



Charge Exchange Recombination Spectroscopy (CXRS) on the Neutral Beam Injection (NBI) (Ladungsaustauschspektroskopie am Neutralheizstrahl)

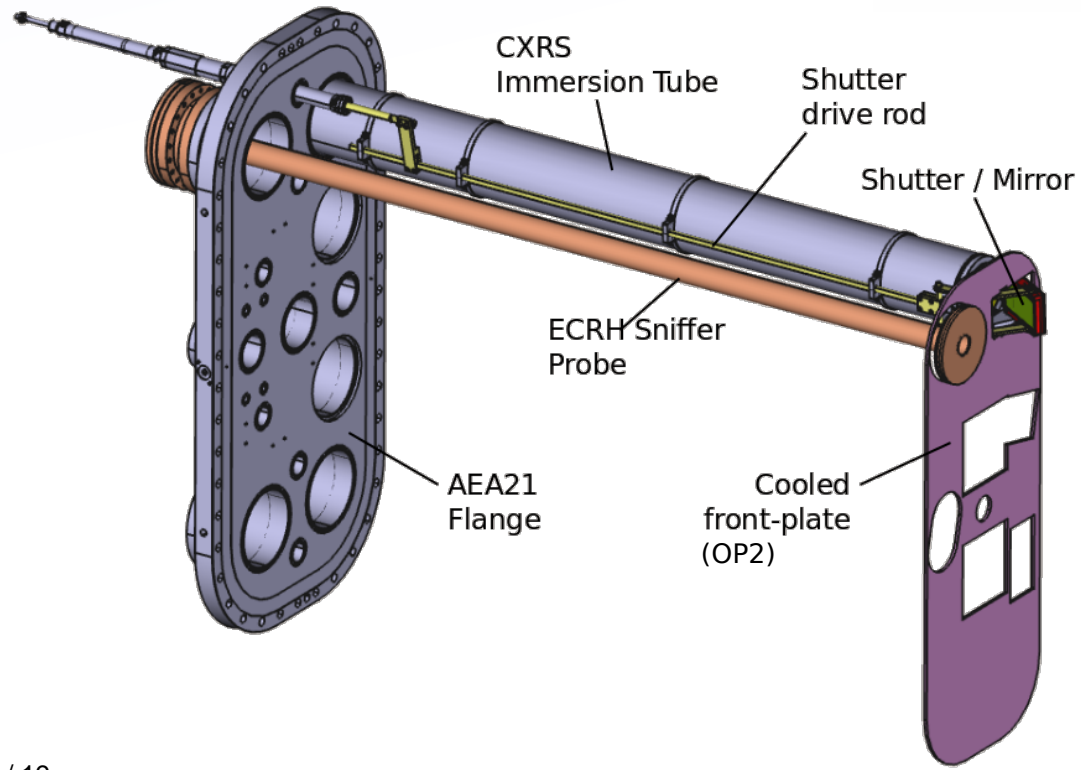
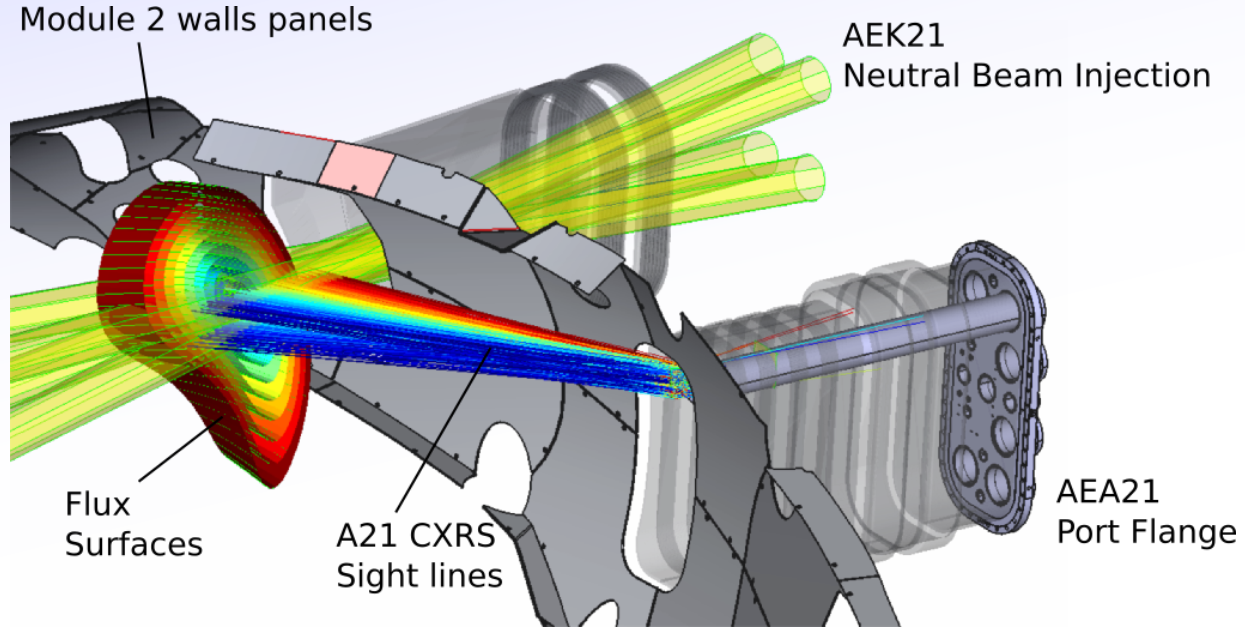
Design Review AEA21 Immersion Tube 2nd Nov 2017

O. P. Ford¹, M. Steffen¹, C. Biedermann¹

1: Max-Planck Institut für Plasmaphysik, Greifswald, Germany

- Concept for AEA21 observation system:
- 1) Mirror to view beam, also as shutter.
 - 2) Immersion tube similar to AEM21
 - 3) Lenses and fibres in internal holder.
- Design complete for OP1.2b.
 - Some consideration given to OP2. Initial calculations show the system should be applicable with minor modifications.

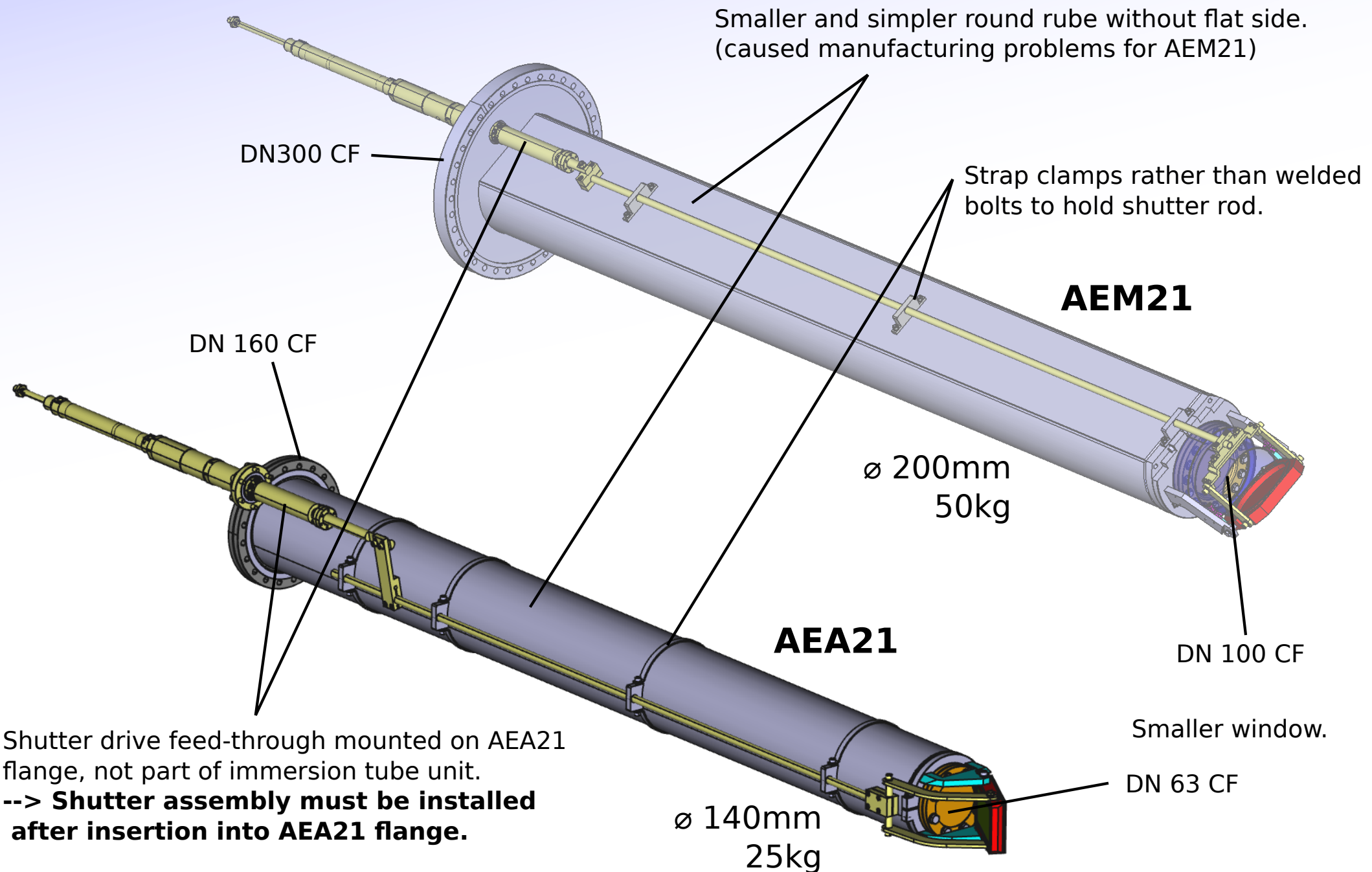
Concept



Immersion tube installed as plug-in to AEA21 flange.

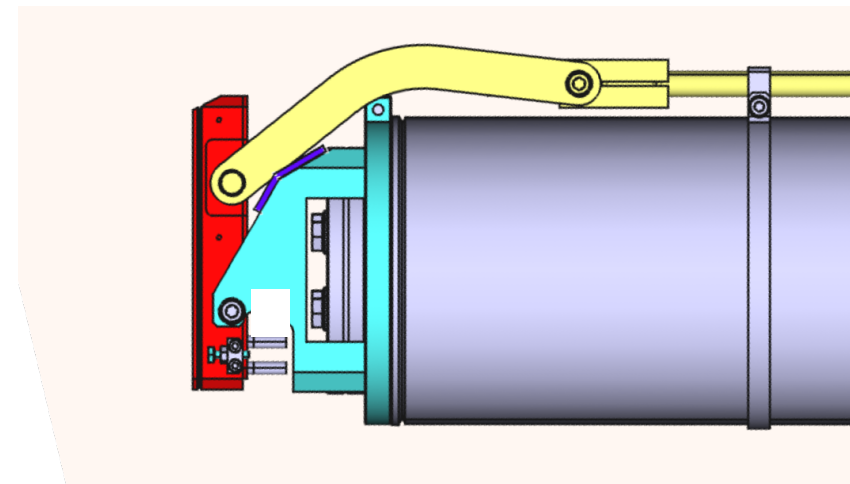
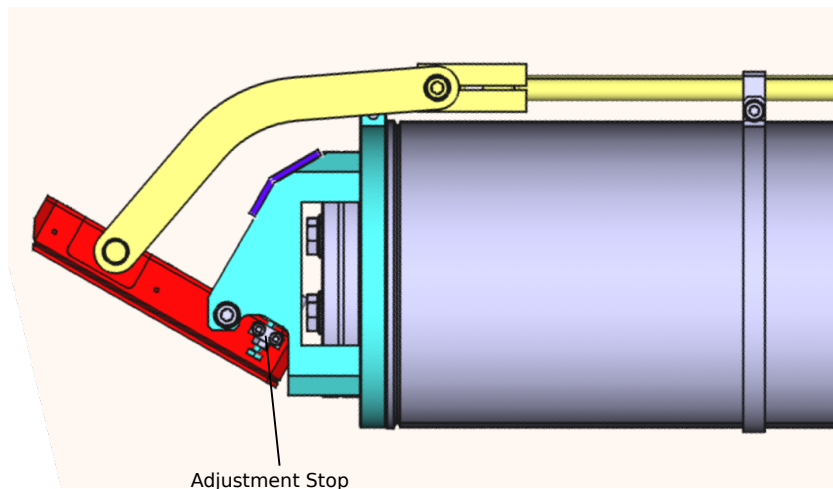
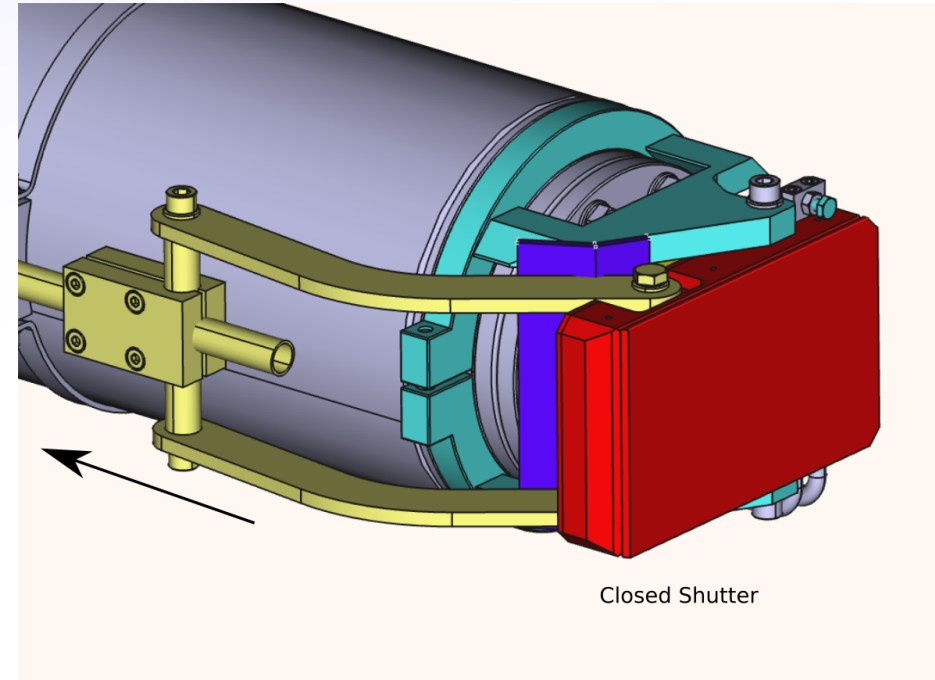
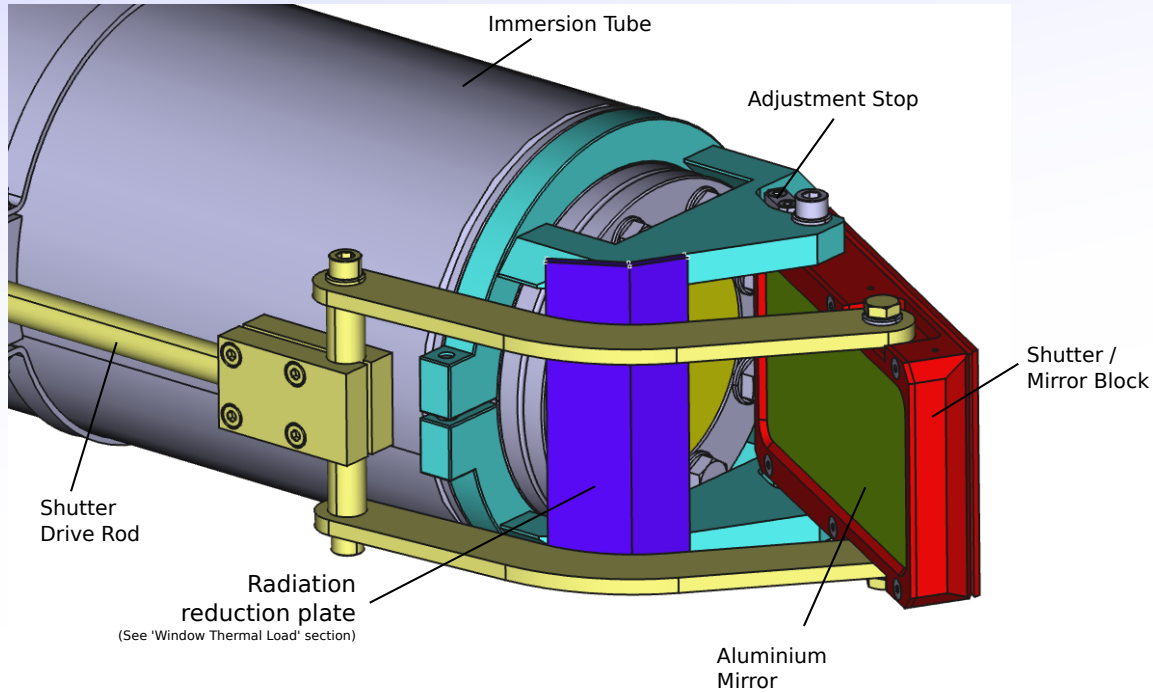
OP2: AEA21 will have a cooled front plate instead of port liner. The CXRS plug-in is already integrated with the initial design.

Immersion tube: AEA21 vs AEM21



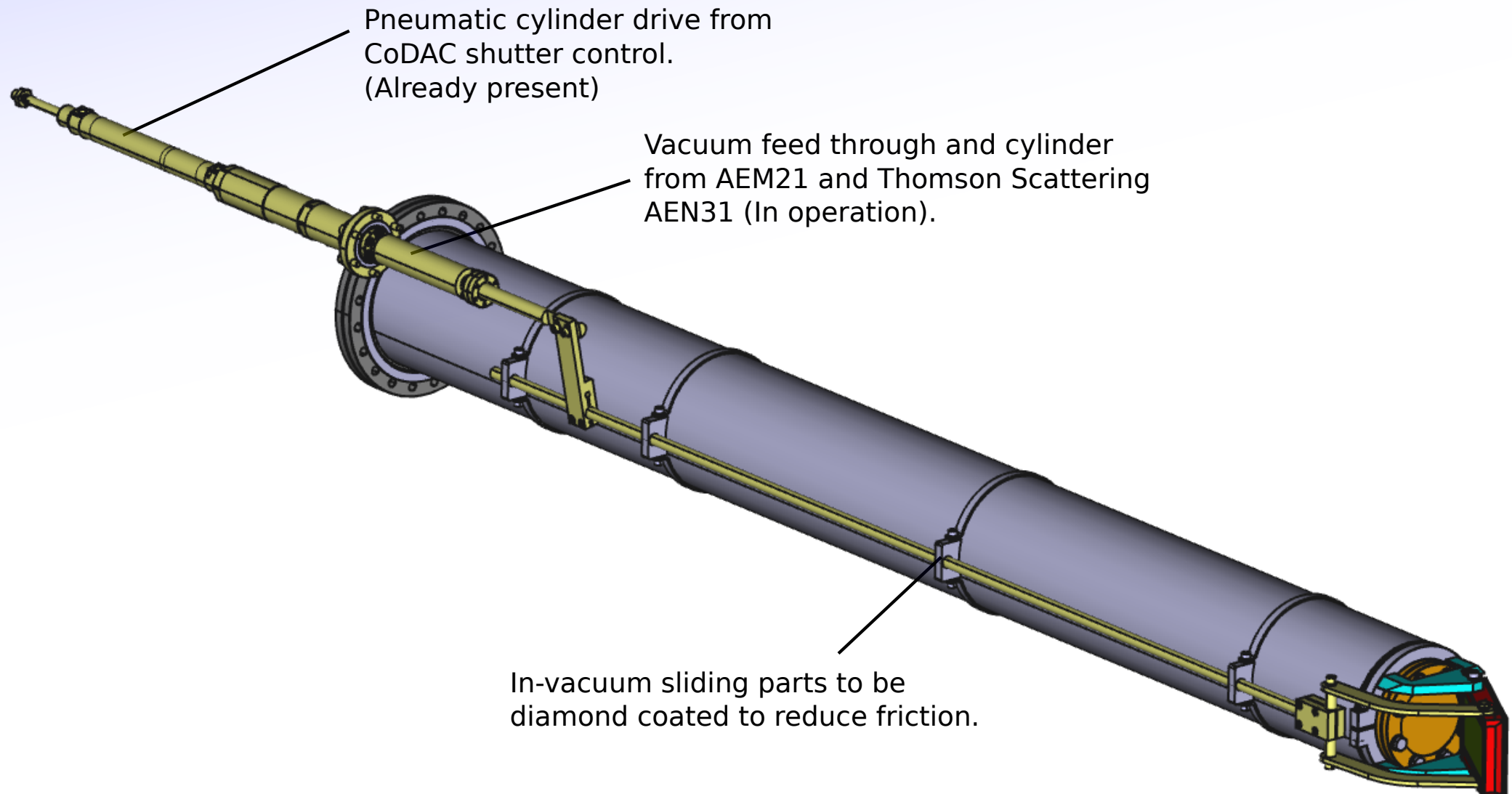
Shutter

The mirror is mounted to a steel block used as the shutter.



Shutter Drive

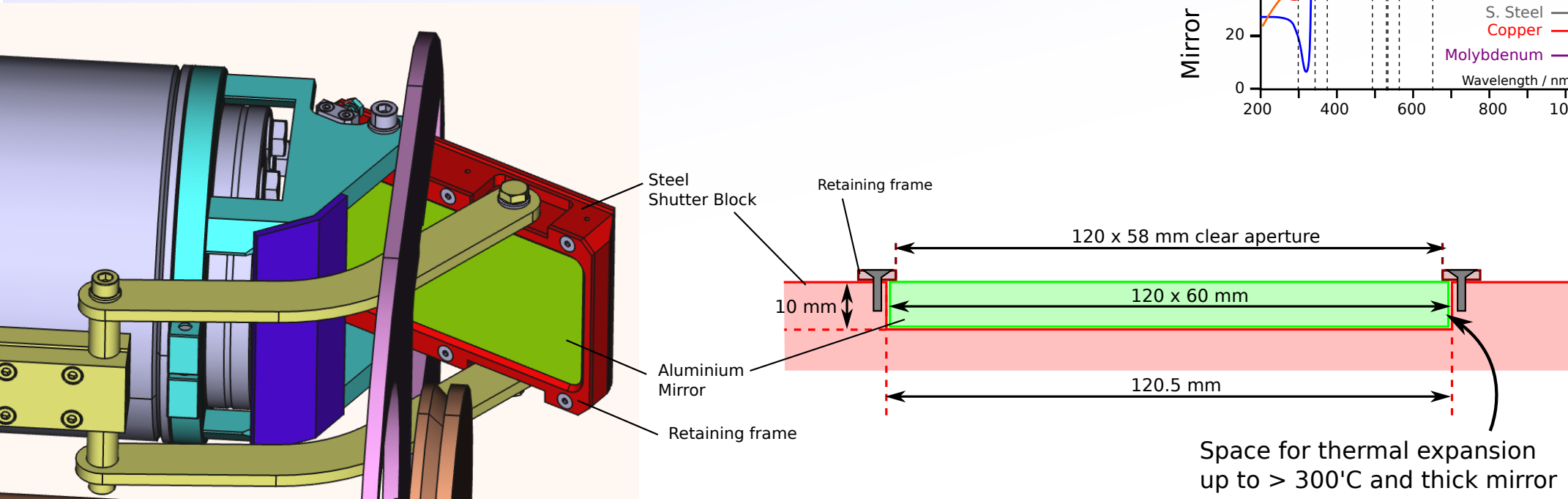
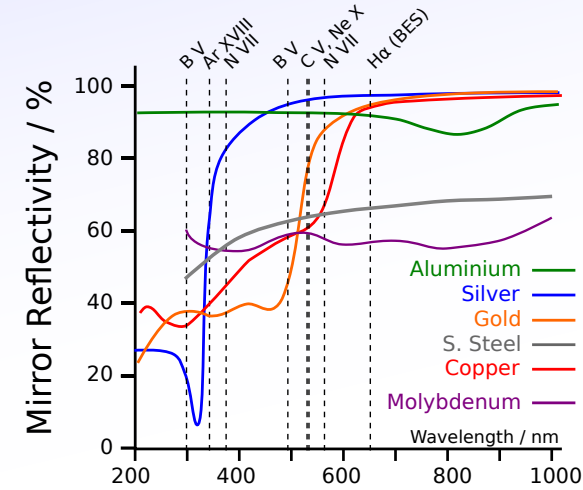
Almost identical to AEM21. No issues.



Mirror

Material selection:

- Aluminium for required reflectivity < 400nm.
- No dielectric coating - causes arcing and damage to layer.
- > Aluminium, polished to optical quality.



Space for thermal expansion up to > 300°C and thick mirror to avoid bending when hot.

RSA-905: High temperature tolerant (up to 300°C), polishing friendly aluminium alloy.

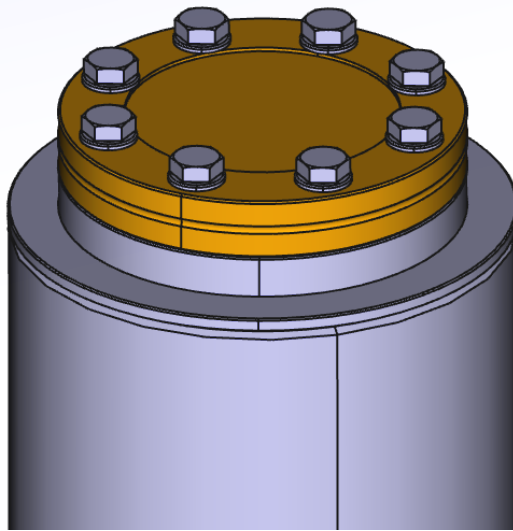
- Sonderfreigabe obtained for AEM21 (1-QSK-Q0002). Repeat --> 1-QSK-Q0009 (In progress).
- Non-magnetic, vacuum compatible, no issue with radiation.
- Expect slow loss of reflectivity due to coatings from plasma.

Vacuum Window

VACOM standard DN 63 CF Fused Silica vacuum window UHV compatible. Max 200'C.

ITO coated on air side to exclude ECRH stray radiation from tube.

As used in AEM21 - measured performance was good.

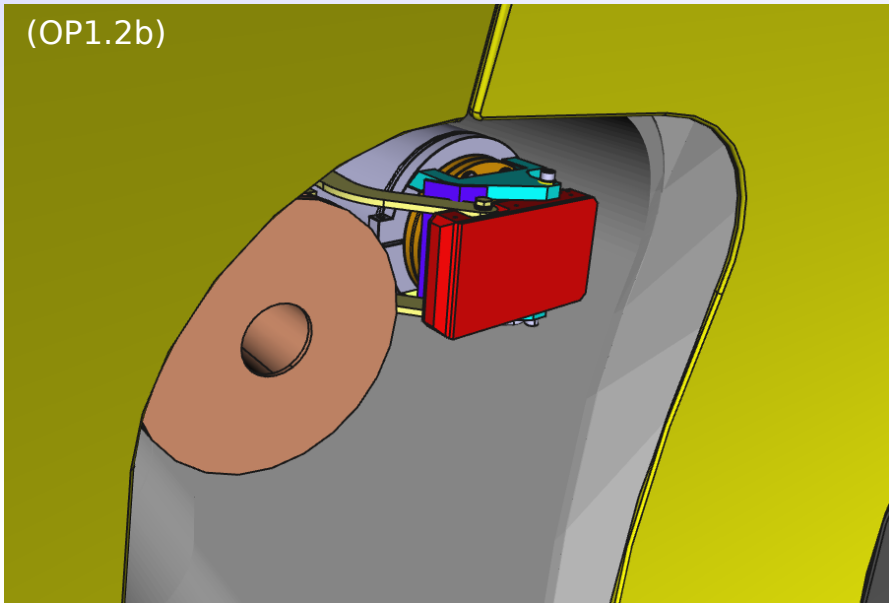


Window protection

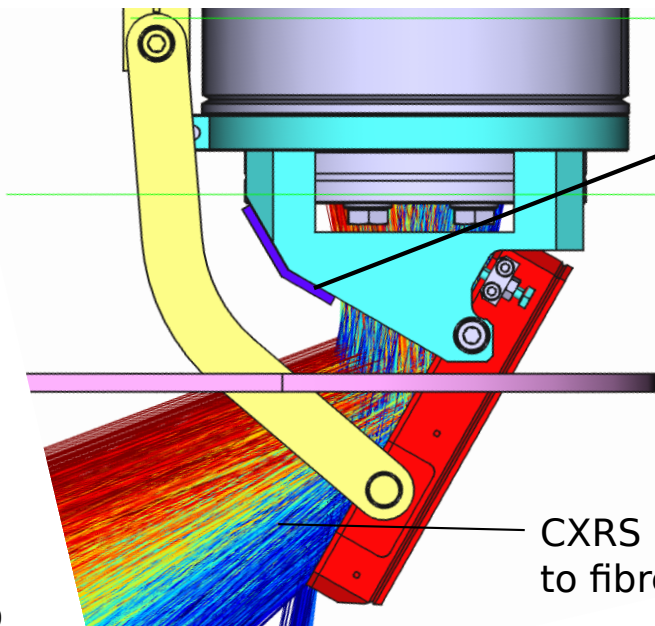
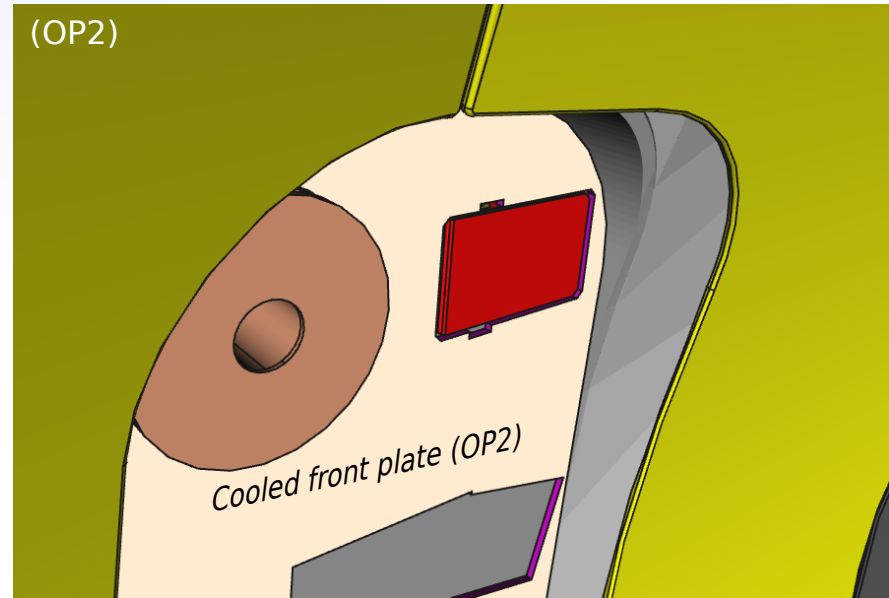
Window and mirror are protected from glow discharge and plasma when shutter is closed.

Full closure with cooled front plate in OP2:

(OP1.2b)

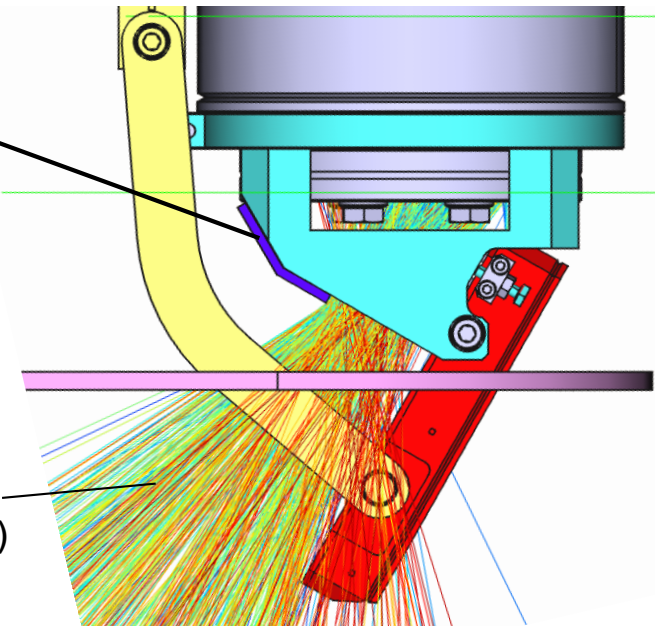


(OP2)



Blocking plate to reduce window exposure when shutter is open

CXRS light to fibres



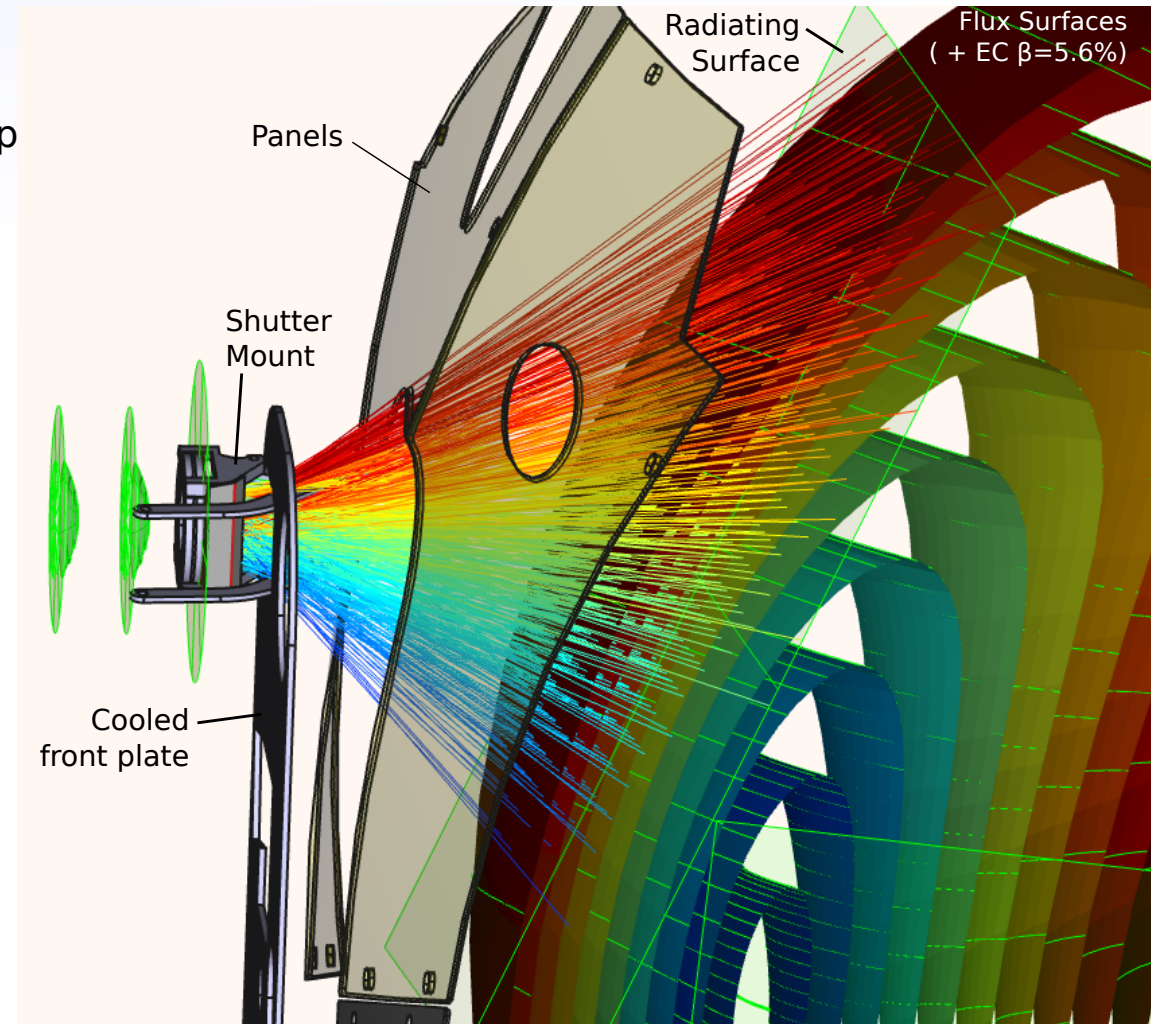
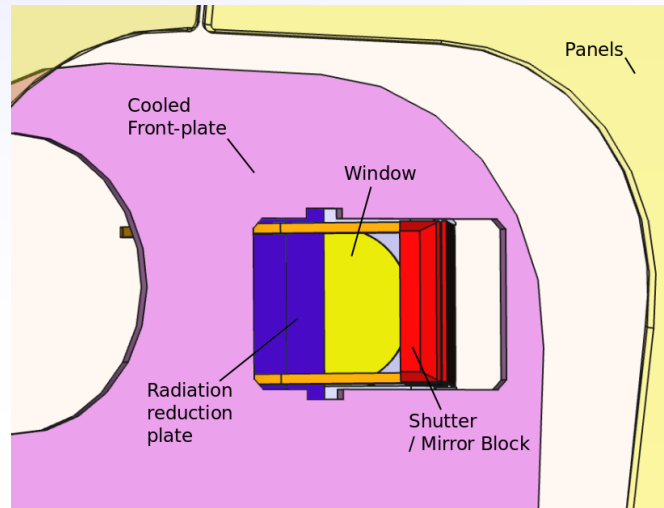
Thermal radiation from plasma (OP2)

Heating of window by plasma.

Open shutter, OP1.2 and OP2. worst case: 10 seconds of open shutter.

- Aluminium conductivity is high, so no issue for mirror surface on short timescale.
- CF window exposure is more critical - max 200°C, vacuum barrier.

- Reduced exposure as much as possible with steel p



Calculate radiation reaching window/flange
from 200kW m⁻² emitted from surface at
plasma boundary:

$$= 10\text{kW m}^{-2} \text{ heat flux}$$

$$= 40\text{W heating for 10 seconds.}$$



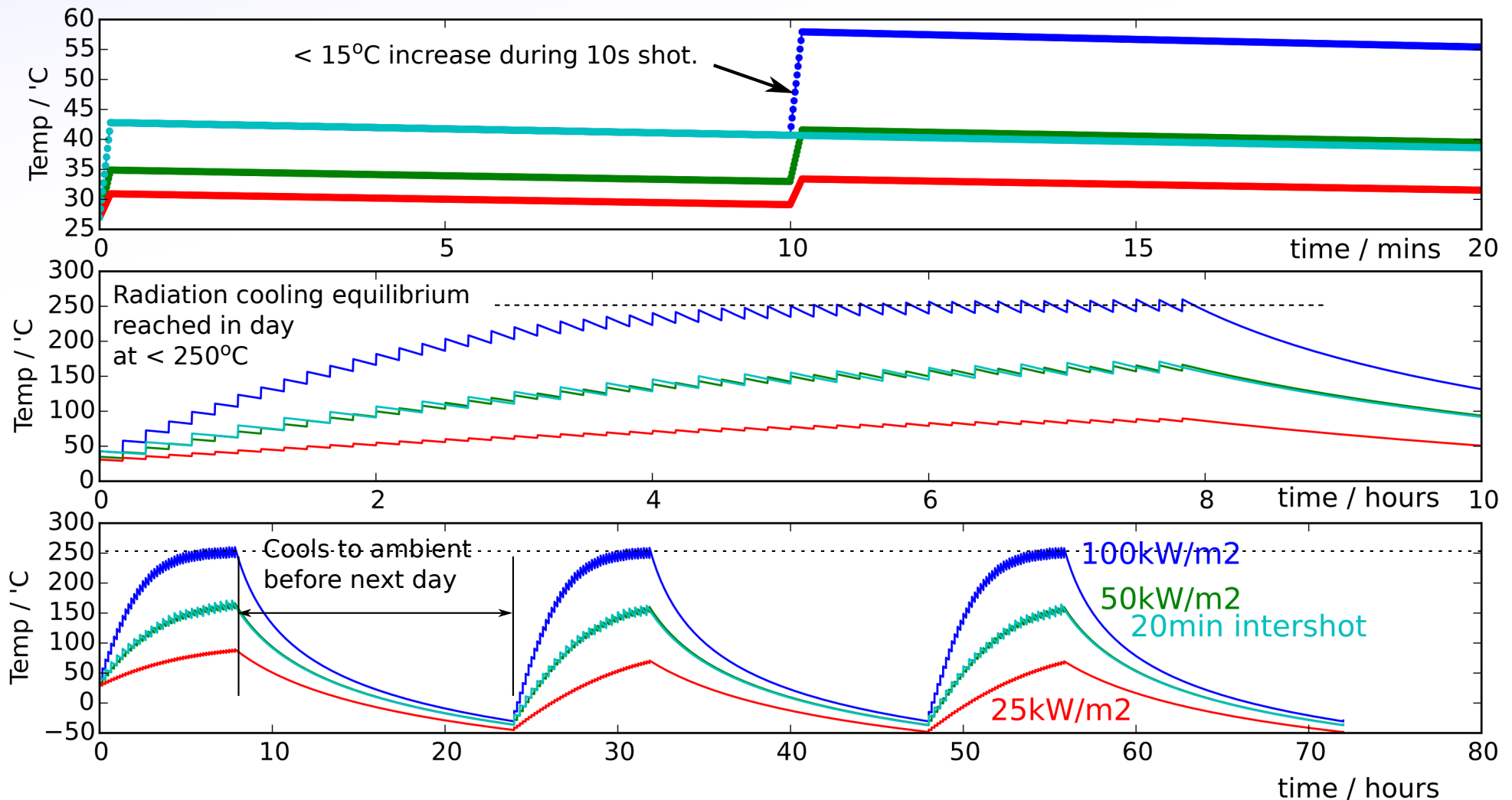
Heating of closed mirror/shutter by plasma (OP1.2)

Closed shutter, OP1.2b worst case - pulsed operation with only radiative cooling:

AEM21 calculations remain valid for AEA21 in OP1.2b.

Worst case scenario: 100kW m⁻², 10s shots, 10 minute pause.

- Mirror surface max 30'C above bulk.
- Bulk temperature equilibrates at max 250'C (worst case scenario)
- Cools before start of next day.



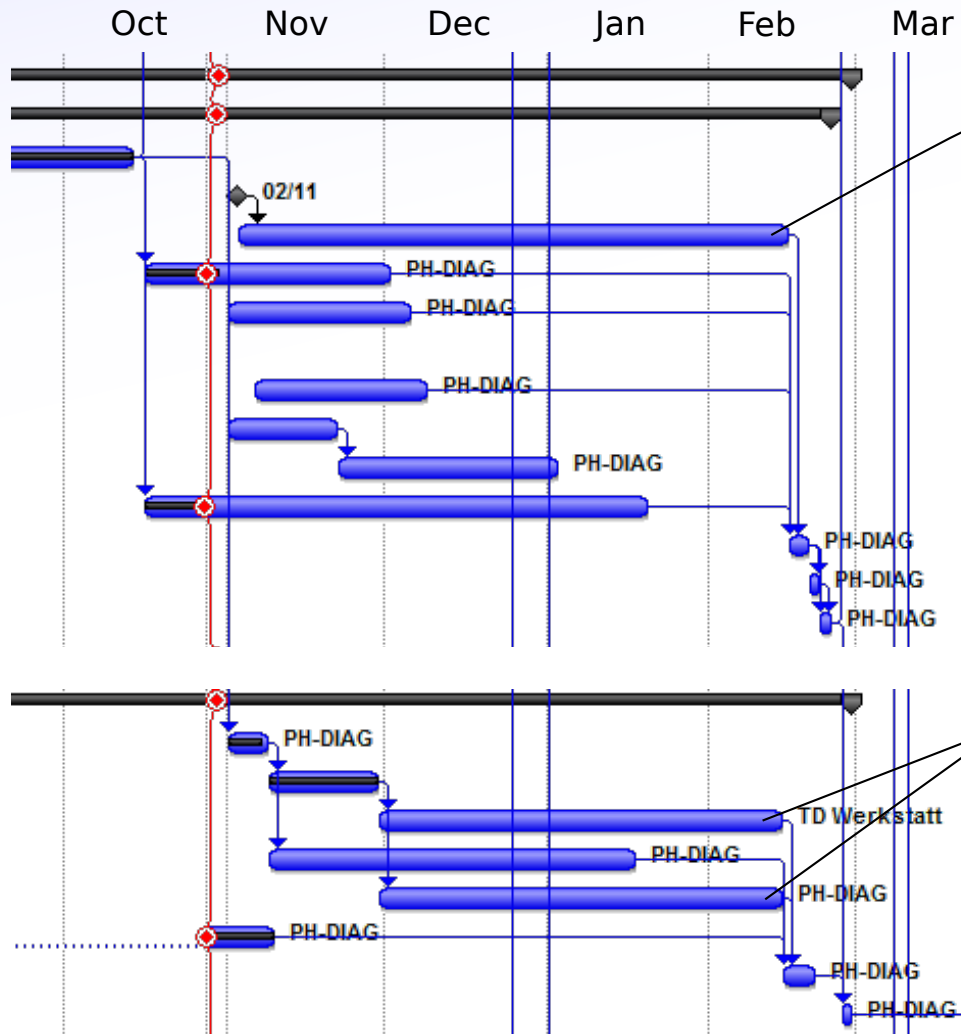


Time plan

Feb 2018: AEM21 immersion tube delivered, ready to install in AEA21 flange.
 March 2018: AEM21 optics ready (calibration possible).

- [-] K1: Immersion tube AEA21 (OP1.2b+)
- [-] Immersion tube / vacuum side
- Design+Drawings Immersion Tube AEA21
- Design Review QSK an AEA21
- Order Immersion Tube AEA21
- Order vacuum window
- Order mirror
- Order Shutter Drive Cylinder (ordered with K2)
- Order shutter drive components
- Shutter Components (For diamond coating)
- Order diamond coating
- Shutter Components (TD)
- Assemble immersion tube AEA21
- Test Immersion Tube AEA21
- Install Immersion Tube AEA21 (OP1.2b)

- [-] Optics / air-side
- Optical design AEA21
- Design optic holder
- Manufacture optics holder (TD)
- Order lenses
- Order in-tube fibres
- Order patch panel mating sleeves
- Assemble optics for AEA21
- Install AEA21 optics



Immersion tube worst case manufacturing time estimate (Trinos)

Optics may not be ready in time.

Can be installed after vacuum closing - (will have to rely on AET2x and AEM21 calibration).

Calibration (AS Schedule)

The system should be calibrated before operation, there are two possibilities, depending on AS schedule:

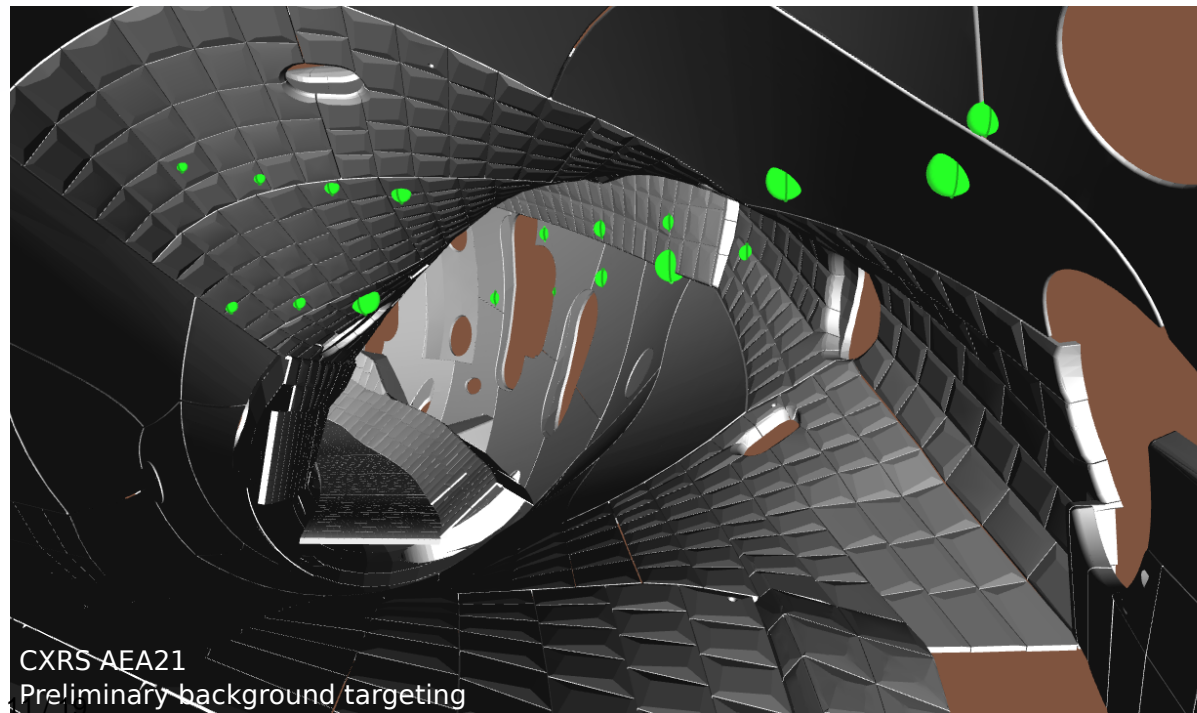
- 1) **Preferred:** In-Vessel calibration (Also for AEA21, AEM21, AET20, AET21).
- 2) **Acceptable:** Calibration shortly before AEA21 closing.
- 3) **Worst case:** Optical fibre head not ready - rely on cross-calibration with AET2x and AEM21.

1) In-vessel calibration:

AEM21, AET21, AET20 all need to be done this way in any case. If this is after AEA21 installation, they can all be done at the same time: < 5hrs in vessel work.

Spatial: Backlight fibres and photograph position on first wall.

Intensity: Hold calibration sphere in front of tube. (~50cm diameter sphere)



Example: AET21 HST before OP1.2a



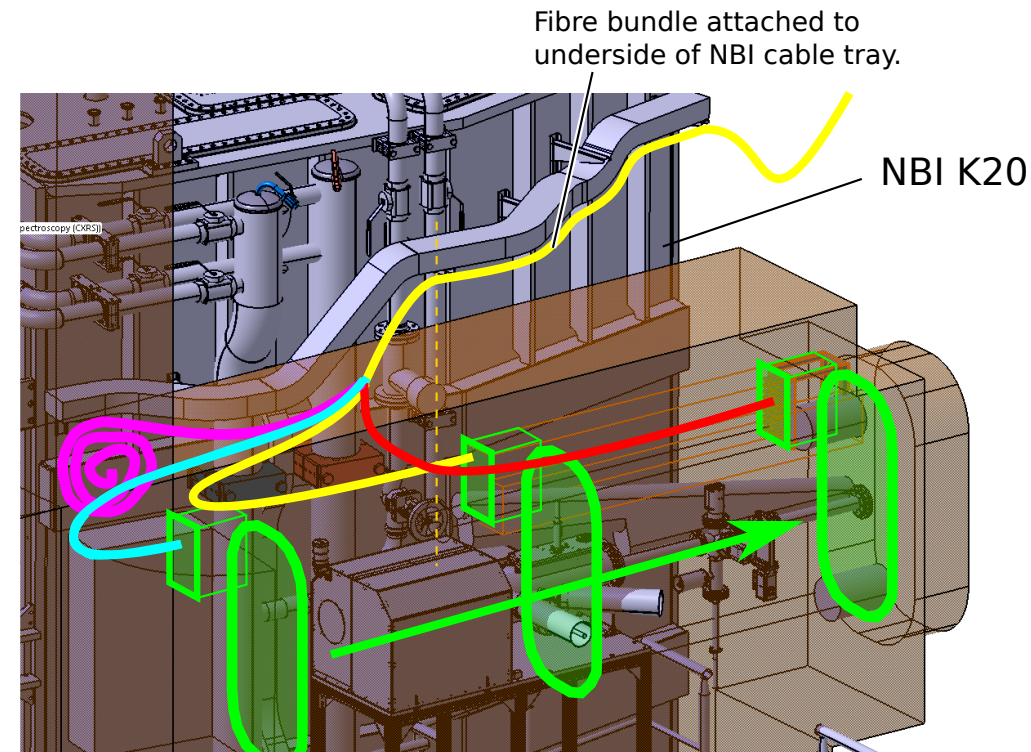
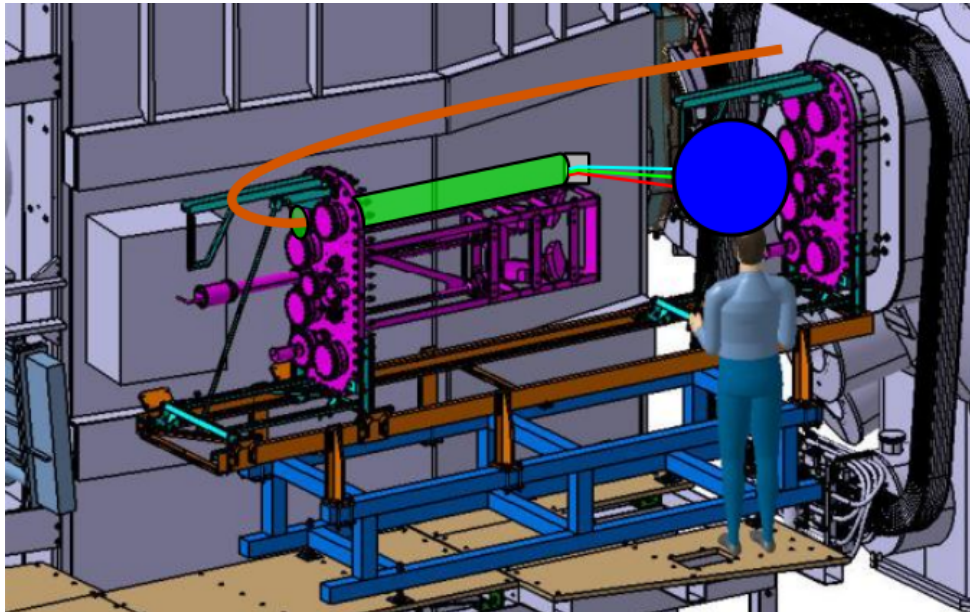
Calibration (AS Schedule)

The system should be calibrated before operation, there are two possibilities, depending on AS schedule:

- 1) **Preferred:** In-Vessel calibration (Also for AEA21, AEM21, AET20, AET21).
- 2) **Acceptable: Calibration shortly before AEA21 closing.**
- 3) **Worst case:** Optical fibre head not ready - rely on cross-calibration with AET2x and AEM21.

Spatial: Set up in lab relative to tube. Check using in-vessel cameras.

Intensity: Hold calibration sphere in front of tube shortly before insert of AEA21 flange.
Fibre bundles **must not be disconnected** after calibration and must move with flange on rails:





Mirror/Shutter thermal consideration (OP2.1)

2) Closed shutter, OP2.1.. worst case - pulsed operation with only radiative cooling:

(AEM21 calculations remain valid for AEA21)

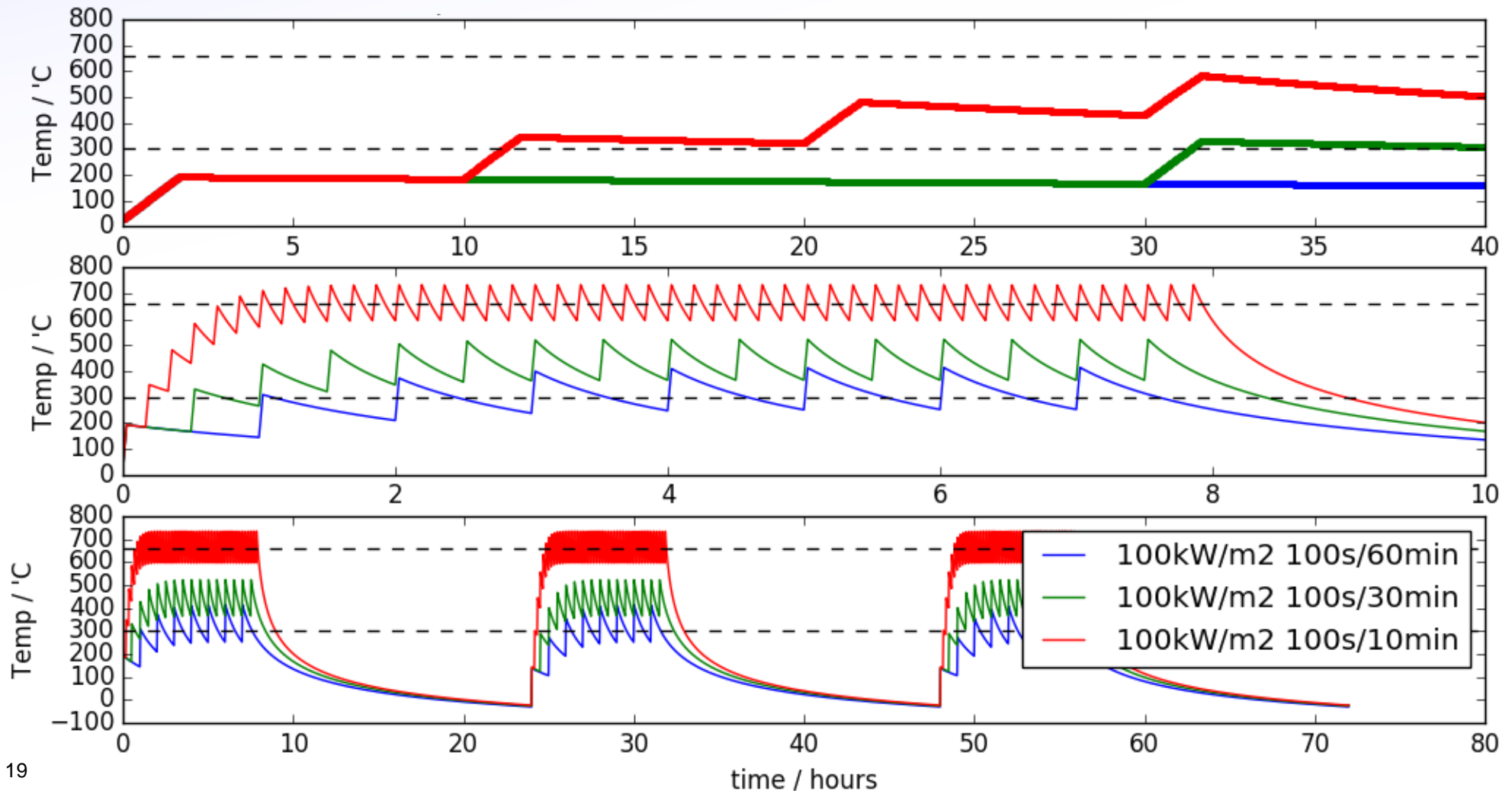
Worst case scenario: 100kW m⁻², **100 second shots**, 10/30/60 minute pauses:

10 mins: Intolerable. Max Temp 720'C, above melting point.

30 mins: Marginal. Max Temp 520'C, Aluminium softens.

60 mins: Max Temp 410'C, above rated temp but probably tolerable for diagnostic. No danger for W7-X.

--> Cooling of shutter high desirable, even for 100s shots.

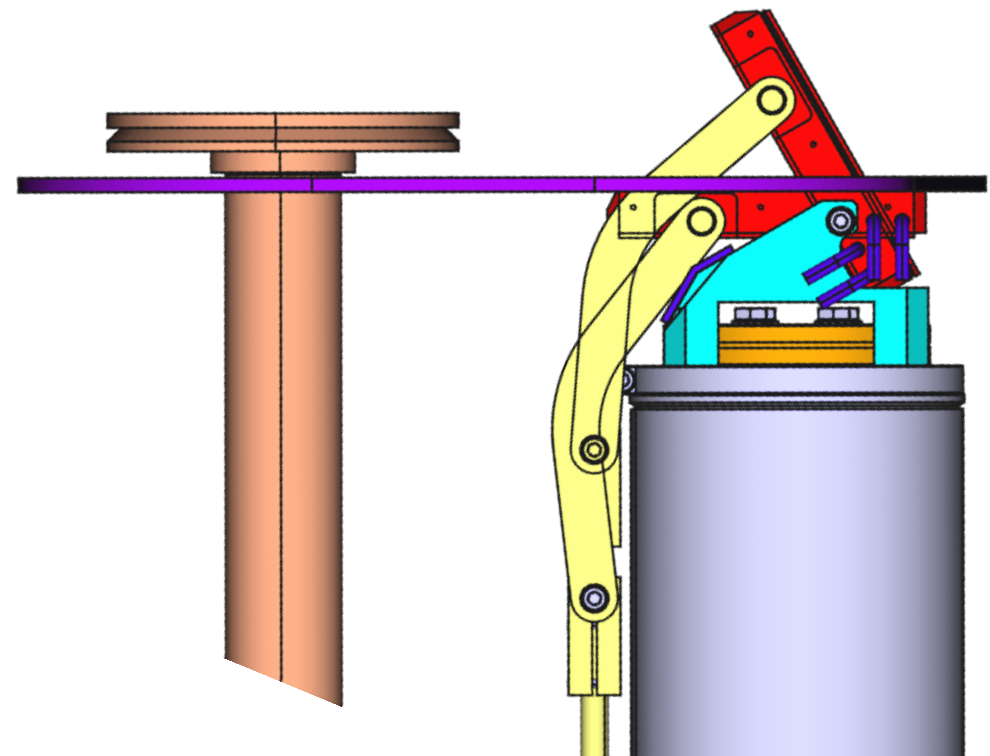
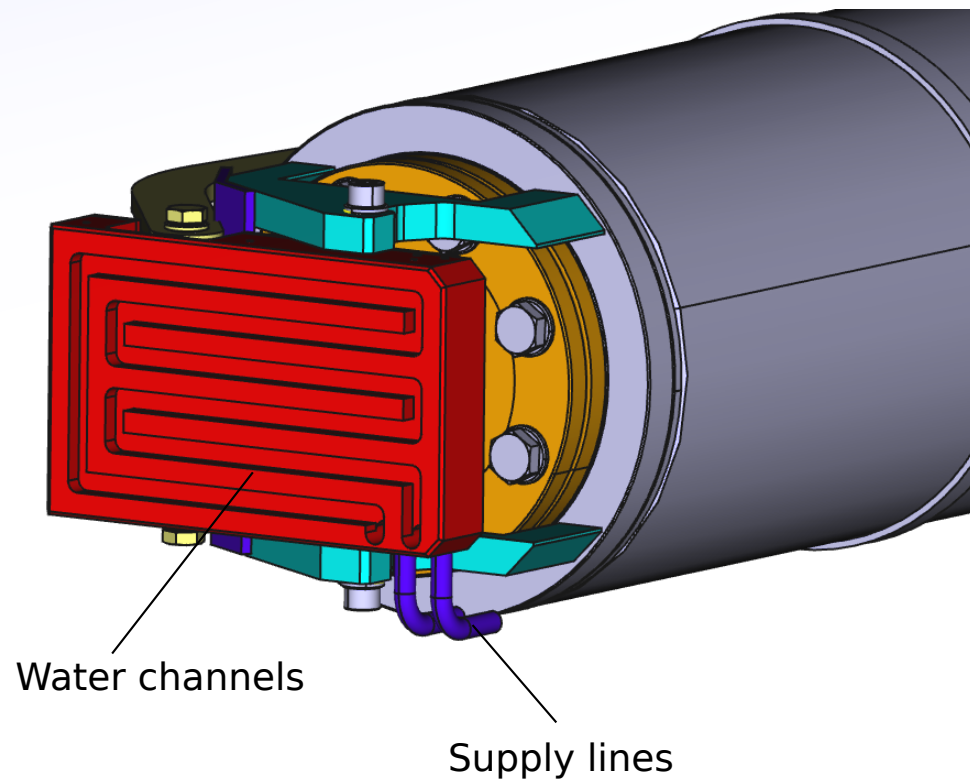


Mirror/Shutter thermal consideration (OP2 Preliminary)

For full OP2 operation, the shutter will be replaced with one with cooling channels (Preliminary design)

Not yet complete:

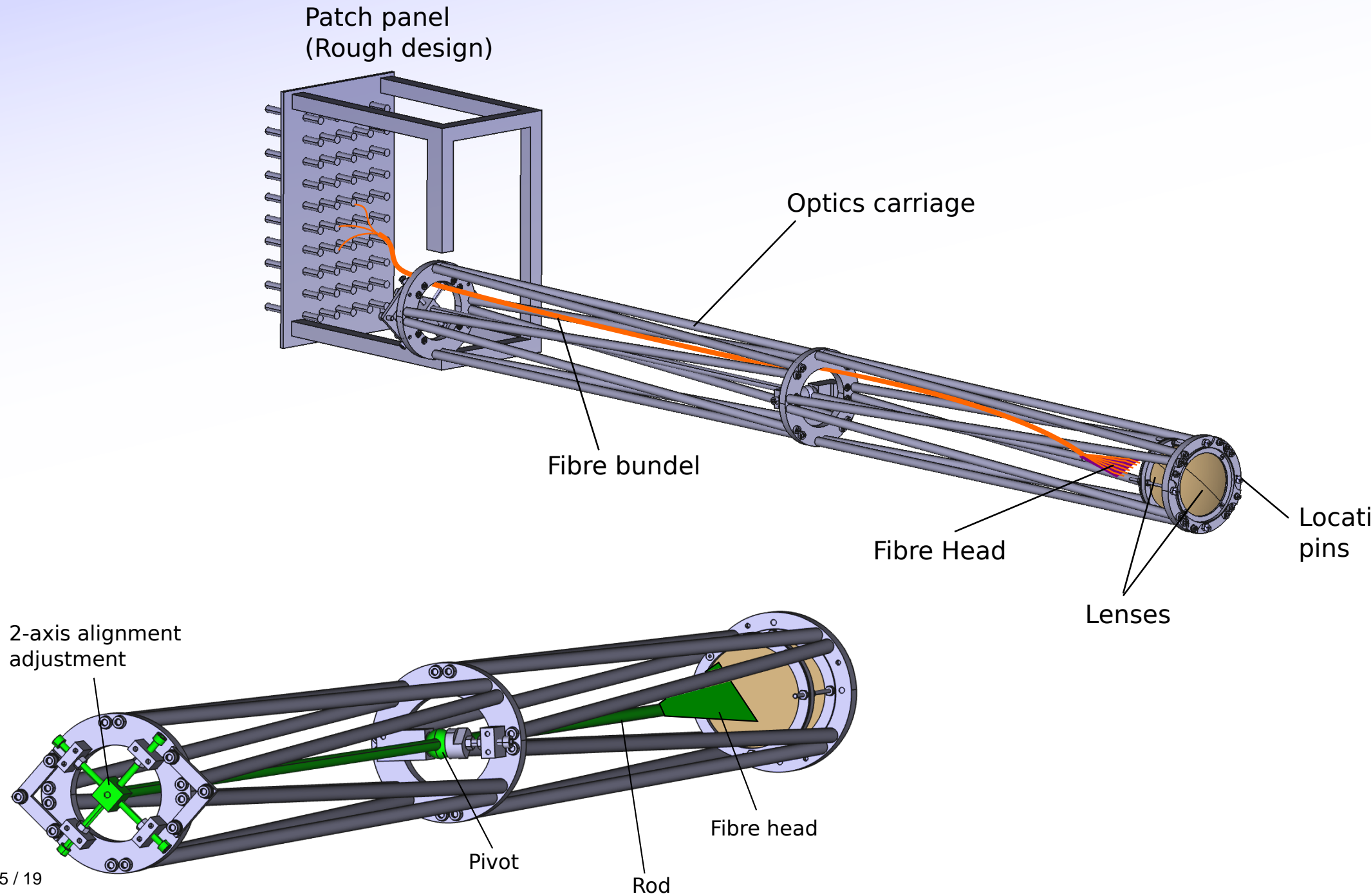
- Study of flexible cooling feed pipes (as ECRH/Thomson).
- Water supply feed-through on AEA21 flange.





Optics carriage.

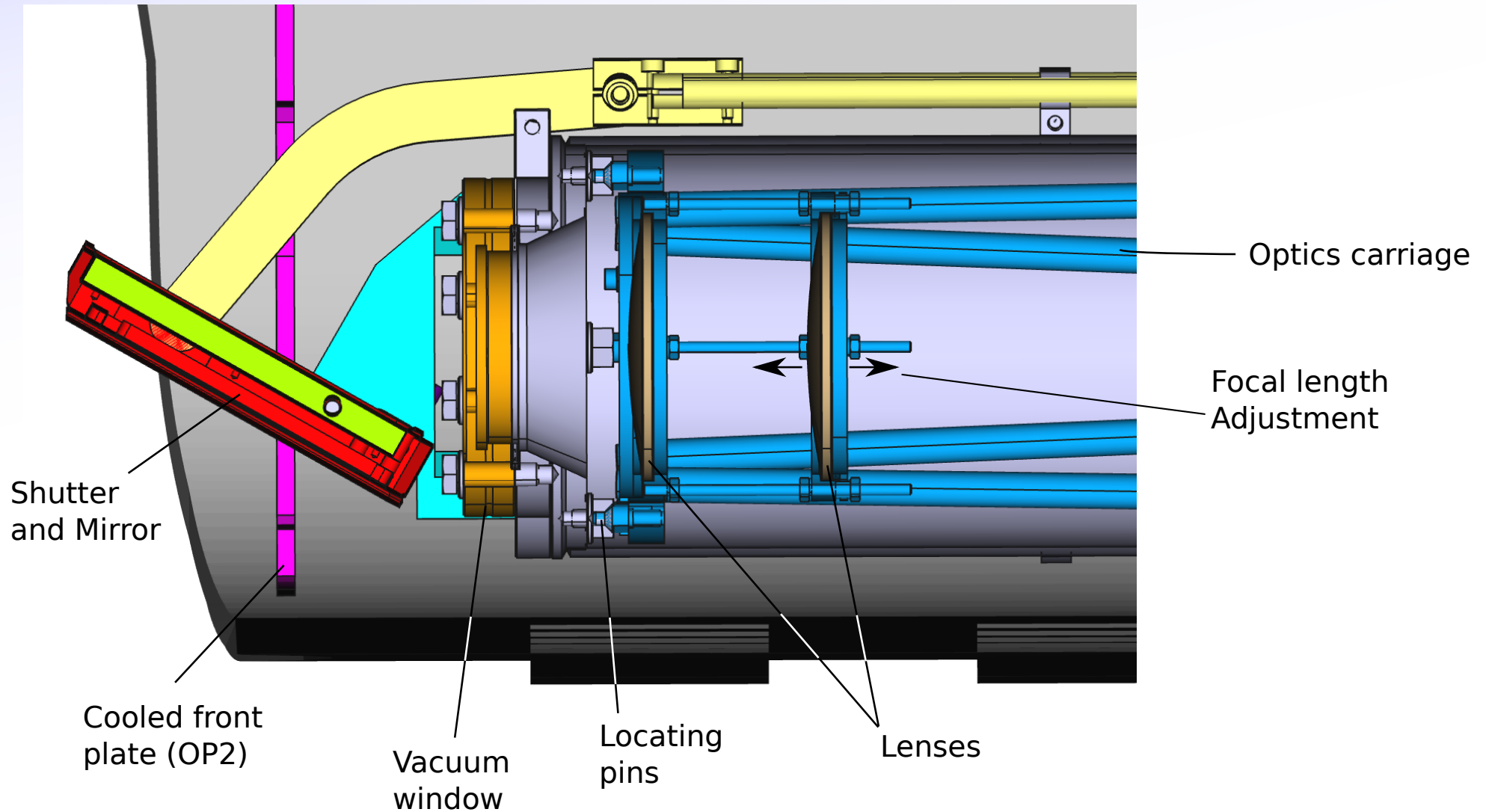
Optics





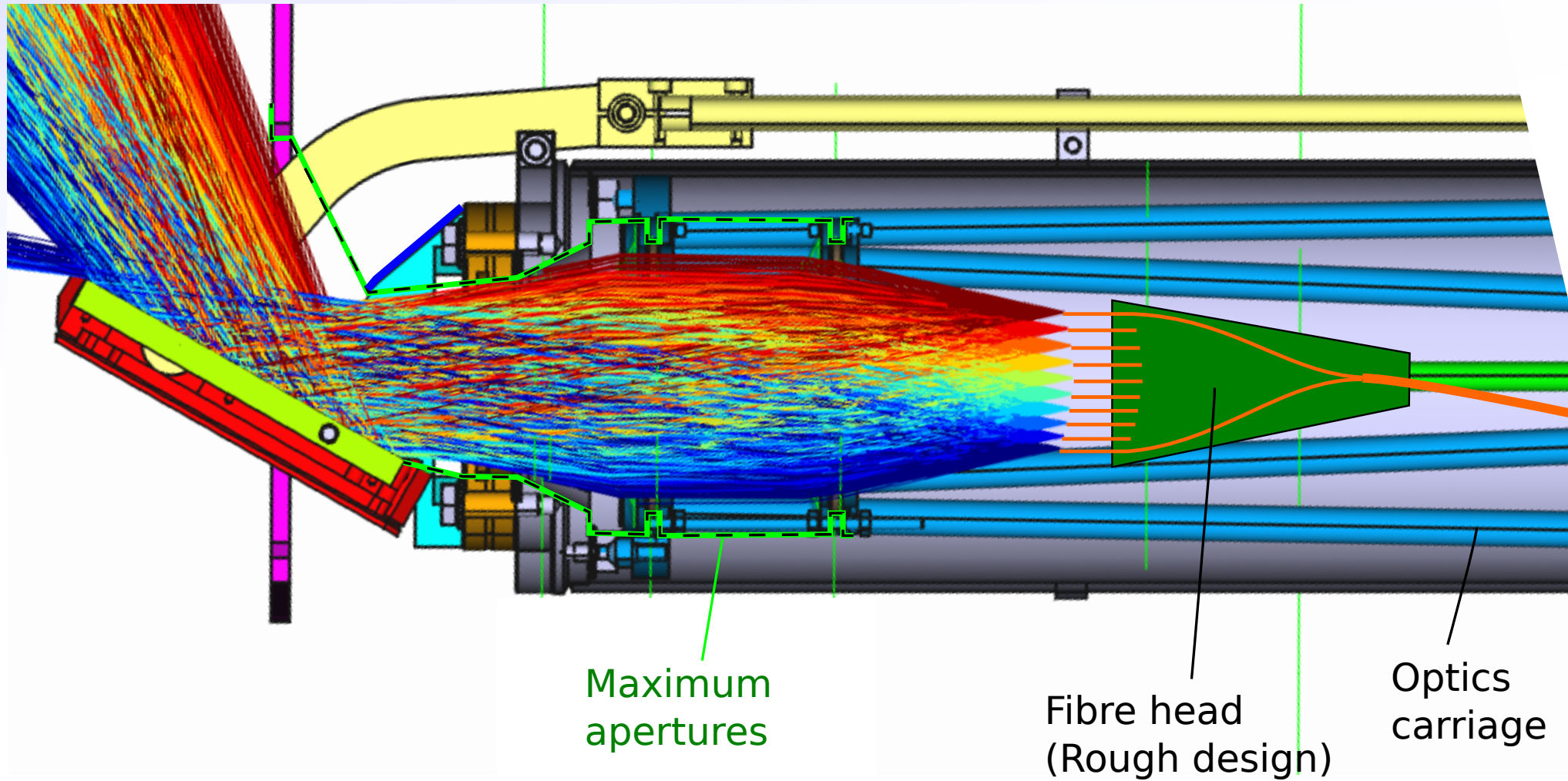
Optics carriage.

Optics



Optics carriage.

Optics



Optics carriage.

Optics

