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Target and Dump Proton Beam Imaging Systems CDR
Thermal Heat Load Analysis of First Mirror

	Name	Role/Title
Owner	Maren C. Lithun	Mechanical Engineer
Reviewer	Erik Adli, Cyrille Thomas	Oslo in-kind manager, ESS Imaging System responsible
Approver		

TABLE OF CONTENT **PAGE**

1. SCOPE

The purpose of this document is to provide an overview of the thermal heat load analysis for the first mirror located in the lower part of PBIP (Proton Beam Instrument Plug). The document covers description of the analysis model, boundary conditions and results.

2. INTRODUCTION

In order to choose a suited mount design, a simplified heat load analysis has been run in Autodesk Nastran, to evaluate:

- What temperate will be generated in the mirror and mirror mount, by the heat load.
- How the heat is able to be lead through the mirror, mirror mount and to the PBIP mounting surface, which is cooled down by the water cooling system.
- Mirror deflections caused by the heat load. Deflection values from Nastran will be used to do a further analysis in Zemax software, on how the deflections might affect the beam path.

3. GLOSSARY

See also: https://confluence.esss.lu.se/display/BIG/Abbreviations

4. DOCUMENT REVISION HISTORY

Revision	Reason for and description of change	Author	Date
1	CDR	Maren C. Lithun	2017-10-03

5. HEAT LOAD ANALYSIS - BENDAMOUNT

5.1. FEM Model

The base plate represents the section of the PBIP that the mount is mounted onto. The base plate is constrained with fixed constraint for all surfaces, except from the top surface. There is bonded contact between the mount and base plate, and between the mount and mirror.

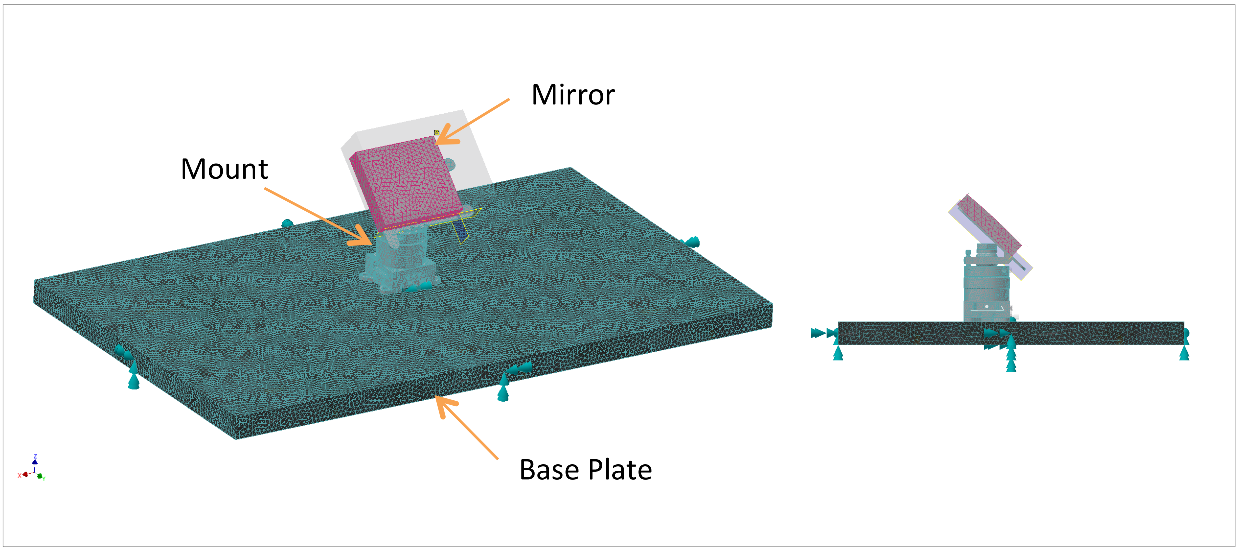


Figure 1: Constraints and contacts

The table below lists the mesh settings

Element Order	Parabolic
Avg. Element Size	0,0226484
Refinement Ratio	0,6
Min Triangle Angle	20 deg
Max Triangle Angle	30 deg
Max Element Growth Rate	1,5

Table 1: Mesh settings

Material Properties

Component	**Material**	**Young's Modulus [GPa]**	**Poisson`s ratio [-]**	**Yield Strength [MPa]**	**Ultimate Tensile Strength [MPa]**
Mirror	Aluminium 6061	68.9	0.33	276	310
Base Plate	Stainless Steel	193	0.30	250	540

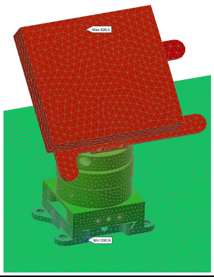
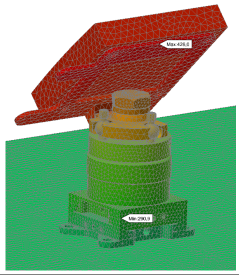
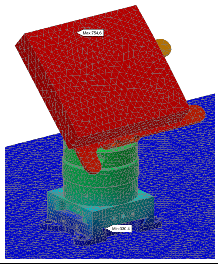
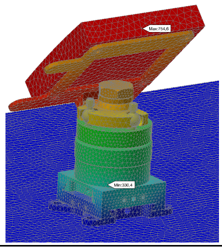
Table 2: Material Properties

The table below lists boundary conditions, including any relevant comments

Type of boundary condition	**Value**	**Comment**
Initial temperature of mirror and mount.	308 K (35 C)	Same boundary condition as used for PBIP thermal analysis. (Thermal deformation of the PBIP, 3rd March 2016).
Base plate temperature	333 K (60 C)	This value is taken from the old analysis: Thermal deformation of the PBIP, 3rd March 2016. Value should be updated according to new result.
Convection from mirror and mount, to surrounding gas/vacuum	0,5 W/m^2K	With specified ambient temp 308 K (35 C)
Heat radiation emissivity for Aluminium	0,05	With specified ambient temp 308 K (35 C)
Heat radiation emissivity for Steel	0,1	With specified ambient temp 308 K (35 C)

Table 3: Boundary conditions

5.2. Load cases and Results

Type of result plot	Load case	Result	Figure
Thermal	21600 W/m^3 heat load Steel Mount	Temperature of mirror is 426 K / 153˚C	 
	4 x 10^5 W/m^3 heat load Steel Mount	Temperature of mirror is 755 K / 482˚C	 

5.3. Discussion

The temperature in mirror is very high. The main reason for this is the small contact surface between the mirror mount`s components.

It has been decided to model a simpler mount, to get larger surface contact between the components.

In addition, we will check the difference in temperature and deflection plots for two mirror mount materials; Steel and Aluminium.

6. HEAT LOAD ANALYSIS – SIMPLIFIED MOUNT

6.1. FEM Model

The base plate represents the section of the PBIP that the mount is mounted onto. The base plate is constrained with fixed constraint for all surfaces, except from the top surface. There is bonded contact between the mount and base plate, and between the mount and mirror.

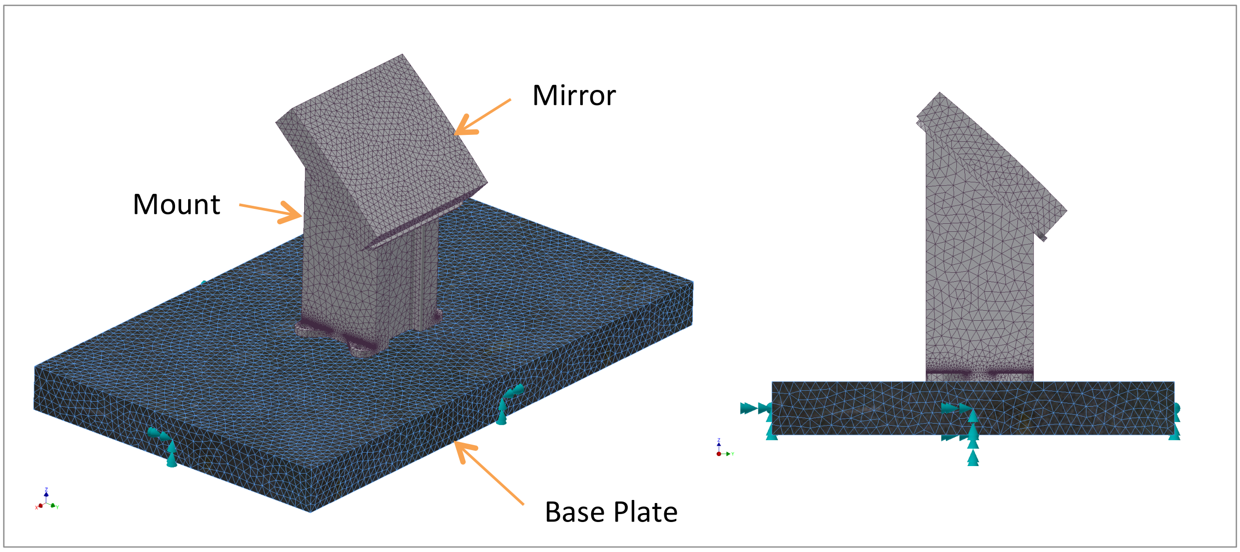


Figure 2: Constraints and contacts

The table below lists the mesh settings

Element Order	Parabolic
Avg. Element Size	0,0119519
Refinement Ratio	0,6
Min Triangle Angle	20 deg
Max Triangle Angle	30 deg
Max Element Growth Rate	1,5

Table 4: Mesh settings

Material Properties

Component	**Material**	**Young's Modulus [GPa]**	**Poisson`s ratio [-]**	**Yield Strength [MPa]**	**Ultimate Tensile Strength [MPa]**
Mirror	Aluminium 6061	68.9	0.33	276	310
Base Plate	Stainless Steel	193	0.30	250	540

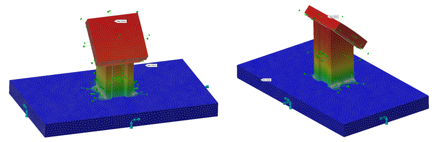
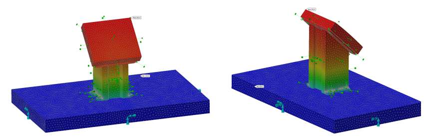
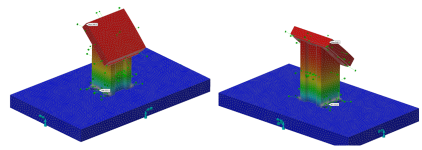
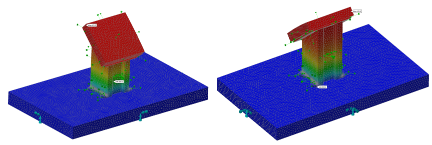
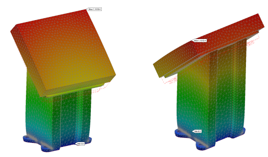
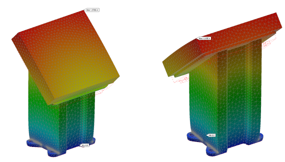
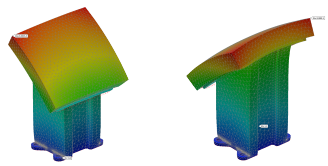
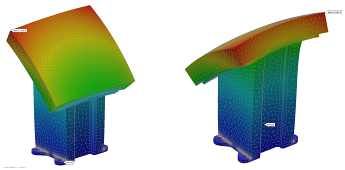
Table 5: Material Properties

The table below lists boundary conditions, including any relevant comments

Type of boundary condition	**Value**	**Comment**
Initial temperature of mirror and mount.	308 K (35 C)	Same boundary condition as used for PBIP thermal analysis. (Thermal deformation of the PBIP, 3rd March 2016).
Base plate temperature	333 K (60 C)	This value is taken from the old analysis: Thermal deformation of the PBIP, 3rd March 2016. Value should be updated according to new result.
Convection from mirror and mount, to surrounding gas/vacuum	0,5 W/m^2K	With specified ambient temp 308 K (35 C)
Heat radiation emmisivity for Aluminium	0,05	With specified ambient temp 308 K (35 C)
Heat radiation emmisivity for Steel	0,1	With specified ambient temp 308 K (35 C)

Table 6: Boundary conditions

6.2. Load cases and Results

Type of result plot	Load case	Result	Figure
Thermal	21600 W/m^3 heat load Aluminium Mount	Temperature of mirror is 334 K / 61˚C	
	4 x 10^5 W/m^3 heat load Aluminium Mount	Temperature of mirror is 353 K / 80˚C	
	21600 W/m^3 heat load Steel Mount	Temperature of mirror is 340 K / 67˚C	
	4 x 10^5 W/m^3 heat load Steel Mount	Temperature of mirror is 476 K / 203˚C	
Deflection	21600 W/m^3 heat load Aluminium Mount (B_SIMPLE_24Aug)	Displacement 1,161 x 10^{-4} m	
	4 x 10^5 W/m^3 heat load Aluminium Mount (B_SIMPLE_24Aug)	Displacement 1,578 x 10^{-4} m	
	21600 W/m^3 heat load Steel Mount (B_SIMPLE_28June_test)	Displacement 8,586 x 10^{-5} m	
	4 x 10^5 W/m^3 heat load Steel Mount (B_SIMPLE_28June_test)	Displacement 3,175 x 10^{-4} m	

6.3. Discussion

Mirror temperatures are much lower, compared to the previous mirror mount design. It has been reduced with about 86˚C for the average heat load of 21600 W/m^3, and with about 280˚C for the max heat load of 4 x 10^5 W/m^3.

The mirror temperature is lower for aluminium mount, compared to steel mount. The difference is very high for the max heat load of 4 x 10^5 W/m^3.

Comparing deflections for the two mirror mount materials, shows that deflections are smallest for Steel Mount for the average heat load of 21600 W/m^3, but largest for the max heat load of 4 x 10^5 W/m^3.

For the further heat simulation analysis, mount height will be reduced, to see what effect this has on mirror temperature and deflections.

7. HEAT LOAD ANALYSIS – LOW MOUNT

7.1. FEM Model

The base plate represents the section of the PBIP that the Mount is mounted onto. The base plate is constrained with fixed constraint for all surfaces, except from the top surface. There is bonded contact between the mount and base plate, and between the mount and mirror.

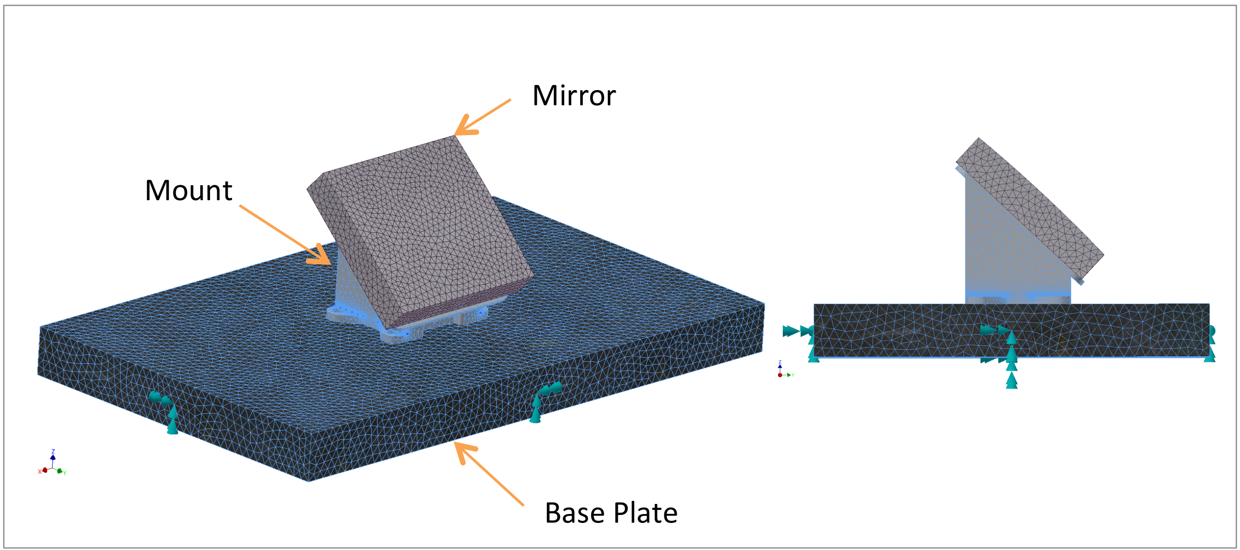


Figure 3: Constraints and contacts

The table below lists the mesh settings

Element Order	Parabolic
Avg. Element Size	0,0113754
Refinement Ratio	0,6
Min Triangle Angle	20 deg
Max Triangle Angle	30 deg
Max Element Growth Rate	1,5

Table 7: Mesh settings

Material Properties

Component	Material	Young's Modulus [GPa]	Poisson`s ratio [-]	Yield Strength [MPa]	Ultimate Tensile Strength [MPa]
Mirror	Aluminium 6061	68.9	0.33	276	310
Base Plate	Stainless Steel	193	0.30	250	540

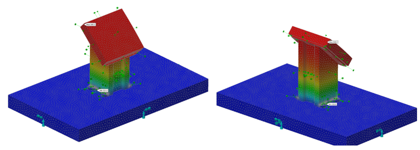
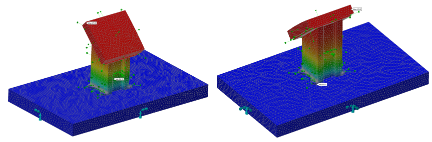
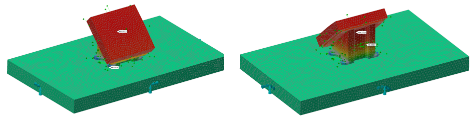
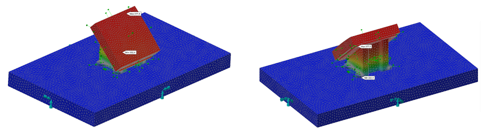
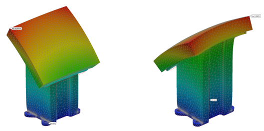
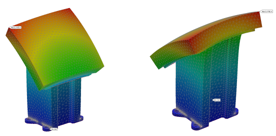
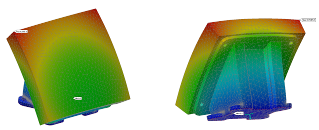
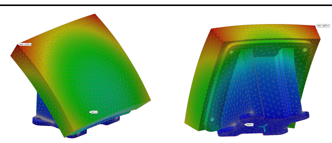
Table 8: Material Properties

The table below lists boundary conditions, including any relevant comments

Type of boundary condition	Value	Comment
Initial temperature of mirror and mount.	308 K (35 C)	Same boundary condition as used for PBIP thermal analysis. (Thermal deformation of the PBIP, 3rd March 2016).
Base plate temperature	333 K (60 C)	This value is taken from the old analysis: Thermal deformation of the PBIP, 3rd March 2016. Value should be updated according to new result.
Convection from mirror and mount, to surrounding gas/vacuum	0,5 W/m^2K	With specified ambient temp 308 K (35 C)
Heat radiation emissivity for Aluminium	0,05	With specified ambient temp 308 K (35 C)
Heat radiation emissivity for Steel	0,1	With specified ambient temp 308 K (35 C)

Table 9: Boundary conditions

7.2. Load cases and Results

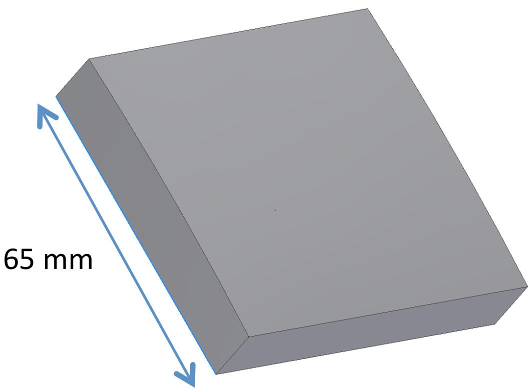
Type of result plot	Load case	Result	Figure
Thermal	21600 W/m^3 heat load Steel Mount	Temperature of mirror is 340 K / 67˚C	
	4 x 10^5 W/m^3 heat load Steel Mount	Temperature of mirror is 476 K / 203˚C	
	21600 W/m^3 heat load Short Steel Mount	Temperature of mirror is 334 K / 61˚C	
	4 x 10^5 W/m^3 heat load Short Steel Mount	Temperature of mirror is 378 K / 105˚C	
Deflection	21600 W/m^3 heat load Steel Mount	Displacement 8,586 x 10^{-5} m	
	4 x 10^5 W/m^3 heat load Steel Mount	Displacement 3,175 x 10^{-4} m	
	21600 W/m^3 heat load Short Steel Mount	Displacement 6,703 x 10^{-5} m	
	4 x 10^5 W/m^3 heat load Short Steel Mount	Displacement 1,567 x 10^{-4} m	

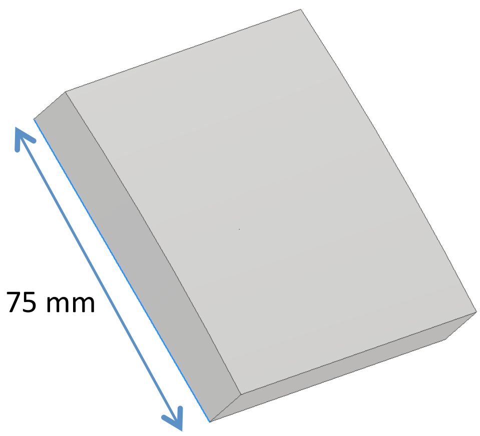
7.3. Discussion

Mirror temperatures are lower, compared to the taller mirror mount design. It has been reduced with about 6˚C for the average heat load of 21600 W/m^3, and with about 90˚C for the max heat load of 4 x 10^5 W/m^3.

Comparing deflections for the two mirror mount materials, shows that deflections are smaller for the short mount design. For the max heat load of 4 x 10^5 W/m^3, the deflection for short mount is about half that of the tall mount.

For the further heat simulation analysis, a new larger mirror will be included in the low mount simulation model.





8. HEAT LOAD ANALYSIS – LARGER MIRROR

8.1. FEM Model

The base plate represents the section of the PBIP that the Mount is mounted onto. The base plate is constrained with fixed constraint for all surfaces, except from the top surface. There is bonded contact between the mount and base plate, and between the mount and mirror.

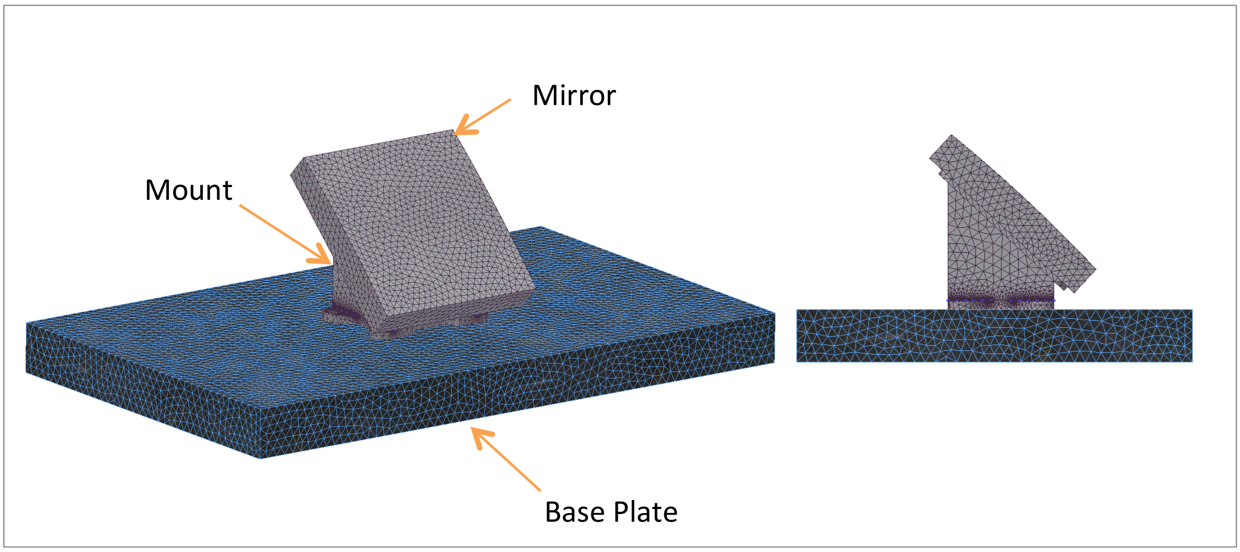


Figure 4: Constraints and contacts

The table below lists the mesh settings

Element Order	Parabolic
Avg. Element Size	0,0114113
Refinement Ratio	0,6
Min Triangle Angle	20 deg
Max Triangle Angle	30 deg
Max Element Growth Rate	1,5

Table 10: Mesh settings

Material Properties

Component	Material	Young's Modulus [GPa]	Poisson`s ratio [-]	Yield Strength [MPa]	Ultimate Tensile Strength [MPa]
Mirror	Aluminium 6061	68.9	0.33	276	310
Base Plate	Stainless Steel	193	0.30	250	540

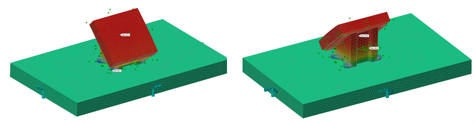
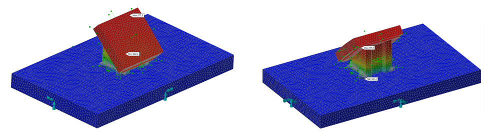
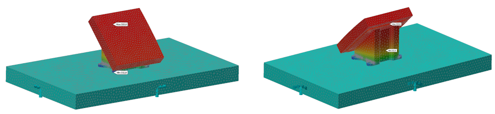
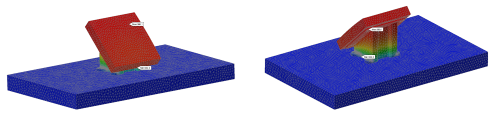
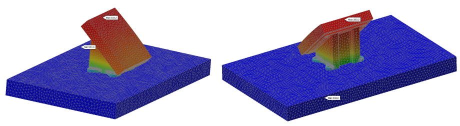
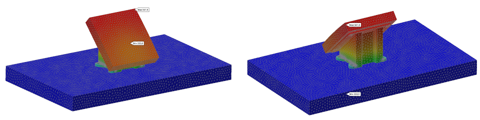
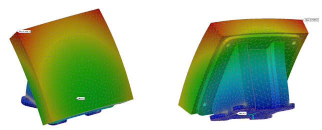
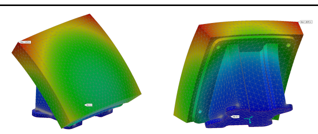
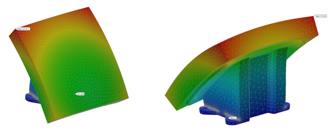
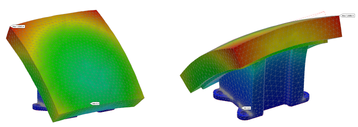
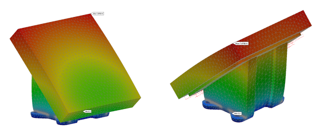
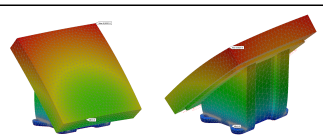
Table 11: Material Properties

The table below lists boundary conditions, including any relevant comments

Type of boundary condition	Value	Comment
Initial temperature of mirror and mount.	308 K (35 C)	Same boundary condition as used for PBIP thermal analysis. (Thermal deformation of the PBIP, 3rd March 2016).
Base plate temperature	333 K (60 C)	This value is taken from the old analysis: Thermal deformation of the PBIP, 3rd March 2016. Value should be updated according to new result.
Convection from mirror and mount, to surrounding gas/vacuum	0,5 W/m^2K	With specified ambient temp 308 K (35 C)
Heat radiation emissivity for Aluminium	0,05	With specified ambient temp 308 K (35 C)
Heat radiation emissivity for Steel	0,1	With specified ambient temp 308 K (35 C)

Table 12: Boundary conditions

8.2. Load cases and Results

Type of result plot	Load case	Result	Figure
Thermal	$21600\ W/m^3$ heat load Short Steel Mount	Temperature of mirror is 334 K / 61˚C	
	$4 \times 10^5\ W/m^3$ heat load Short Steel Mount	Temperature of mirror is 378 K / 105˚C	
	$21600\ W/m^3$ heat load Short Steel Mount – Large Mirror	Temperature of mirror is 334 K / 61˚C	
	$4 \times 10^5\ W/m^3$ heat load Short Steel Mount – Large Mirror	Temperature of mirror is 380 K / 107˚C	
	$21600\ W/m^3$ heat load Short Al Mount – Large Mirror	Temperature of mirror is 333 K / 60˚C	
	$4 \times 10^5\ W/m^3$ heat load Short Al Mount – Large Mirror	Temperature of mirror is 342 K / 69˚C	
Deflection	$21600\ W/m^3$ heat load Short Steel Mount	Displacement $6{,}703 \times 10^{-5}$ m	
	$4 \times 10^5\ W/m^3$ heat load Short Steel Mount	Displacement $1{,}567 \times 10^{-4}$ m	
	$21600\ W/m^3$ heat load Short Steel Mount – Large Mirror	Displacement $7{,}211 \times 10^{-5}$ m	
	$4 \times 10^5\ W/m^3$ heat load Short Steel Mount – Large Mirror	Displacement $1{,}558 \times 10^{-4}$ m	
	$21600\ W/m^3$ heat load Short Al Mount – Large Mirror	Displacement $7{,}876 \times 10^{-5}$ m	
	$4 \times 10^5\ W/m^3$ heat load Short Al Mount – Large Mirror	Displacement $8{,}582 \times 10^{-5}$ m	

8.3. Discussion

For the average heat load of 21600 W/m^3, the mirror temperature is at the same level for old and new mirror design. For the max heat load of 4 x 10^5 W/m^3, the temperature is about the same for large mirror on steel mount. Temperature of large mirror on aluminium mount is about 38˚C lower, compared to large mirror on steel mount.

Comparing deflections for the two mirror designs, shows that deflections are slightly larger for large mirror, when applying average heat load of 21600 W/m^3. For the max heat load of 4 x 10^5 W/m^3, the deflections are approximately the same for large and small mirror.

Comparing large mirror mount on steel mount and large mirror mount on aluminum mount, the deflections are highest for the aluminium mount when applying average heat load of 21600 W/m^3. For the max heat load of 4 x 10^5 W/m^3, large mirror, the deflections are 8,582 x 10^{-5}m lower for the aluminium, compared to steel mount.

9. HEAT LOAD ANALYSIS – STRAIGHT MOUNT

9.1. FEM Model

The base plate represents the section of the PBIP that the Mount is mounted onto. The base plate is constrained with fixed constraint for all surfaces, except from the top surface. There is bonded contact between the mount and base plate, and between the mount and mirror.

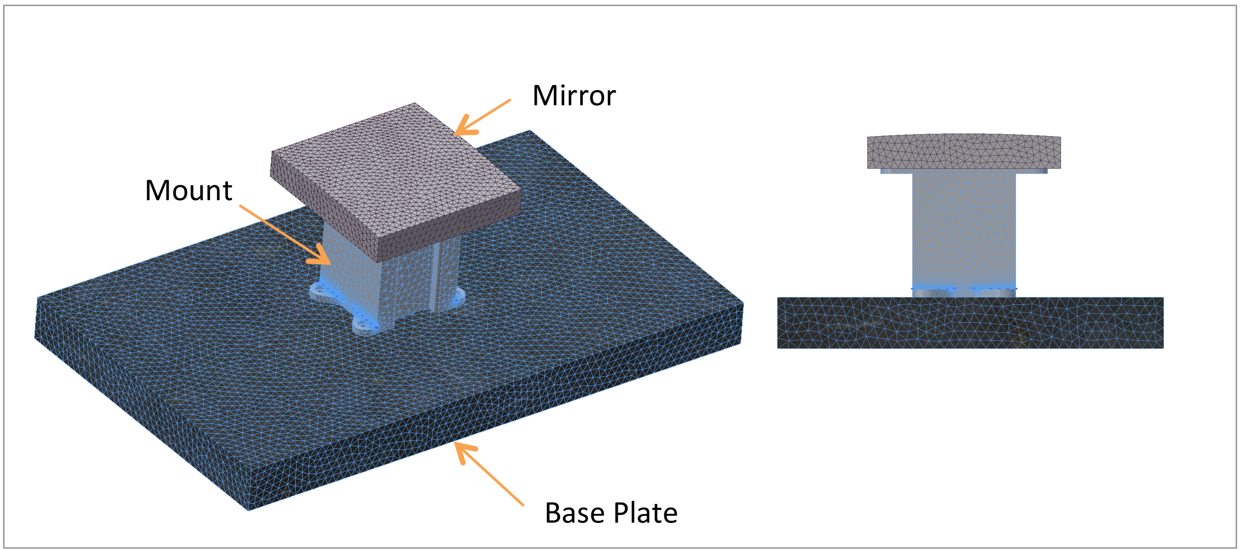


Figure 5: Constraints and contacts

The table below lists the mesh settings

Element Order	Parabolic
Avg. Element Size	0,0113714
Refinement Ratio	0,6
Min Triangle Angle	20 deg
Max Triangle Angle	30 deg
Max Element Growth Rate	1,5

Table 13: Mesh settings

Material Properties

Component	Material	Young's Modulus [GPa]	Poisson`s ratio [-]	Yield Strength [MPa]	Ultimate Tensile Strength [MPa]
Mirror	Aluminium 6061	68.9	0.33	276	310
Base Plate	Stainless Steel	193	0.30	250	540

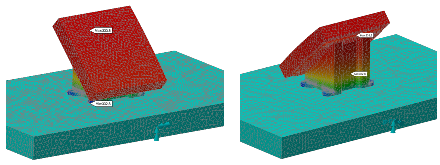
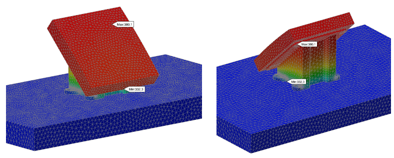
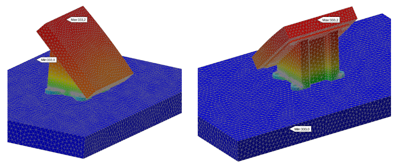
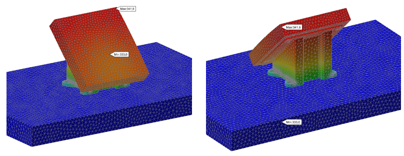
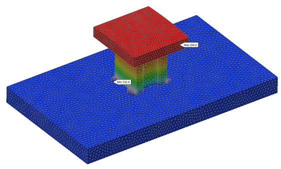
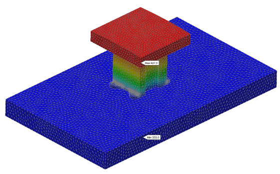
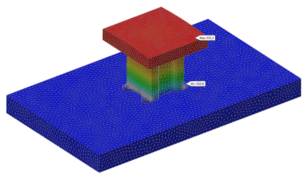
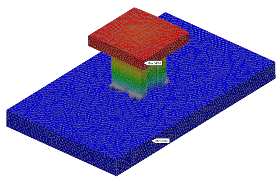
Table 14: Material Properties

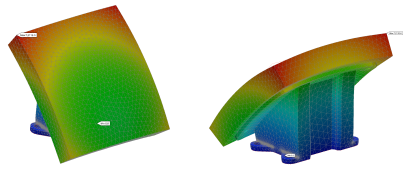
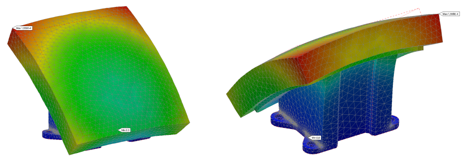
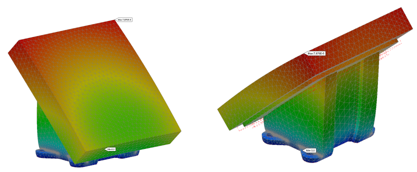
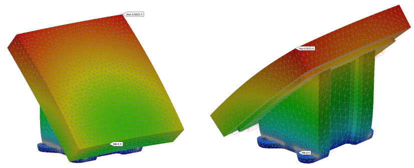
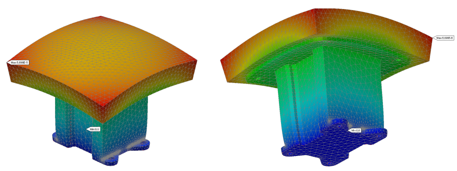
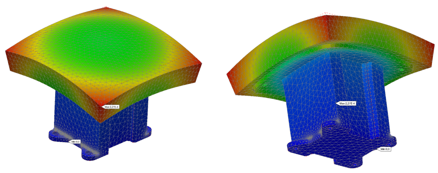
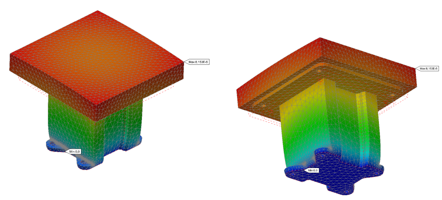
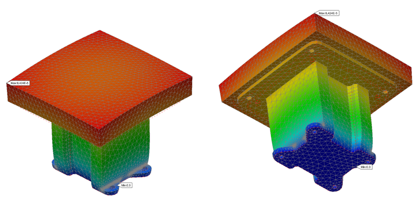
The table below lists boundary conditions, including any relevant comments

Type of boundary condition	Value	Comment
Initial temperature of mirror and mount.	308 K (35 C)	Same boundary condition as used for PBIP thermal analysis. (Thermal deformation of the PBIP, 3rd March 2016).
Base plate temperature	333 K (60 C)	This value is taken from the old analysis: Thermal deformation of the PBIP, 3rd March 2016. Value should be updated according to new result.
Convection from mirror and mount, to surrounding gas/vacuum	0,5 W/m^2K	With specified ambient temp 308 K (35 C)
Heat radiation emissivity for Aluminium	0,05	With specified ambient temp 308 K (35 C)
Heat radiation emissivity for Steel	0,1	With specified ambient temp 308 K (35 C)

Table 15: Boundary conditions

9.2. Load cases and Results

Type of result plot	Load case	Result	Figure
Thermal	21600 W/m^3 heat load Short Steel Mount – Large Mirror	Temperature of mirror is 334 K / 61˚C	
	4×10^5 W/m^3 heat load Short Steel Mount – Large Mirror	Temperature of mirror is 380 K / 107˚C	
	21600 W/m^3 heat load Short Al Mount – Large Mirror	Temperature of mirror is 333 K / 60˚C	
	4×10^5 W/m^3 heat load Short Al Mount – Large Mirror	Temperature of mirror is 342 K / 69˚C	
	21600 W/m^3 heat load Straight Steel Mount – Large Mirror	Temperature of mirror is 335 K / 62 ˚C	
	4×10^5 W/m^3 heat load Straight Steel Mount – Large Mirror	Temperature of mirror is 428 K / 155 ˚C	
	21600 W/m^3 heat load Straight Al Mount – Large Mirror	Temperature of mirror is 333 K / 60 ˚C	
	4×10^5 W/m^3 heat load Straight Al Mount – Large Mirror	Temperature of mirror is 344 K / 71 ˚C	

Type of result plot	Load case	Result	Figure
Deflection	21600 W/m^3 heat load Short Steel Mount – Large Mirror	Displacement 7,211 x 10^{-5} m	
	4 x 10^5 W/m^3 heat load Short Steel Mount – Large Mirror	Displacement 1,558 x 10^{-4} m	
	21600 W/m^3 heat load Short Al Mount – Large Mirror	Displacement 7,876 x 10^{-5} m	
	4 x 10^5 W/m^3 heat load Short Al Mount – Large Mirror	Displacement 8,582 x 10^{-5} m	
	21600 W/m^3 heat load Straight Steel Mount – Large Mirror	Displacement 5,696 x 10^{-5} m	
	4 x 10^5 W/m^3 heat load Straight Steel Mount – Large Mirror	Displacement 2,27 x 10^{-4} m	
	21600 W/m^3 heat load Straight Al Mount – Large Mirror	Displacement 8,153 x 10^{-5} m	
	4 x 10^5 W/m^3 heat load Straight Al Mount – Large Mirror	Displacement 8,424 x 10^{-5} m	

9.3. Discussion

For the average heat load of 21600 W/m^3, the mirror temperature is at the same level for angled and straight mirror mount for both steel and aluminium material.

For the max heat load of 4×10^5 W/m^3, the mirror temperature is at the same level for angled and straight mirror mount for aluminium material. For mount in steel material, the mirror temperature is about 50˚C higher for the straight mount.

Mirror deflections are highest for steel mount with applied max heat load of 4×10^5 W/m^3. Deflections are slightly higher for straight mount, compared to angled mount.

For the average heat load of 21600 W/m^3, steel mount, the mirror deflections are highest for the angled mount.

For the average heat load of 21600 W/m^3, aluminium mount, the mirror deflections are highest for the straight mount. For the max heat load on the other hand, the deflection are slightly higher for the angled mount.

10. RESULTS SUMMARY AND DISCUSSION

For the different simulation models that have been run, the boundary conditions and maximum and average heat load have been the same. The variables of all the analysis have been the mount design and mount material. In addition, the mirror design changed slightly in size for the final simulations, but the mirror curvature is the same for all the analysis.

- The first simulation was with the original bendamount design, steel material.
    - The simulations for both maximum and average heat load showed that the mirror was not able to transport the applied heat energy sufficiently enough, resulting in high temperature of mirror. The reason for this is most likely the small contact surfaces between the Mirror mount components.
- The mount design was simplified, to obtain larger contact surfaces between mirror and mount, and mount components. In addition, we chose to run analysis for mount in both steel and aluminium.
    - As, expected the resulting mirror temperatures were much lower.
    - The mirror temperatures were highest for the steel mount.
    - When comparing deflections, which material generates the highest deflection, depends on applied heat load, thus there is no clear preference between steel and aluminium at this point.
- Next, the mirror height was reduced; to see if this would lower the resulting mirror temperature. For a lower mount, there will be less volume exposed to the heat load, and the mirror will be located closer to the relatively cooler surface of the plug. The analysis was only run with mount in steel material.
    - The resulting mirror temperatures were lower for the short mount design, compared to the original taller one. The difference was greatest for the max heat load.
    - Deflections were also lower in value for the short mount design.
- The mirror size was changed, since there was available space for it in the plug, and for the mirror positioning and resulting beam path, to be less sensitive to mirror deflections/tilting. In addition, for the larger mirror design, the simulations were run for mount in both steel and aluminium material.
    - With regards to mirror temperature, the only clear difference in results was for the max heat load, large mirror, between steel and aluminium mount. Temperature for large mirror on aluminium mount is about 38˚C lower, compared to large mirror on steel mount.
    - Deflections are slightly larger for large mirror, when applying average heat load. For the max heat load, the deflections are approximately the same for large and small mirror. The difference in deflection is so small, that there will be an advantage to go for the larger mirror design.
    - For the large mirror, the deflections are highest for the aluminium mount when applying average heat load. For the max heat load, large mirror, the deflections are $8{,}582 \times 10^{-5}$m lower for the aluminium, compared to steel mount. Thus aluminium is the best alternative, for worst case heat load, and thus the safest alternative.

- A straight instead of angled mount design was created, to check if a straight mount design results in lower deflection/tilt of mirror.
    - The main difference between the deflection for angled and straight mount, is that for the angled mount, it is mainly the top edge of the mirror that deflects. For the straight mount, all outer edges/corners of the mirror deflect in the same way. No clear advantage of choosing a straight mount design, since the deflections are low for both mount designs. Since a straight mount design will require angled surface in plug, the angled mount will be used

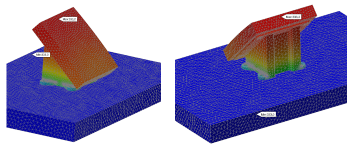
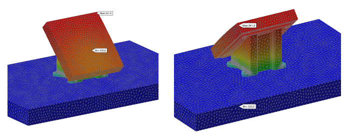
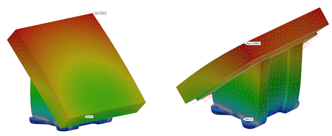
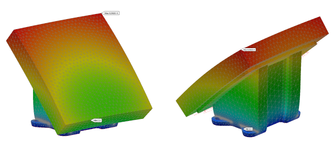
As commented in the boundary conditions tables, the base plate temperature should be updated according to new results, but a new thermal deformation simulation as not been run yet for the PBIP.

11. CONCLUSION

From the result summary above, the best mirror mount design is:

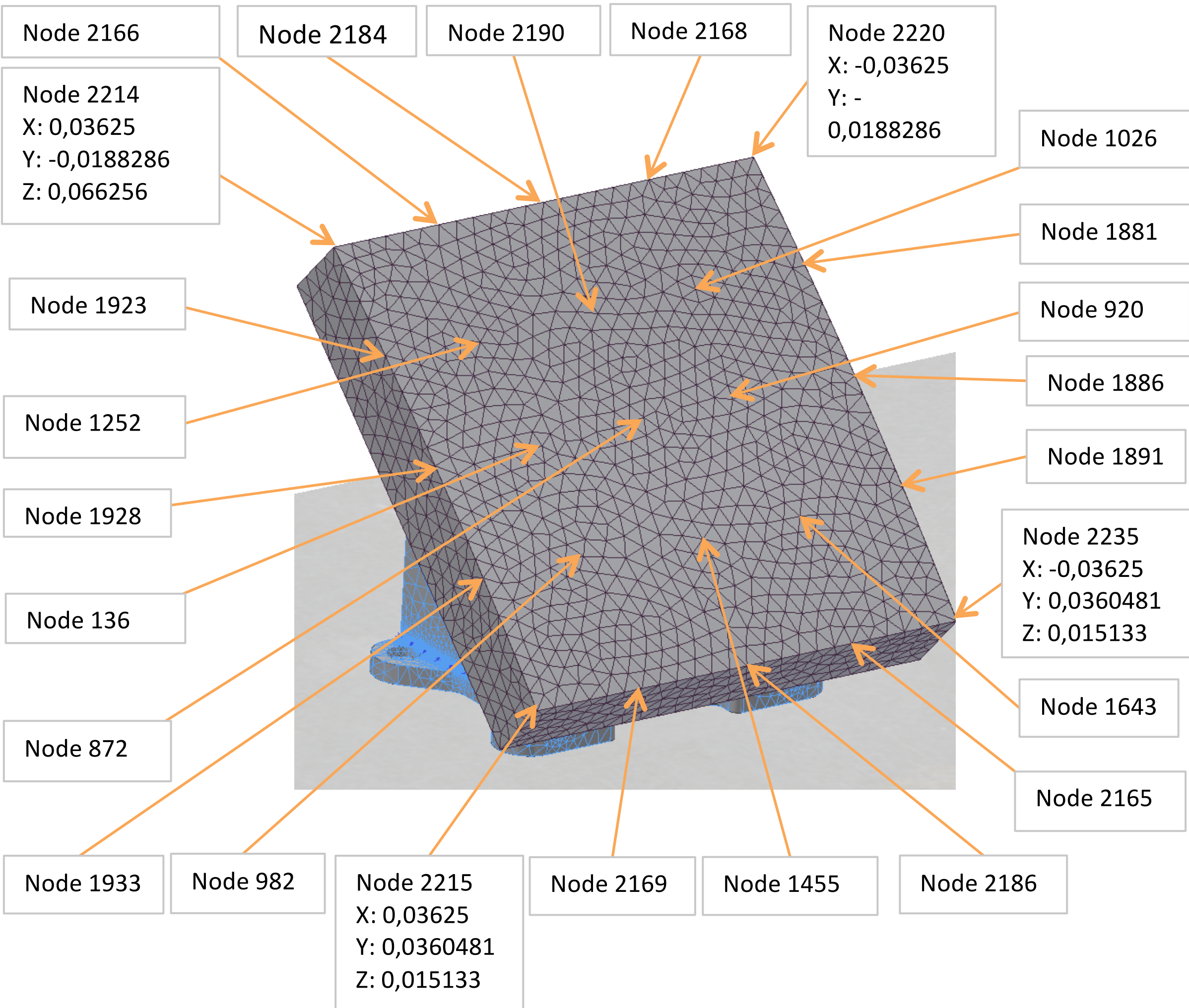
- Simplified mount design
- Short mount
- Angled mount design (do not need to implement angled surface in plug)
- Aluminium material

The preliminary study of the deformation of mirror on short aluminium mount shows that the alignment and surface deformations are within tolerances, as shown in the document ESS-0149766.

Type of result plot	Load case	Result	Figure
Thermal	21600 W/m^3 heat load Short Al Mount – Large Mirror	Temperature of mirror is 333 K / 60°C	
	4 x 10^5 W/m^3 heat load Short Al Mount – Large Mirror	Temperature of mirror is 342 K / 69°C	
Deflection	21600 W/m^3 heat load Short Al Mount – Large Mirror	Displacement 7,876 x 10^{-5} m	
	4 x 10^5 W/m^3 heat load Short Al Mount – Large Mirror	Displacement 8,582 x 10^{-5} m	

12. NODAL DISPLACEMENT PLOT

Below is an overview of the selected nodes



Result plot of heat load 21600 W/m^3, low angled aluminium mount, large mirror.

Node	X Coordinate	Y Coordinate	Z Coordinate	TX Disp. [m]	TY Disp. [m]	TZ Disp. [m]
2214	0,03625	-0,01882860	0,0662558	3,53E-05	-1,62E-05	6,85E-05
2220	-0,03625	-0,0188286	0,066256	-3,53E-05	-1,62E-05	6,85E-05
2215	0,03625	0,0360481	0,0151329	3,53E-05	3,17E-05	1,22E-05
2235	-0,03625	0,0360481	0,0151329	-3,53E-05	3,18E-05	1,23E-05
2166	0,018125	-0,018829	0,066256	1,77E-05	-1,61E-05	6,88E-05
2184	0	-0,018829	0,066256	-4,13E-09	-1,62E-05	6,89E-05
2168	-0,018125	-0,018829	0,066256	-1,77E-05	-1,62E-05	6,88E-05
1923	0,03625	-0,00504	0,054665	3,53E-05	-3,46E-06	5,66E-05
1252	0,0203551	-0,004239	0,0053968	2,00E-05	-2,60E-06	5,63E-05
2190	- 0,000199485	-0,004614	0,054295	-2,02E-07	-2,93E-06	5,70E-05
1026	-0,0173583	-0,005028	0,054655	-1,71E-05	-3,33E-06	5,70E-05
1881	-0,03625	-0,00504	0,054665	-3,53E-05	-3,46E-06	5,66E-05
1928	0,03625	0,008368	0,042637	3,55E-05	8,85E-06	4,36E-05
136	0,0179827	0,008729	0,042301	1,79E-05	9,54E-06	4,44E-05
872	-0,000026	0,007955	0,043019	-2,90E-08	8,91E-06	4,60E-05
920	-0,0153321	0,008097	0,042888	-1,53E-05	8,97E-06	4,52E-05
1886	-0,03625	8,37E-03	4,26E-02	-3,55E-05	8,85E-06	4,36E-05
1933	0,03625	0,021382	0,030183	3,55E-05	2,01E-05	2,92E-05
982	0,0189288	0,021377	0,030188	1,90E-05	2,10E-05	3,10E-05
1455	-0,00110994	0,022242	0,029330	-1,15E-06	2,26E-05	3,19E-05
1643	-0,0180474	0,022036	0,029535	-1,82E-05	2,17E-05	3,04E-05
1891	-0,03625	0,021382	0,030183	-3,55E-05	2,01E-05	2,93E-05
2169	0,018125	0,036048	0,015133	1,80E-05	3,33E-05	1,46E-05
2186	0	0,036048	0,015133	2,06E-09	3,45E-05	1,66E-05
2165	-0,018125	0,036048	0,015133	-1,80E-05	3,33E-05	1,46E-05

Table 16: Result plot, 21600 W/m^3

Result plot of heat load 4x10^5 W/m^3, low angled aluminium mount, large mirror

Node	X Coordinate	Y Coordinate	Z Coordinate	TX Disp. [m]	TY Disp. [m]	TZ Disp. [m]
2214	0,03625	-0,01882860	0,0662558	4,35E-05	-3,22E-05	6,66E-05
2220	-0,03625	-0,0188286	0,066256	-4,35E-05	-3,22E-05	6,66E-05
2215	0,03625	0,0360481	0,0151329	4,19E-05	3,22E-05	5,42E-06
2235	-0,03625	0,0360481	0,0151329	-4,20E-05	3,23E-05	5,45E-06
2166	0,018125	-0,018829	0,066256	2,20E-05	-2,98E-05	6,98E-05
2184	0	-0,018829	0,066256	-1,88E-09	-2,88E-05	7,10E-05
2168	-0,018125	-0,018829	0,066256	-2,20E-05	-2,98E-05	6,98E-05
1923	0,03625	-0,00504	0,054665	4,35E-05	-1,27E-05	5,64E-05
1252	0,0203551	-0,004239	0,0053968	2,47E-05	-9,03E-06	5,92E-05
2190	-0,000199485	-0,004614	0,054295	-2,46E-07	-8,29E-06	6,14E-05
1026	-0,0173583	-0,005028	0,054655	-2,11E-05	-9,79E-06	6,04E-05
1881	-0,03625	-0,00504	0,054665	-4,35E-05	-1,27E-05	5,64E-05
1928	0,03625	0,008368	0,042637	4,33E-05	4,84E-06	4,32E-05
136	0,0179827	0,008729	0,042301	2,19E-05	8,40E-06	4,72E-05
872	-0,000026	0,007955	0,043019	-3,45E-08	8,49E-06	4,99E-05
920	-0,0153321	0,008097	0,042888	-1,87E-05	7,91E-06	4,84E-05
1886	-0,03625	8,37E-03	4,26E-02	-4,33E-05	4,84E-06	4,32E-05
1933	0,03625	0,021382	0,030183	4,28E-05	1,92E-05	2,68E-05
982	0,0189288	0,021377	0,030188	2,29E-05	2,27E-05	3,16E-05
1455	-0,00110994	0,022242	0,029330	-1,36E-06	2,52E-05	3,33E-05
1643	-0,0180474	0,022036	0,029535	-2,18E-05	2,35E-05	3,09E-05
1891	-0,03625	0,021382	0,030183	-4,28E-05	1,92E-05	2,68E-05
2169	0,018125	0,036048	0,015133	2,13E-05	3,61E-05	1,08E-05
2186	0	0,036048	0,015133	3,06E-09	3,81E-05	1,39E-05
2165	-0,018125	0,036048	0,015133	-2,13E-05	3,61E-05	1,08E-05

Table 17: Result plot, 4x10^5 W/m^3