QSK (CXRS) - Assessment of forces on susceptible components due to fast current discharge

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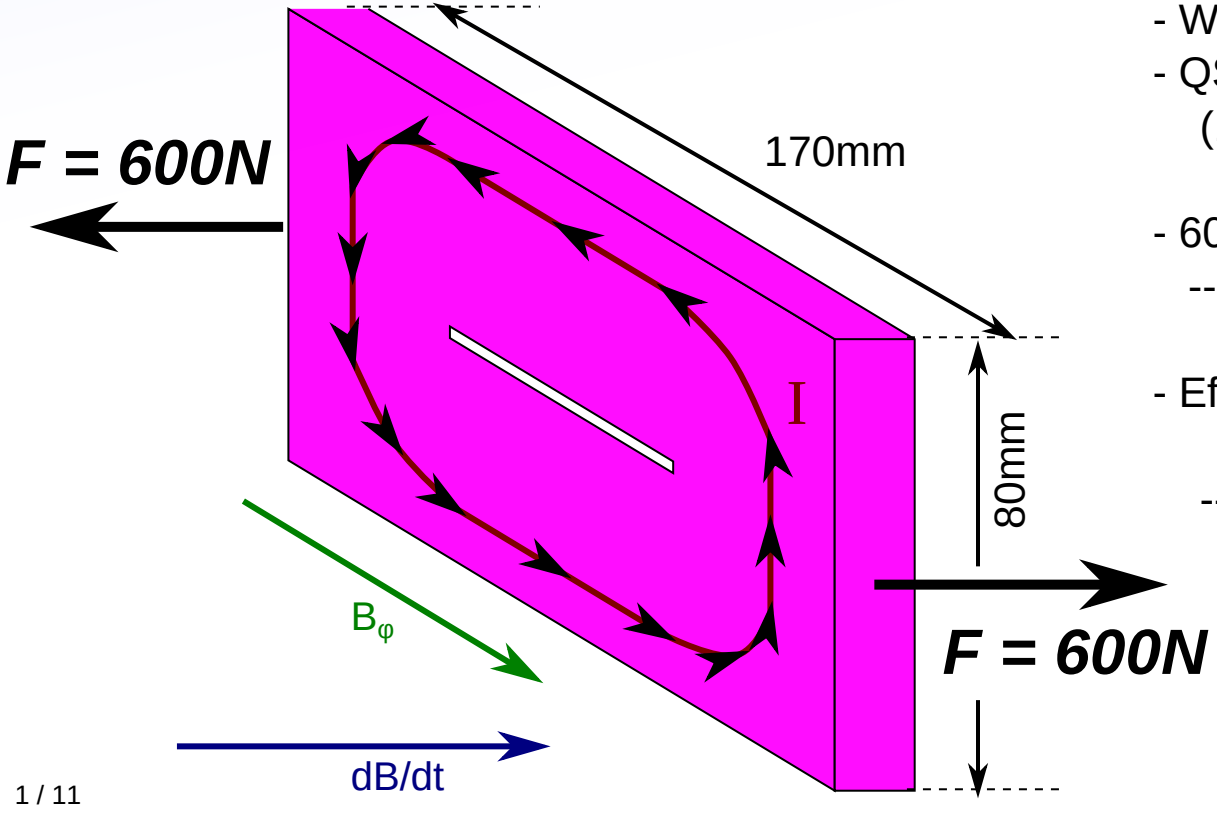
Forces due to fast current shutdown

4 components of interest with lower resistivity:

1) AEA21 Mirror (RSA-905 Aluminium)
2) AEA21 Copper-plated front-plate - Not handled here --> QMR
3) AEM21 Mirror (RSA-905 Aluminium)
4) AEM21 Copper-plated front plate.
5) Copper thermal straps

Calculation for long-pulse video endoscopes (QRT) RSA905 mirrors performed by J. Fellinger:

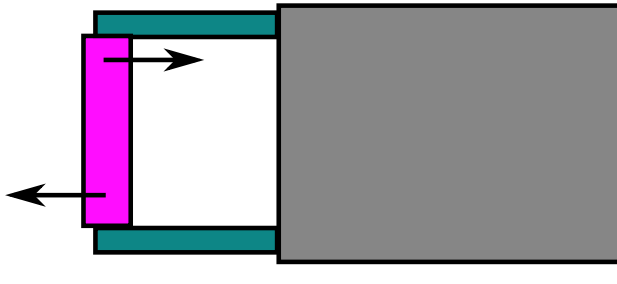
[1-QRT02-T0017.0, J. Fellinger, "Impact of fast plasma decay on front mirrors of AEA endoscopes"]



- Worst case scenario of vectors --> 600N
- QSK mirrors are smaller, and F ~ r^2 (or r^3)
  (120 x 60mm or ⌀=120mm)

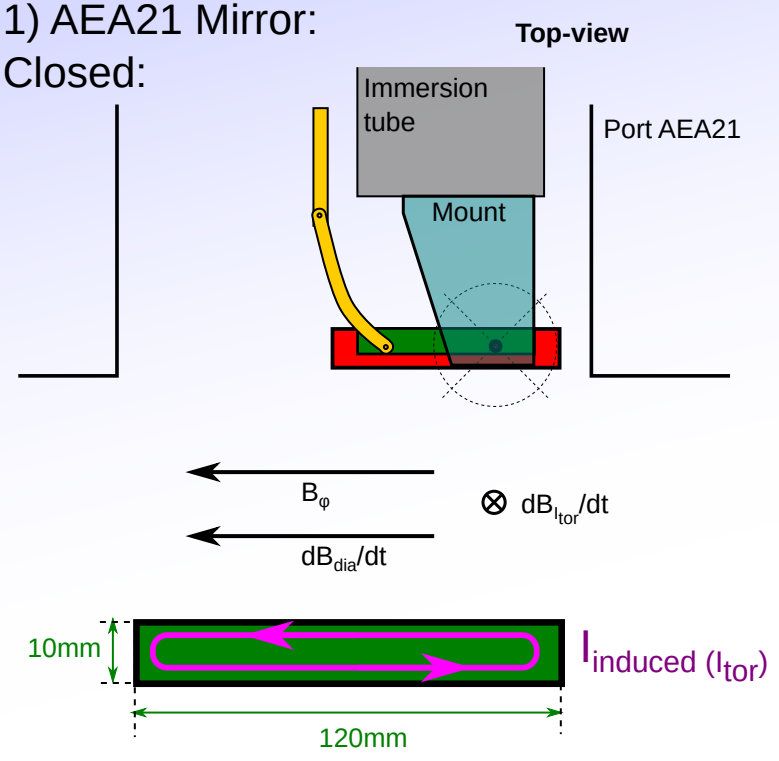
- 600N force acceptable on each mount.
  --> Should be OK regardless of QSK details.

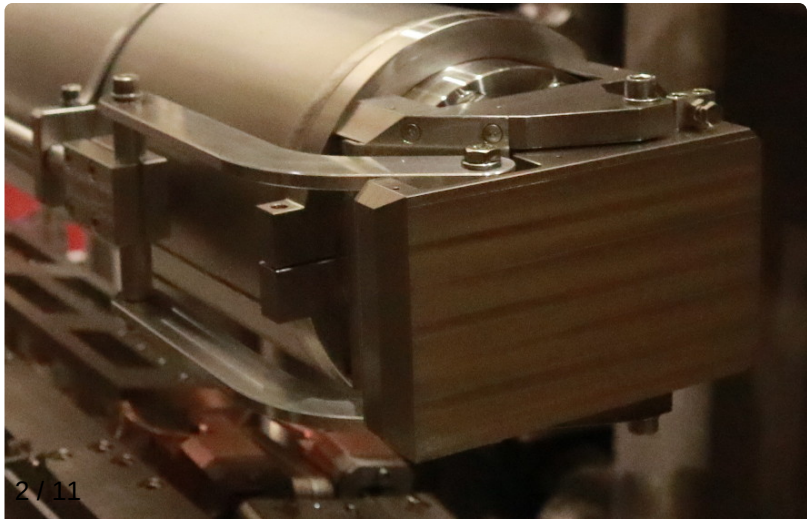
- Effect is always a twisting moment or stretch/compression of material.
  --> No net force on immersion tube.

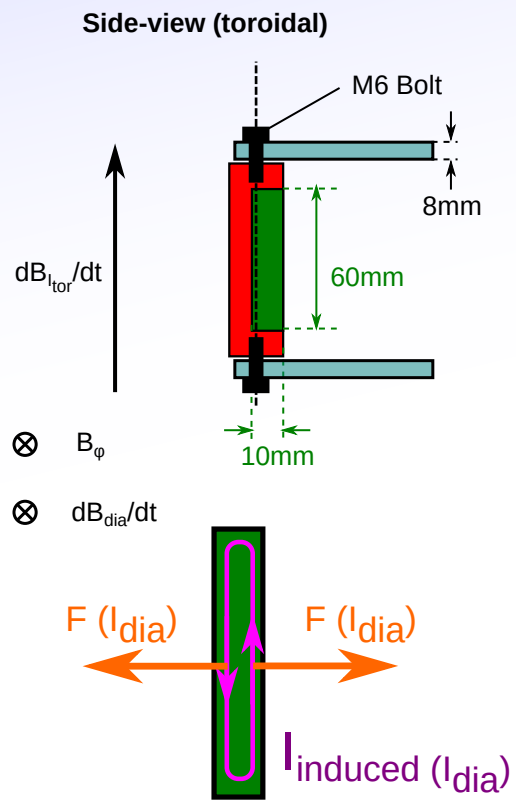


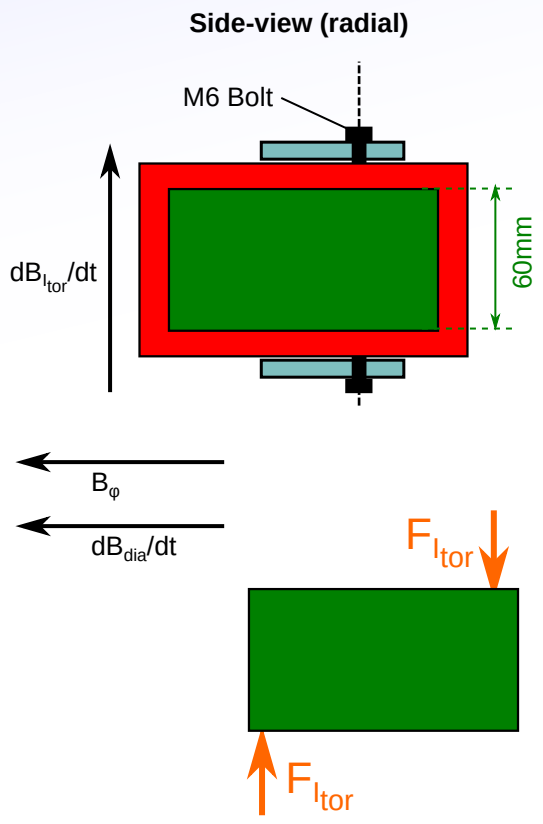
Forces due to fast current shutdown

1) AEA21 Mirror:
Closed:









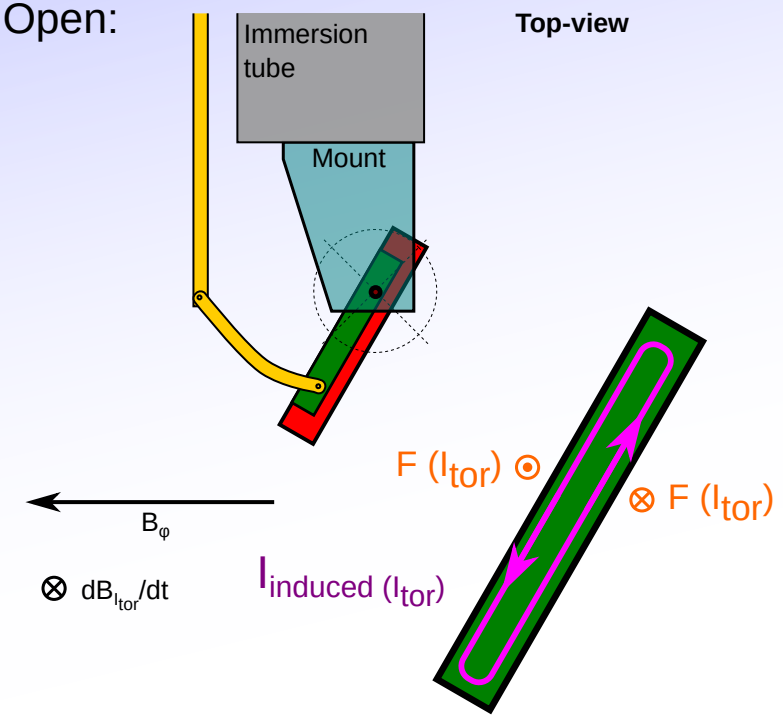
Itor changes:
- Negligible induction area: 120mm x 10mm
- j x B force rotates mirror in plane against two M6 bolts in 8mm thick steel mounts.

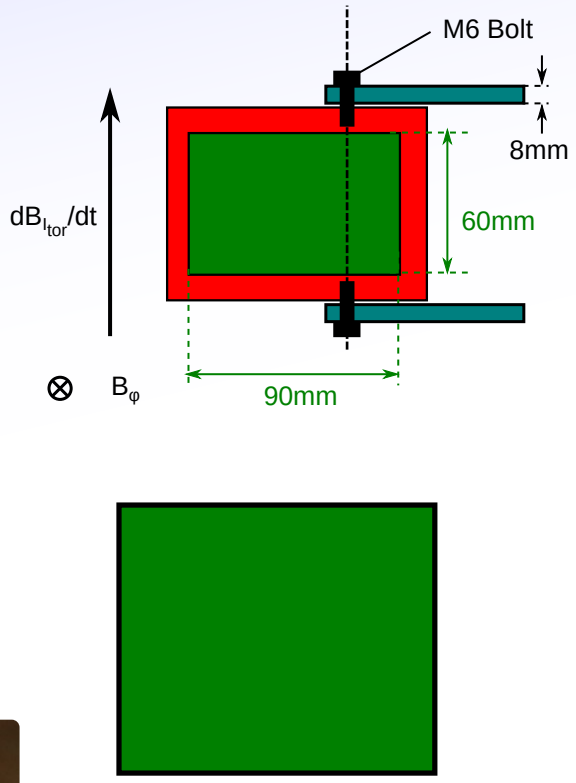
Idia changes:
- Negligible induction area: 60mm x 10mm
- j x B force act outwards on mirror --> no rotation

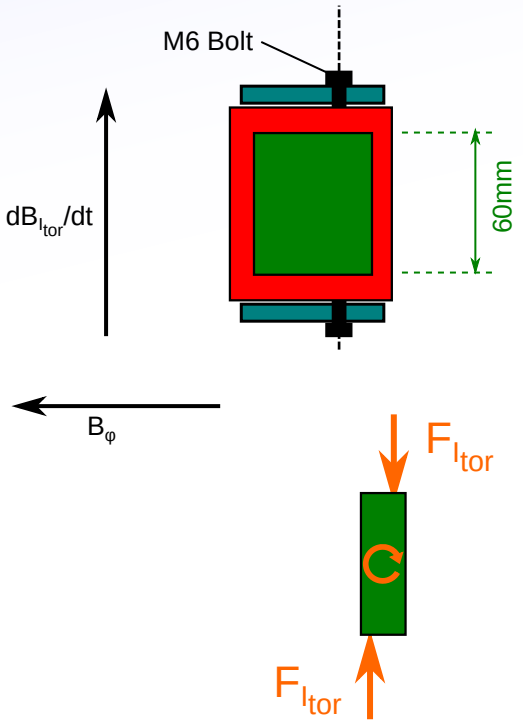
--> No conceivable mechanical failure

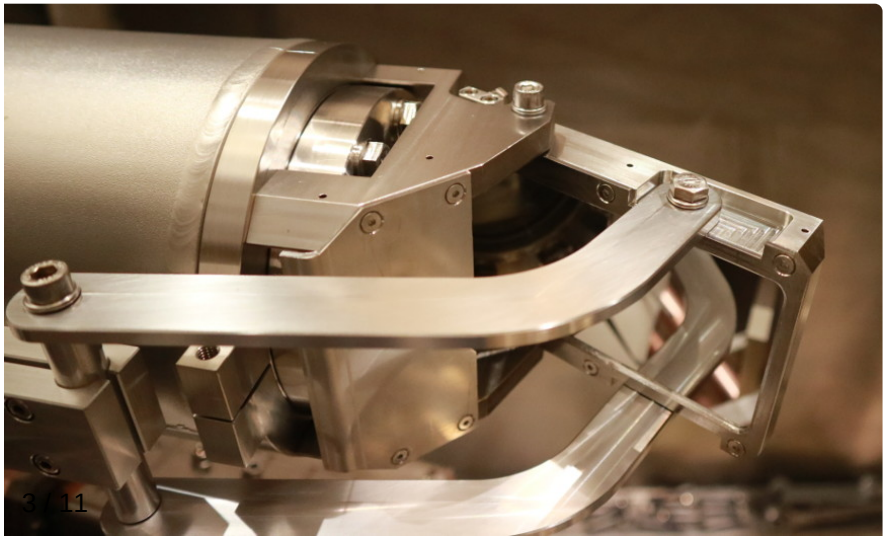
Forces due to fast current shutdown

1) AEA21 Mirror:
Open:





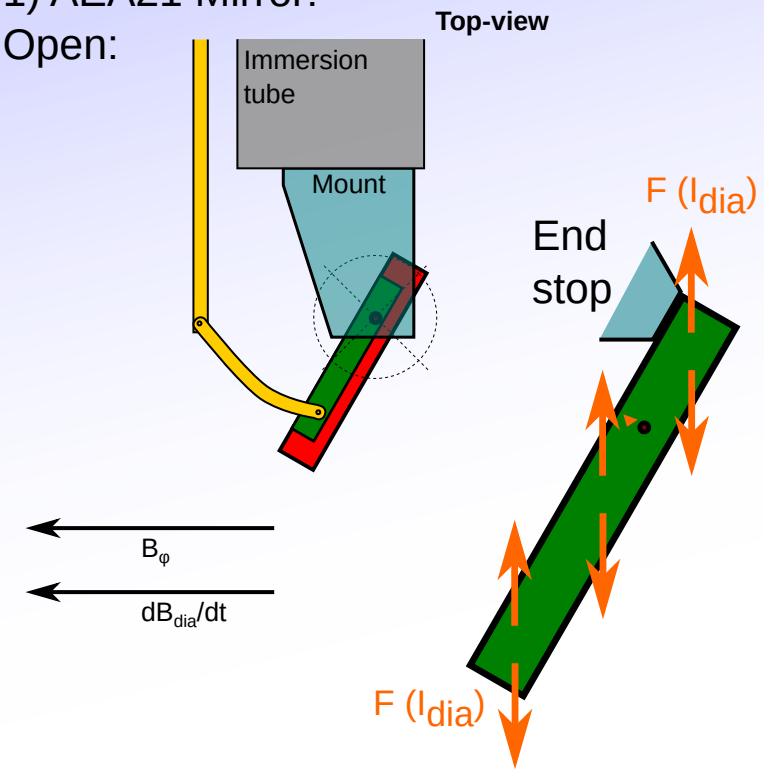


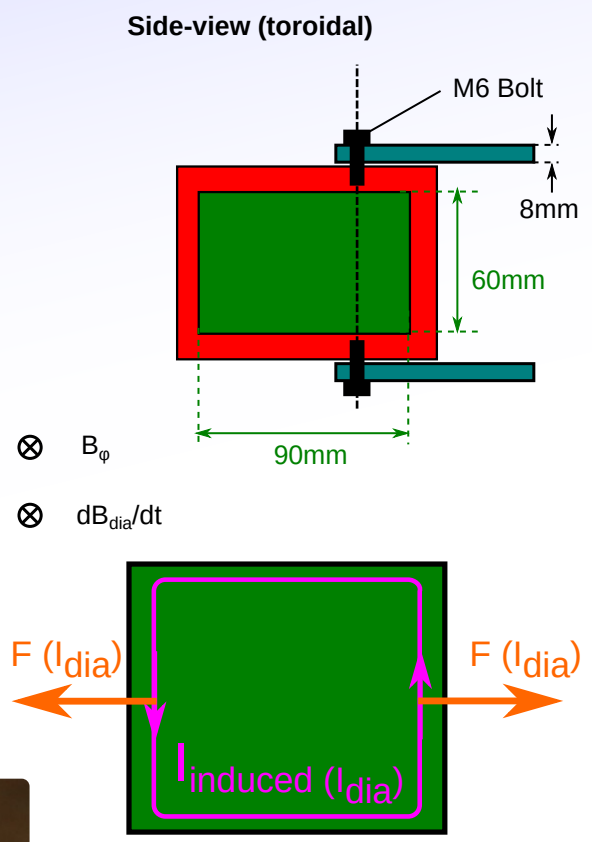


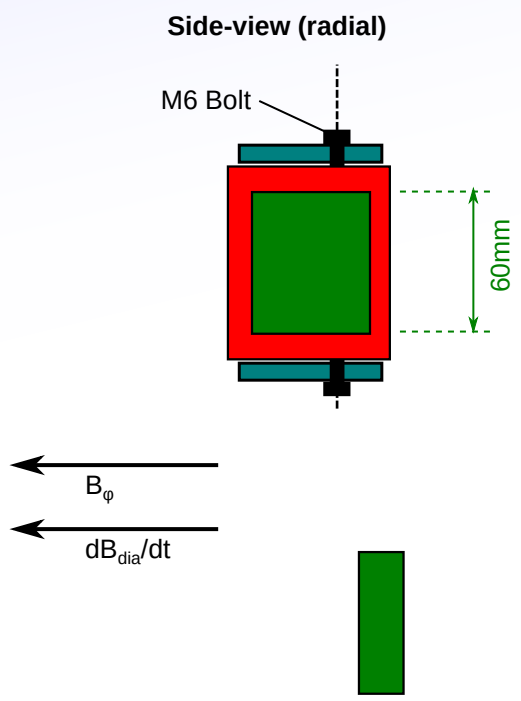
Itor changes:
- Negligible induction area: 120mm x 10mm
- j x B force rotates mirror around horizontal axis against two M6 bolts in 8mm thick steel mounts.

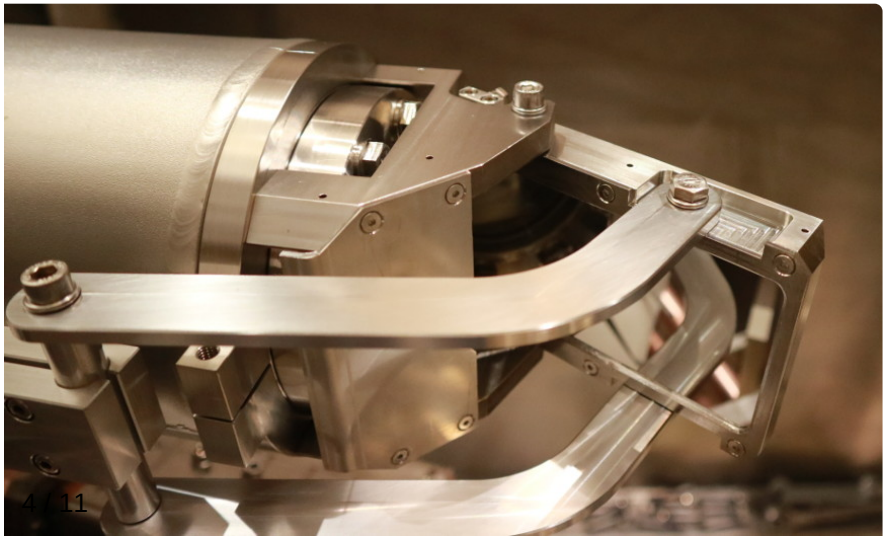
Forces due to fast current shutdown

1) AEA21 Mirror:
Open:









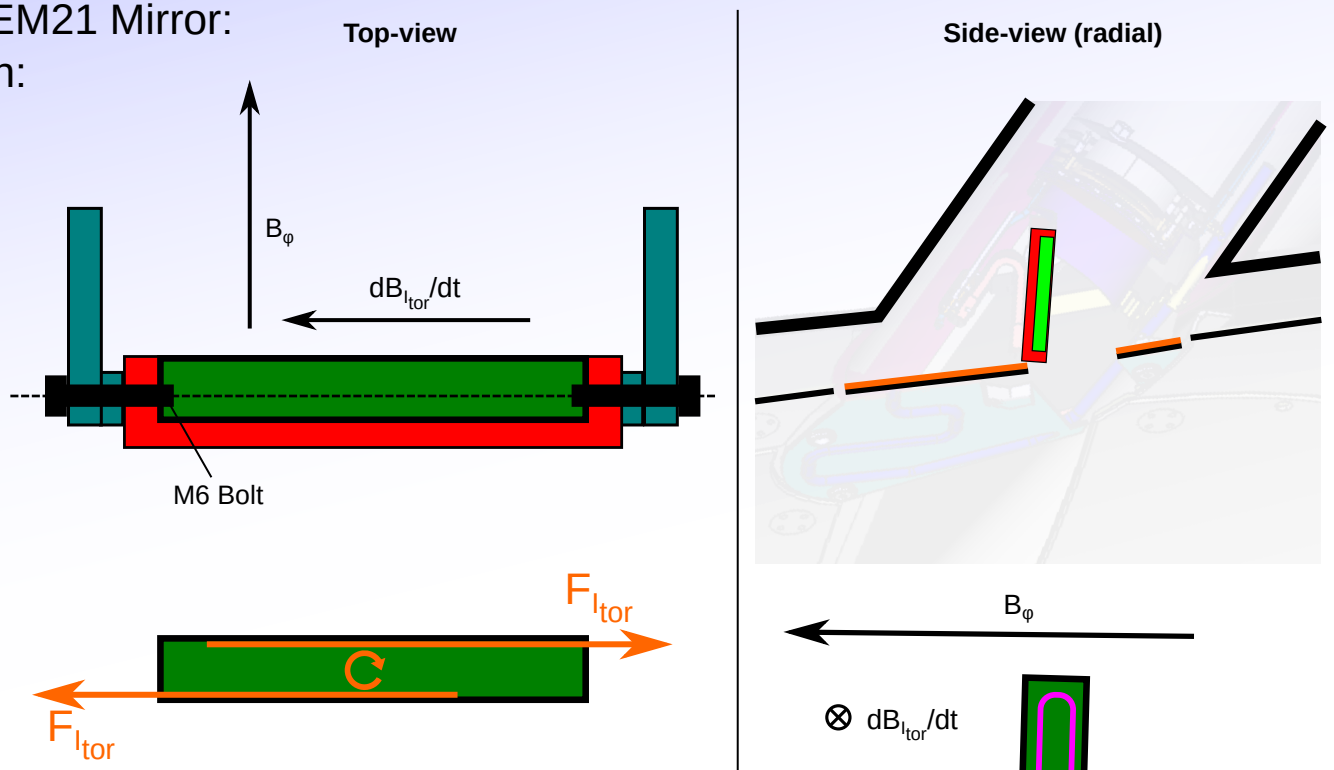
Itor changes:
- Negligible induction area: 120mm x 10mm
- j x B force rotates mirror around horizontal axis against two M6 bolts in 8mm thick steel mounts.

Idia changes:
- Induction area: ~90mm x 60mm
- j x B force act outwards on mirror --> no rotation

--> No conceivable mechanical failure

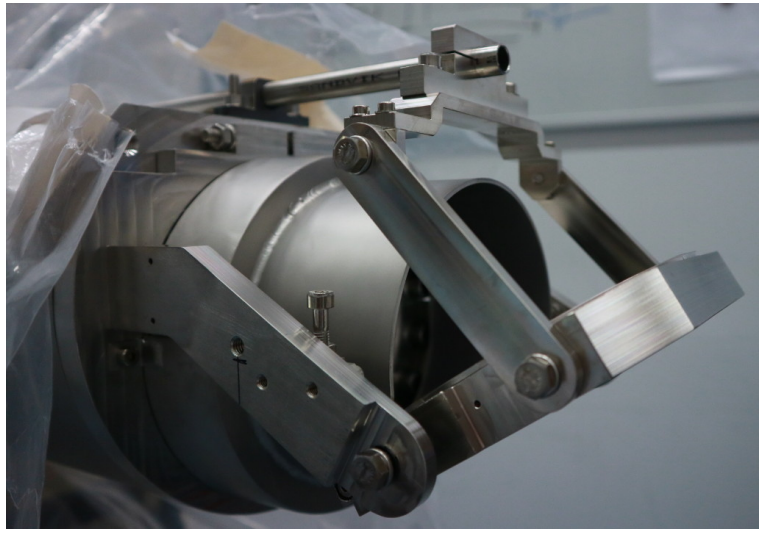
Forces due to fast current shutdown

3) AEM21 Mirror:
Open:



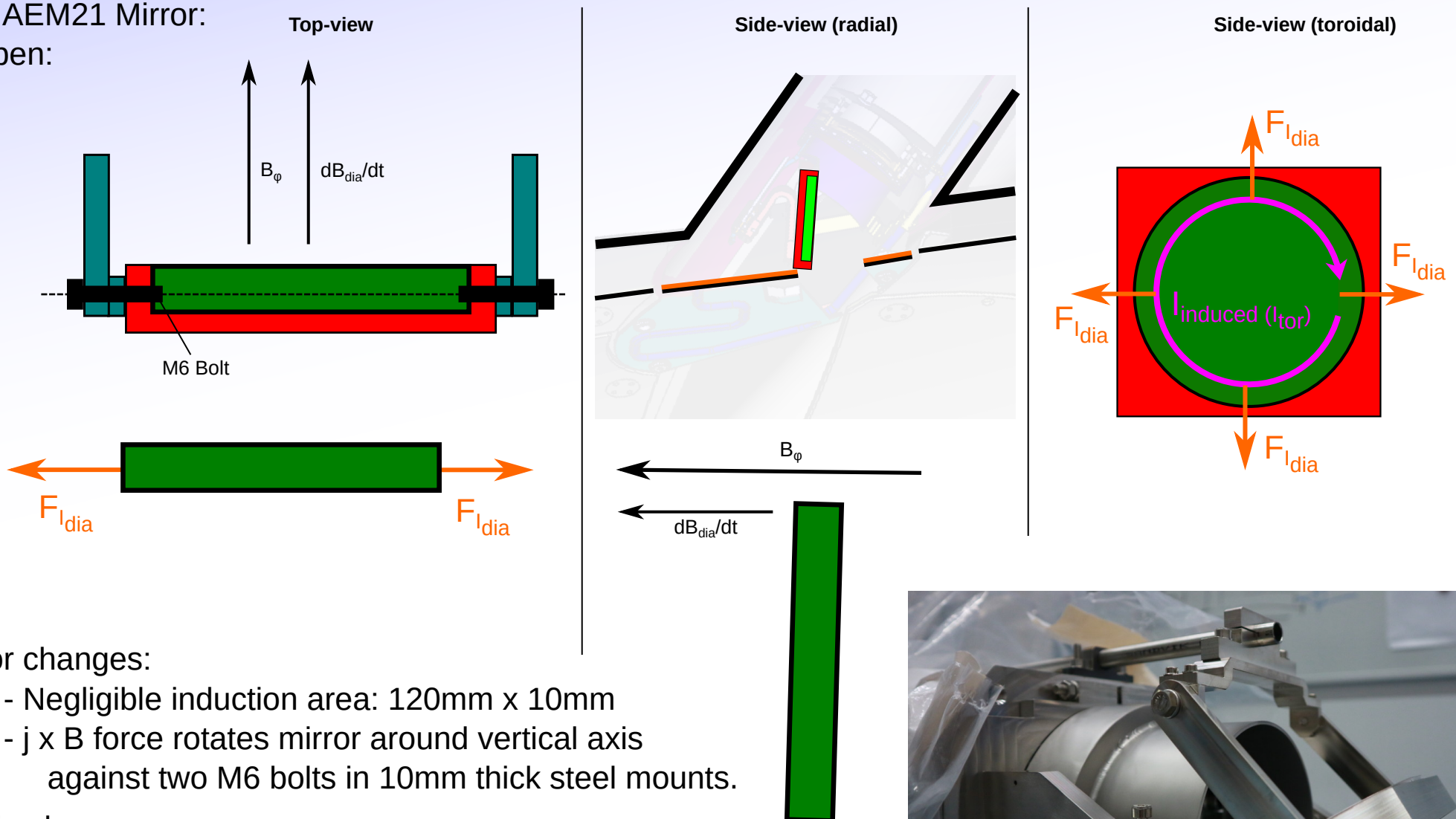
Itor changes:

- Negligible induction area: 120mm x 10mm
- j x B force rotates mirror around vertical axis against two M6 bolts in 5mm thick steel mounts.



Forces due to fast current shutdown

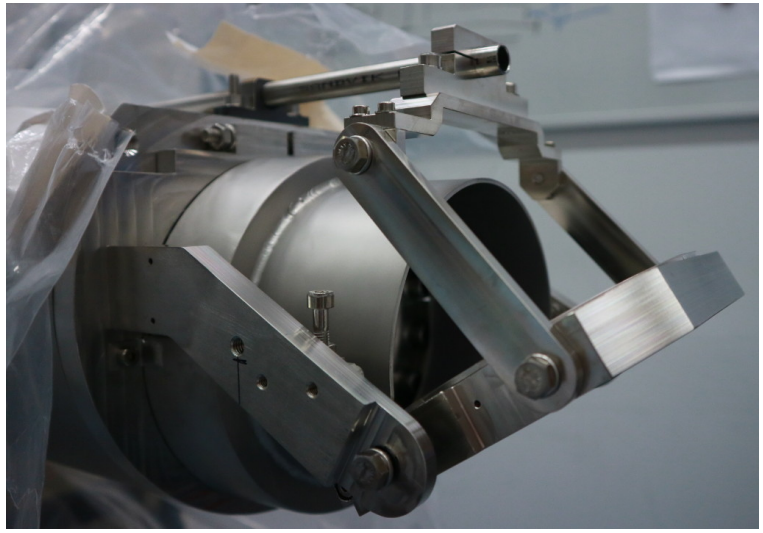
3) AEM21 Mirror:
Open:



Itor changes:
- Negligible induction area: 120mm x 10mm
- j x B force rotates mirror around vertical axis against two M6 bolts in 10mm thick steel mounts.

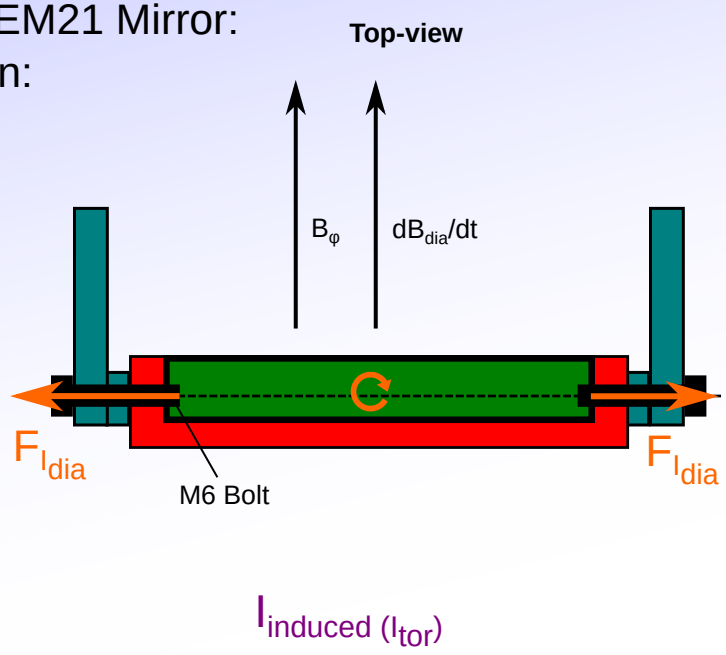
Idia changes:
Negligible induction area: 60mm x 10mm
j x B force act outwards on mirror --> no rotation

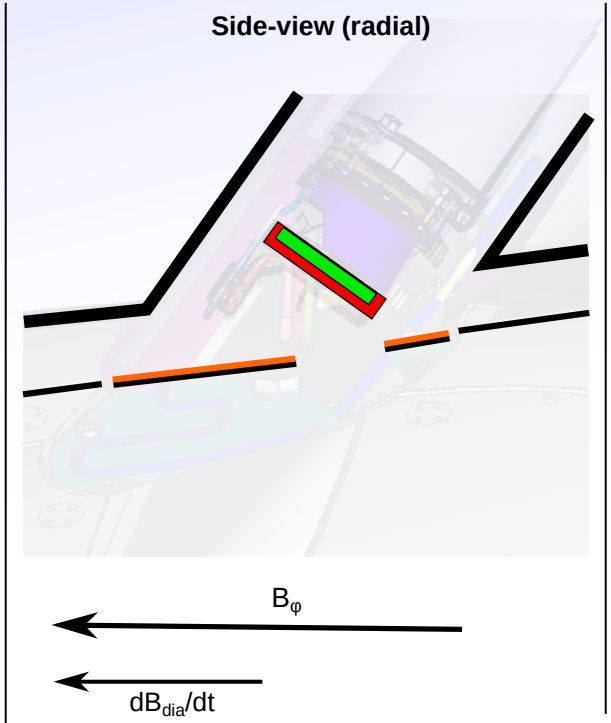
--> ***No conceivable mechanical failure***

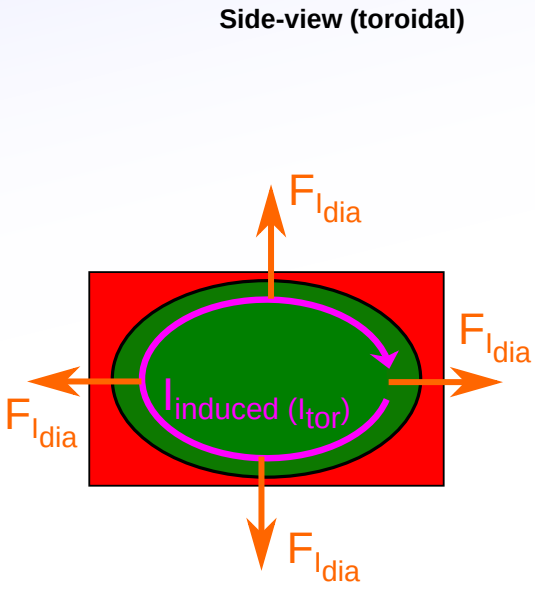


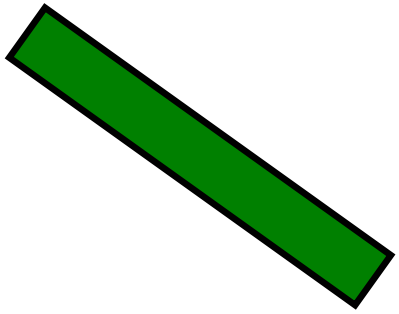
Forces due to fast current shutdown

3) AEM21 Mirror:
Open:







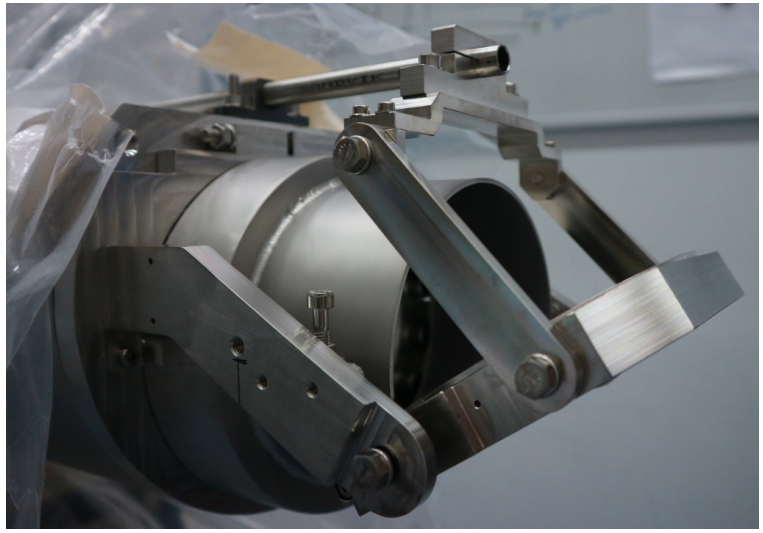


Itor changes:
- As open

Idia changes:
As open, but:
1) less induction area --> less force.
2) Force acts slightly to open mirror.

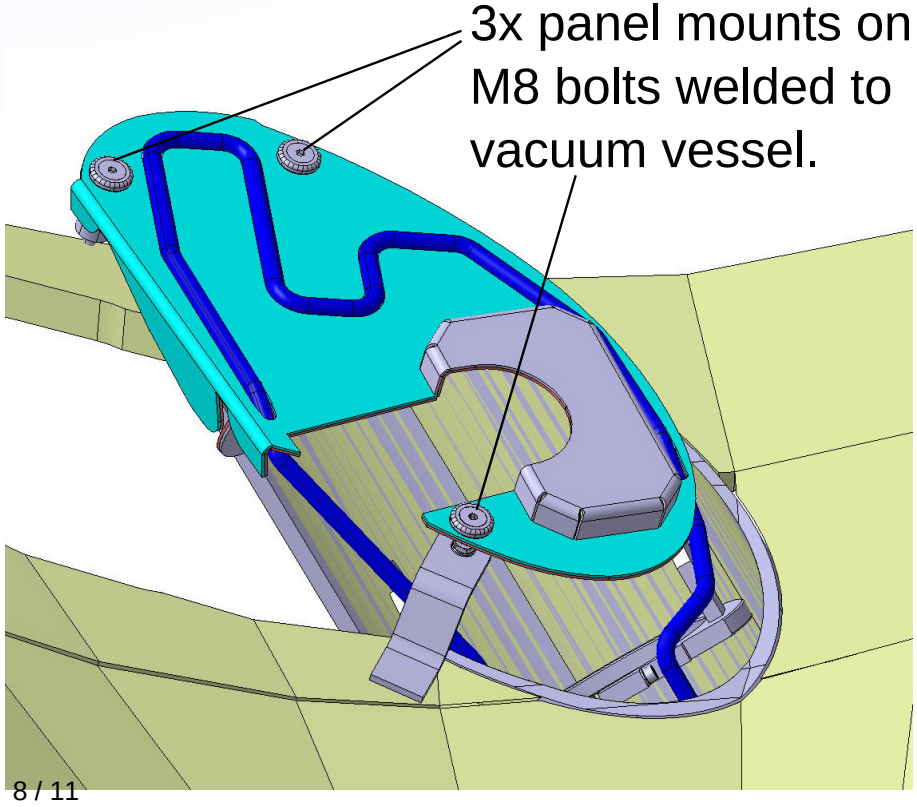
--> No conceivable mechanical failure

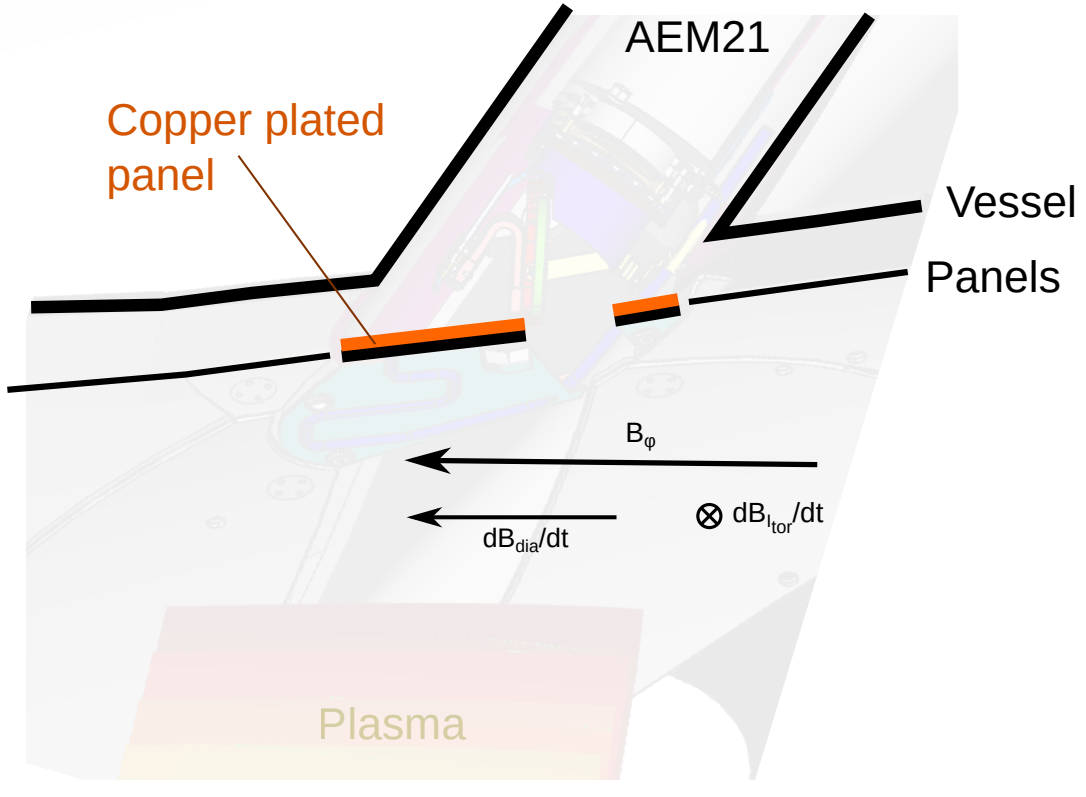
--> Worst case: Shutter opens briefly against pneumatic drive.



Forces due to fast current shutdown

4) AEM21 Panel:
- Copper plated stainless steel panel.
- Follows contour of panels --> dB_{Itor}/dt and dB_{Idia}/dt are both ~parallel to surface.
- Mounted by 3 panel mounts welded to PG.



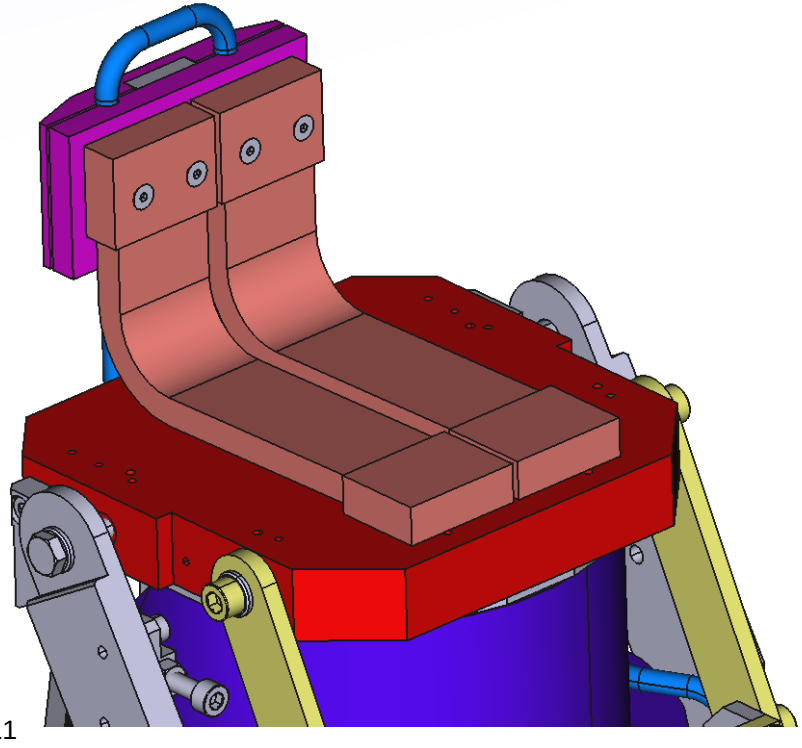


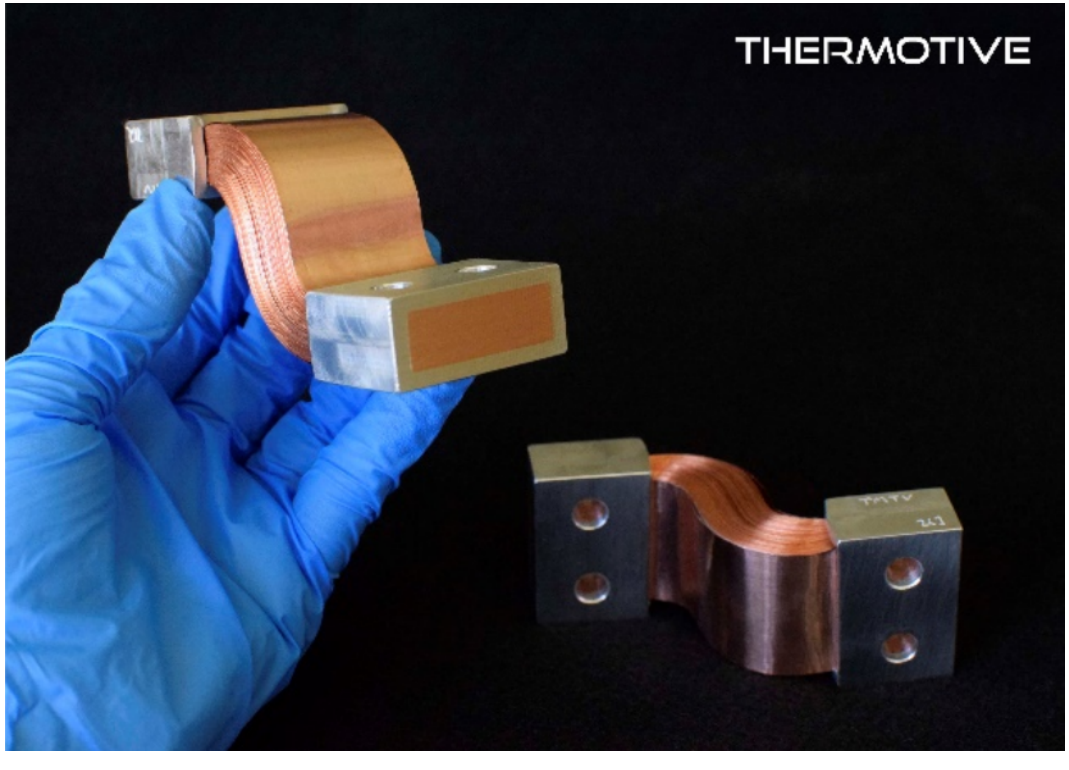
Forces due to fast current shutdown

5) Copper thermal straps:
Two small copper blocks screwed firmly (2x M4+) to shutter or to immersion tube structure:
- Much smaller than previous calculations --> No significant moment transferred to structure.

Many thin (0.2mm) foils of strap:
- Possible movement of flexible foils, but unlikely to result in significant force.

Absolute worst case: Broken foils, reduced cooling that will be detected by thermocouple on shutter.
--> No significant risk





Forces due to fast current shutdown

- Assuming worst case of J. Fellinger calculation, force would be 600N twist on mirror.
- M6 bolts and pivot mounts can withstand worst case 600N.
- No net force on immersion tube as forces are always twisting or stretching.
- Mirrors are always in favourable direction --> Induction area much lower than J.Fellinger calculation.
- No signficant force on AEM21 Panel due to mounting paralell to both fields.
- No expected problems with thermal straps and failure would be detectable and non-destructive.

--> No significant risks