spherical Torus)

- **Specification of Device & Upgraded data**



	Present	Upgrade
R [m]	0.4	0.4
a [m]	0.3	0.3
B_T [T]	0.18	< 0.3
Aspect Ratio	> 1.33	> 1.33
I_p [kA]	< 170	> 300
P_{NBI} [eV, W]	15k, 600k	20k, 1.2M

Fig. 1 Poloidal geometry of VEST.

1.2. Specification of spectroscopy currently in use

- Ion Doppler Spectroscopy for C III lines (464.74 nm)
  - passive spectroscopy
  - line-integrated signal data
  - Able to measure CIII lines at plasma core due to low plasma temperature (T_i =20-30eV)
  - using EMCCD Andor iXon Ultra 888 r = 0.39~0.7 [m], for 10ch 1ms / 1ch 0.2ms

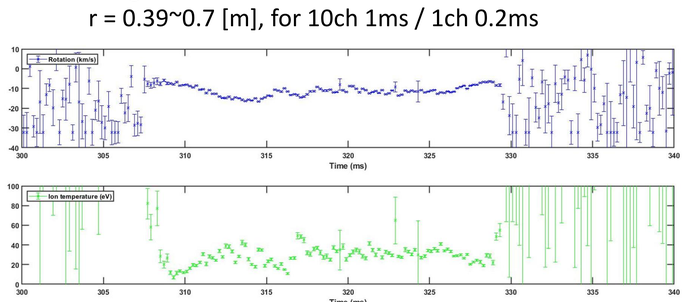


Fig. 2 Ion rotation speed, ion temperature data of VEST plasma

1.3. Charge Exchange Spectroscopy & Beam Emission Spectroscopy

- Charge Exchange Spectroscopy for upgraded VEST plasma
  - $C^{6+} + H \rightarrow C^{5+} + H^{+}$ (529.05nm)
  - Localized measurement
  - Intrinsic consistency of temperature, rotation and density
- Beam Emission Spectroscopy
  - $H + e \rightarrow H^{*} + e$ (656.3nm)
  - Localization of active volume
  - Local beam density
  - Density fluctuations

2. Motivation and Objective

- **Motivation and objective**
  - **From passive spectroscopy to active spectroscopy**
    - In passive spectroscopy, inversion process needed because of line-integrated spectrum data. But inversion process because it is able to measure local T_i, v_in active spectroscopy, there is no need for inversion process
    - Because the plasma of upgraded VEST is fully ionized, it is unable to measure CIII spectrum. So, it is necessary to measure the spectrum by causing a charge exchange reaction using a neutral beam.
  - **Calculating temporal, spatial distribution of T_i, v_i**
    - Since VEST operation is not a steady state operation, a temporal resolution is also required.

3. Specification of EMCCD Camera

- **Table of Andor iXon Ultra 888 Frame rate – Crop Mode**

Binning / Arraysize	1x1	2x2	4x4
1024x1024	93	170	291
512x512	190	350	601
256x256	670	1150	1772
128x128	2053	3123	4109
1024x100	259	492	887
1024x32	778	1416	2370
1024x1	9690	-	-

The frame per second (fps) must be at least 1000 frame/s to produce the time resolution output of the Doppler spectrometer currently in use(for 10ch, 1ms).

4. The system configuration

- **Geometry of planned system**

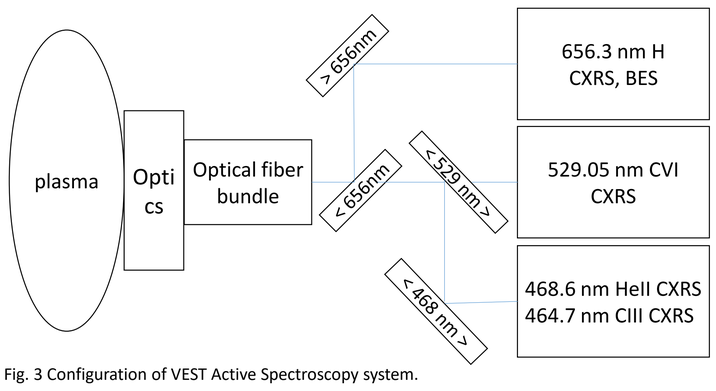


Fig. 3 Configuration of VEST Active Spectroscopy system.

Because the number of ports of the VEST device is insufficient and the CES system must be used even before the new diagnostic neutral beam is manufactured, geometry is constructed by aligning the line-of-sight of the Ion Doppler spectroscopy system so that the existing heating neutral beam can be used for diagnosis.

4. The system configuration

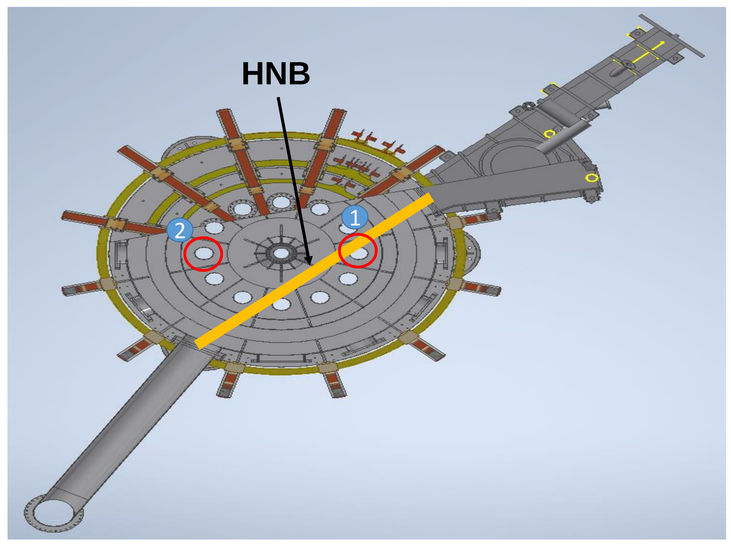


Fig. 4 Geometry of planned VEST Active Spectroscopy system.

The lower port should be used due to insufficient ports on the Z=0 plane. Collecting lens will be installed at locations 1 and 2. At port 1, charge exchange signal will be measured and at port 2, background signal based on toroidal symmetry will be measured because the heating neutral beam can not be modulated.

5. Design of CES system

- **System installation**

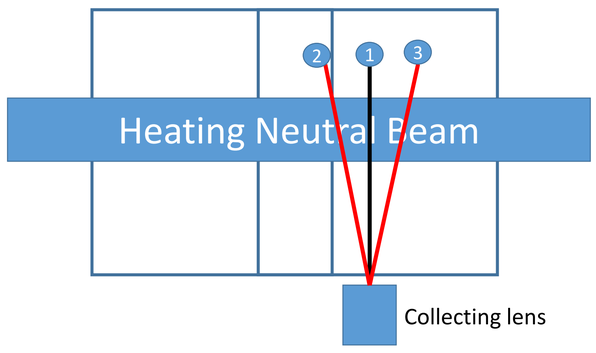


Fig. 5 Cross section of CES system.

First of all, the heating neutral beam is used because the diagnostic neutral beam cannot be used. Since the heating neutral beam has a large beam size unlike the diagnostic neutral beam on other devices, if line-of-sight 2 and 3 shown in Figure 8 are selected, line-of-sight data is obtained, so line-of-sight 1 which is perpendicular to the beam must be selected.

As mentioned earlier, since heating neutral beam cannot be modulated, it is possible to measure the background signal at the opposite position (position 2 in Fig 8) through a collecting lens looking in the vertical direction, such as line-of-sight 1, and obtain the active change signal from the heating neutral beam.

6. Plan to measure signal in toroidal

- **Geometry of toroidal measurement**

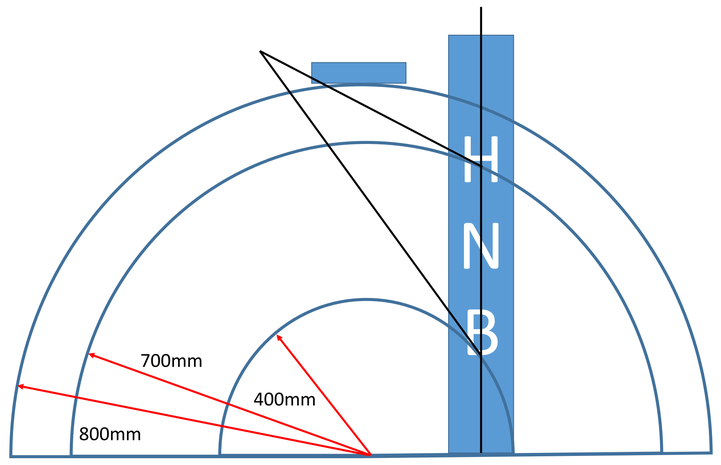


Fig. 6 toroidal line-of-sight of Charge exchange system

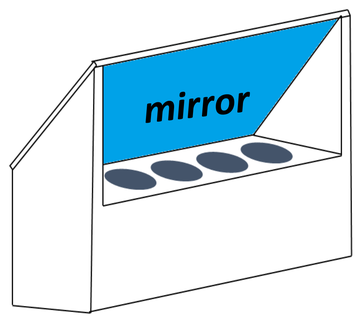


Fig. 7. Aluminum component to allows light to go toward the bottom port

If the CES signal is measured at toroidal geometry, it has no choice but to be also a line-integrated signal because the size of heating neutral beam is big.

However, since passive ion Doppler spectroscopy(IDS) currently in use receives a line-integrated signal, active charge exchange spectroscopy (CES) signal can be obtained by using the data of IDS as background data and subtracting the data from the CES data. For this, the CES system must be directed to the same radial point of the IDS system under toroidal symmetry.

As shown in figure 7, the port of VEST in toroidal geometry is insufficient and its location is no appropriate for measuring toroidal active CES signal. So, an aluminum component seen in figure 8 will be installed in VEST vessel to measure a line-integrated signal at the bottom port with charge exchange spectroscopy collecting lens.

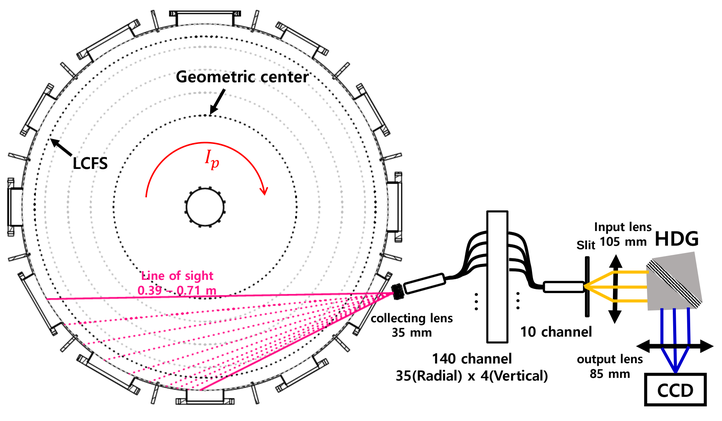


Fig.8 geometry of ion Doppler spectroscopy system currently in use.

7. Conclusion

- **Combined active spectroscopy system with CES an BES using diagnostic neutral beam will be made. But, in the current VEST situation, the CES system which measures He II and C III lines, will be configured at the bottom port of the VEST using a heating neutral beam.**
- For measuring CES signal in toroidal geometry, additional component will be installed because the size of HNB is big, so the system achieves line-integrated signal.

8. Reference

[1] K. J. Chung *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] YooSung Kim *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] Ko, Won-Ha *et al*., "KSTAR charge exchange spectroscopy system." *IEEE transactions on plasma science* 38.4 (2010): 996-1000.

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