Thermography and Spectroscopic Diagnostics Evaluation of NSTX-U

K.F. Gan, P. Adebayo-Ige and B.D. Wirth, (UTK), T.K. Gray(ORNL),
B. Stratton, and R. Maingi, (PPPL)

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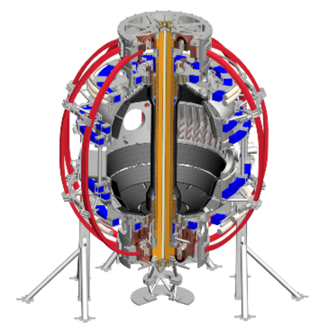
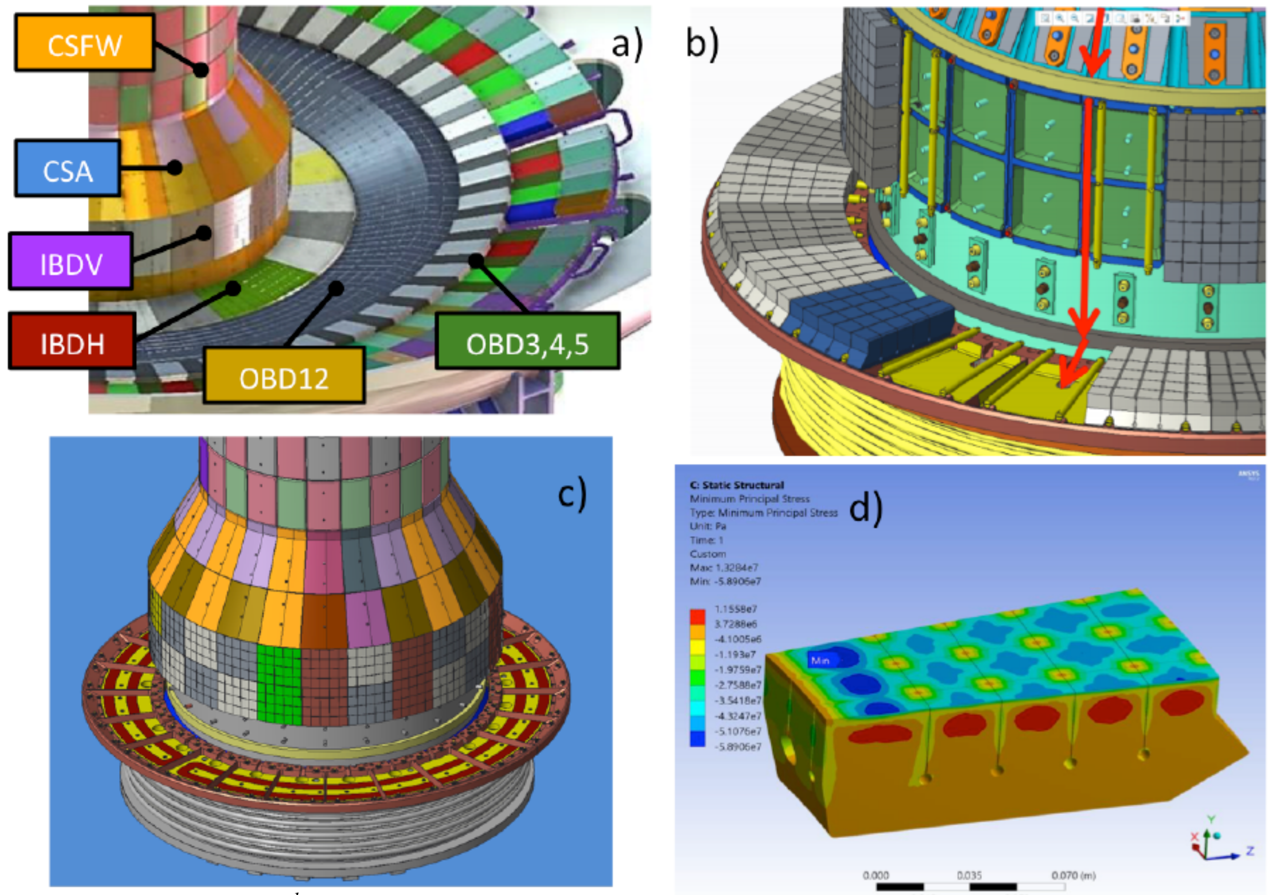


Motivation: Thermography

- Recovery project installing new 'fish-scaled' graphite divertor targets on both inner and outer divertor as well as the central stack first wall

- High heat flux tiles to experience loadings ≥ 10 MW/m^2 which challenge 1600°C surface temperature limit

- Embedded thermocouple diagnostics (Looby-Reinke)



[S. Gerhart et al., 27th IAEA Fusion Energy Conf. 2018]

UTK plans for thermography & spectroscopy

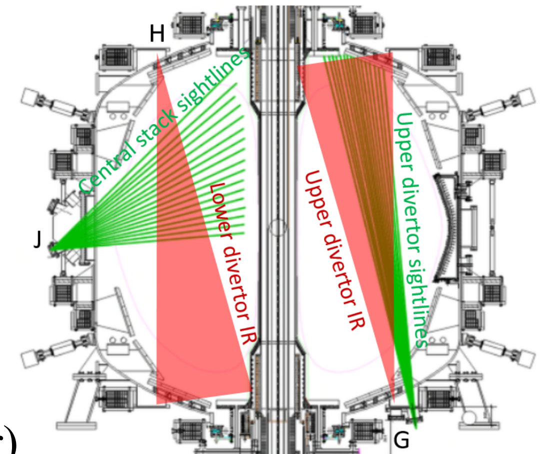
Objective: Utilize recently installed spectroscopy, and newly proposed installation of infrared thermography, diagnostics to map the spatial heat flux profiles in the upper and lower divertor, and to lead the assessment of NSTX-U heat flux width, with an assessment of lithium versus boron wall conditioning on power balance/heat flux and SOL impurity transport.

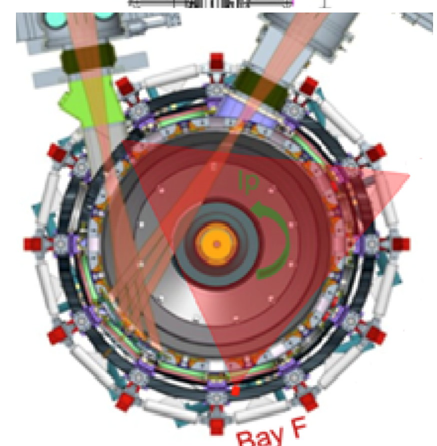
Diagnostics deliverables:

- Improved UV-VIS-NIR spectroscopic diagnostics (1st run year)
- Install new lower divertor thermography diagnostic (1st run year)
- Install new upper divertor thermography diagnostic (1st – 2nd run year)
- Install new wide angle thermography diagnostic (2nd run year)
- Divertor temperature feedback control system to support operation (3rd run year)

Impact:

- Will provide the temperature and heat flux evolution on the lower & upper outer divertor and the central stack, contributing to divertor temperature control system and enable assessment of the lifetime of new NSTX-U plasma-facing components
- Will provide impurity data at the upper divertor and central stack



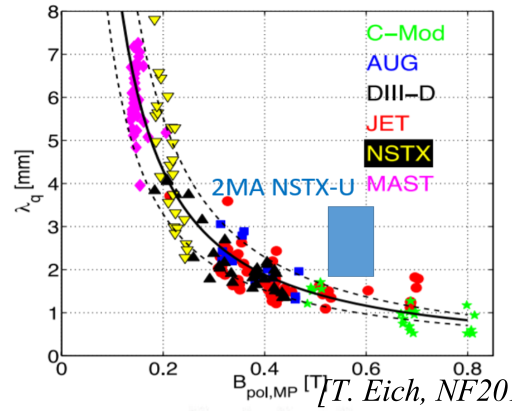


Wide angle thermography diagnostic

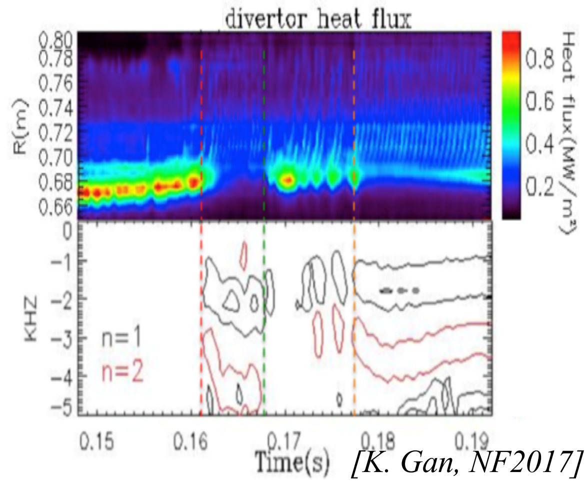
UTK research plans for thermography & spectroscopy

Research deliverables:

- Temperature and heat flux evolution on divertor tiles Objective 3 Thrust 1
- Assess impurity transport through the SOL with lithium versus boron wall conditioning Objective 3 Thrust 3
- Assess the divertor peak heat flux and SOL λ_q with scans of I_p and dr_{sep} over range of heating power and wall conditioning and divertor configurations Objective 3 Thrust 2
- Research the mechanisms of counter-current EHO & impact on heat flux width Objective 3 Thrust 2
- Assess the ELM heat flux characteristics Objective 3 Thrust 4
- Feedback control of divertor temperature Objective 3 Thrust 2



[T. Eich, NF2013]

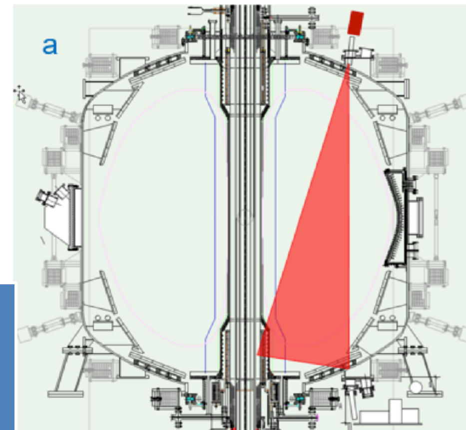


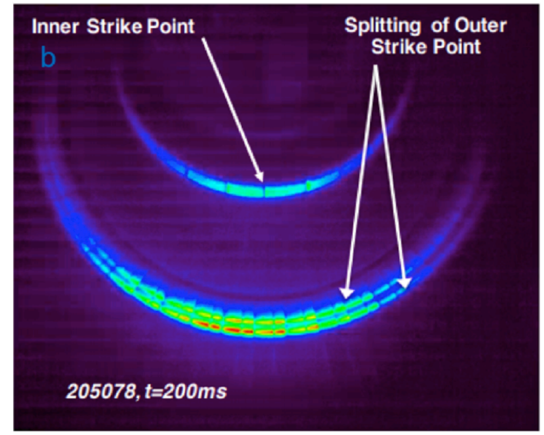
[K. Gan, NF2017]

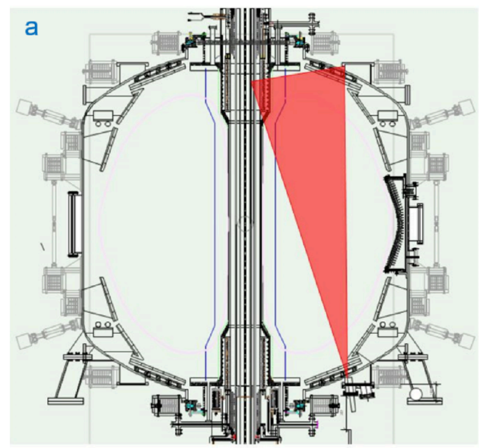
IR camera plans: Upper & lower divertor

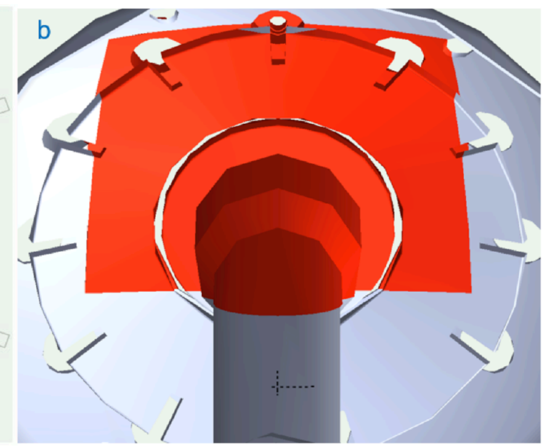
- Install new, fast IR cameras to view outer strike points in the top and bottom divertor

IR Camera	Wave length (μm)	Spatial resolution	Frame rate
TELOPS L200 (upper)	7.7 – 9.3	Full frame 640 x 512, pitch size 15 μm	234 Hz (full); 17 kHz (160x2 frames)
TELOPS Fast V1K	7.5 – 11.5	Full frame 640 x 512, pitch size 25 μm	1 kHz (full); 40 kHz (64x8)





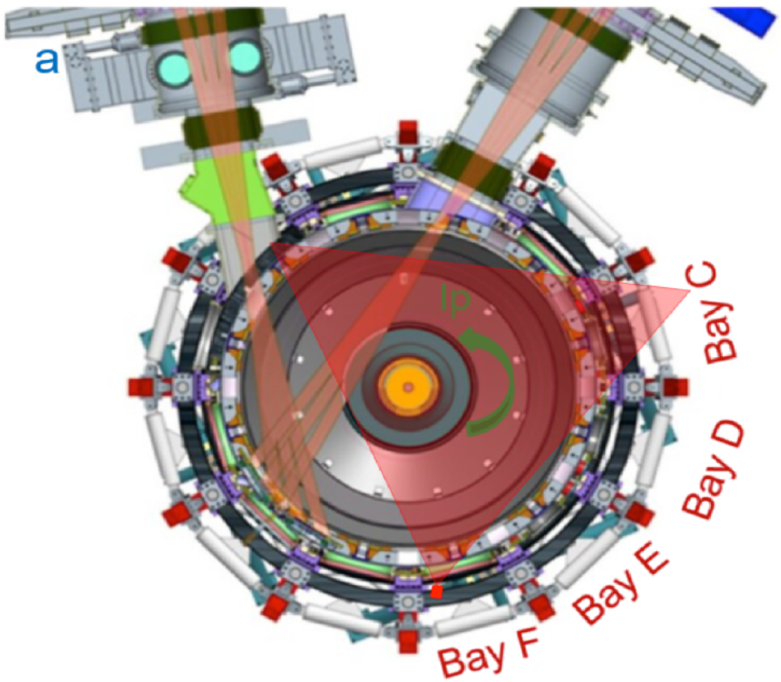


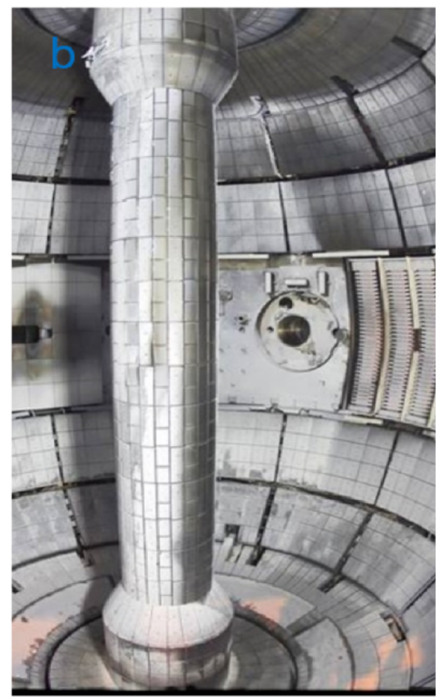


IR camera plans: Wide angle view

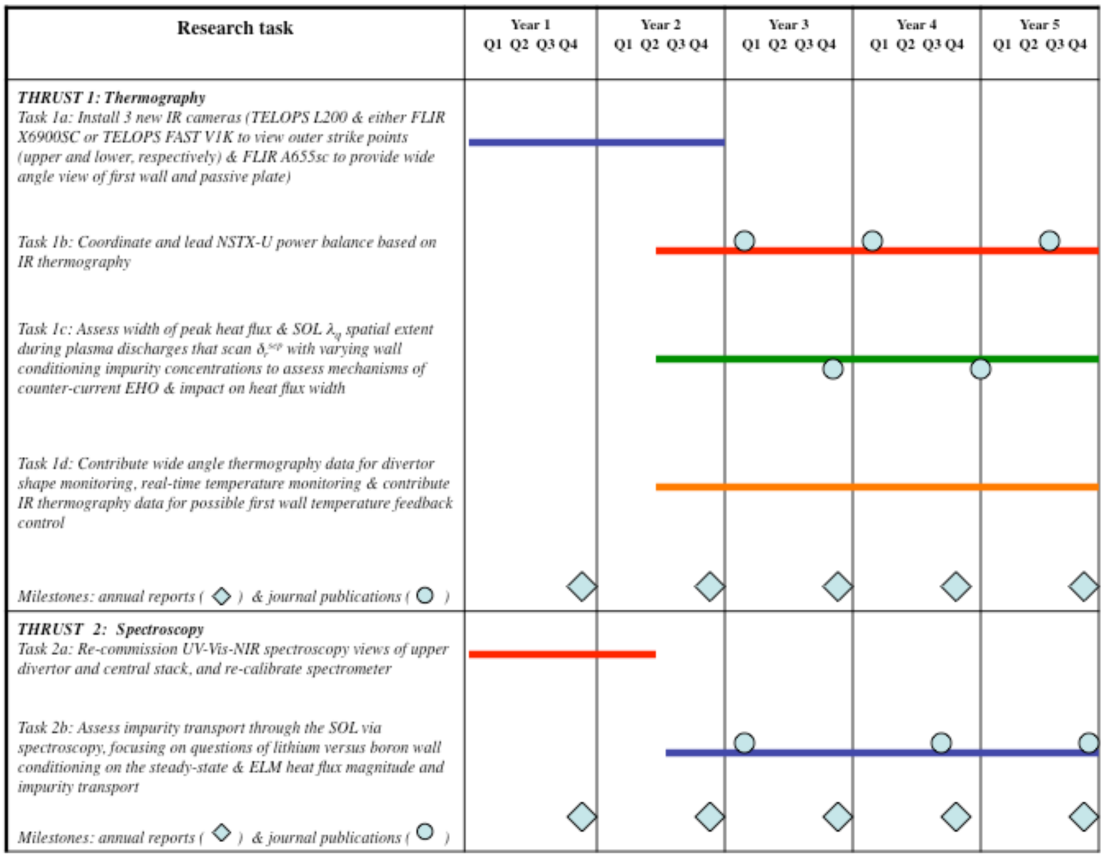
- Install new IR camera in Bay F with wide angle view to provide divertor shape monitoring, real-time temperature measurements and first wall temperature feedback control

Still evaluating camera options based on port access





Planned timetable & outcomes



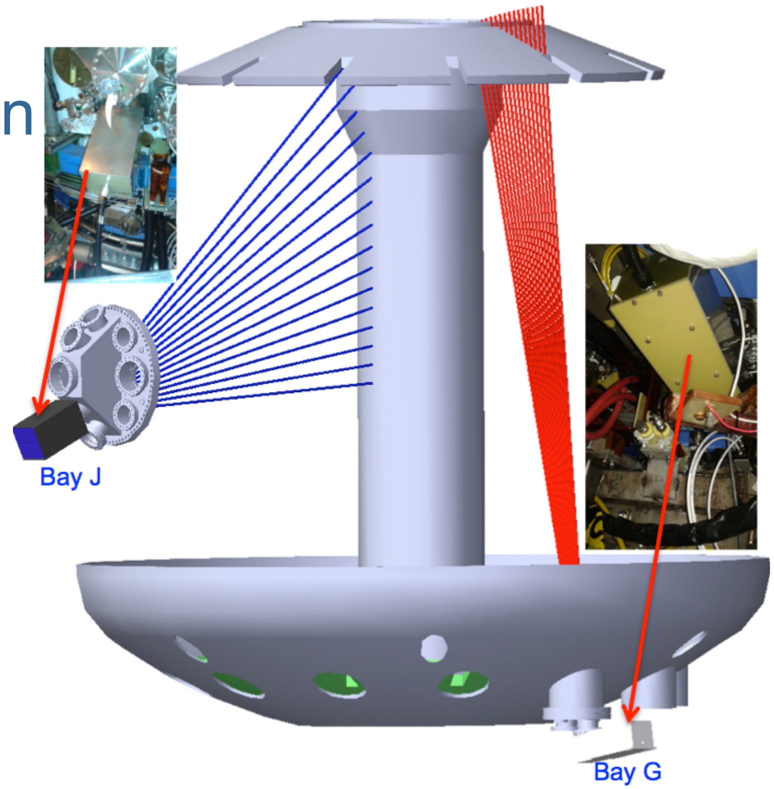
Outcomes:

- Measure upper-lower heat flux (power balance) with I_p and δ_r^{sep} scans (simultaneously with spectroscopic measurements of impurity transport) and varying wall conditioning levels
- Measure divertor heat flux and SOL power decay length (λ_q)

Opportunities to assess counter-current EHO impact on divertor heat flux and heat flux dissipation in ELMs

Spectroscopy (installed but re-commission)

- Extend diagnostic coverage to support Li program
  - Effectiveness of Li evaporation
  - Studies of material evolution and migration
- Upper divertor views (Bay G bot)
  - 16 LOS for UV-NIR spectroscopy
- Central stack view (Bay J mid)
  - 16 LOS, for UV-NIR spectroscopy
- ProEM-HS 512 camera with IsoPlane SCT320 spectrometer in DARM, with 16 fibers input to spectrometer



Summary

- Planned installation of wide angle, upper and lower IR diagnostics will be installed for the first run campaign, together with the central stack and upper divertor spectroscopy diagnostics, can be used to assess the performance and lifetime of new NSTX-U plasma-facing components and research the heat flux width.

- Providing IR thermography diagnostic within a team framework, supporting the temperature probe/feedback control and to be available to the diagnostic/thermography and impurity transport objectives

- Challenges with IR thermography installation relates to engineering the magnetic shielding and optics system into available port windows

Backup slides

The Lower divertor IR diagnostic

Telops Fast V1k IR camera (cooled)

- 1 KHz full frame (640 × 512), 2.4 KHz (320 × 256) 40KHz (64 × 8)
- 7.5-11.5 μm
- Automatic exposure control
- Spatial resolution on the divertor: 1.7mm

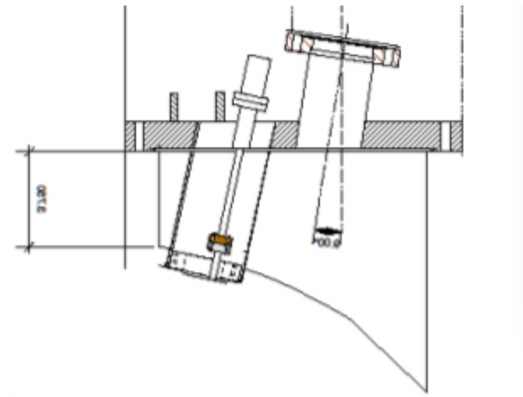
Lens

- ➢ 4 50.8mm focal length, 2” ZnSe Aspheric Lens
- ➢ 50mm IR lens for the Fast V1k IR camera
- ➢ Field of view:18º×14.5º

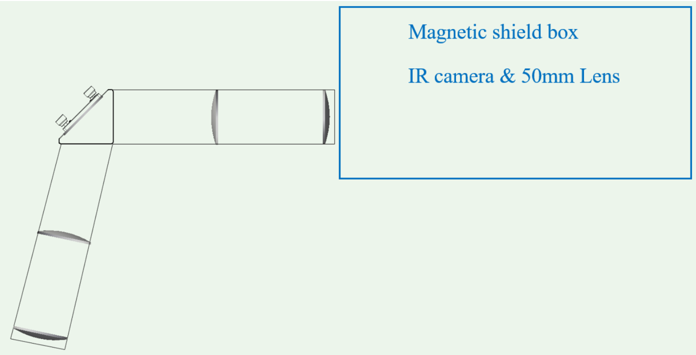
Requirement

- ➢ Design the magnetic shielding box with cold air cooling.
- ➢ bracket for the IR optics and shield box.

Re-entrant IR port on bay H top



Lower divertor IR diagnostic layout



The Upper divertor IR diagnostic

Telops fast L200 IR camera (cooled)

- 234Hz full frame (640 × 512), 1 KHz (256 × 256) 17.2KHz (160 × 2)
- 7.7-9.3 μm
- Automatic exposure control
- Spatial resolution on the divertor: 2mm

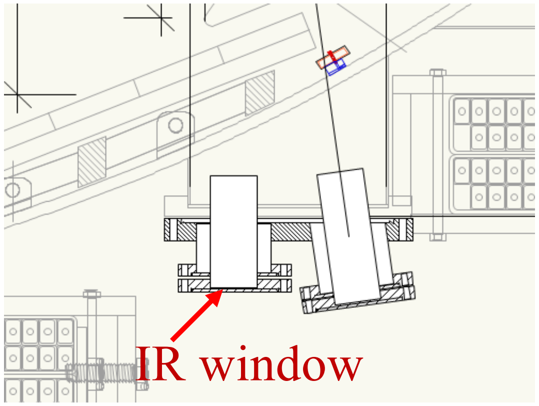
Lens

- 4 50.8mm focal length, 2” ZnSe Aspheric Lens
- 25mm IR lens for the Fast L200 camera
- Field of view:21º×16º

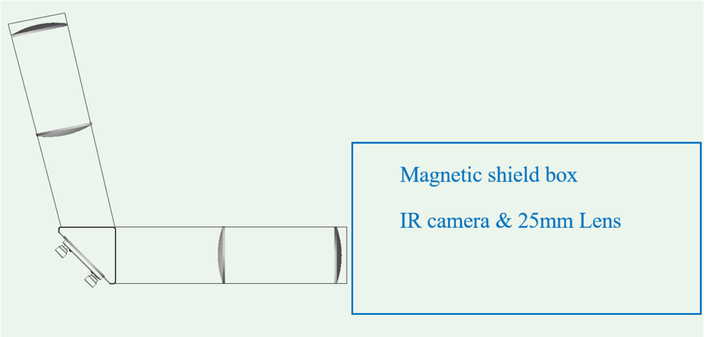
Requirement

- IR window machining to re-entrant window.
- bracket for the IR optics and shield box.

Current Bay G bottom



Upper divertor IR diagnostic layout



Wide angle IR diagnostic

Telops Fast V1k IR camera (cooled)

- 1 KHz full frame (640 × 512), 2.4 KHz (320 × 256) 40KHz (64 × 8)
- 7.5-11.5 μm
- Automatic exposure control
- Spatial resolution on the divertor: 5mm (central stack)

Lens

- Customed 8mm lens
- Field of view: 90º×78º

Requirement

- Design the magnetic shielding box with cold air cooling.
- bracket for the IR optics and shield box.