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ITERの放射線環境下における周辺トムソン散乱計測装置の光学調整手法開発

Development of alignment method for Edge Thomson Scattering system under radioactive environment in ITER

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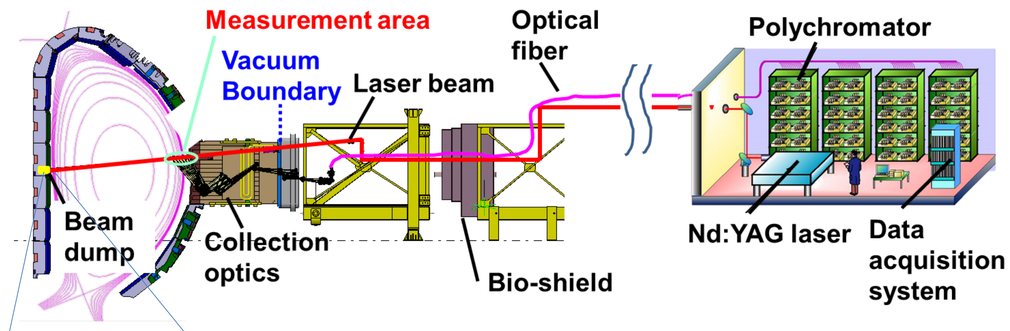
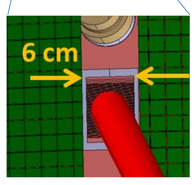
1. Background & Objectives

ITER Edge Thomson Scattering system (ETS)





- Measurements of T_e and n_e with steep gradient in edge
  - ✓ Region: $r/a > 0.85$
  - ✓ Spatial Resolution: 5 mm
- Hard to access near the activated vacuum vessel (VV)

Objectives

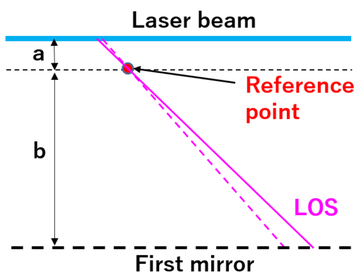
- Accurate and reliable measurement of T_e and n_e for edge pedestal physics investigation and ELM control in ITER
- To develop optical alignment method applicable for ITER which
  - ➢ does not need human access near VV
  - ➢ does not occur failure of component in VV
  - ➢ can be performed frequently

Alignment items

1. Laser beam injection into beam dump center
   - ➢ [Yatsuka, JINST **11**, C01006 (2016)]
2. Field of view (FOV) of the collection optics across the laser beam
   - ➢ [Yoshida, RSI **66**, 143 (1999)]
3. FOV ALONG the laser beam (A method is proposed in this presentation)

2. Principles of the new FOV alignment method

Key idea



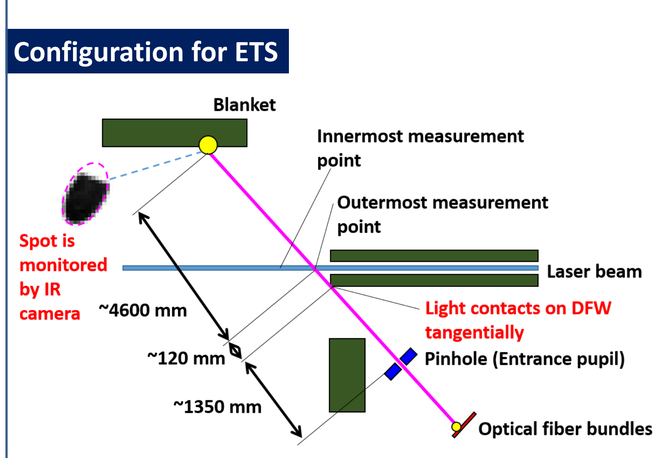
- It is assumed that the line of sight (LOS) has to pass through the reference point.
- If $a \ll b$, displacement of LOS on laser beam is much smaller than that on first mirror.

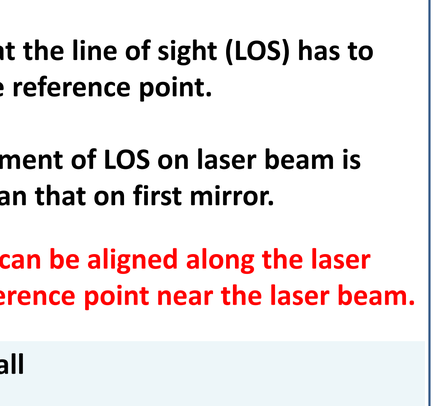
➢ Collection optics can be aligned along the laser beam using a reference point near the laser beam.

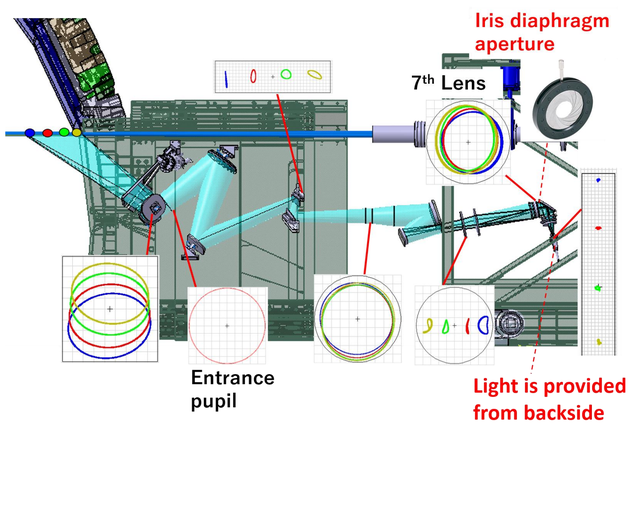
1. Where is the best reference point? ➡ First wall
2. How can we adjust LOS to pass through the reference point?

   ➡ I. Injection of light from an optical fiber at the end of the collection optics
   II. Monitor vignetting of beam spot on the blanket by IR camera
   III. Adjustment of all optical fiber bundles together with the optical fiber for light injection

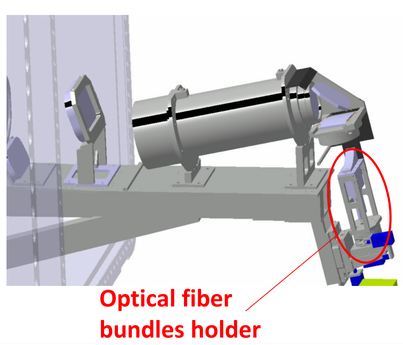
Configuration for ETS







- Iris diaphragm aperture near the 7th Lens allows installing (virtual) pinhole in the port plug.

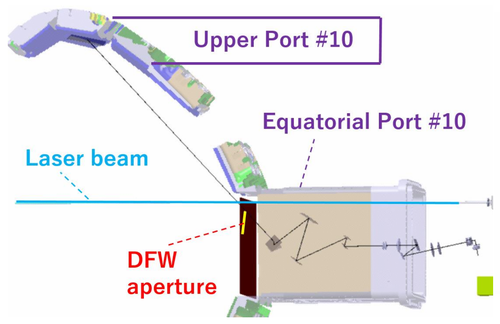


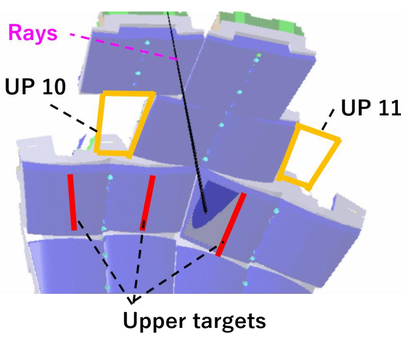
5. Conclusions

- Field of view of the collection optics along the laser beam direction can be aligned by means of back-illumination of the blanket. The spot on the blanket is measured by IR camera.
- The alignment method proposed in this presentation was validated its principle and robustness through ray-tracing simulation. It is free from vacuum venting and does not directly cause failure of components in the vacuum vessel.
- Accuracy of alignment is approximately 0.5 mm. It is much finer than scale length of edge pedestal.

3. Validation of alignment principle by simulations

Location of spot on blanket



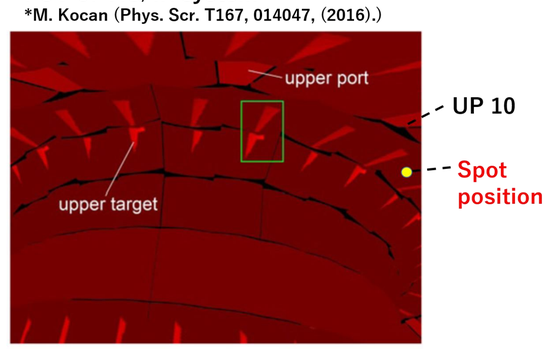


- Ray-tracing was performed by means of ZEMAX.
- Backward rays hit blanket
  - ✓ One notch above UP Level
  - ✓ Between UP 10 and UP 11

Detection of spot

1. Blanket is monitored by Vis/IR Equatorial Port Wide-Angle Viewing System (VIS/IR) installed in EP 9.
2. Positions of the end of the optical fiber bundles are adjusted.
3. By finding the marginal position at which vignetting of the spot occurs, the FOV along the laser beam can be reconstructed.

FOV of VIS/IR system
*M. Kocan (Phys. Scr. T167, 014047, (2016).)



- VIS/IR can detect light with intensity of approximately 10 mW/m^2.
- VIS/IR has spatial resolution of finer than 10 mm.
- Intensity of spot is evaluated as 900 mW/m^2 which is much higher than detectable level assuming the specifications below:
  - ➢ Spot size (when diaphragm aperture is removed): 650 mm;
  - ➢ Transmission of optics with the wavelength of 1064 nm: 10%;
  - ➢ Intensity of existing light source: 3 W (Spectra Physics J20E-V-106C-3000).

Resolution of measurement position

Assumptions:
- ✓ Pixel on blanket: 10 mm
- ✓ Aperture diameter: 20 mm

Spots on blanket when optical components are installed "As Designed"

Fiber position (mm)	-0.7	-0.5	-0.3	-0.1	0	+0.05	+0.1
Measured R (mm)	8368.2	8367.3	8366.5	8365.7	8365.2	8365.0	8364.8

- 0.1 mm change in fiber position causes approximately 0.4 mm change on the laser beam.

➢ Change in measured position within 0.5 mm is detectable from spot shape on blanket.

Case studies of robustness

- Even if optical components move due to thermal expansion, disruption, seismic events, etc., the spot shape allows to recover the measured position.

Case 1: First mirror tilts 0.2 degree relative to its original orientation.

Case 2: First mirror moves 5 mm vertically.

Spots on blanket when optical components are installed "With Misalignment"

Case 1

Fiber position (mm)	-1.1	-1.0	-0.9
Measured R (mm)	8365.7	8365.1	8364.5

Case 2

Fiber position (mm)	-0.5	-0.4	-0.3
Measured R (mm)	8365.7	8365.2	8364.9

4. Prospects

- Because of simple principle, the new alignment method shown in this presentation may be applicable for other optical diagnostic system in ITER, existing and future devices.
- Multiple spot measurement would allow more robust alignment such as magnification of image size by adjusting the optical fiber bundles along the optical axis (defocus).