PANIC Final Design Report

PANIC

PANIC's Mechanical Final Design Report
Final Design Phase

Max-Planck-Institut für Astronomie Heidelberg
Max-Planck Institute for Astronomy Heidelberg

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List of acronyms and abbreviations

AIV	Assembly, Integration, Verification
CAHA	Centro Astronómico Hispano Alemán
CTE	Coefficient of Thermal Expansion
FDR	Final Design Review
FEA	Finite- Element- Analysis
FOV	Field of View
FWHM	Full Width at Half Maximum
GEIRS	Generic InfraRed Software
IAA	Instituto de Astrofísica de Andalucía
LM	Lens Mount
MH	Mirror Holder
MLI	Multi Layer Insulation
MPIA	Max-Planck-Institut für Astronomie
NIR	Near InfraRed
OM	Optics Mount
PANIC	**PA**noramic **N**ear **I**nfrared camera for **C**alar Alto
PDR	Preliminary Design Review
PSF	Point Spread Function
RoE	Read-out Electronics
TBC	To Be Confirmed
TBD	To Be Decided

List of supporting documents

The following documents provide additional information about topics addressed in this FDR document. They are referenced as RDx in the text:

RD 1	PANIC-OPT-TN-08 Complete Mechanical Tolerances Issue 0/1 05 Mar 2009
RD 2	PANIC-MEC-TN-03 Thermal cycling test of a Panic dummy lens.pdf Issue 1
RD 3	PANIC-MEC-TN-04 PANIC - Investigations concerning the Mirror deflection.pdf Issue 1
RD 4	Berechnung Gehäuse_AD-rev.pdf
RD 5	Druckverlust Kryostat NEU.pdf
RD 6	PANIC-OPT-TN-06 Panic Optical Assembly, Integration and Verification Issue 0/1 15 Sept 2008

Contents

1 PANIC GENERAL

A review of potential new instrumentation for Calar Alto, conducted independently at MPIA/Heidelberg and IAA/Granada, came to the unanimous conclusion that an NIR imager for the 2.2 m telescope is the new instrument which is needed most to keep Calar Alto instrumentation up to date. Therefore the project PANIC (**Pa**noramic **N**ear **I**nfrared Camera for **C**alar Alto) was started in October 2006. It is a joint project between IAA and MPIA, with IAA responsible for the software and optics and MPIA for the cryotechnique, mechanics, detectors and read-out electronics.

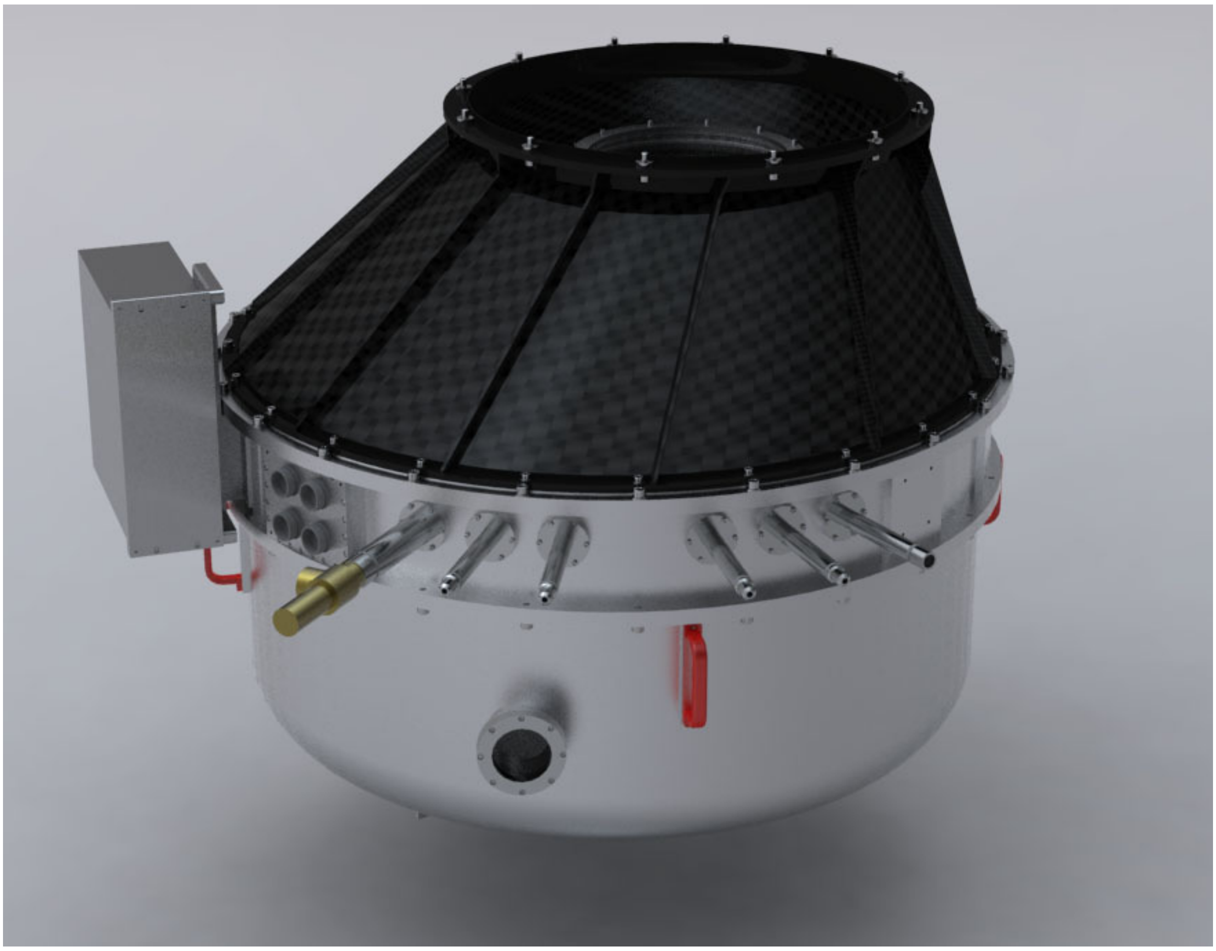


Figure 1: Artificial view of the cryostat with filling pipes, read-out electronics and the conical telescope adapter

1.1 Specifications

The specifications can be summarized as follows:

- 4096 x 4096 pixels
- NIR Spectral range
- Image scale 0.45 arcsec/pixel @ 2.2 m telescope,
  0.22 arcsec / pixel @ 3.5 m telescope
- Cold stop to minimize thermal background
- Allow narrow band (bandwidth = 1% of central wavelength) filters
- Fit the 2.2m telescope, i.e. maximum length 120 cm, maximum mass 400kg
- Fit into the elevator cabin in the dome building

At the 2.2m telescope the instrument has a pixel scale of 0.45 arcsec/pixel and a field of view of 0.5 x 0.5 degrees and so is perfectly suited for survey-type observations.

A high resolution mode can be realized at the 3.5 m telescope since the f/10 beam at the 3.5 m telescope has twice the focal length of the f/8 beam at the 2.2m telescope. At the 3.5 m telescope the image scale is therefore halved which makes the instrument well suited for observations at a high spatial resolution in a still large 0.25 x 0.25 degree field. The only additional element required is a wheel to change between the 2 cold stops for the different telescopes. An adapter, which ensures the same focal position when instruments designed for the 2.2 m telescope are mounted on the 3.5 m telescope, already exists at Calar Alto (see section 5.1.1).

The standard auto-guiding system can not be used with PANIC since it would vignette the field. However, the detectors allow non-destructive read-out of parts of the field which can be used for auto guiding. Guiding is probably not necessary even with narrow band filters since the Calar Alto telescopes are very stable over a few minutes. We will also implement a mode that will allow a read-out of a window of 34 x 34 pixel at a rate of a few ms; this mode would be useful for certain variability studies of stars.

1.2 Overall design of PANIC

1.2.1 Optics

PANIC is designed as a pure lens optics with 9 lenses (as shown in Figure 2). The image quality is 80% ensquared energy in 2 pixels over the whole field of view for all wavelengths. The wavelength range also includes the astronomical Z band, so PANIC will cover the whole spectral range from Z to K bands (0.82 - 2.5 µm).

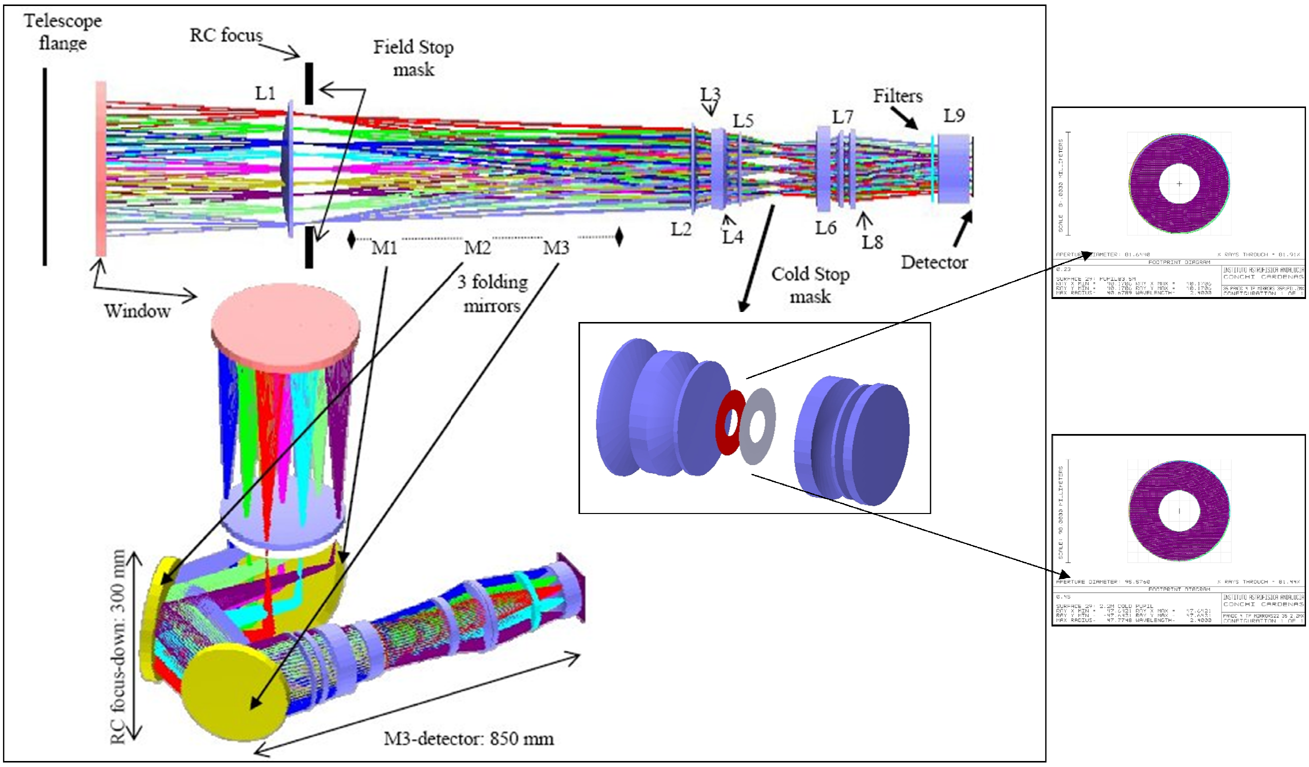


Figure 2: PANIC optical layout, original (top) and folded (bottom)

1.2.2 Detectors

PANIC uses 4 HAWAII-2 RG detectors. They are mounted into a single module (see Figure 3) with a gap of 167 pixel between the individual detectors. This design results in a very nice footprint. The module dimensions are 136 x 136 x 60 mm, with a light sensitive area of 79 x 79 mm. The alignment of the 4 detectors within one plane has been measured by the manufacturer Teledyne and is within our tolerances. The module also contains heaters and temperature sensors.

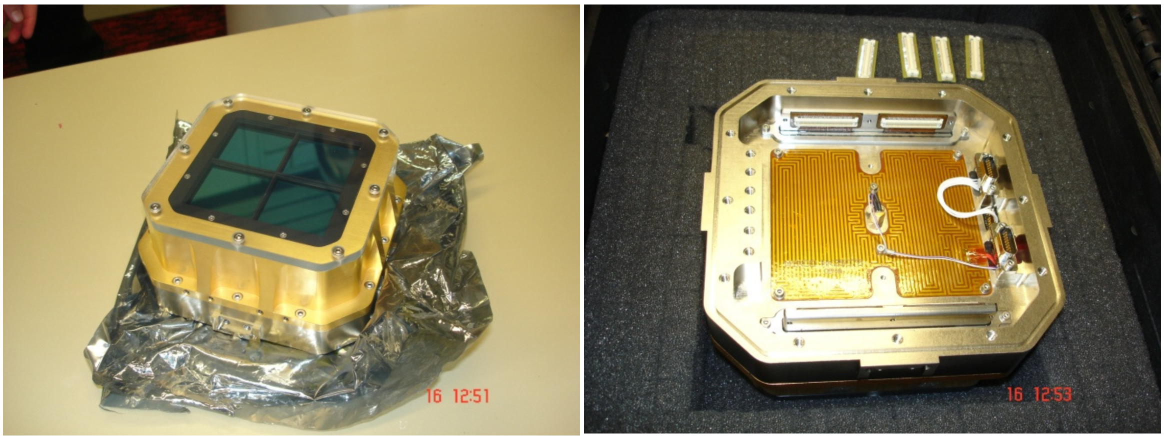


Figure 3: The focal plane array. The greenish areas are the 4 light sensitive areas (left). The back of the module with connectors and heaters (right)

The detectors operate at a temperature of 77-80 K which must be held constant within ±0.1 K. A LN_2 cryostat will be used to cool the instrument. To ease operation at CAHA we aim at a holding time of about 24 hours.

1.2.3 Layout of the Instrument

Since the optical train is about 2 m long, much longer than the maximum allowable length, a folded design is needed. Our design is shown in Figure 4 and Figure 5. Light enters the cryostat through an entrance window and then passes through lens L1 and the field stop, which limits the field of view. The mirrors M1, M2 and M3 fold the light path along a cold optical bench. All optical elements are mounted to this bench in order to minimize flexure effects. An image of the telescope primary mirror is formed between the lenses L5 and L6. At this position a cold stop mask blocks light rays which do not come from the main mirror and therefore reduces the thermal background in the K bands. Two cold-stop masks are mounted on a wheel which allows changing between the 2 cold stops required for the two different telescopes. The filter wheel module, located between the L8 and L9 lenses, contains 4 filter wheels each with 6 positions, therefore 19 filters can be mounted at a time. One of the filter wheels carries a pupil imager lens which serves to control the alignment of the cold-stop. PANIC has no focussing mechanism of its own as the focussing is done with the telescope secondary mirror.

In order to save weight we have not used the widespread nested tanks design, but rather use a second small LN_2 tank to cool the detector module.

PANIC is mounted to the telescope(s) by the conical structure shown in Figure 5. This will be discussed in chapter 5.1.

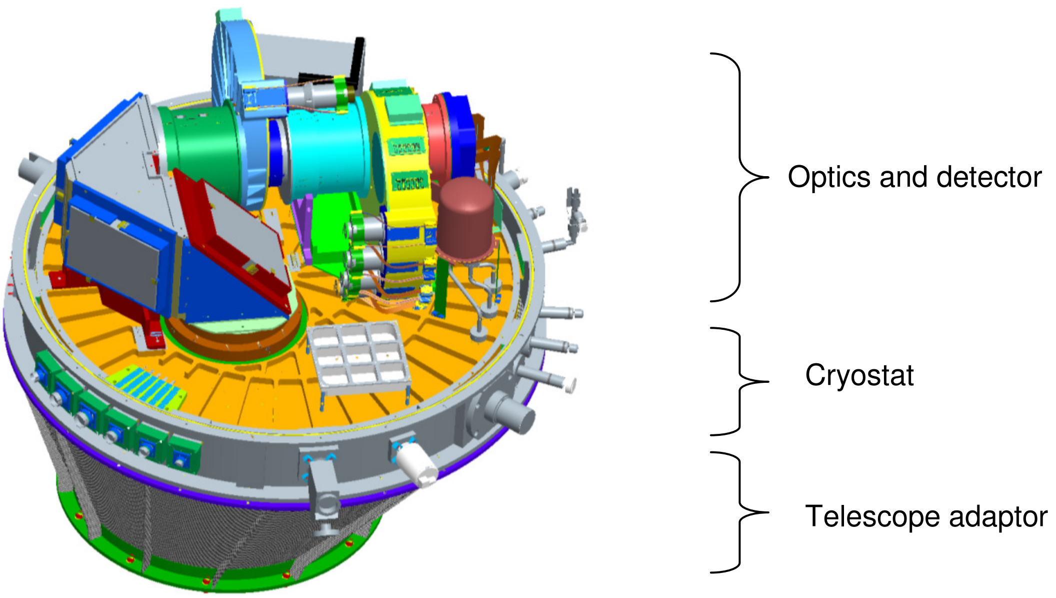


Figure 4: Layout of PANIC

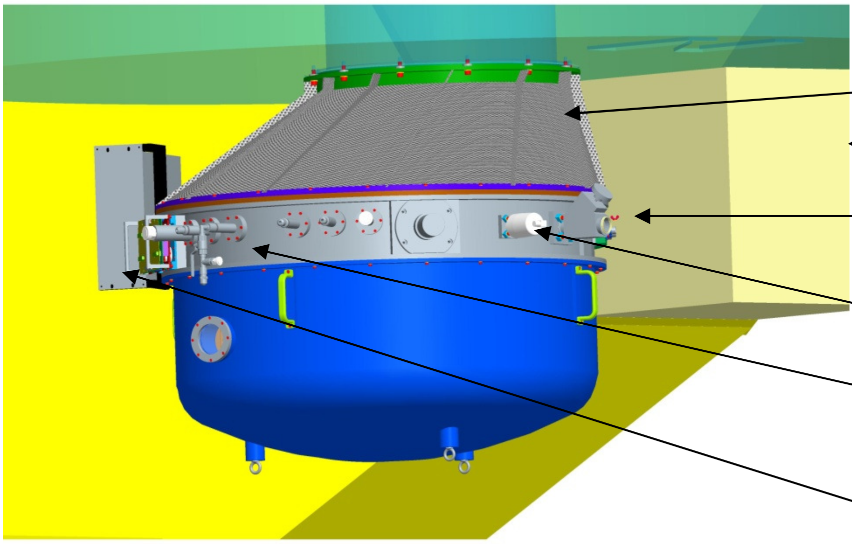


Figure 5: PANIC at the 2.2m telescope

Advantages of this design:

- Compact dimensions
- Light-weight
- All optical elements are mounted to one bench, flexure effects are minimized
- Closed modules minimize stray-light

Critical design aspects are:

- 400 kg mass limit. The mass limit originally set by the manufacturer of the telescope was 300 kg, but the identical ESO/MPG 2.2 m telescope in La Silla works perfectly for many years now with 400 kg CAFOS and WIFI instruments. Experiments have shown that the performance of the telescope is not degraded even with a 10% larger load.

- Tight tolerances for the optics and detector, which are on the order of 30-50 µm for some elements.

Our design makes use of experience gained in many projects, particularly Omega2000. This is possible because dimensions and tolerances are comparable in both instruments. Previous solutions can obviously not be implemented exactly 1:1 but we have taken over the underlying design ideas, especially for the lens holders and the wheels.

1.2.4 Electronics and Software

Read-out will be done with MPIA's own electronics (see Figure 6) which is a further development of the Omega2000 read-out electronics. The electronics will be mounted to the cryostat in order to minimize the length of the connection between detectors and the electronics. Laboratory tests of the read-out electronics with a multiplexer and also with the science detectors have been very successful.

The wheels are controlled with MPIA's standard motor control electronics which have been successfully used in many instruments. Commercially available devices supplied by LakeShore are used to monitor and control pressure and temperature of the cryostat.

Figure 6: The read-out electronics.

The instrument is controlled by MPIA's GEIRS software. An observation tool is the graphical user interface and facilitates the observations. Templates will be supplied to ensure that even an un-experienced observer avoids errors. A quick-look tool will allow checking of the data quality online. A pipeline will supply the observer with state of the art reduced data.

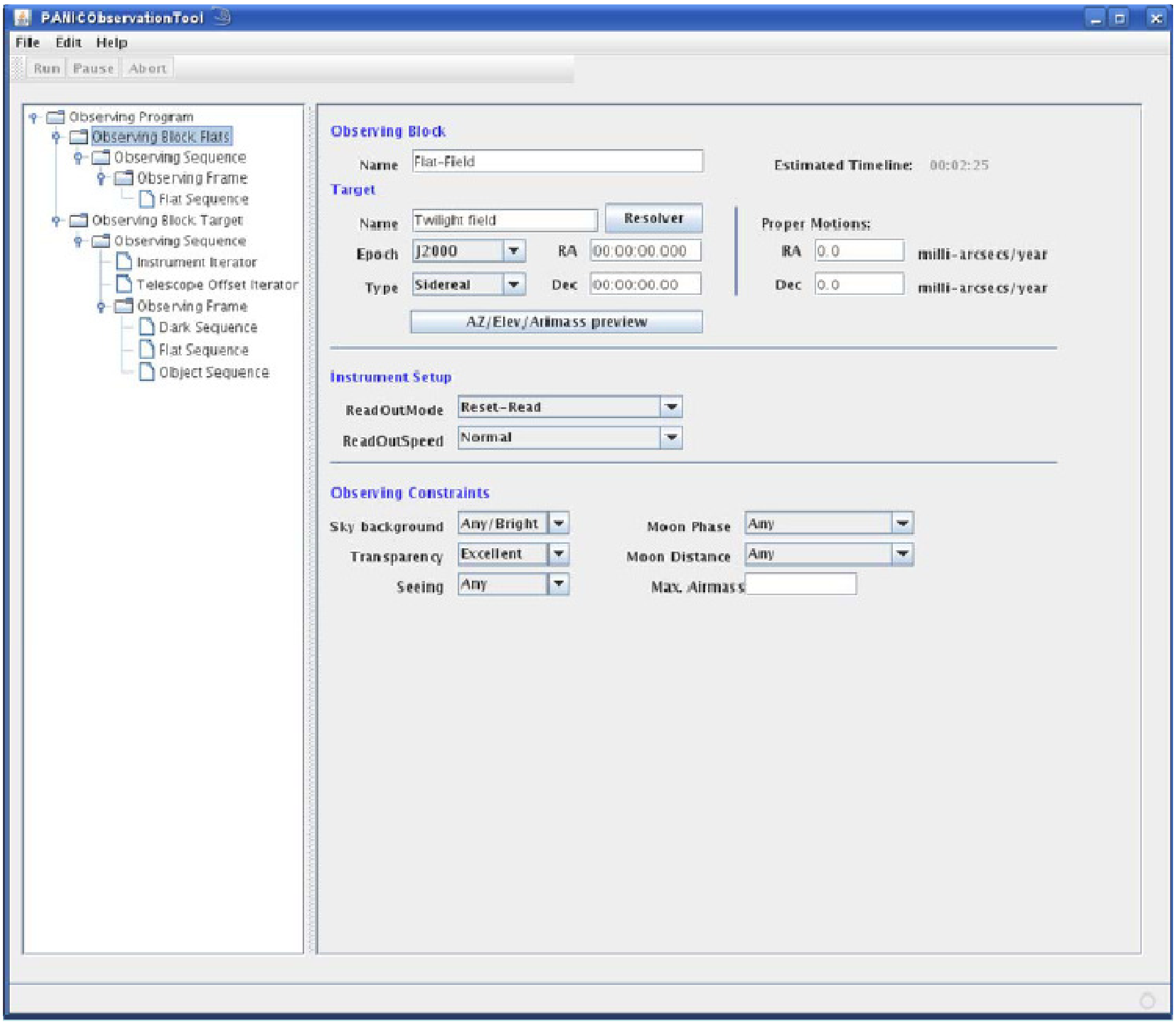


Figure 7: An example of the observation tool, the graphical user interface for PANIC.

2 OPTOMECHANICS

The baseline design for the opto-mechanics is a file directly derived from the optical simulation program Zemax. This file is used to determine the exact position of the optical elements. It is taken into account that the mechanical design, manufacturing and assembly will be done at ambient conditions whereas the operation temperature is at 80 K. This temperature change from manufacturing / assembly to operation causes shrinkage of the distances between the optical elements.

The tolerances for the optics are taken from the technical note PANIC-OPT-TN-08 (RD 1) from March 2009.

The optical layout is shown in Figure 8. Figure 9 explains how the optical elements are grouped into various compounds.

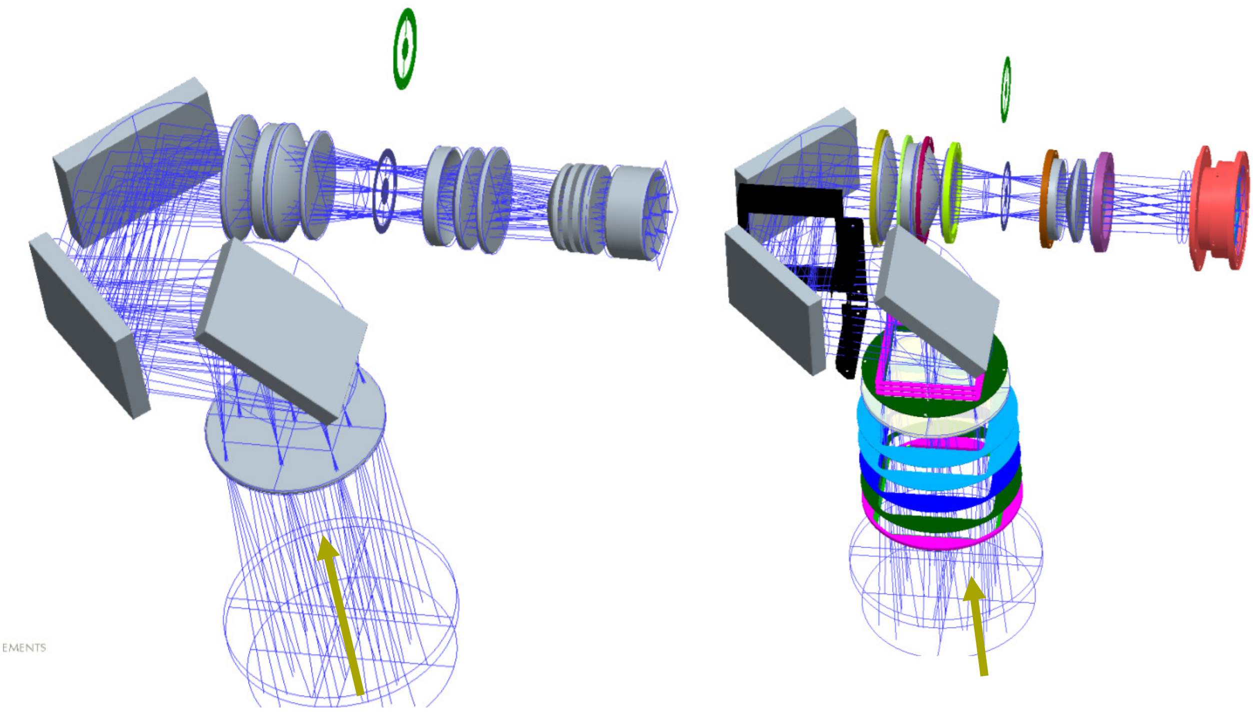


Figure 8: The optical layout with lenses and mirrors(left) and with baffles (right)

<table>
<tr><th>Optical element</th><th>Window</th><th>L1</th><th>M1</th><th>M2</th><th>M3</th><th>L2</th><th>L3</th><th>L4</th><th>L5</th><th>Cold stop</th><th>L6</th><th>L7</th><th>L8</th><th>Filter wheel</th><th>L9</th><th>FPA</th></tr>
<tr><td rowspan="4">Groups</td><td rowspan="3"></td><td>LM 1</td><td>MH1</td><td>MH2</td><td>MH3</td><td colspan="3">LM 2a</td><td>LM 2b</td><td rowspan="2"></td><td colspan="3" rowspan="2">LM 3</td><td rowspan="2"></td><td colspan="2" rowspan="2">LM 4</td></tr>
<tr><td colspan="4">Mirror Structure</td><td colspan="4">LM2</td></tr>
<tr><td colspan="9">Optics Mount 1</td><td colspan="6">Optics Mount 2</td></tr>
<tr><td colspan="16">Complete Optics</td></tr>
</table>

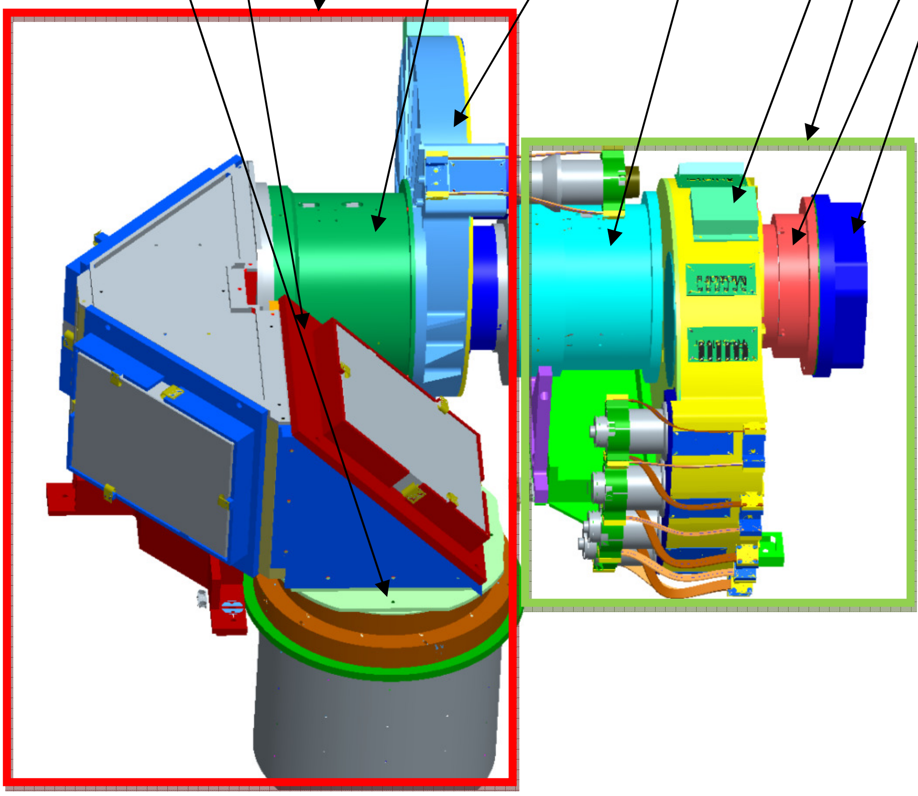


Figure 9: Overview over the optical elements and their mounts

Alignment tolerances

This chapter is copied from PANIC-OPT-TN-08 and summarizes the tolerances for the optical mounts

Alignment (telescope-whole instrument)					
Element	**TILT X (arc min)**	**TILT Y (arc min)**	**DECENTER X (mm)**	**DECENTER Y (mm)**	**POSITION Z (mm)**
Whole instrument	± 3.00'	± 3.00'	0.50	0.50	± 5

Complete Optics (Window-OM1-OM2)					
Element	**TILT X (arc min/μm)**	**TILT Y (arc min/μm)**	**DECENTER X (μm)**	**DECENTER Y (μm)**	**POSITION Z (μm)**
Window	± 4.80'/230	± 4.80'/230	--	--	± 1000
OM1-	± 1.02'	± 1.02'	± 50	± 50	± 200
OM2	± 1.50'	± 1.50'	± 50	± 50	± 200

OM1 (LM1-MS-LM2)					
Element	**TILT X (arc min/μm)**	**TILT Y (arc min/μm)**	**DECENTER X (μm)**	**DECENTER Y (μm)**	**POSITION Z (μm)**
LM1 (L1)	± 1.20'/45	± 1.20'/45	± 70	± 70	± 200
MS	± 1.20'	± 1.20'	± 50	± 50	± 200
LM2	± 1.02'	± 1.02'	± 50	± 50	± 200

MS (M1-M2-M3)					
SINGLET	**TILT X (arc min/μm)**	**TILT Y (arc min/μm)**	**DECENTER X (μm)**	**DECENTER Y (μm)**	**POSITION Z (μm)**
M1	± 1.50'/62	± 1.80'/75	--	--	± 200
M2	± 1.50'/57	± 1.50'/57	--	--	± 200
M3	± 1.50'/52	± 1.40'/48	--	--	± 200

LM2 (L2-L3-L4-L5)					
SINGLET	TILT X (arc min/µm)	TILT Y (arc min/µm)	DECENTER X (µm)	DECENTER Y (µm)	POSITION Z (µm)
L2	± 1.32'/34	± 1.32'/34	Compensator ± 350	Compensator ± 350	± 100
L3	± 1.44'/34	± 1.44'/34	± 50	± 50	Compensator (mm) + 1.2; -1.4
L4	± 1.50'/36	± 1.50'/36	± 50	± 50	± 100
L5	± 1.50'/33	± 1.50'/33	± 50	± 50	± 100

OM2 (LM3-LM4-FPA)					
Element	TILT X (arc min/µm)	TILT Y (arc min/µm)	DECENTER X (µm)	DECENTER Y (µm)	POSITION Z (µm)
LM3	± 1.20'	± 1.20'	± 50	± 50	± 90
LM4 (L9)	± 1.50'/28	± 1.50'/28	± 50	± 50	± 90
FPA	± 2.40'/27	± 2.40'/27	--	--	+ 200, -50

LM3 (L6-L7-L8)					
SINGLET	TILT X (arc min/µm)	TILT Y (arc min/µm)	DECENTER X (µm)	DECENTER Y (µm)	POSITION Z (µm)
L6	± 1.50'/31	± 1.50'/31	Compensator ± 130	Compensator ± 130	± 100
L7	± 1.50'/31	± 1.50'/31	± 50	± 50	Compensator (mm) + 2.0; -2.5
L8	± 1.50'/33	± 1.50'/33	± 50	± 50	± 100

Element	TILT X (arc min//µm)	TILT Y (arc min//µm)	DECENTER X (µm)	DECENTER Y (µm)	POSITION Z (µm)
Filters	± 3.00'/55	± 3.00'/55	--	--	--

2.1 Cryogenic Lens Mounts

The development of a lens mounting system capable of both ensuring that the optical tolerances are met and protecting the elements to survive cooling is challenging.
It was chosen to implement the very successful principle developed for OMEGA2000.

2.2 Adjustment and Alignment

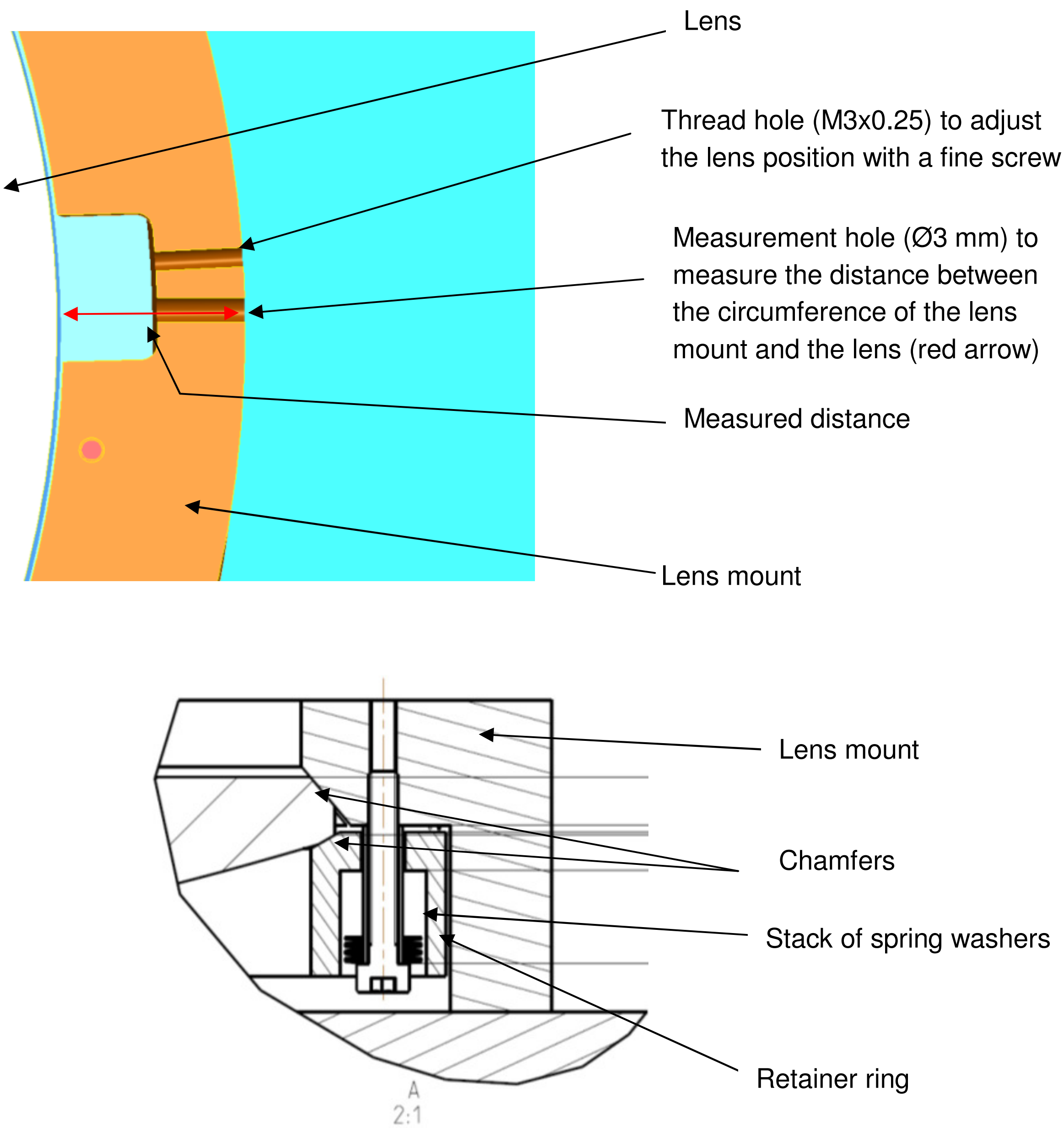


Figure 10: Cross-sectional view through the lens alignment design (explanation in the text)

All lenses will be aligned individually. The raw alignment is done with well polished chamfers. The alignment is tuned by four pairs of holes drilled for each lens into the circumference of the lens mounts. Every pair consists of a measurement hole (Ø3 mm) and an adjustment hole with a fine thread (M3x0.25) for a fine screw (as shown in Figure 10).

For aligning, the distance between the circumference of the lens mount and the lens is measured at all four positions. The distances are then adjusted with the fine screws. The lens is centered in its mount if the measured distance is equal in all four measurement holes.

Finally the alignment screws are removed and the mounting screws are fastened to conserve the achieved position.

2.3 Cool-down and Warm-up

The lenses rest in the conical surfaces of the mount. Chamfers allow the lenses to move in their mounts. The retainer rings keep the lenses in this position with eight disk spring packages each. Temperature changes result in diameter changes of the parts. These changes lead to an axial displacement of the lenses and retainer rings because the parts can slide on the chamfer surfaces relatively to each other, assuming that the chamfers are manufactured very precisely and that friction can be neglected.

Cooling of the mount components and the lenses does not start simultaneously. The lenses are cooled by the mountsd, and the retainer rings are cooled by the corresponding lenses and by the screws in the spring packages. Figure 11 shows the displacements of a lens and a retainer ring due to thermal shrinkage during the cool-down from ambient temperature to 77 K. The arrows in the axial direction show movements relative to the lens mount supporting surface. a) All parts at room temperature, b) Lens mount cooling, lens and ring still much warmer, c) Cold lens mount, lens cooling, retainer ring still much warmer, d) Cold lens and lens mount, retainer ring cooling.

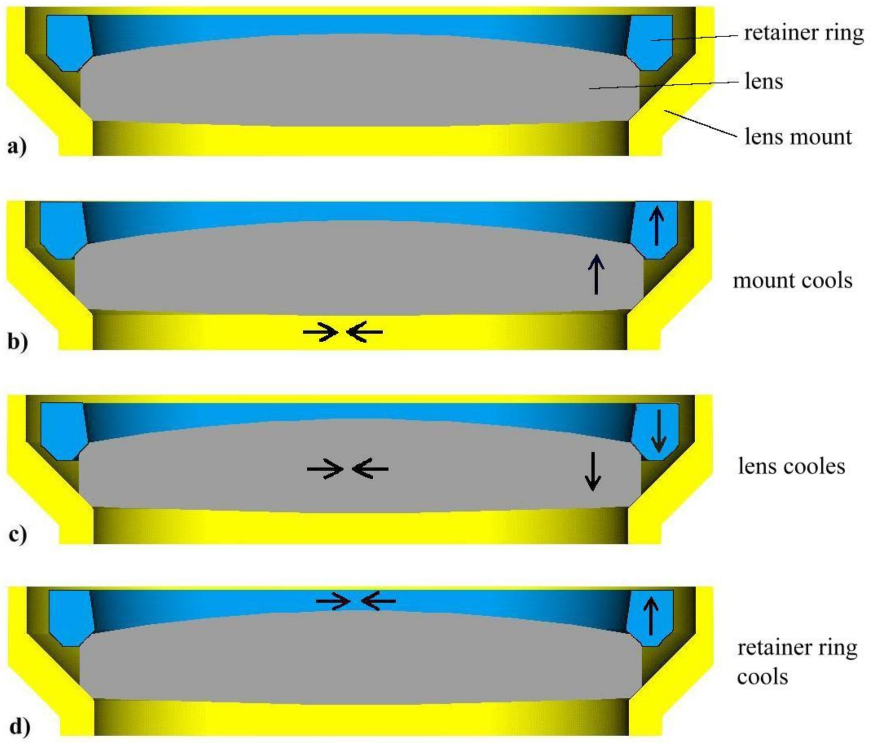


Figure 11: Displacements of lens and retainer ring due to thermal shrinkage while cooling down (explanation in the text)

This cooling model is of course only an approximation. The real process is much more complicated as the components change their dimensions simultaneously after a certain time. The delay depends very much on material properties like thermal conductivity (which is a function of the temperature itself) and thermal expansion as well as on the size and quality of contact surfaces. A rough surface will slide less easily and give a poorer thermal contact to another component than a smooth one. For this reason, the chamfers are diamond turned. Note that low thermal conductivity will lead to an inhomogeneous temperature distribution inside one component.

Although this principle was successfully used in OMEGA2000 and PYRAMIR, a test set-up was made to evaluate the capabilities of this mounting principle with the larger PANIC-lenses. The test was conducted with a dummy of the L1 lens, which is the largest lens in the PANIC optical design. Figure 12 shows the dummy lens in its mount inside the test cryostat.

The test demonstrated that this principle can be successfully implemented with the larger PANIC lenses. Furthermore it was investigated whether the surface quality of the chamfers can be relaxed. This test showed that it is necessary to meet the high requirements surface quality requirement . More details about this can be found in RD 2:

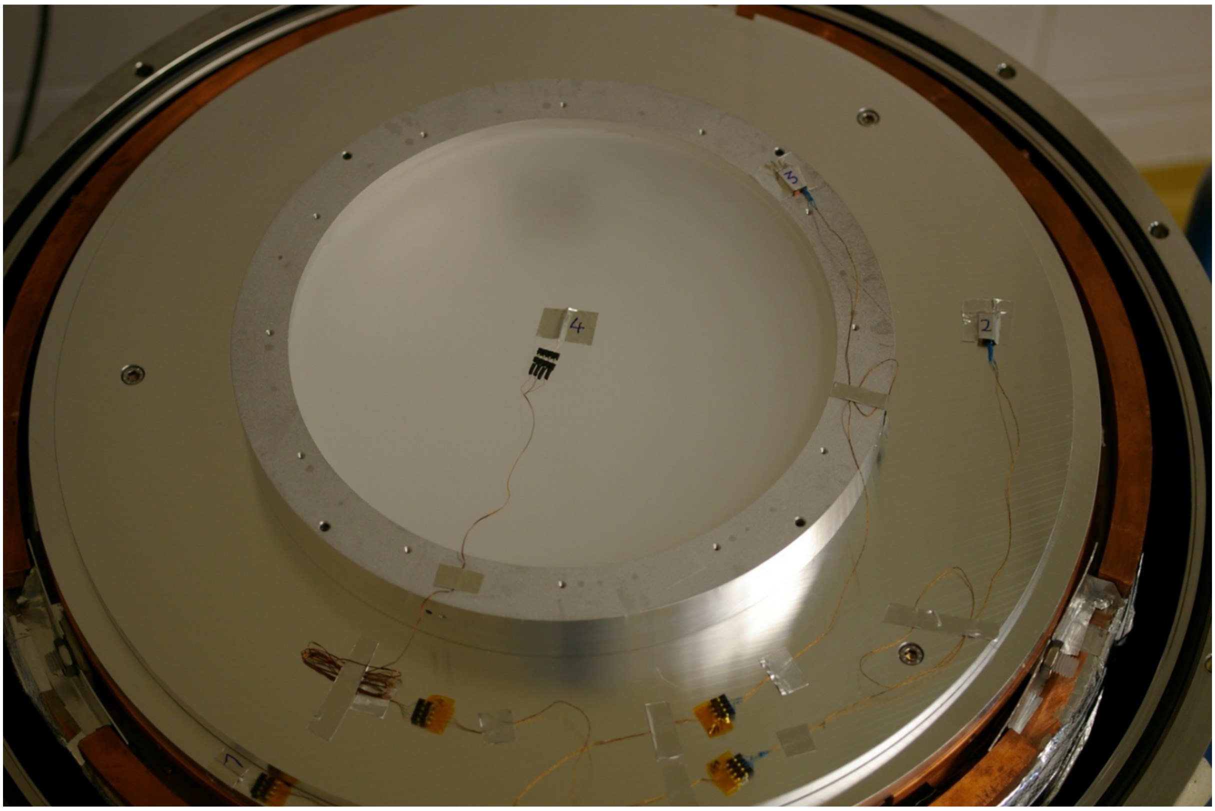


Figure 12: Test set-up for Thermal cycling test with lens 1 dummy.

2.4 Complete Optics

The complete optics is shown in Figure 9. For the tolerance budget "complete optics" means the optical path from the telescope interface to the cryostat cold bench.

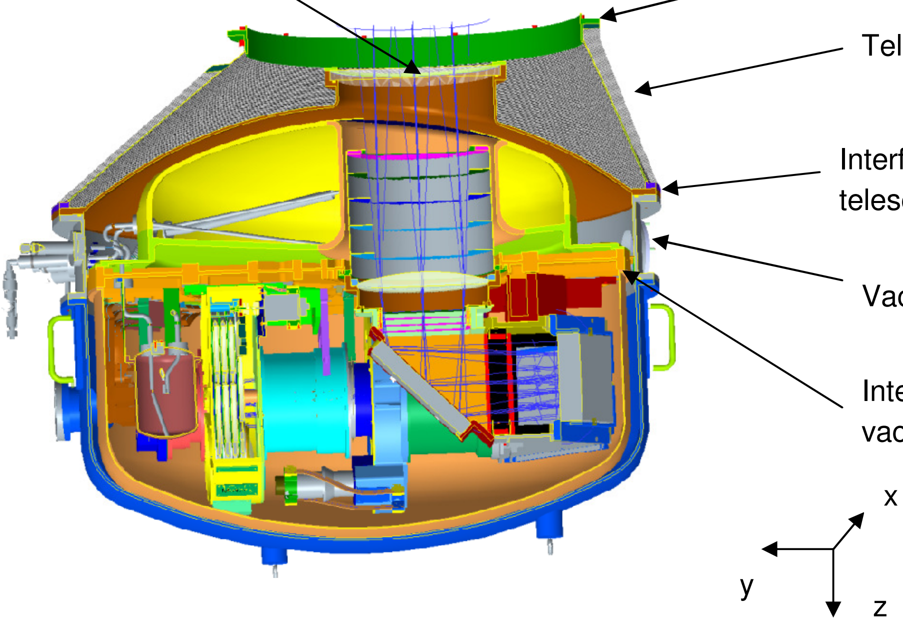


Figure 13: Interfaces and components included in "complete optics"

The table below shows the tolerance budget for the complete optics with respect to the telescope adapter. Figure 13 shows the parts between the telescope adapter and the optics. The main deformation is caused by the telescope adapter (300 µm, see chapter 5.1) and the spacer stacks (80 µm, see below). The tolerances of manufacturing and assembly must therefore be kept within 120 µm.

Tolerances:

	Tilt x [arcmin]	Tilt y [arcmin]	Decenter x [µm]	Decenter y [µm]	Position z [µm]
	±3	±3	±500	±500	±5000
Achieved by	Manufacturing				

The cold bench is the link between the cryostat and the optics. This part was analyzed with FE-simulations to ensure sufficient stiffness and to minimize mass. Figure 14 shows the (meshed) FE-Model. The spacer stacks are fixed at the interface to the vacuum vessel. This means the simulation shows the flexure of the spacer and the bench itself due to own weight and different orientations of the gravity vector. The masses of optics mount 1 and optics mount 2 are represented by dummies.

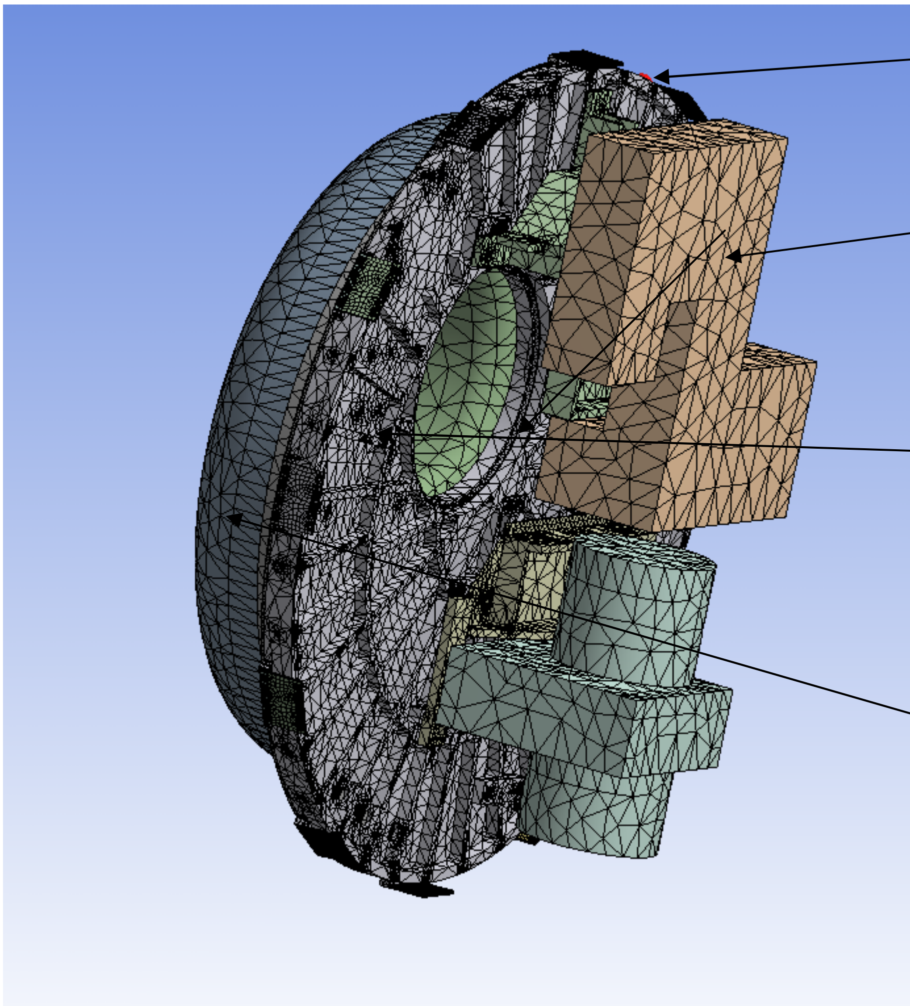
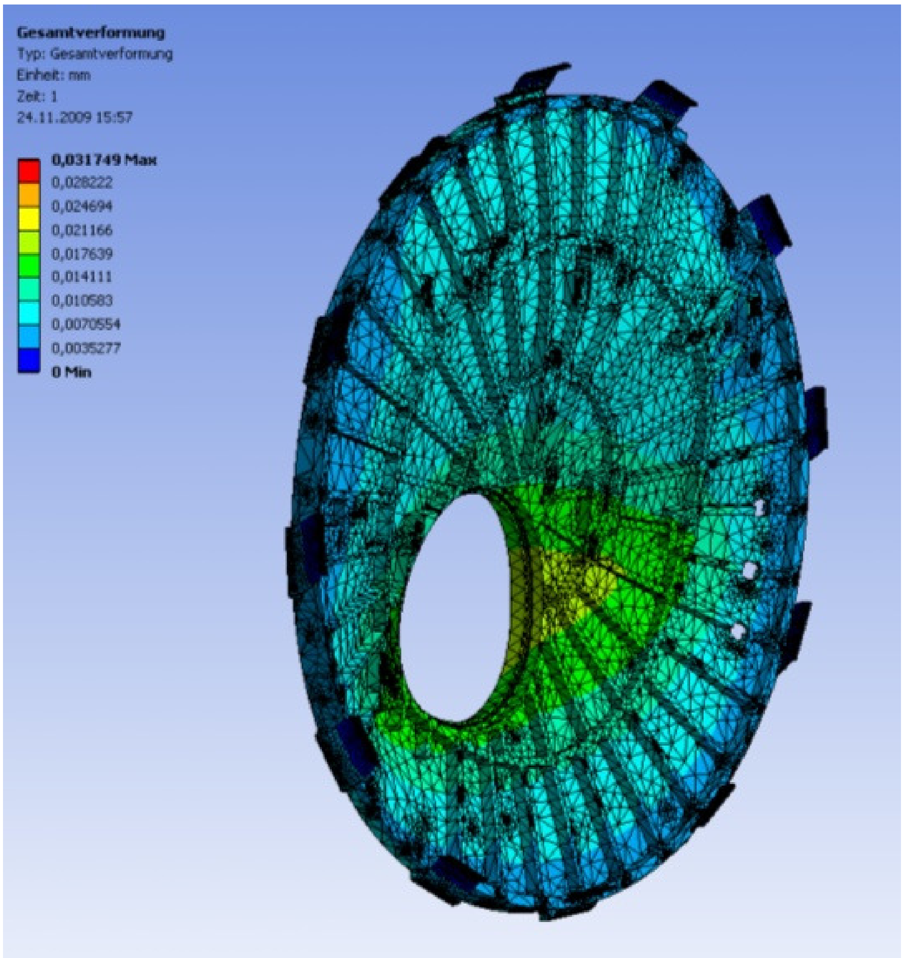


Figure 14: Simulation of the cold bench including the dummy masses.



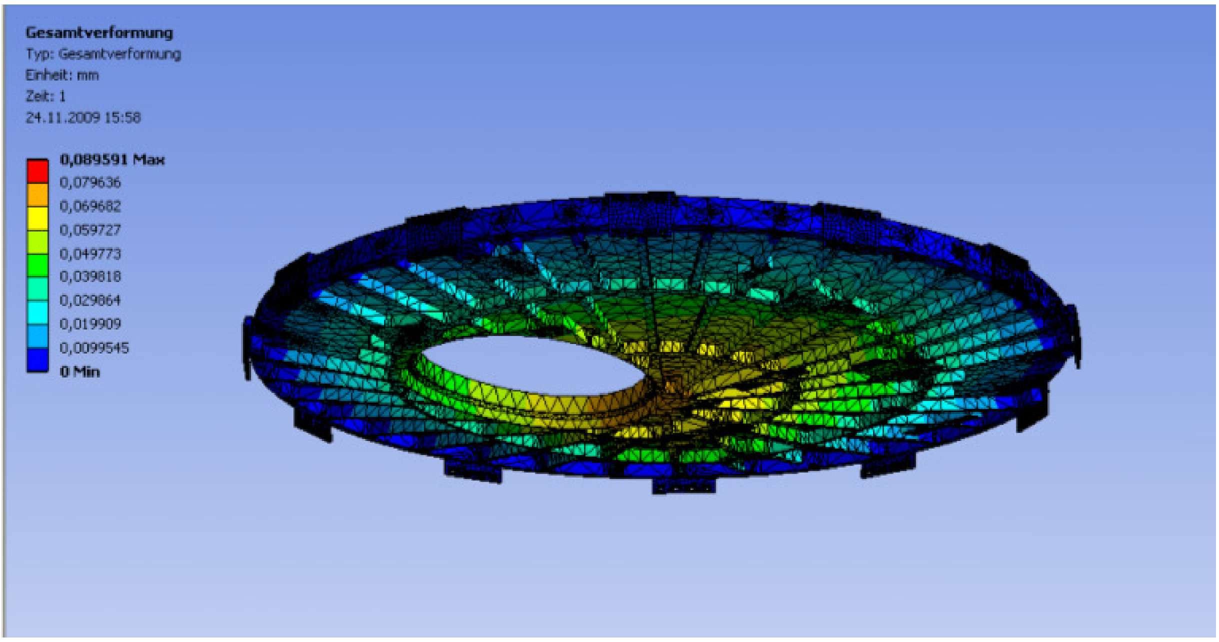


Figure 15: Results of the simulation with different orientations. top: telescope pointing to horizon, bottom: telescope pointing to zenith

The results in Figure 15 show that the deflection is in the order of about 18 µm if the telescope is pointing to horizon and 80 µm if pointing to zenith. Both of these values are within the tolerances.

2.4.1 Entrance Window

The entrance window is a 20 mm thick flat disc made of Infrasil 302.

Tolerances:

	Tilt x [arcmin]	Tilt y [arcmin]	Decenter x [µm]	Decenter y [µm]	Position z [µm]
	±4.8	±4.8	---	---	±1000
Achieved by	Manufacturing				

2.5 Optics Mount 1

Optics mount 1 is the assembly comprising of the lenses one to five, the three mirrors and the cold stop wheel. These subassemblies will be integrated and verified separately.

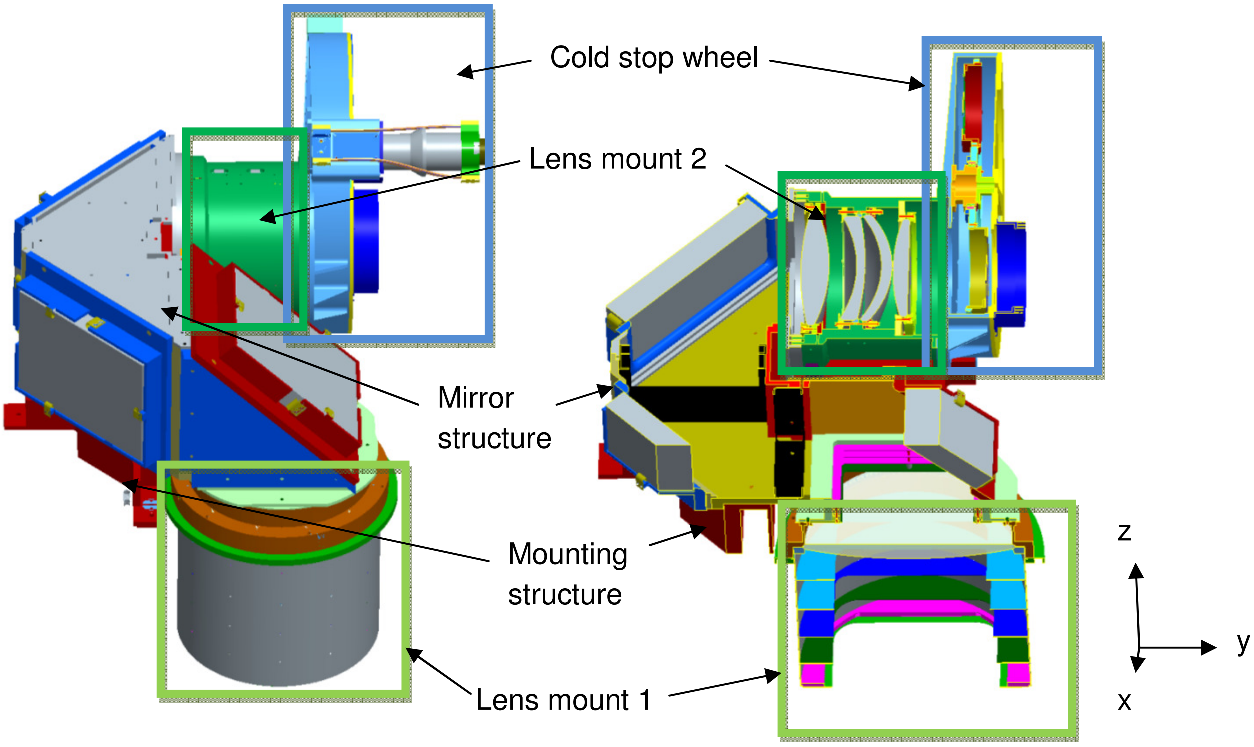


Figure 16: Optics mount 1 and its sub-components

Tolerances:

	Tilt x [arcmin]	Tilt y [arcmin]	Decenter x [µm]	Decenter y [µm]	Position z [µm]
	±1.02	±1.02	±50	±50	±200
Achieved by	Manufacturing		Adjustment	Adjustment	Manufacturing

Optics mount 1 can be shifted in x and y with screws. The same screws allow adjusting of the the tilt perpendicular to the cold plate (tilt z). Tilt x and tilt y are defined by the planarity of the mounting structure.

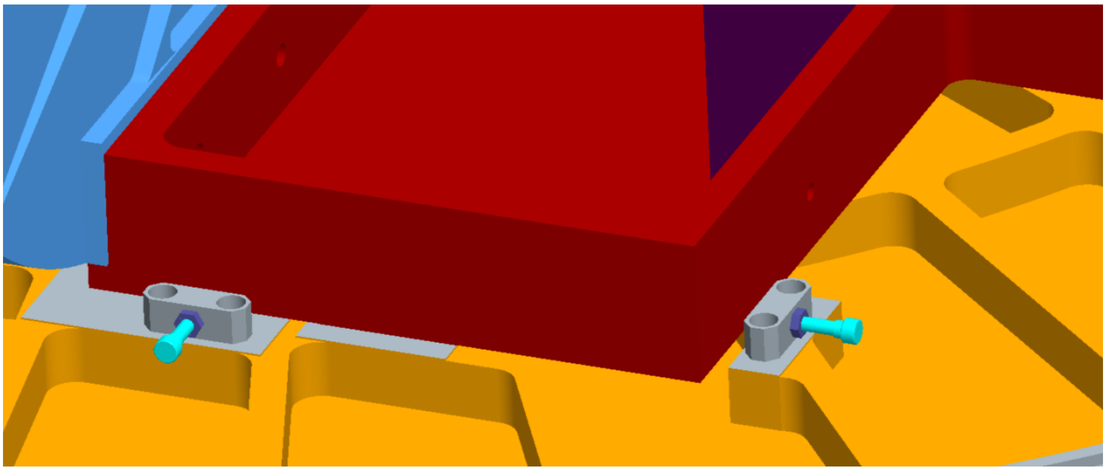


Figure 17: Adjustment screws allow optics mount 1 to be shifted in x and y direction.

The alignment is made by using four fine thread screws and one end-stop as rotation center. Turning two screws simultaeously will shift the complete assembly linearly. Rotation can be achieved by attaching the block and turning only one of the y-screws.

Figure 18: Optics mount 1 adjustment principle

2.5.1 Lens Mount 1

Lens mount 1 is a mount to hold the first lens before the folding mirrors. This lens is the largest lens in the instrument. The field stop and the bafffle B2 are attached to this lens mount.

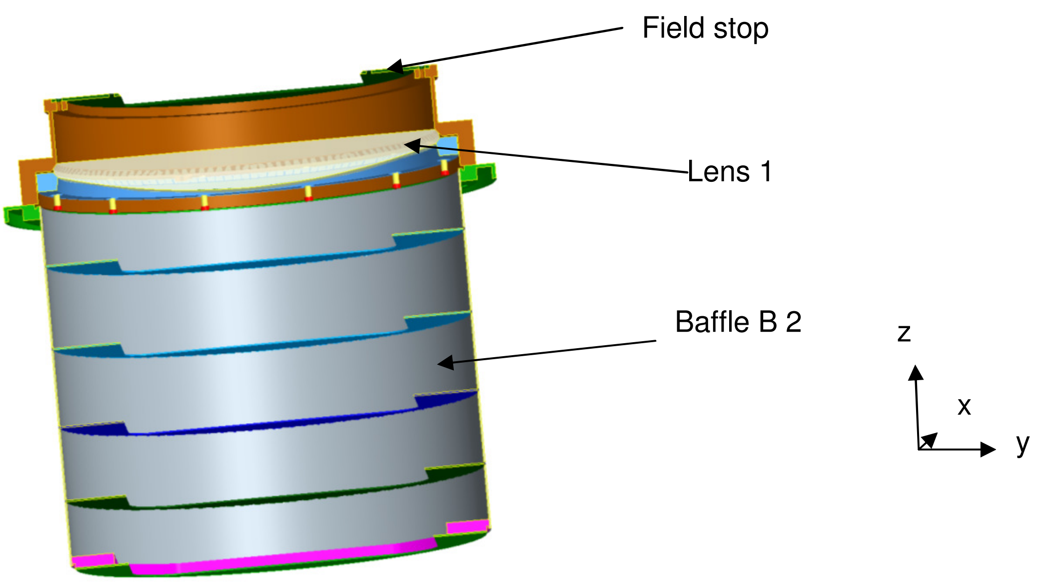


Figure 19: Lens mount 1 with lens 1, the field stop and the baffle B2

Tolerances:

	Tilt x [arcmin]	Tilt y [arcmin]	Decenter x [µm]	Decenter y [µm]	Position z [µm]
	±1.2	±1.2	±50	±50	±100
Achieved by	Manufacturing		Fitting diameter		Manufacturing

The decentring value is minimized by a fitting diameter. The z-position of the interface surface provides the correct z-position of lens mount 1

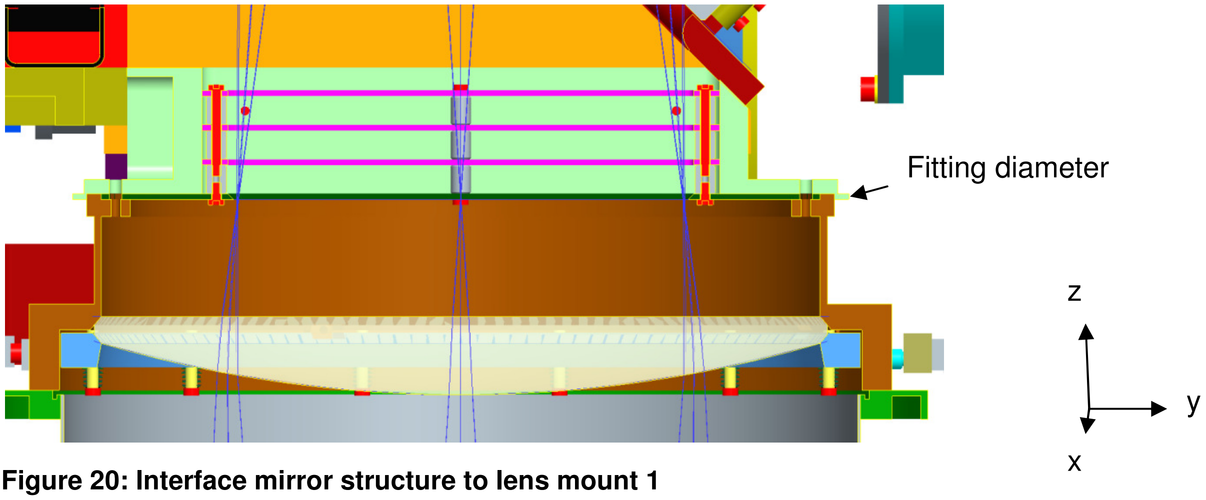


Figure 20: Interface mirror structure to lens mount 1

2.5.1.1 Lens 1

Lens 1 is directly attached to lens mount 1. The correct integration of lens 1 into the mount will be achieved by measuring and re-adjusting the actual lens position as described in section 2.2.

2.5.1.2 Baffle B2

Baffle B2 is the largest baffle in the system and placed in front of lens mount 1.

2.5.2 Mirror Structure

The mirror structure folds the optical beam three times by 90°.

Due to limited mass budget the mirror sizes must be reduced to an absolute minimum. Therefore FE-analysis investigating circular, elliptical and rectangular mirrors has been performed. The results show that a rectangular shape meets the requirements with the lowest mass.

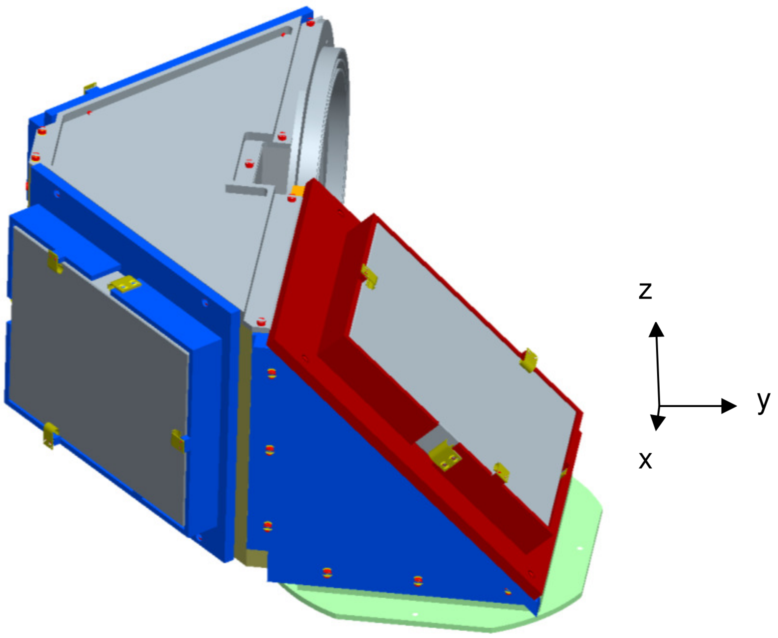


Figure 21: The mirror structure

Tolerances:

	Tilt x [arcmin]	Tilt y [arcmin]	Decenter x [µm]	Decenter y [µm]	Position z [µm]
	±1.2	±1.2	±50	±50	±100
Achieved by	Manufacturing precision and doweling				

The mirror structure will be doweled to the optics mount 1 to achieve the required precision. All interface surfaces will be remachined after assembly of the structure to provide the required tolerances.

2.5.2.1 Mirror Holders

The mirrors are mounted in mirror holders (MH) using a three point mounting. The mirrors are clamped to their mounts with spring elements allowing the aluminum to shrink differently than the mirror substrate which is made of Zerodur.
Two springs (radial springs) clamp the mirror in x- and y- direction by pressing the mirror against three support surfaces (shown white in Figure 22). Three additional springs press the mirror against the support surfaces in z-direction (shown white in Figure 22).

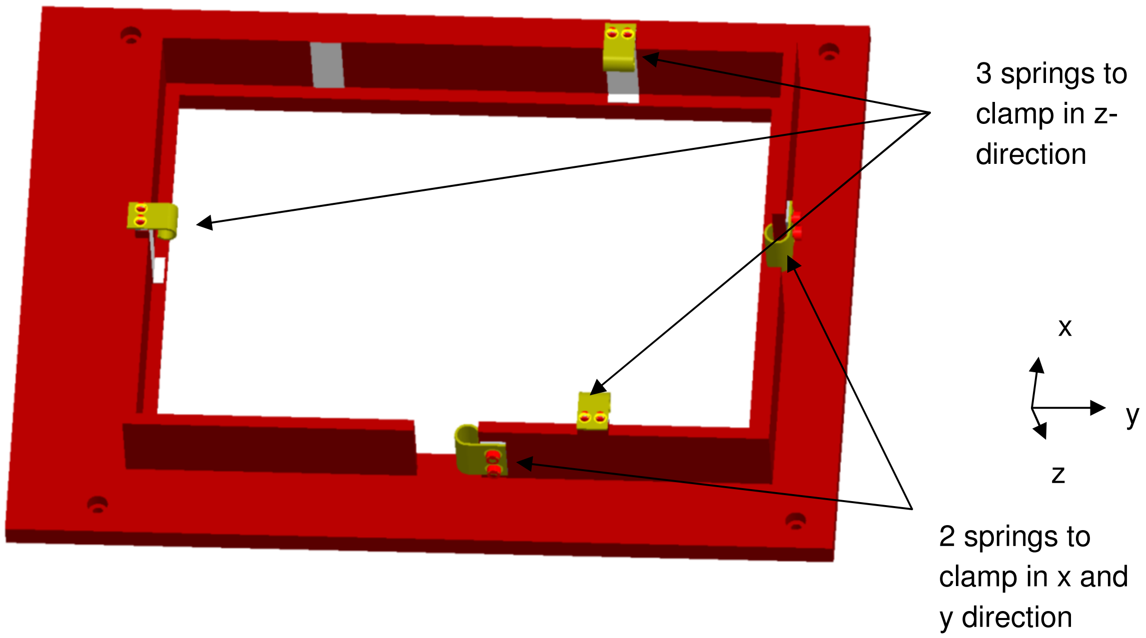


Figure 22: Mirror holder design for supporting the three mirrors. Three springs clamp the mirror in x direction, one in y and one in z direction.

Tolerances:

The tolerances are equal for every mirror holder and include the positioning of the mirror inside the holder.

	Tilt x [arcmin]	Tilt y [arcmin]	Decenter x [µm]	Decenter y [µm]	Position z [µm]
	±1.5	±1.5	±100	±100	±100
Achieved by	Initial measurement with possibility for remachining				

Before integration into the optics mount 1 the mirror holders, including the mirrors, will be assembled and measured. Each mirror holder will be oversized 0.5 mm. According to the results of these measurements the holders will be milled to their final value.

2.5.2.2 Mirror Size

To determine the thickness of the mirrors the self-weight deflection has been analyzed using FE-analysis. Figure 23 shows the boundary conditions used in the model.

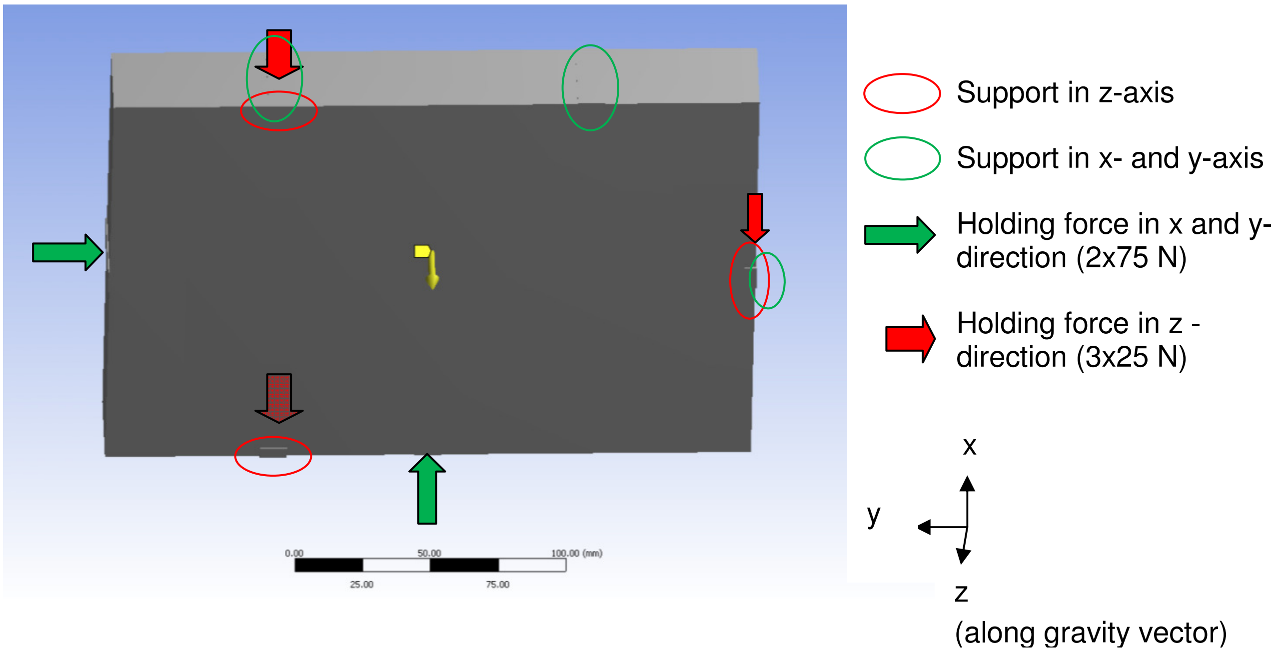


Figure 23: Boundary conditions to model the mirror support

The yellow arrow shows the gravity vector. The mirror is supported in z-direction by three support surfaces (red ellipses in the figure above). The support in x- and y-direction is made by three support surfaces on two sides (green ellipses). Four fixation spring clamps press the mirror against these support surfaces. The force is calculated to be 75 N (twice the gravity force). The green arrows point to the surfaces where the forces for the x- and y-directions are applied. Each arrow represents a force of 75 N. The z-direction force (red arrows) is split over three surfaces exactly opposite to the support surfaces. Each arrow represents a force of 25 N resulting in a total force of 75 N.

With these conditions several test runs at different mirror shapes and mirror thicknesses were made to determine the most lightweight mirror geometry. The calculations resulted in rectangular mirrors with a size of:

Mirror	Surface	Thickness	Mass
M1	174 mm x 238 mm	30 mm	3.15 kg
M2	236 mm x 170 mm	30 mm	3.05 kg
M3	236 mm x 170 mm	35 mm	3.55 kg

The details of this analysis can be found in RD 3.

2.5.3 Lens Mount 2

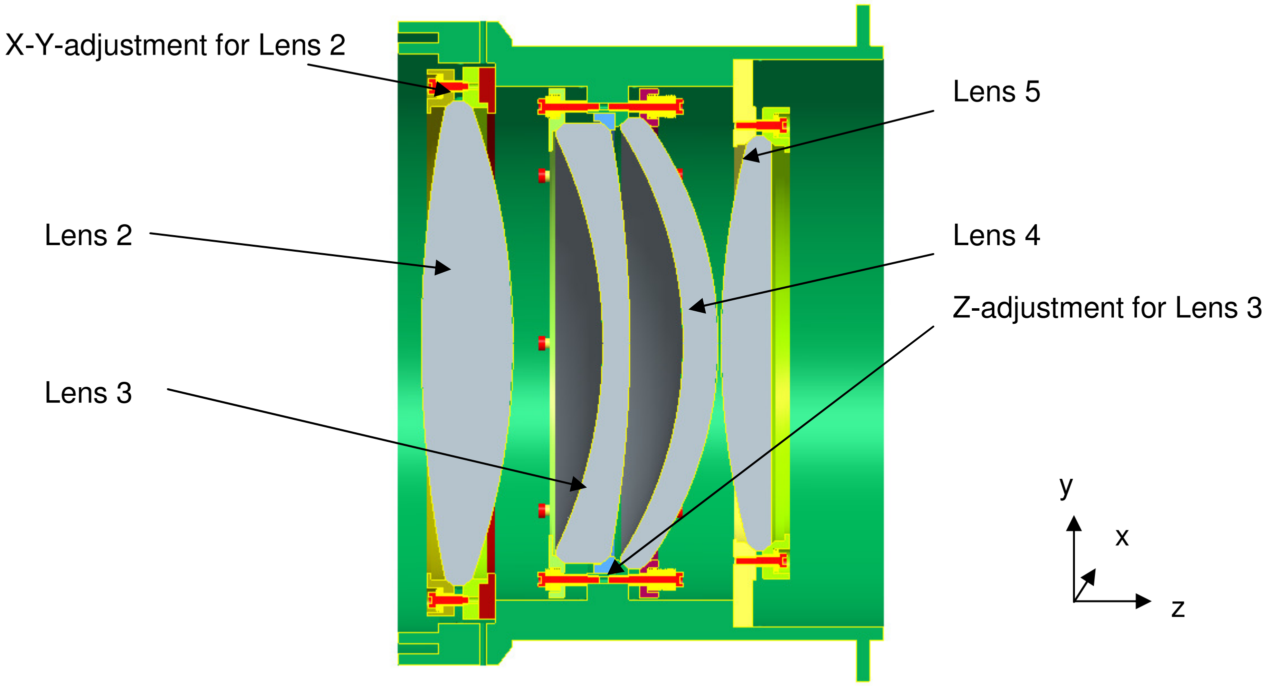


Figure 24: Boundary lens mount 2 group

The lenses L2 to L5 are assembled to a common mount (lens mount 2).

Deairing

The air between the lenses can dissipate via opaque sintered aluminum elements. Lens mount 2 has two of these elements. To deaerate the volume between lens 3 and lens 4 there are three slots in the z-adjustment ring for lens 3 allowing the air to flow into the volume between lens 3 and lens 2.

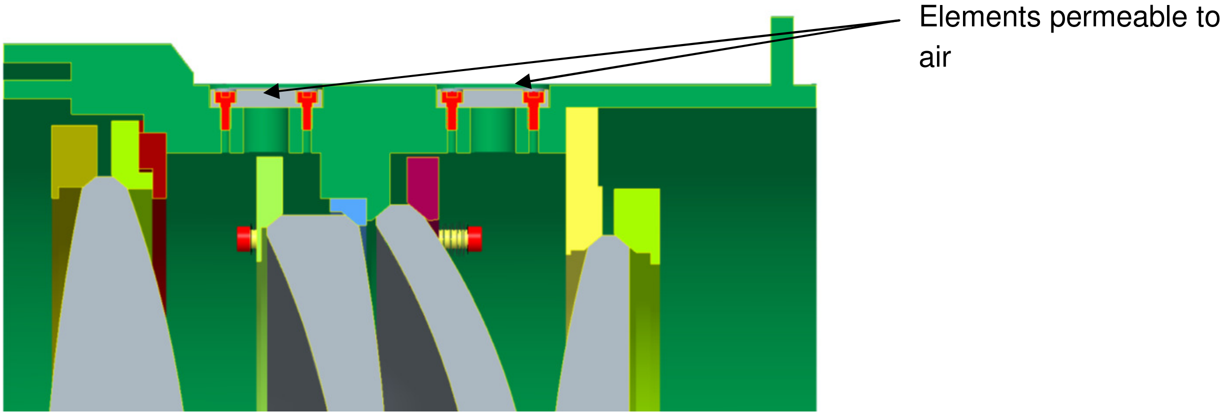


Figure 25: Deairing is done by sintered aluminum elements which are permeable to air

Tolerances:

	Tilt x [arcmin]	Tilt y [arcmin]	Decenter x [µm]	Decenter y [µm]	Position z [µm]
	±1.2	±1.2	±50	±50	±100
Achieved by	Manufacturing (fitting diameter + additional support)				

The tube of lens mount 2 is inserted into a fitting diameter of the cold stop wheel housing. This diameter guarantees the position in x, y and z. An additional support is attached at the opposite side.

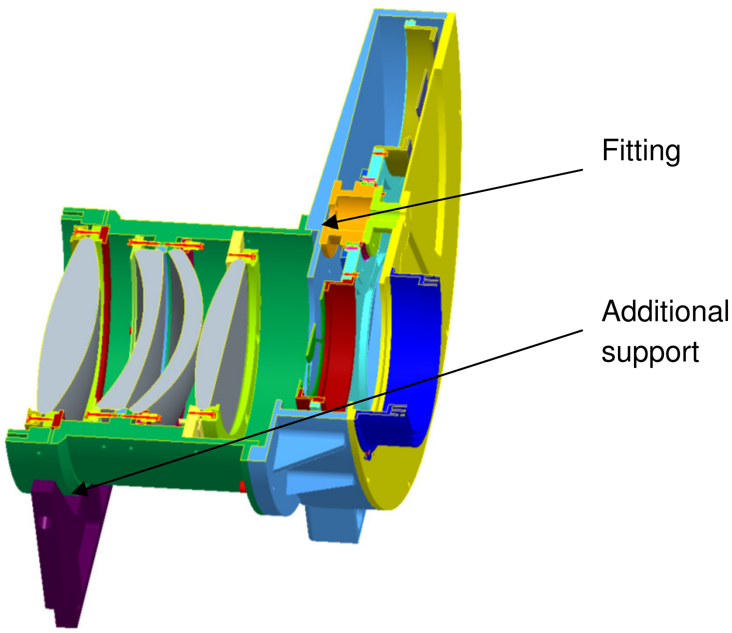


Figure 26: Positioning of lens mount 2

2.5.3.1 Lens 2

Lens 2 is adjustable in x and y direction in order to align lens mount 2 and to allow less tight tolerances.
The adjustment unit for lens 2 allows it to be shifted in the in x and y direction (perpendicular to the optical axis). The unit consists of two rings with parallel flat surfaces that allow the attached lens to slide along this surface.

Adjustment unit for Lens 2

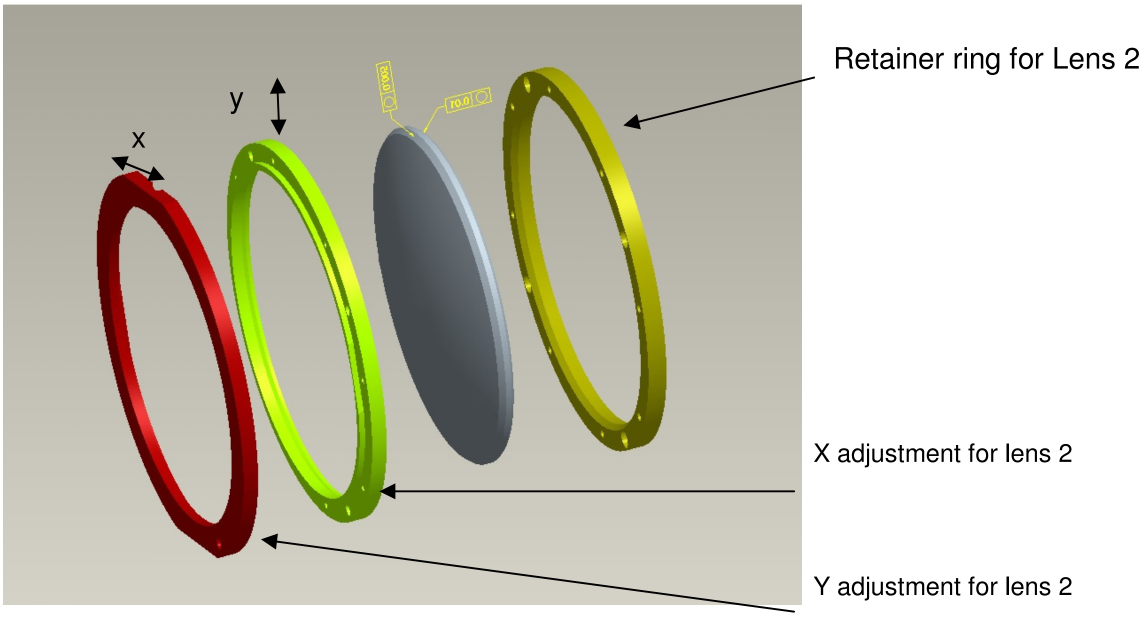


Figure 27: Adjustment unit for Lens 2

The alignment will be done with micrometer screws. After aligning, the achieved position will be fixed by fastening the mounting screws.

2.5.3.2 Lens 3

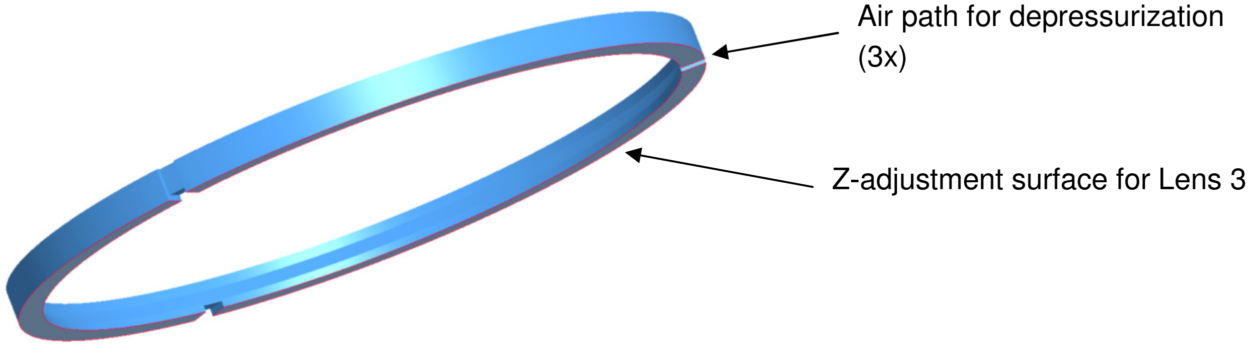


Figure 28: Adjustment ring for lens 3

Lens 3 is attached via a spacer ring. This ring will be adapted to the correct size during integration. The task of this ring is to define the correct distance between lens 3 and lens 2 in order to compensate assembly and manufacturing tolerances in the lens mount 2 group.

2.5.3.3 Lens 4

Lens 4 is directly attached to lens mount 2.

2.5.3.4 Lens 5

Lens 5 would require a large diameter to fit over lens 4. A small mount holding lens 5 was designed to avoid this. This mount is screwed to lens mount 2 and allows lens 5 to have a reduced diameter. To achieve exact positioning the mount for lens 5 will have a fitting diameter to fit into lens mount 2.

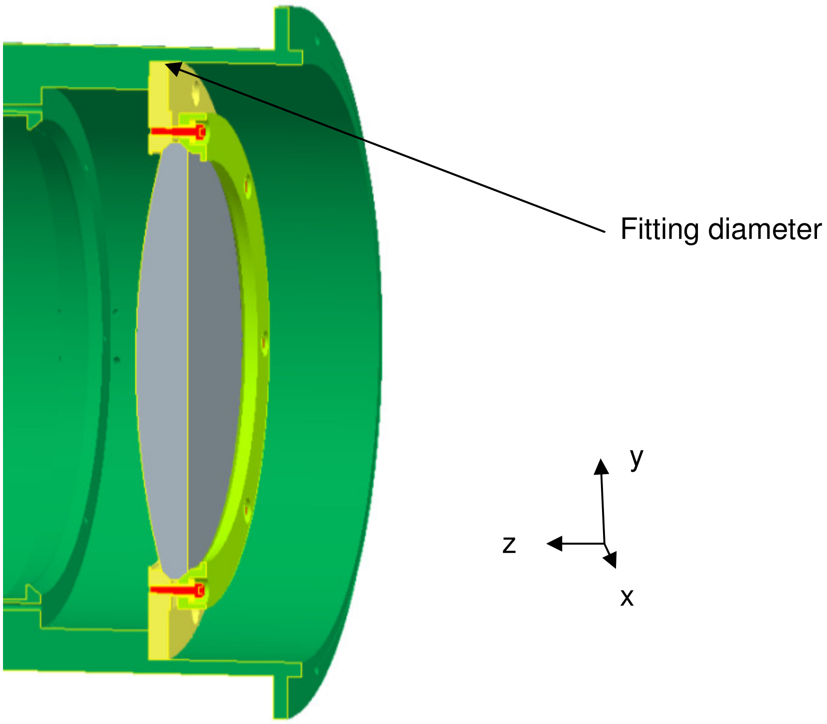


Figure 29: Lens 5 with its support in lens mount 2

2.5.4 Cold Stop Wheel

The last optical element in optics mount 1 is the cold stop wheel. Its task is to insert either the cold stop mask for the 2.2 m telescope or the mask for the 3.5 m telescope into the optical beam. The wheel also includes open positions to allow measurements without a mask in the optical beam.

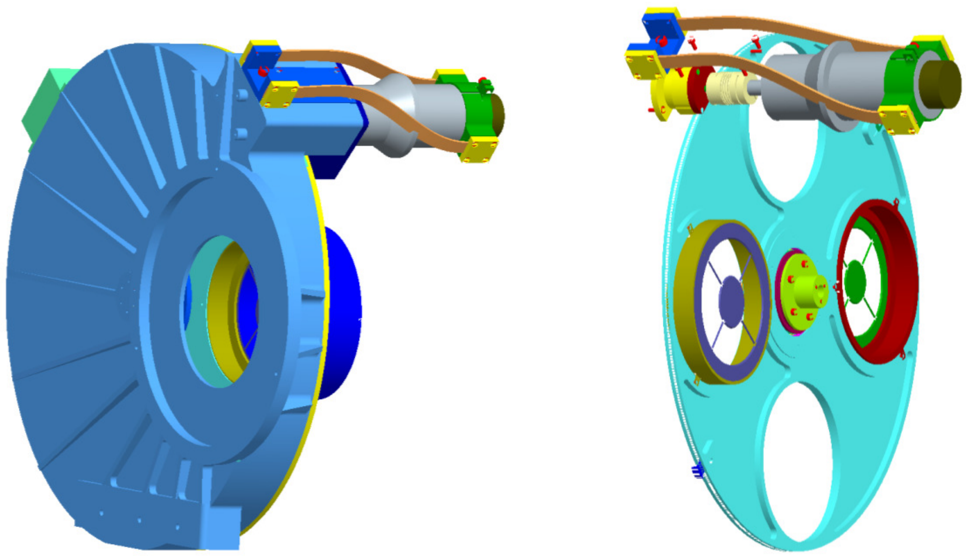


Figure 30: The cold stop wheel; left the complete view right without cover

Details about the wheel mechanisms can be found in chapter 3 which describes all aspects of the PANIC wheel mechanisms.

2.6 Optics Mount 2

Optics mount 2 is the assembly comprising the lenses six to nine and the filter wheel. These subassemblies will be integrated and verified separately.

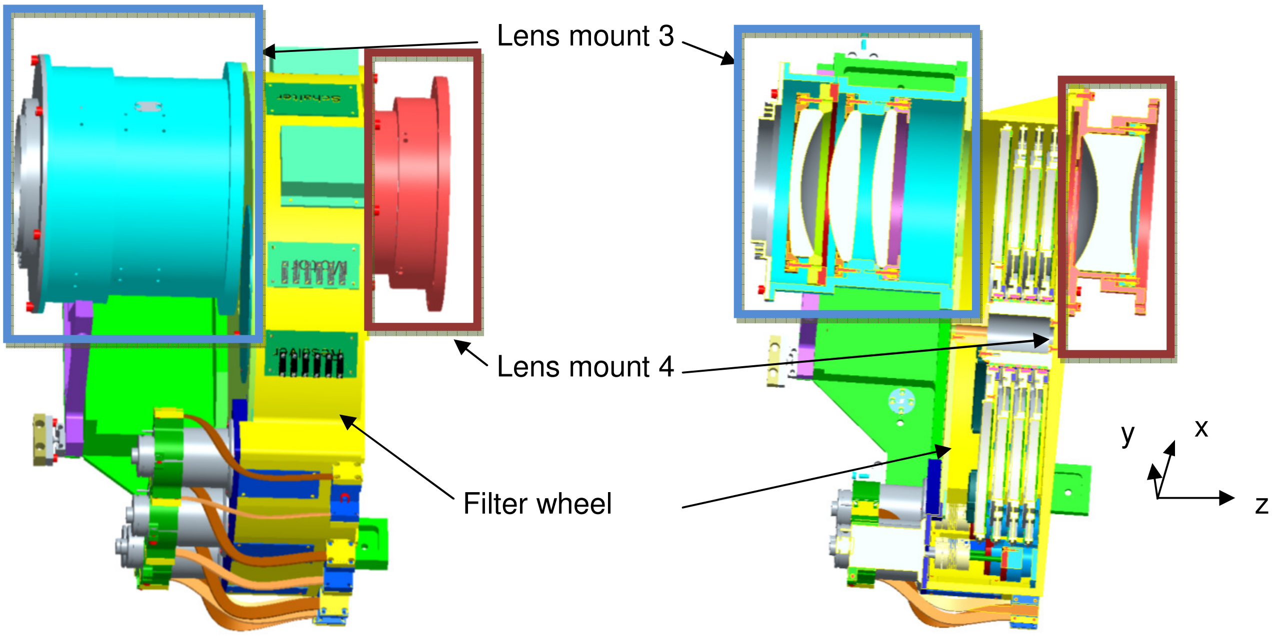


Figure 31: Optics mount 2 and its components

Tolerances:

	Tilt x [arcmin]	Tilt y [arcmin]	Decenter x [µm]	Decenter y [µm]	Position z [µm]
	±1.50	±1.50	±50	±50	±100
Achieved by	Manufacturing	Adjustable	Adjustable	Manufacturing	Adjustable

Optics mount two can be shifted in x and y with screws. The same screws allow correcting the tilt perpendicular to the cold plate (tilt y). Tilt x and tilt z are defined by the flatness of the mounting structure. The alignment concept is the same as for the optics mount 1. (see chapter 2.5)

2.6.1 Lens Mount 3

Lenses 6 to lens 8 are grouped to lens mount 3. This assembly is similar to lens mount 2.

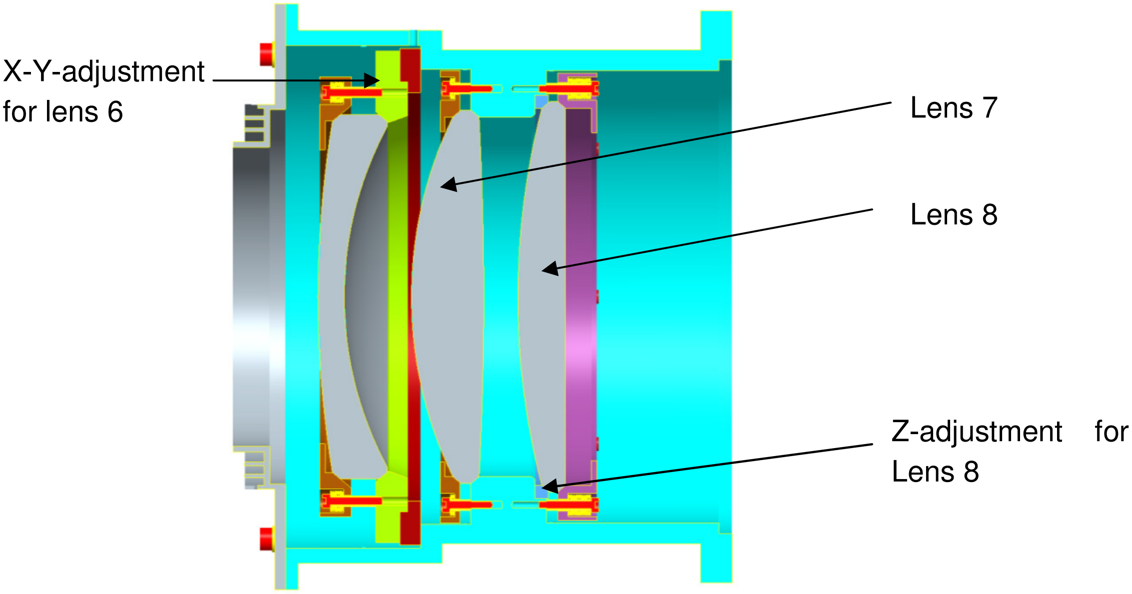


Figure 32: Lens mount 3 group

Tolerances:

	Tilt x [arcmin]	Tilt y [arcmin]	Decenter x [µm]	Decenter y [µm]	Position z [µm]
	±1.2	±1.2	±50	±50	±90
Achieved by	Manufacturing (fitting diameter + additional support)				

The tube of lens mount 3 is inserted into a fitting diameter on the filter wheel housing. This diameter guarantees the position in x, y and z. An additional support is attached at the opposite side.

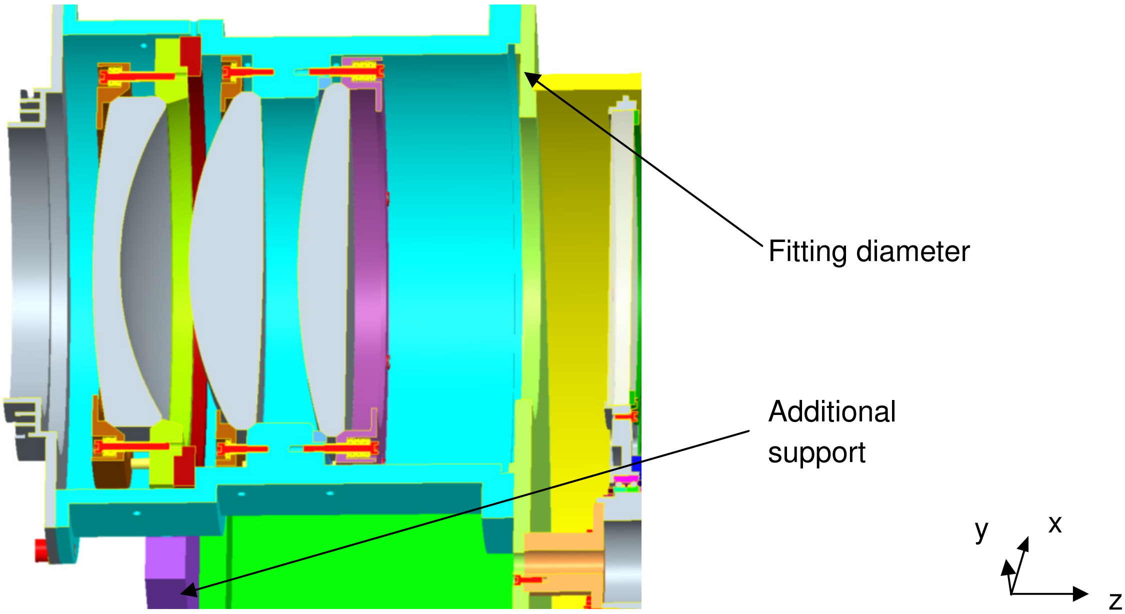


Figure 33: Positioning of lens mount 3

2.6.1.1 Lens 6

Lens 6 is adjustable in the x and y direction for alignment purposes. This adjustment is done in the same way as described in chapter 2.5.3.1 for lens 2.

2.6.1.2 Lens 7

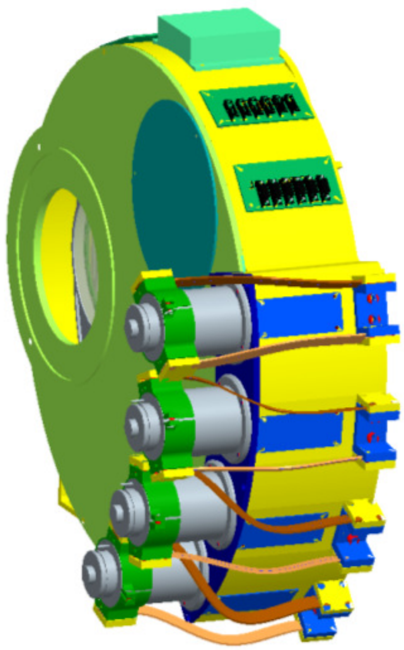
Lens 7 is directly attached to lens mount 3.

2.6.1.3 Lens 8

Lens 8 can be adjusted in z-direction via a spacer ring in a similar manner to lens 5 in lens (chapter 2.5.3.4).

2.6.2 Filter Wheel Unit

The filter wheel unit comprises four filter wheels each with six positions. 19 different filters can be mounted in total. All wheels include an open position. Wheel 1 also carries the pupil imager lens for alignment purposes.



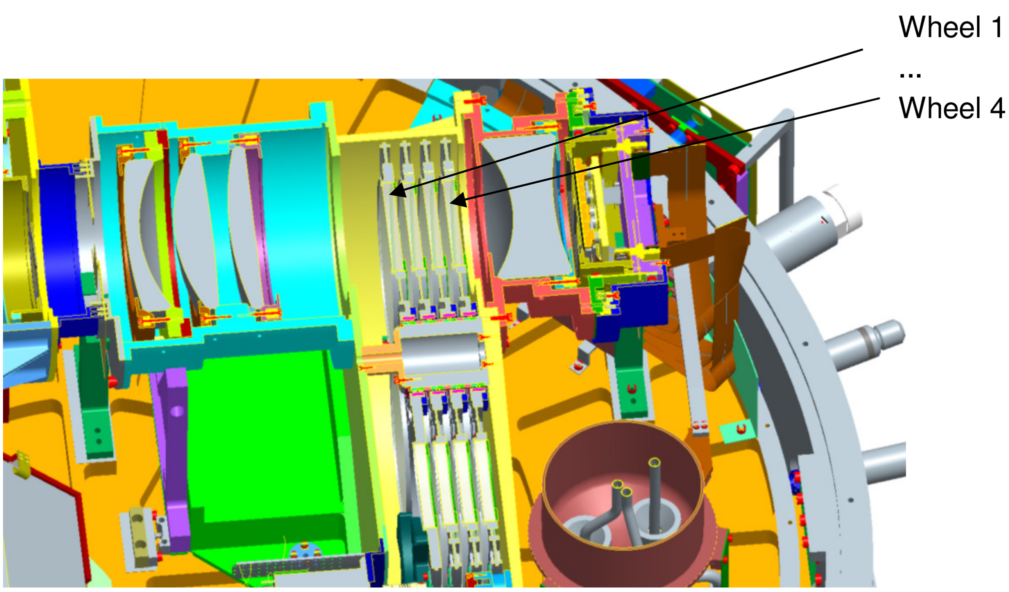


Figure 34: The wheels are numbered according to their order in the light-path

2.6.2.1 Pupil Imager Lens

The pupil imager lens is attached to filter wheel 1. This lens is mounted in the same way as the other lenses.

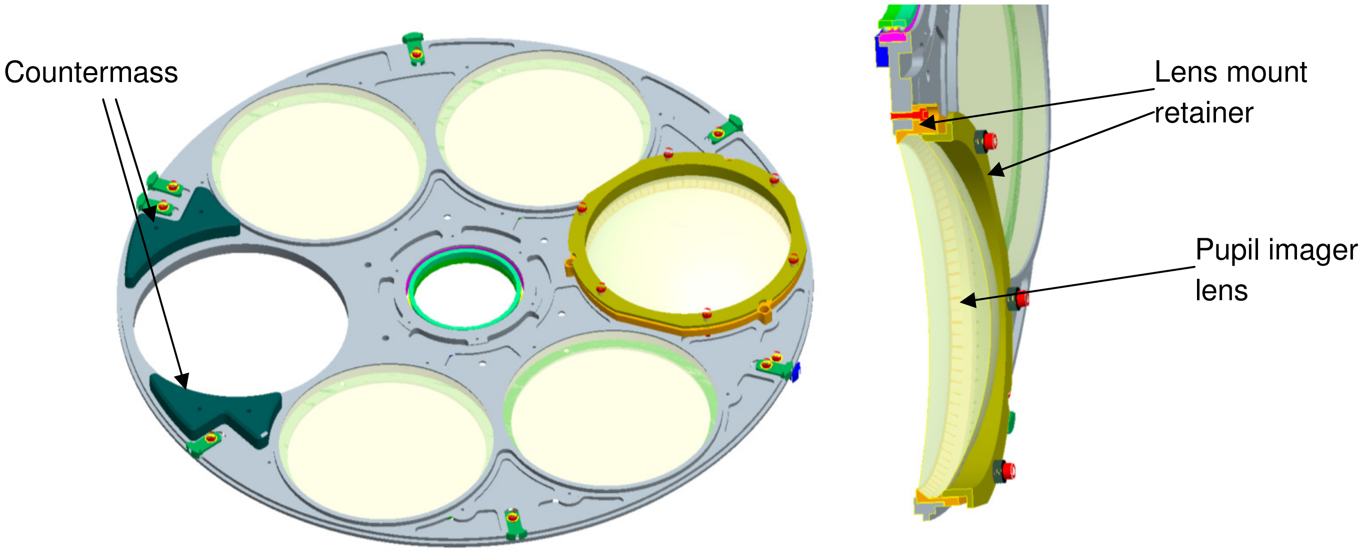


Figure 35: Filter wheel 1 with the pupil imager lens and counterweights

2.6.2.2 Filters

The filter wheels 2, 3 and 4 are identical and hold 5 filters each.

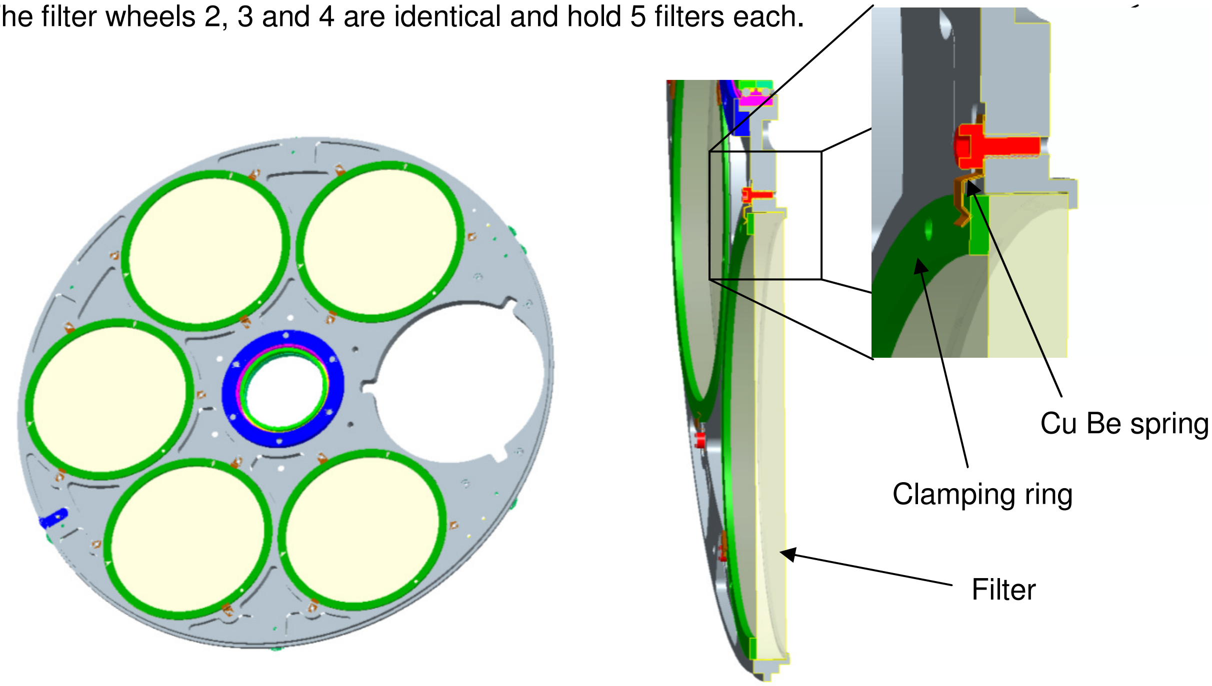


Figure 36: Left: Design of the filter wheels 2 - 4. Right: Cross section showing mounting concept.

2.6.2.3 Changing Filters

It is possible to change the mounted filters without disassembling the filter wheel unit. A hole is therefore incorporated in the filter wheel housing to allow access to the wheel disks.

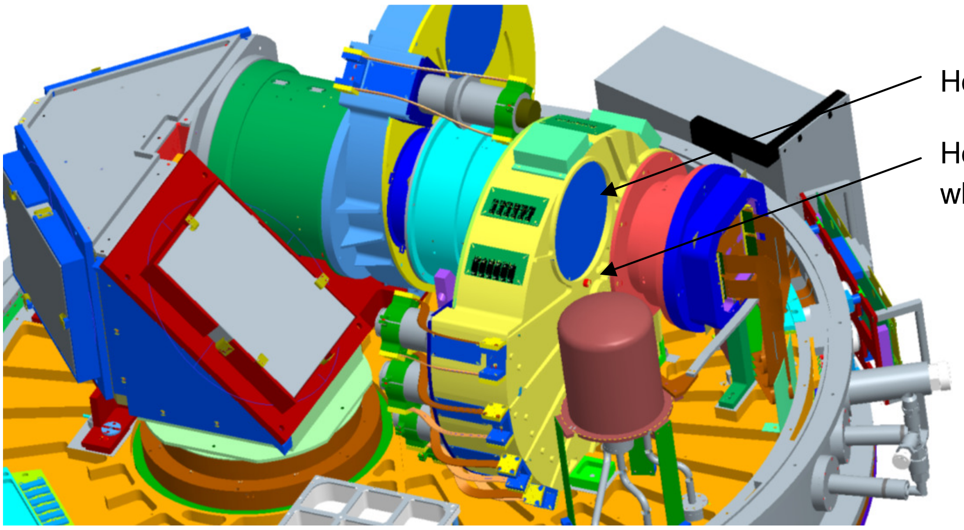


Figure 37: Filter access

The details of this filter change concept is summarized in the following text:

Preparation

- The PANIC instrument is mounted in its test caddy inside a clean room.
- The vacuum vessel is opened and the shield is removes as described in chapter 4.5.1.
- The wheels are moved to their maintenance position. Each wheel has an open position, which allows access to the filters behind.
- The wheels are locked against unintended movement with the locking rod.

Removal of a filter

- The three filter mounting screws are unscrewed. The spring elements can then be turned.
- The filter and the clamping ring are removed with a vacuum lifter.

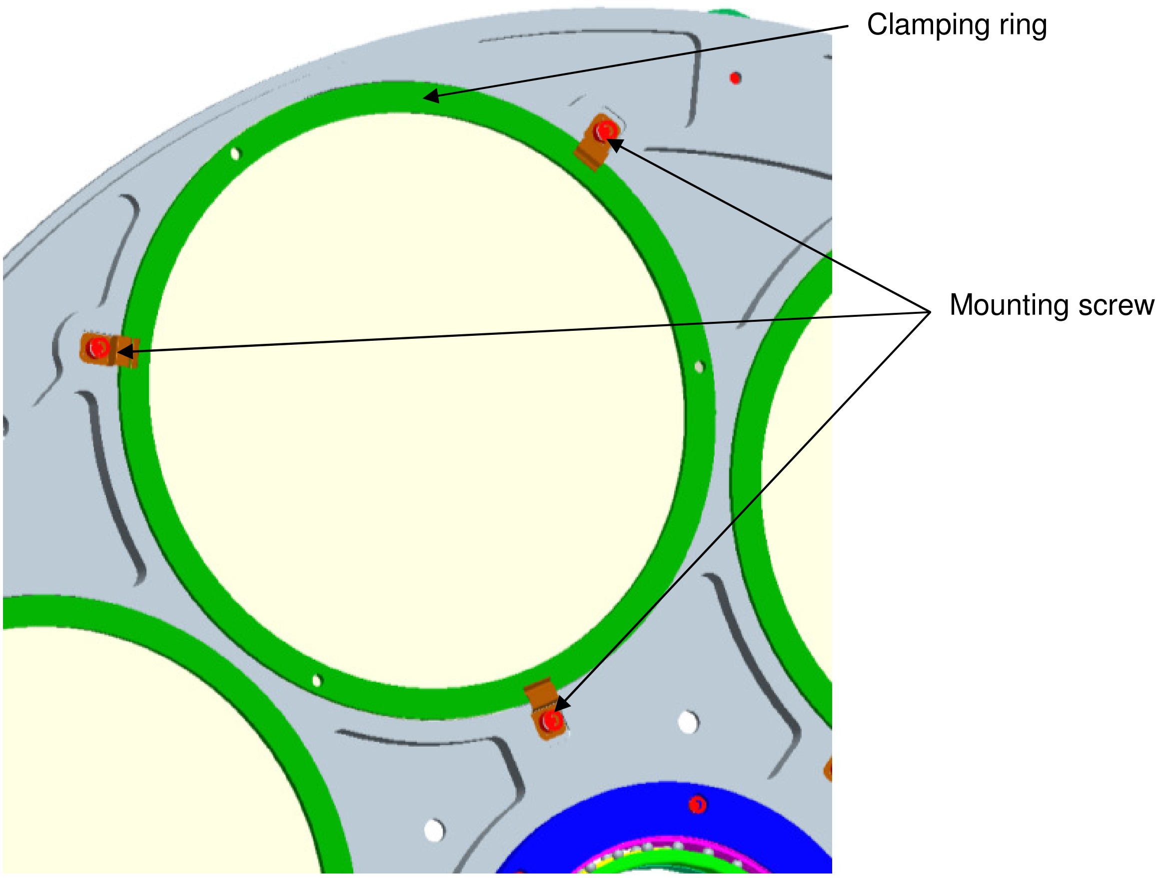


Figure 38: Filter mounting elements

Inserting a new filter

- A new filter is inserted with the vacuum lifter. The clamping ring is inserted and the spring elements are turned back.
- The screws are fastened

Final work

- The locking rod is removed and the cover is closed

2.6.3 Lens Mount 4

Lens mount 4 carries lens 9 and is directly attached to the filter wheel housing. Lens mount 9 also provides the interface to the detector unit.

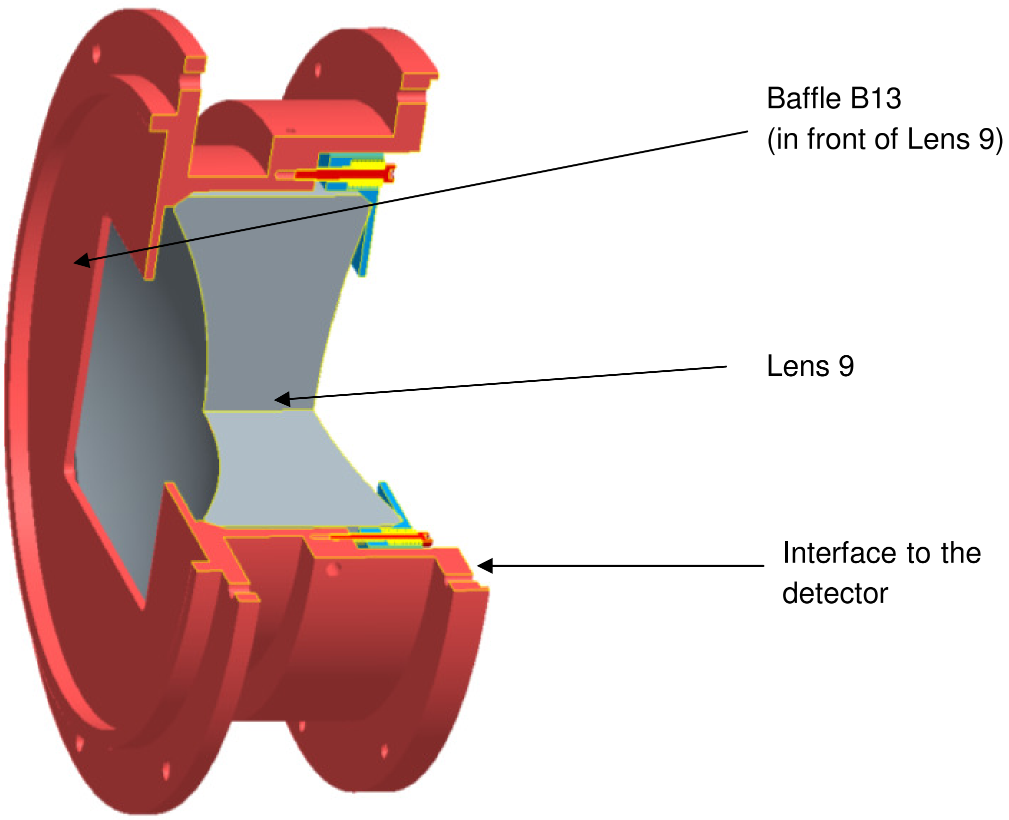
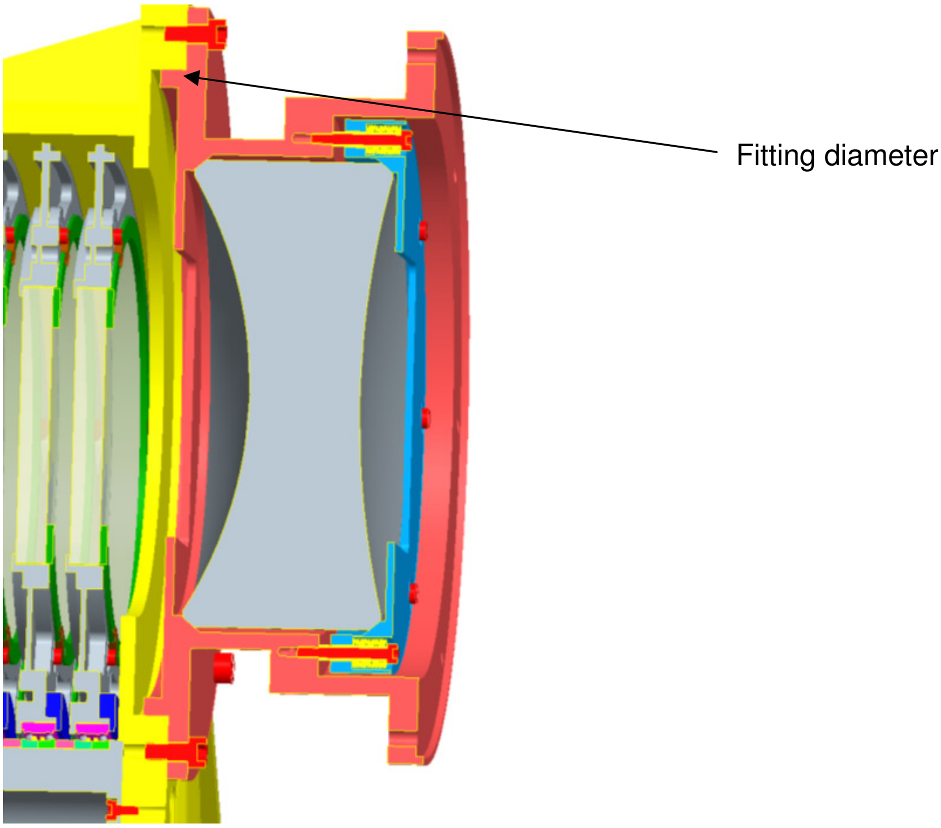


Figure 39: Lens mount 4 with lens 9 attached.

Tolerances:

	Tilt x [arcmin]	Tilt y [arcmin]	Decenter x [µm]	Decenter y [µm]	Position z [µm]
	±1.5	±1.5	±50	±50	±90
Achieved by	Manufacturing (fitting diameter)				

Lens mount 4 is attached in a similar way as lens mount 3. Again a fitting diameter is used to ensure the correct position of the mount.



2.6.3.1 Lens 9

Lens 9 is directly attached to lens mount 4. Unlike the other lenses lens 9 has a rectangular baffle, an aspect that must be considered during assembly since its orientation is important.

2.6.4 Detector Interface

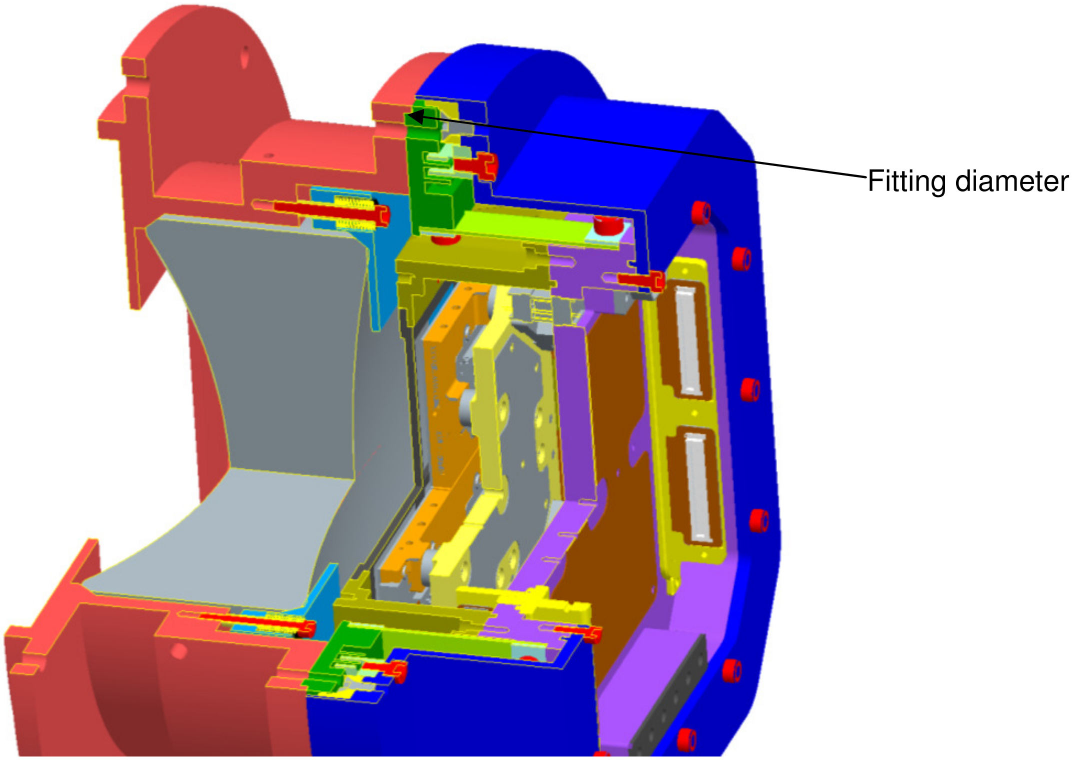


Figure 40: The interface to the detector

The detector is attached directly to the rear surface of lens mount 4.

Tolerances:

	Tilt x [arcmin]	Tilt y [arcmin]	Decenter x [µm]	Decenter y [µm]	Position z [µm]
	±2.4	±2.4	-	-	+200 / -50
Achieved by	Manufacturing (fitting diameter)				

The detector is attached to lens mount 4 in the same way that lens mount 4 is attached to the filter wheel housing. Again a fitting diameter is used to ensure the correct position of the mount.

3 WHEEL MECHANISMS

3.1 General

PANIC has 5 wheels, 4 filter wheels and 1 cold stop wheel. They have teeth on the outer circumference and are driven by bevel wheels. The filter wheels each have six positions including one open position.

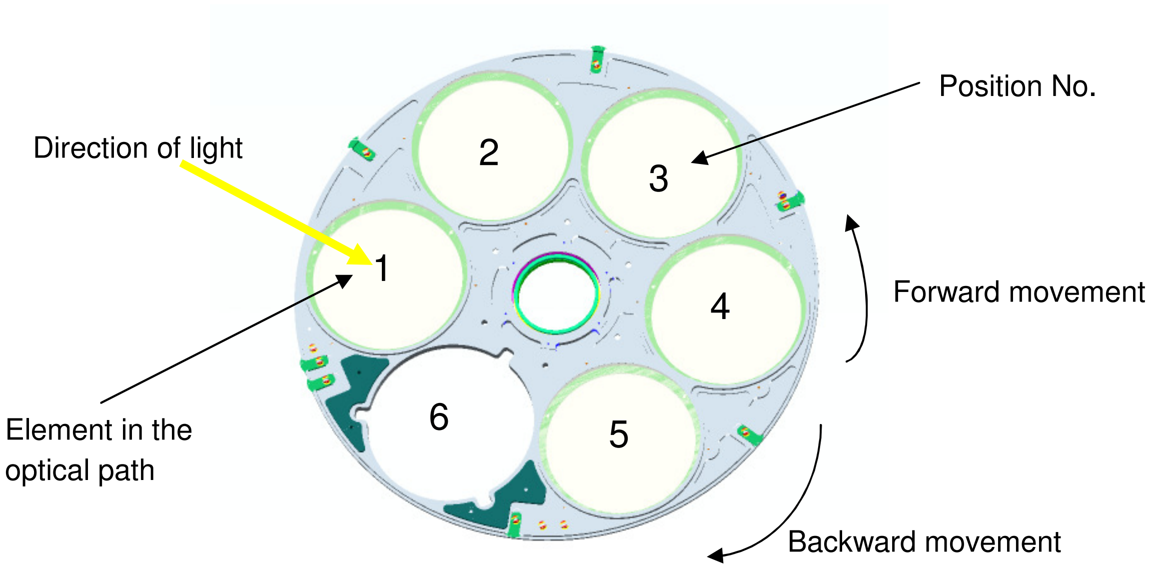


Figure 41: Definition of wheel positions and directions

It is obvious that a gear between the motor and the bevel wheel improves the positional accuracy. However, since the lifetime of cryogenic gears (Harmonic Drive) have a maximum of 10000 turns at the output, we must consider not only positional accuracy, but also lifetime.

3.2 Lifetime

a) Cold stop wheel

The cold stop wheel will be moved only a few times per year, so the lifetime of a gear in this mechanism is not an issue.

b) Filter wheels

The number of turns of the bevel wheels is given by

N = mpn x npy x tpm

Where

mpn = movements per night. Based on existing experience on Calar Alto with Omega2000 the number of filter movements is between 1 and 100 per night, depending on the astronomical program. We assume a mean value of 30 movementsper night but expect the actual number to be lower than this.

npy = nights per year in which PANIC is used. We assume npy = 100

tpm = turns of bevel wheel per movement of wheel. Each filter movement requires the movement of at least 1 filter wheel, up to 180°. With a transmission ratio wheel/gear of 1:13.4 (see below) the motor turns ½ x 13.4 = 6.7 times per filter change. Thus we obtain

N = 30 x 100 x 6.7 = **19,000 turns per year.**

This would mean a lifetime of only 0.5 years for the gears It is clear that these gears would be unsuitable for the wheel mechanism. The wheels have been designed to incorporate drive systems without gears.
The lifetime of the motors is expected to be 150000 revolutions. With 19000 revolutions per year this would lead to an expected lifetime of 7.7 years and therefore is sufficient. Nevertheless we plan to accumulate the number of turns made by each motor in the software and issue a warning when the end of the lifetime is approached.

Positional accuracy

a.) Filter wheels

Each step of the motor corresponds to a displacement dx of the filter wheel which is obviously given by

$$\frac{dx}{2\pi \cdot r} = \frac{1}{200}\frac{1}{13.4}$$

Here r is the radius of the filter wheel on the optical axis. With r = 129 mm we obtain dx = 0.3 mm. Using the control software we will ensure that the motor actually stops in a magnetic detent. This is possible since the resolution of the resolvers used for position control is 1/24 of a motor step. The positional repeatability is obviously higher than 1 step, probably by a factor of around 15, so we conclude dx ~20 µm which corresponds to ~ pixel.

The positional repeatability has some importance for the instruments' flat field calibration. If the filter wheel is moved between sky flats and object exposures, the shadow of a dust grain on the filter moves by 1 pixel on the detector. However, the image of a 500 micron radius dust grain on a filter is 1.5 microns on the detector and will reduce the flux in that pixel by about 1%. Any residuals in the flat field correction will be removed by kappa-sigma clipping when stacking the dithered images.

b.) Pupil imager lens

The requirement for the *absolute position* of the pupil imager lens is dx = 0.1 mm. This can be easily reached since the motors are actually moved in microsteps, where 1 step = 256 microsteps. The motor is held in position by sustaining the motor current.

c.) Cold stop wheel

The cold stop has a diameter of 94 mm for the 2.2 m telescope and 79 mm for the 3.5 m telescope (including 3% oversize). It has been demonstrated that this oversize increases the background noise in the K bands by only about 5% of the sky background. The absolute positional accuracy in a drive with gear is obviously much higher than needed. Nevertheless we will use a gear here since this allows maintaining the position of the cold stop with an unpowered motor.

3.3 Drive

The main parts of the drives are shown in Figure 42. The drives are identical for the 4 filter wheels, but the drive for the cold-stop has an additional gear.

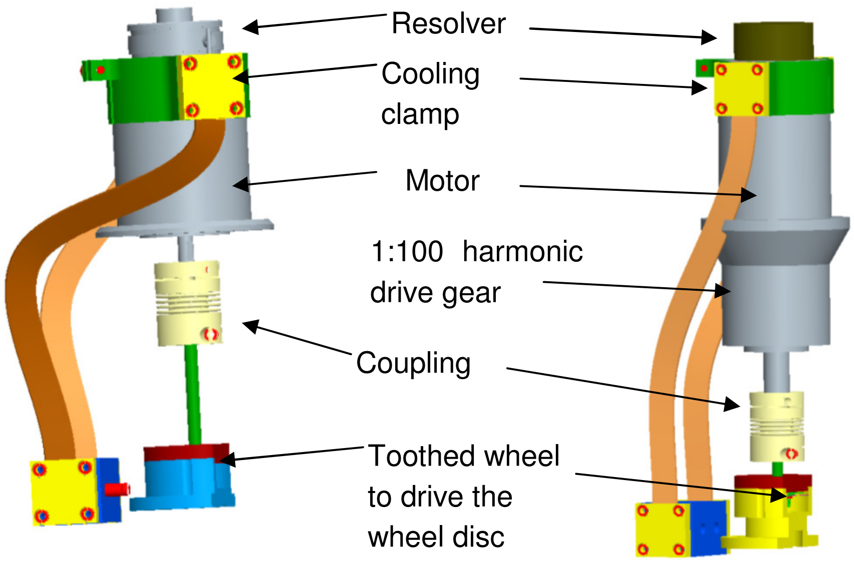


Figure 42: The main parts of the wheel drives. Left: one of four identical filter wheel power trains, right: the power train for the cold stop wheel

All wheels in PANIC have an identical diameter of 395 mm. The central bearing is a thin section duplex bearing with Dicronite (WS_2) lubrication. The filter wheels have 563 teeth and the bevel wheels have 42 teeth, this results in a 1:13.4 gear ratio.

The modulus of the gear is 0.7

All wheels are driven by Phytron VSS 52.200.2.5-UHVC-HD-LTN-4Lp motors. These stepper motors are specially designed for vacuum and cryogenic applications.

All motors are equipped with a resolver (LTN RE15-1-A14 from LTN Servotechnik). These resolvers supply position information.

3.4 Heat Dissipation

During movement of the wheels the power dissipated from the motors is 5.8 W, assuming 40 rpm, 1.5 A_{rms}, 256 microsteps and 77 K. 40 rpm at the motor result in 40/13.4 = 3 rpm at the wheels, which results in time to change a filter of <10 sec. The heat dissipated by the wheels is therefore negligible.

Once a position has been reached the current of the motors will be turned off in order to reduce power dissipation. The holding torque of the motor is 13 mNm, which corresponds to 174.2 mNm for the filter wheels and 8.7 Nm for the cold stop wheel. The filter wheels require balancing, since 1 (unbalanced) filter would cause a torque of 600 mNm. The cold stop wheel is naturally very well balanced.

In order to maintain the position of the pupil imager on a micro step, the motor current must not be turned off completely. If the current is reduced by 50% then the heat dissipation is 280 mW. This is not a problem since the pupil imager is used only for a quick check after installation of PANIC at the telescope.

3.5 Position Control

Position control of the wheels is achieved by positional switches that are activated by cams on the wheels. Figure 43 and Figure 44 show the how a wheel position is detected. One switch operated by one cam on the rear side is used to detect the absolute position. In addition there is a second switch operated by six cams (one cam per position) to detect if the wheel is in a working position or in between positions. This second cam switch is not able to identify which position is in the optical path. Although this system is sufficient to determine the absolute wheel position, a redundancy is introduced. A second cam close to the cam between position 1 and 6 provides absolute position information.

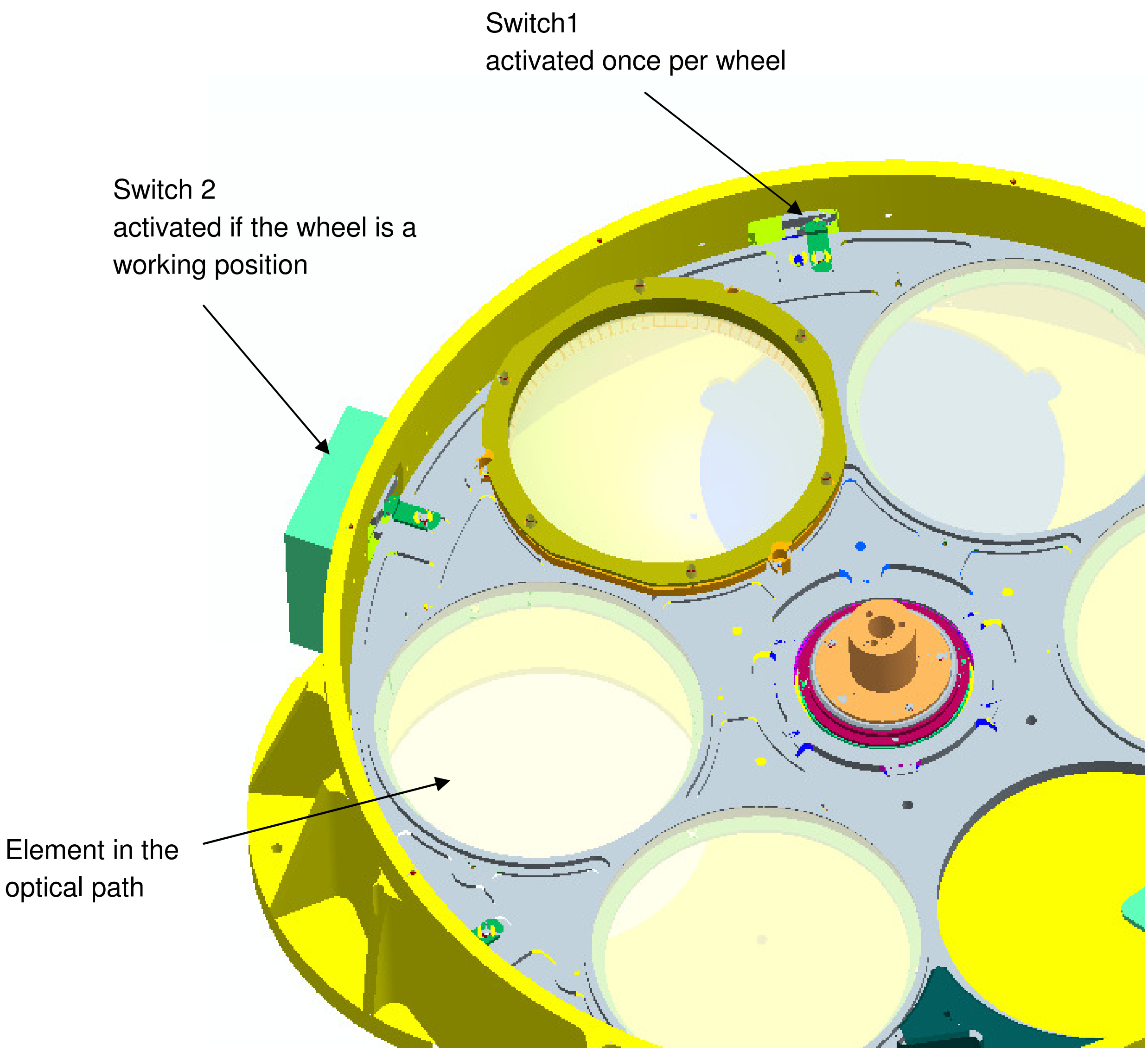


Figure 43: Two switches per wheel provide information about the actual wheel position

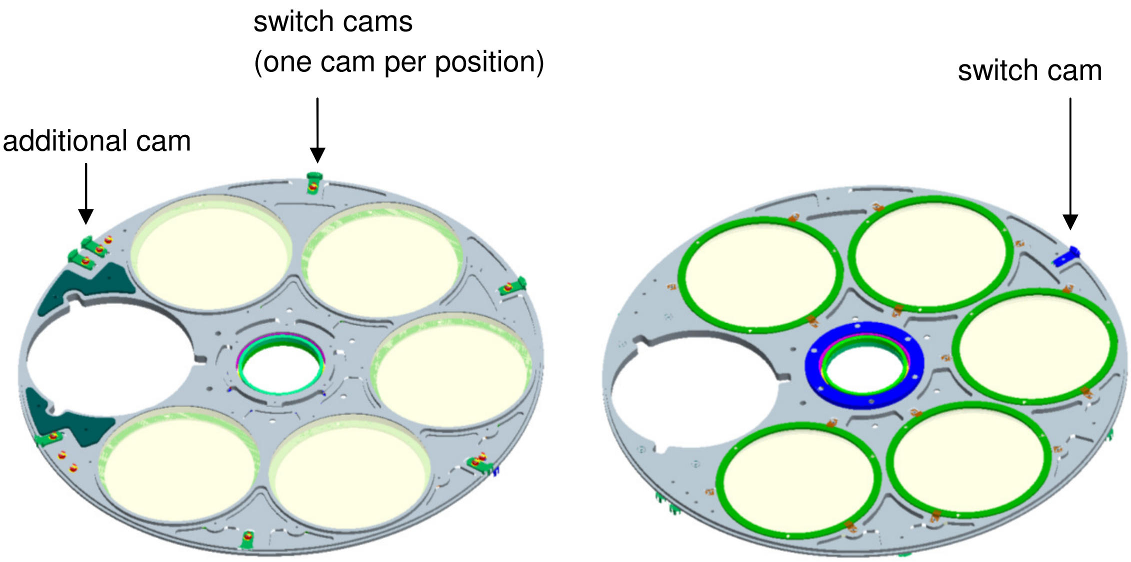


Figure 44: The filter wheel disc front side (left) has one cam per position, the rear side (right) has only one cam.

Two switches operated by one cam each are used to identify the two cold stop mask positions.

Experience with Omega2000 has shown that additional position information is desirable. We have therefore added resolvers on the motor axes which provide independent absolute position information.

4 CRYOSTAT

To provide the cold environment for the optics and the detector the complete instrument is built into a cryostat. The cryostat is designed as a nitrogen bath cryostat in order to cool the complete optics to a temperature below 100 K.

4.1 Requirements

Cold optics temperature	<100 K
Detector operation temperature	77 ±2 K
Detector temperature stability	± 0.1 K
Detector warm up and cool down rate	<1 K/min
Time between service / refilling	> 30 h
Total mass including optical bench, excluding optics, detector and LN_2 filling	< 180 kg
Total mass for the complete instrument	< 400 kg

4.2 Design

The cryostat is a nitrogen bath cryostat with a large vessel to cool the complete structure. To reduce LN_2 consumption and thermal gradients we use 20 layers of multilayer insulation (MLI) on the cold surface. This should reduce the heat load from radiation to about 5 W/m^2. For a constant detector temperature we use a second small LN_2 vessel to cool the detector exclusively. For weight reduction we will use dished ends on the vacuum can instead of flat thick walled plates.

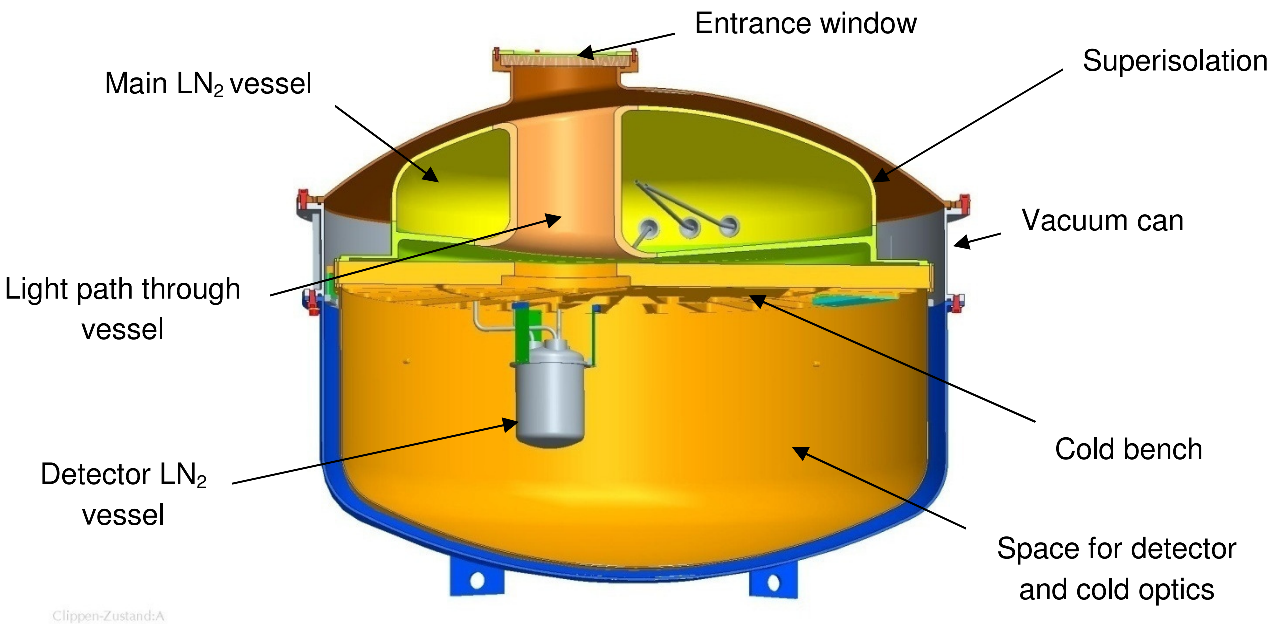


Figure 45: cross section through the cryostat

4.2.1 Vacuum Vessel

The vacuum vessel consists of 3 parts. There is a central ring which houses the cold to warm connections to the optical bench with spacers from glass-fiber reinforced plastics (GRP). Also mounted to this ring are all the electrical feedthroughs, the LN_2 feedthroughs, the vacuum pumping flange, the safety valve and the vacuum gauge.
On the telescope side there will be a dished flange with the entrance window (called the "upper part").
At the opposite side there will be a dome flanged to the central ring (called the "lower part"). The dome uses a dished boiler end.
All parts of the vacuum vessel are made from aluminum for weight reduction. All flanges and walls are weight optimized to meet the weight limitations of the telescope.

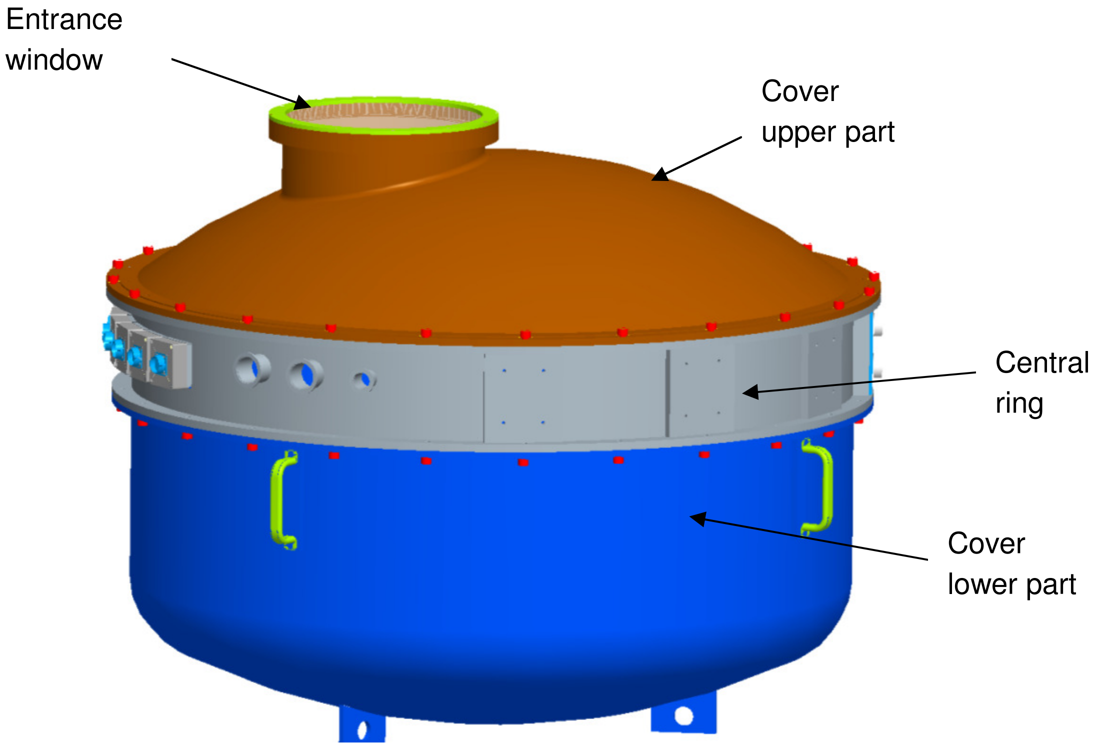


Figure 46: The vacuum vessel.

4.2.1.1 Central Ring

The central ring contains the following components:

- Cable feedthroughs for instrument control electronics
- Cable feedthroughs for read out electronics
- LN_2 feedthroughs for the main vessel and the detector vessel
- Flange to mount the detector-read-out electronics
- Mounting flanges to the caddy
- Vacuum ports for pumping and the vacuum gauge
- Vacuum safety valve
- Spacers to the cold bench (inside)

4.2.1.2 Covers

The cover "upper part" includes the entrance window and the connection flange to the telescope adapter.
The cover "lower part" includes the side window for alignment and crane hooks.

4.2.1.3 Windows

The vacuum vessel has two windows: The entrance window for the telescope beam and an additional window behind the detector. This exit window will be used during integration and assembly for alignment only. To avoid unwanted reflections the window is tilted by 5 deg. After the detector is attached, and before the instrument is mounted to the telescope this window will be closed.
The entrance window will be made of fused silica.

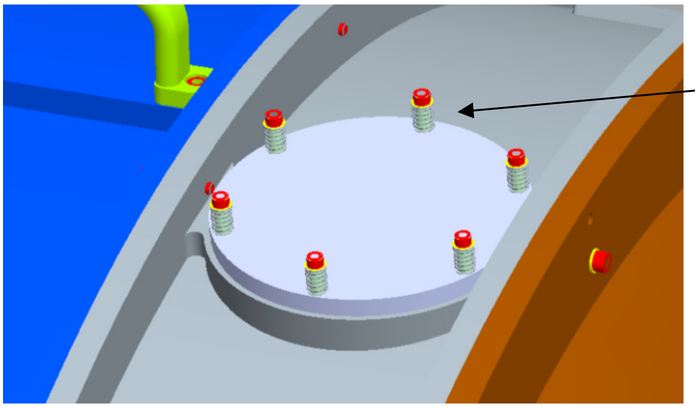
4.2.1.4 Auxiliary Parts

Vacuum valve

The vacuum vessel will be pumped by a small turbo molecular pump. Due to its weight the pump will be removed and the vacuum will be sealed with a DN40 KF valve.

Vacuum safety valve

In case of overpressure in the vacuum vessel (e.g. from a leak in the LN_2 vessel) the vacuum vessel is protected by a spring loaded disk. The valve opens at an overpressure of roughly 100 mbar.



Springs to press the cover towards the ring

Figure 47: Safety valve

Pressure gauge

As a pressure gauge we will use a PKR 251 with DN 25 KF flange. The gauge covers the complete pressure range from $5 \cdot 10^{-9}$ mbar to 1000 mbar.

4.2.2 Nitrogen Main Tank

A nitrogen vessel will be used to cool the cold bench. The upper part of the vessel is a dished boiler end. The light path goes through the vessel and therefore a vertical tube must be welded into it. The vessel will have a geometrical volume of about 100 liters. Due to the movement on the telescope it is only possible to half fill it. The resulting max filling will be about 46 l. We will have a filling tube and an exhaust gas tube. In addition there will be an additional third tube for the safety valve. The vessel will be filled from the side through the central ring. Filling will be done by pointing the telescope to zenith. The filling tube from the side goes to the bottom of the LN_2 vessel. The exhaust gas line ends in the center of the vessel. The vessel will be filled until LN_2 is spilled out of the exhaust gas line. A third tube is used for a safety valve. This tube will end roughly in the center of the LN_2 vessel. If the vessel is full the filling line will be closed and the exhaust gas line open. If it is necessary to drain the vessel the filling line is opened and the exhaust gas line is closed. The pressure of the evaporating gas will force the LN_2 out of the filling line when the telescope is pointing to the zenith.

The thermal contact area to the cold bench is a ring shape on the rim of the bottom flange. This is due to the deformation of the vessel with pressure inside, which should not have any influence on the optical bench.

The weight reduced LN_2 vessel for the cold bench could not be calculated in a standard way. It was therefore necessary to perform FE calculations. Due to uncertainties in these calculations we had a crosscheck of the results with an external company. The results of these calculations and the report can be found as RD 4 and RD 5.

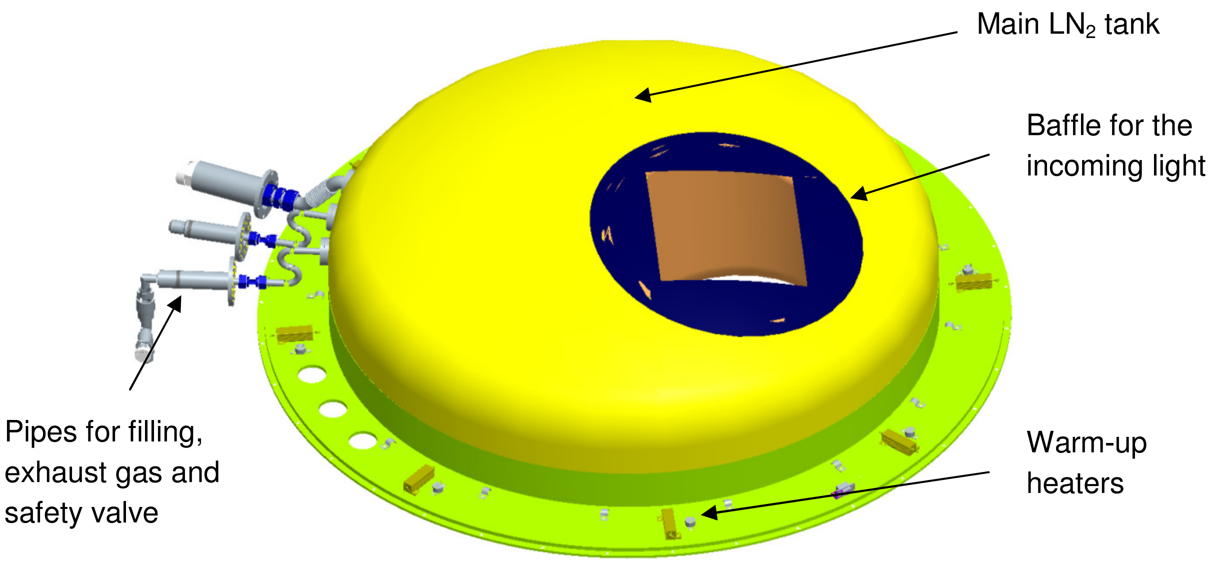


Figure 48: The main tank subassembly

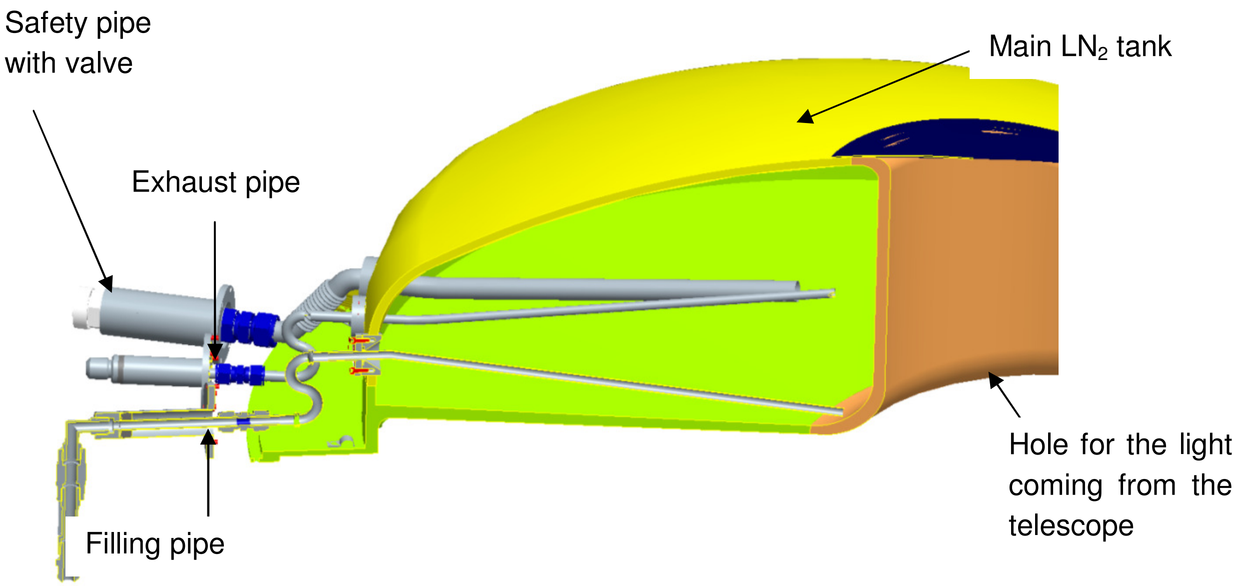


Figure 49: Cross section through the main tank showing the connecting pipes

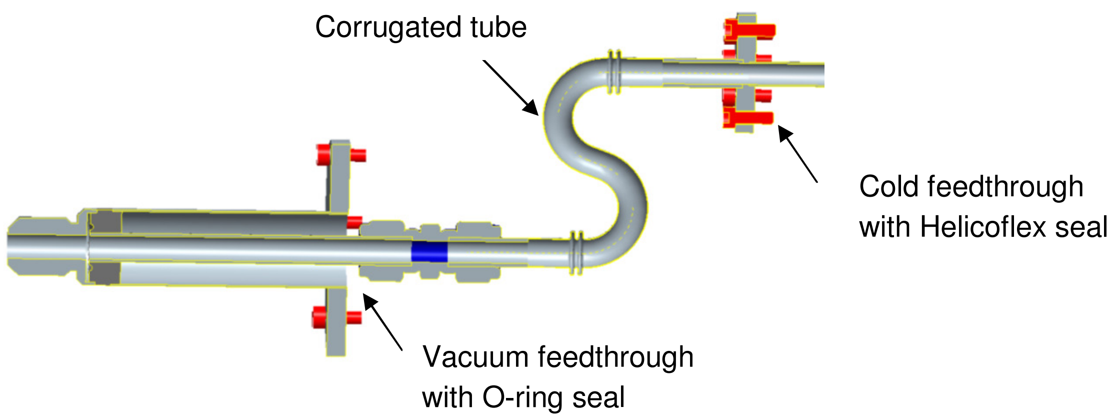


Figure 50: Cross section through the exhaust pipe

The connection of the stainless steel tubing to the aluminium vessel will be done with Helicoflex seals. The O-ring groove is in the aluminium flange and the stainless steel flange is flat.

4.2.3 Nitrogen Vessel Detector

The detector temperature has to be below 80 K. The large vessel could not supply this temperature because it is exposed to room temperature and because it will change its temperature depending on the filling level and the orientation of the telescope.
A second nitrogen vessel is therefore used to exclusively cool the detector array. This vessel is completely enclosed in the cold environment of the cold optics. This will result in a very stable temperature as already seen in other instruments with 2 nitrogen vessels. (e.g. Omega2000, Omega Cass).The expected stability is better ±0.2 K. The required stability of ±0.1 K makes a controller necessary. This controller will also be used to control the warm up and cool down of the detector.

The LN_2 tank will be made of aluminum AlMg4.5Mn.

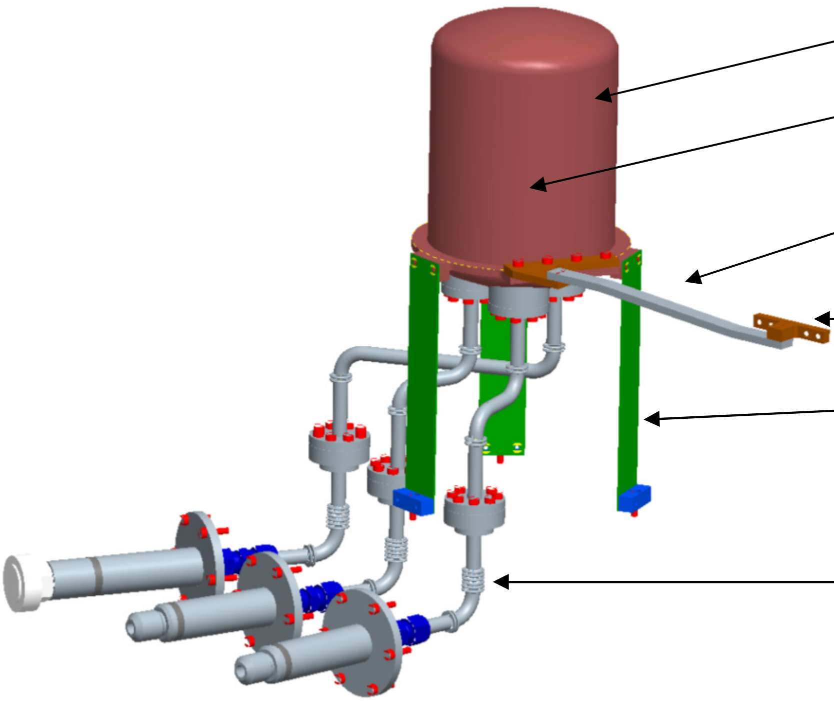


Figure 51: The detector tank subassembly

4.2.4 Cold Bench

The cold bench connects the optics with the tank and provides the mechanical support for the complete cold structure to the vacuum vessel.

The cold bench is made of aluminum and light weighted. To avoid distortions a specially casted and tension free version of AlMg4.5Mn will be used. In order to eliminate tensions raised during the manufacturing process a special heat treatment will be applied to the cold plate prior to finishing the interface surfaces. Therefore the complete cold plate will be heated up to 180℃ for 8 hours and then slowly cooled down to room temperature by a rate of 15 K/h.

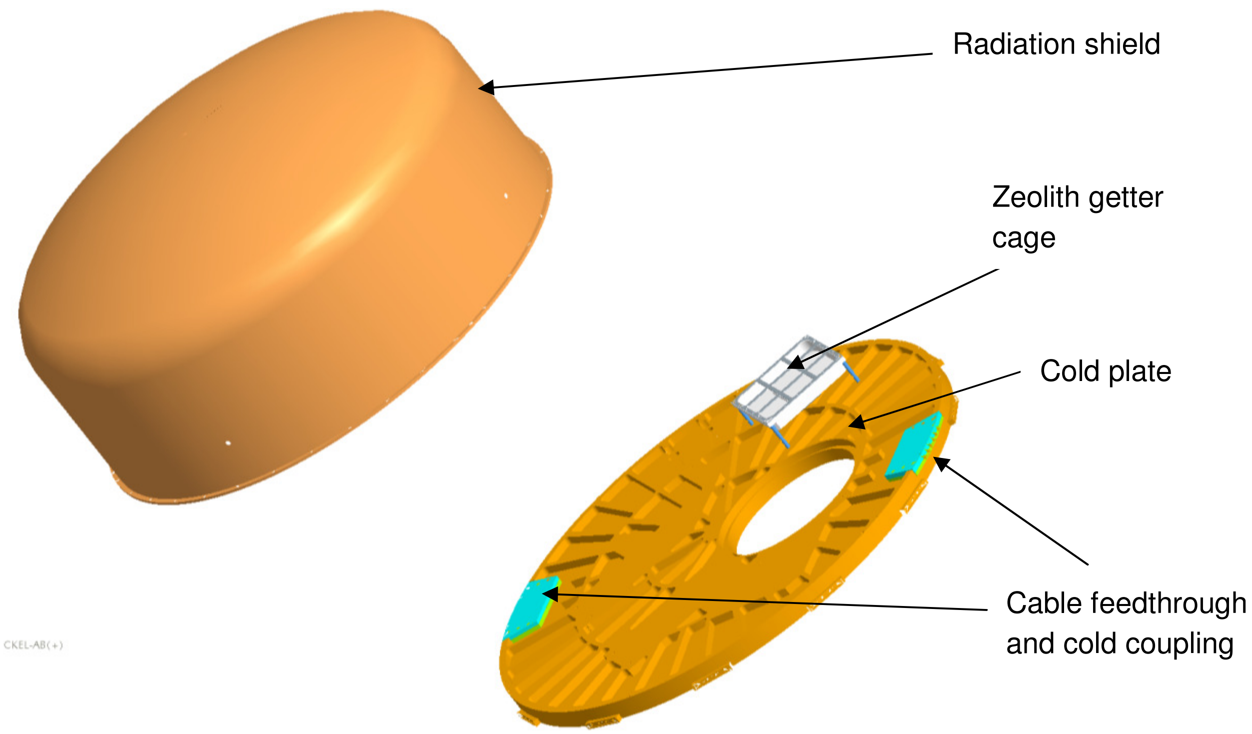


Figure 52: Cold bench assembly

Furthermore the cold bench is the central element of the cold bench assembly which comprises additional parts:

Getter cage

The getter cage is a part to be filled with Zeolith for maintaining the vacuum during observation without pumping the cryostat. The cage is supported by 4 stainless steel feet to have a little thermal decoupling between the cold bench and the getter. At room temperature during vacuum pumping the getter will be heated to about 50°C to remove water vapor. The temperature of the heater is limited by thermal switches.

Spacers to the vacuum vessel

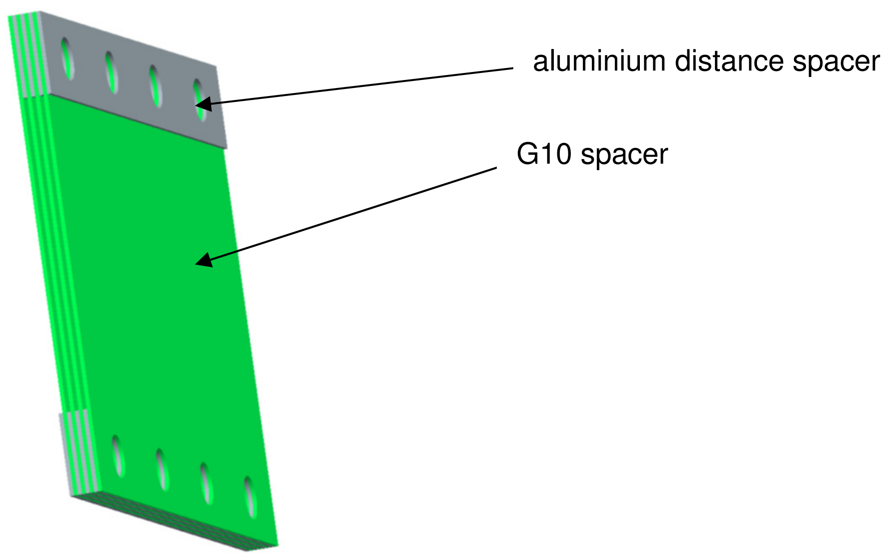


Figure 53: Stack of G10 spacers. Four spacers form a stack at PANIC

The spacers between the cold bench and the vacuum vessel ring are made of G10 fiber material. The diameter of the cold plate shrinks during cool-down from 1065 mm to 1060.8 mm. In order to compensate the shrinking of the plate between room temperature and operating temperature the spacers shall be flexible in the radial direction. To minimize the stress applied to the spacers the distance of the spacers is set between the warm and the cold value (1063 mm). To reduce stress caused by thermal shrinking multiple thin spacers are used and stacked. The number and the thickness of the spacers was investigated. The final design uses 12 spacer stacks each comprising four spacer-plates of 0.5 mm thickness.

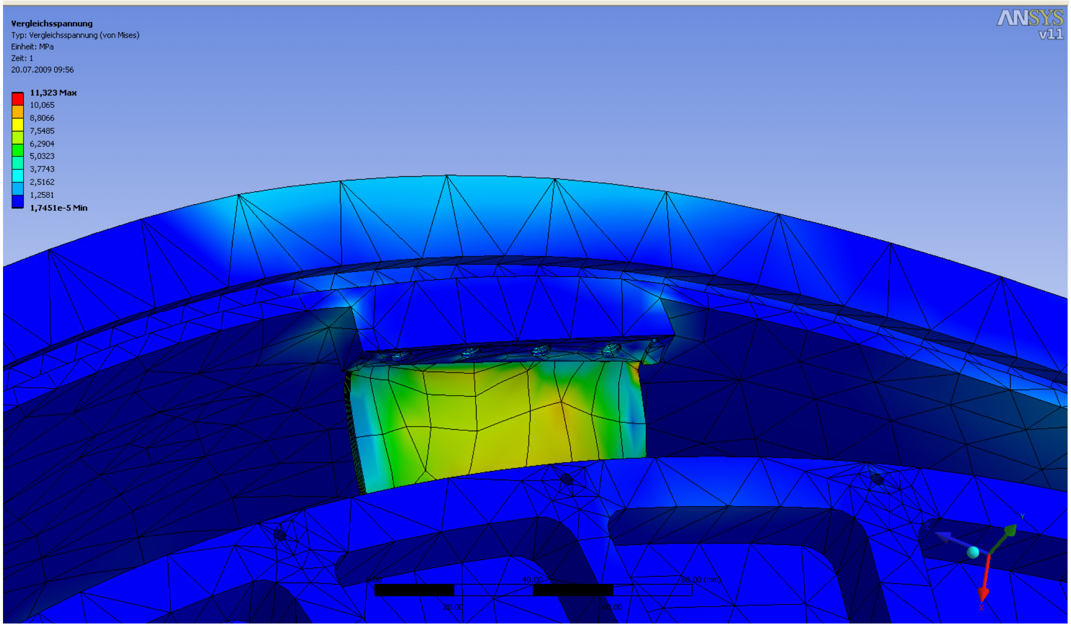


Figure 54: Finite element simulation of the spacers

Thermal coupling

To avoid warm items inside the cold volume all cables coming from the warm environment to the cold must be thermally coupled to the cold bench.

Drive and control harness

The drive and control harness consists of six cable bundles coming from the six vacuum feedthroughs. Each bundle is individually coupled.

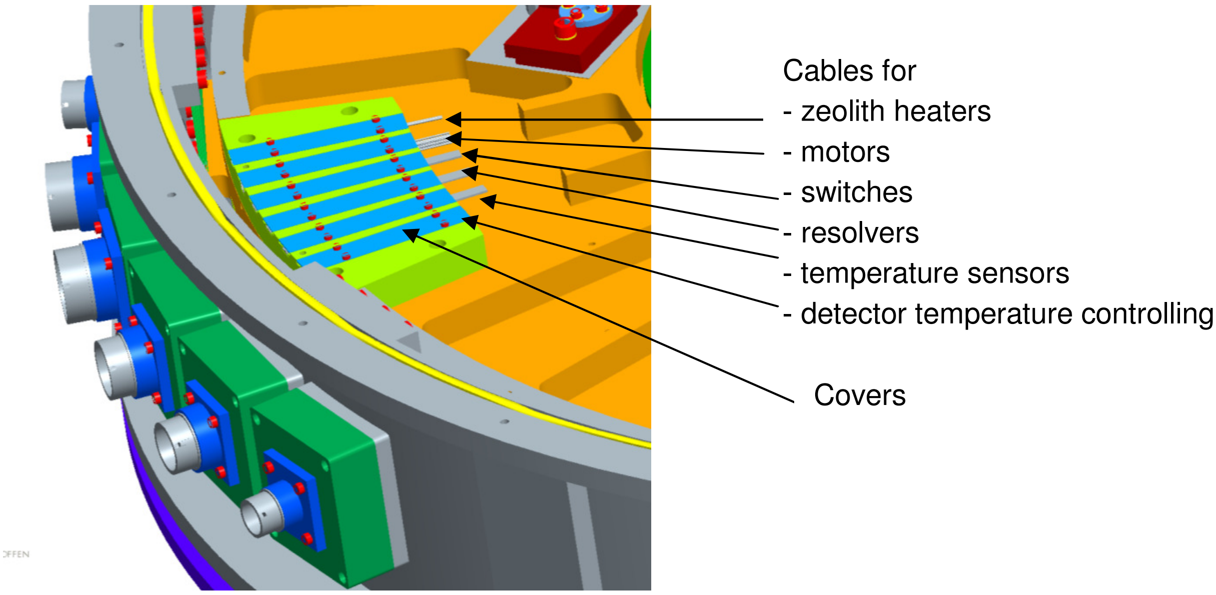


Figure 55: Feedthroughs for the cryostat cabling

Read-out circuits

The read out-circuits use four flex boards (one for each detector quarter). Two of them are coupled together directly after the vacuum feed through.

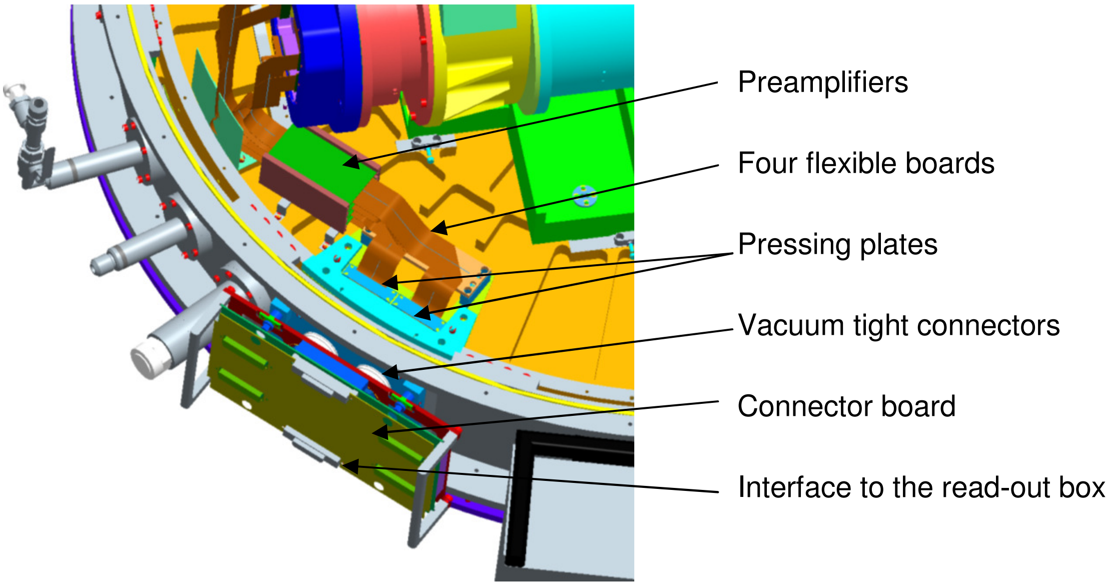


Figure 56: Feedthroughs for the detector read-out.

4.3 Thermal analysis

To minimize mass and volume of the LN_2 vessels it should just be large enough to reach the required hold time of one day. Optimized heat input will therefore also reduce mass.

4.3.1 Main Vessel Heat Input

The main vessel will be exposed to room temperature. To reduce heat input we will use multilayer insulation (MLI). We have a heat input from radiation of about 5 W/m^2 with MLI.

1	Radiation on surface (4.3 m^2) with multilayer insulation	21.5 W
2	Radiation through the window	22.5 W
3	Conductivity through spacers	5.0 W
4	Conductivity through filling tubes	0.1 W
5	Conductivity through cables	3.0 W
6	Power consumption of detector preamplifier and electronics	5.0 W
	Total heat input	57.0 W
	Evaporation rate	1.3 l/h
	Hold time with 45 l LN_2	35.5 h

4.3.2 Detector Vessel Heat Input

The detector's heat dissipation will be compensated by the Nitrogen inside the small vessel. The heat dissipated from the preamplifier has to be cooled by the large Nitrogen vessel.

1	Radiation on surface (0.09 m^2)	0.03 W
3	Conductivity through spacers	0.05 W
4	Conductivity through filling tubes	0.05 W
6	Power consumption of the detector module	0.05 W
	Total heat input	0.18 W
	Evaporation rate	4*10-3 l/h
	Hold time with 1 l LN_2	250 h

4.4 Temperature Control and Monitoring

4.4.1 Cold Bench Temperature Monitoring

The temperature of the cold optics will be monitored, but not controlled. Eight LakeShore DT-670 silicon diodes will be used. A LakeShore 218 temperature monitor is used with these eight sensors. The sensors are placed at the following points:

- N_2 main tank
- N_2 detector tank
- Zeolith gettercage
- Cold plate
- Motor
- Detector preamplifiers
- Nitrogen Shield
- Optics (back side of M1)

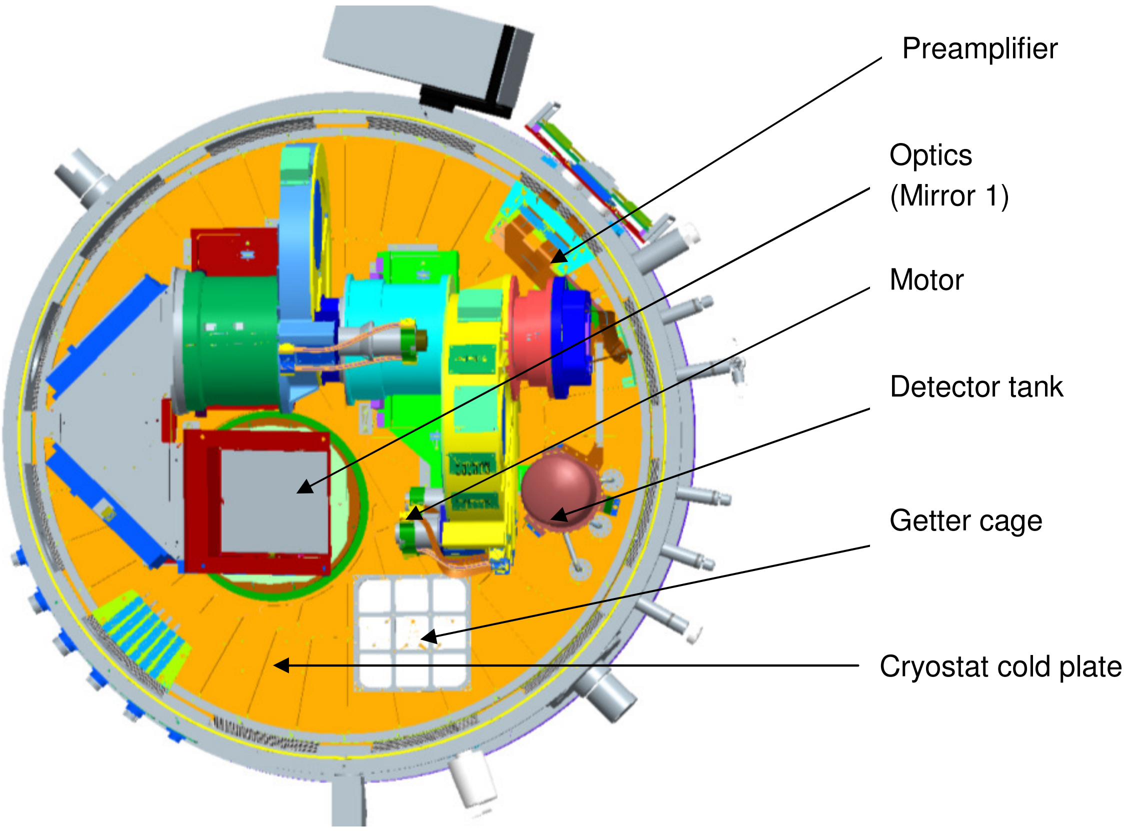


Figure 57: Distribution of the temperature sensors inside the PANIC cryostat. Not shown are the sensors on the LN_2 main tank, on the shield and inside the detector module.

4.4.2 Detector Temperature Control

The detector array will have a temperature control. The array is mounted into a so called mosaic module delivered together with detectors from Teledyne (see chapter 1.2.2). The mosaic has two build in heater foils for temperature control. One is attached to the cold plate with 100 Ω / 10 W. The second foil is mounted to the detector with 75 Ω / 10 W. A LakeShore 332 controller that offers two control loops will be used. It can therefore handle the complete temperature control of the detector module. LakeShore DT-670 silicon diodes will be used as temperature sensors

4.4.3 Warm-up Heaters

Heating up the cryostat

To accelerate warming-up the rear side of the nitrogen tank is equipped with warm-up heaters. In total eight heaters in parallel providing a heating power of 400 W (50 W each) are used. These heaters have a resistance of 47 Ω and are directly connected to the voltage source. This source can supply 50 V, resulting in a power output of 400 W. Thermostat switches monitor the temperature of the tank close to the heaters and switch off the power if the cryostat is warm and the temperature exceeds 26°C.

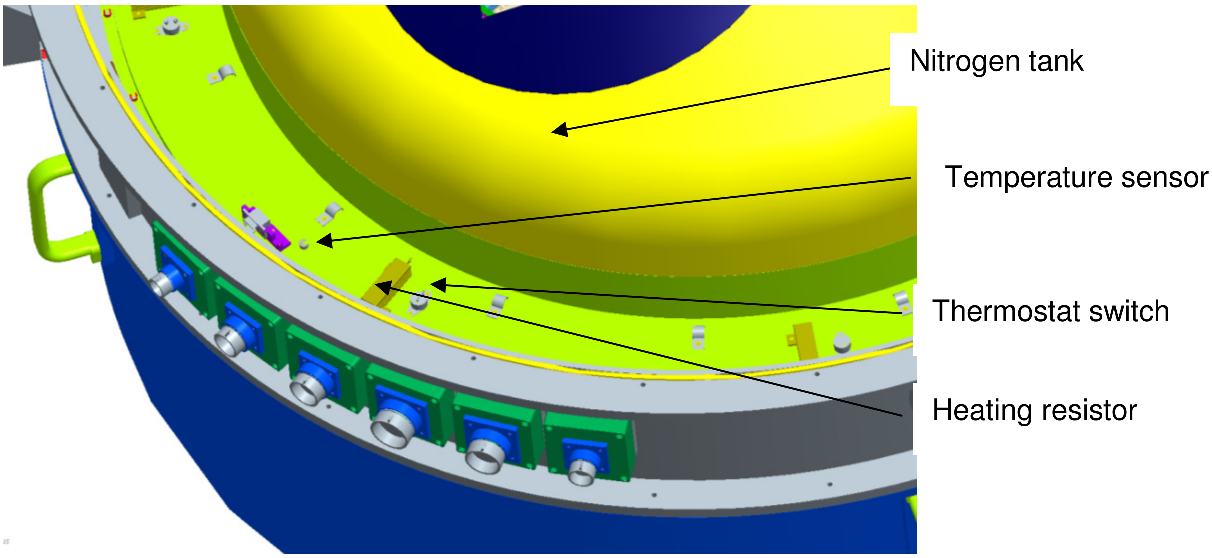


Figure 58: Eight heaters in two circuits attached to the nitrogen tank are used to warm-up PANIC

Heating up the Zeolith getter cage

To recover the Zeolith in the getter cage two heating resistors of 100 Ω are attached to the rear side of the getter cage. These heaters will be powered during vacuum pumping. The temperature is controlled by a thermostat switch which interrupts the power if the temperature exceeds the desired value. For the getter cage heater this temperature is about 50℃.

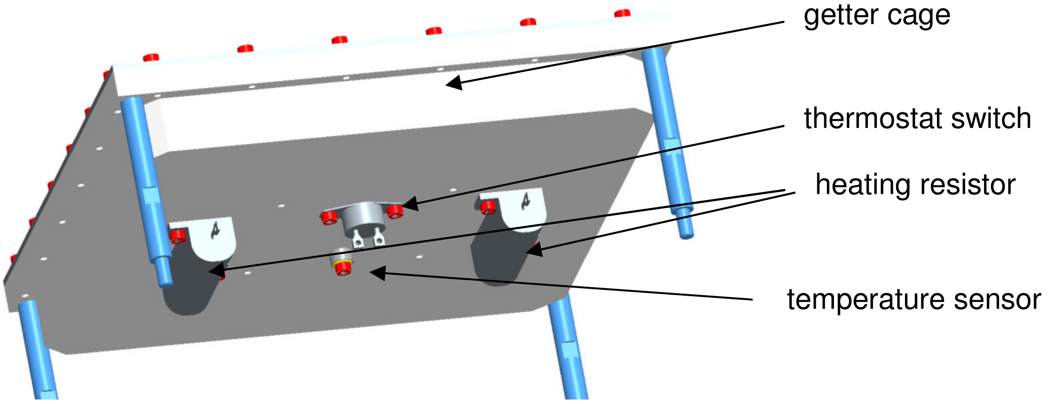


Figure 59: Two heaters, a thermostat switch and a temperature sensor are used to control the temperature of the getter cage

4.5 Cryostat Operation

4.5.1 Opening and Closing

To open and close the PANIC cryostat it must be mounted in the trolley A. Here it can be rotated until the vacuum can points upwards. The trolleys are described in chapter 7.

Opening

For opening the cryostat the vacuum volume must be vented with dry clean air or nitrogen gas. Then the interface screws must be removed. Then the vacuum cover can be lifted with a crane using three hooks on top of the cover. The cover can also be opened by hand using the four handles around the cover. Since the mass of the cover is 33.2 kg the use of a crane is recommended.

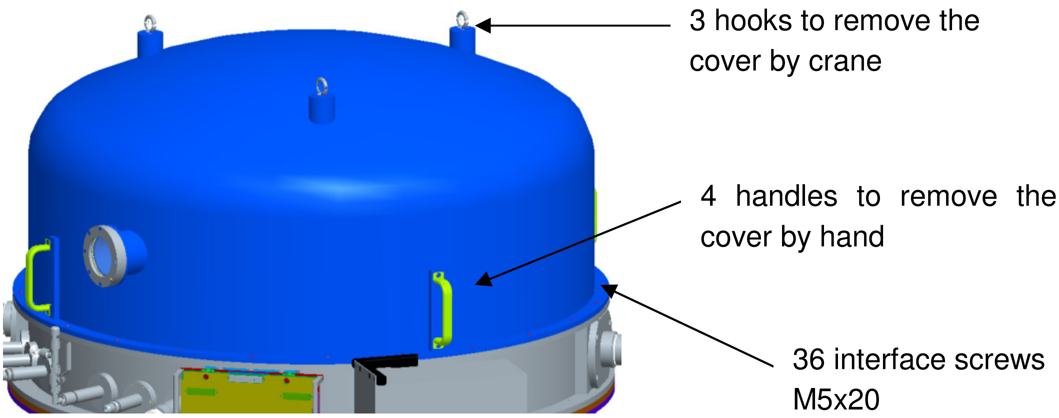


Figure 60: removing the vacuum cover

After removing the cover the LN_2-shield must be removed. To do this the Velcro fasteners of the overlapping MLI-foils have to be opened and the flaps covering the optical bench must be put to the side. Now one has access to the connection flange of the shield. Then the three guiding pins must be inserted. These pins ensure a vertical removal of the shield and avoid unintended collision with the interior parts of the cryostat. Then the screws must be removed and the connector to the temperature sensor must be unplugged. Finally the shield can be lifted by hand.

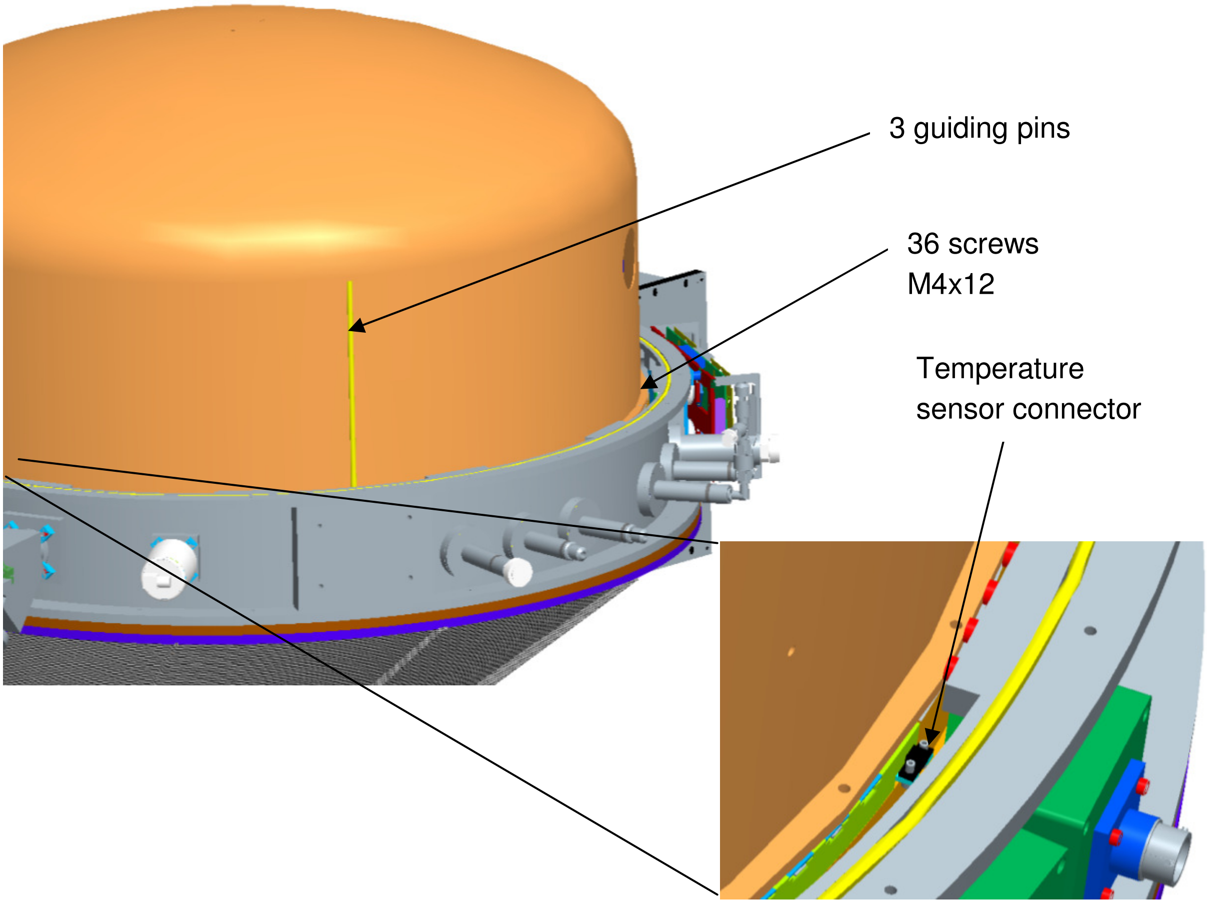


Figure 61: removing the nitrogen shield

Closing the cryostat works in the same way but in reverse order.

4.5.2 Vacuum Pumping

After closing the cryostat PANIC must be rotated to its nominal orientation (entrance window pointing upwards). Then the vacuum pump can be installed.

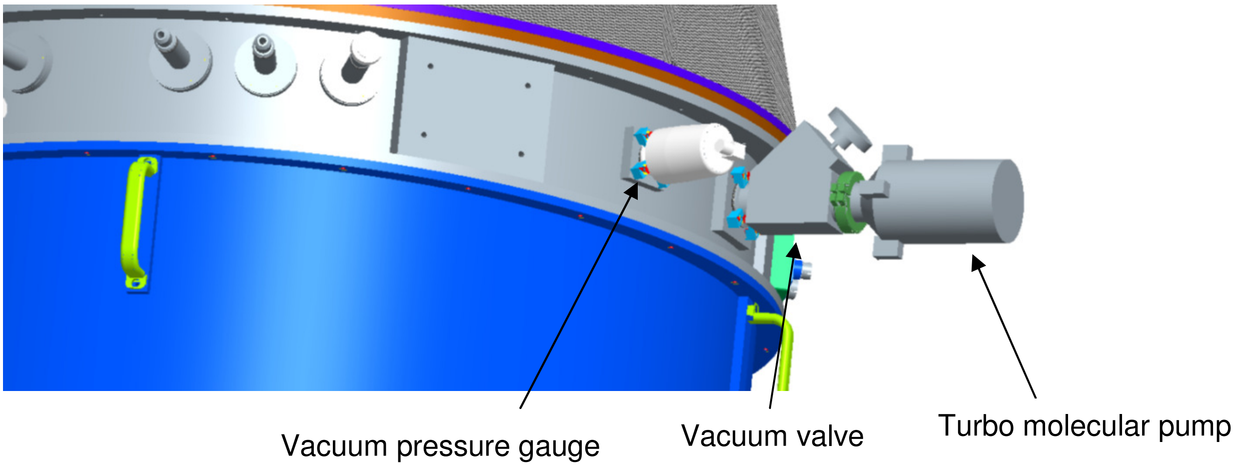


Figure 62: Vacuum pumping

During vacuum pumping the Zeolith getter gage will be heated up in order to prepare the getter material for absorbing gas molecules when the cryostat is cold and the vacuum pump is switched off.
The cryostat will be pumped until the pressure is in the range of 10^{-4} mbar.

4.5.3 Cool-down

Cooling down is realized by slowly filling the tanks with liquid nitrogen. Since the maximum allowed cool-down rate is only 10 K/h the filling must be done carefully and slowly. This requirement is driven by the brittleness of the optical elements and has been supplied by the manufacturer.

Since the nitrogen main tank is at a higher level than the outer end of the filling pipe, nitrogen could flow out of the filling pipe unless it is not sealed. Therefore a valve is attached to this pipe. The attached safety valve avoids overpressure in the filling hose if both valves at the filling pipe and at the nitrogen vessel are closed at the same time.

In order to avoid condensation of frozen gases at the detector module, the detector must always be kept warmer than the cryostat. Therefore it is important to start filling the detector tank after cooling the main tank.

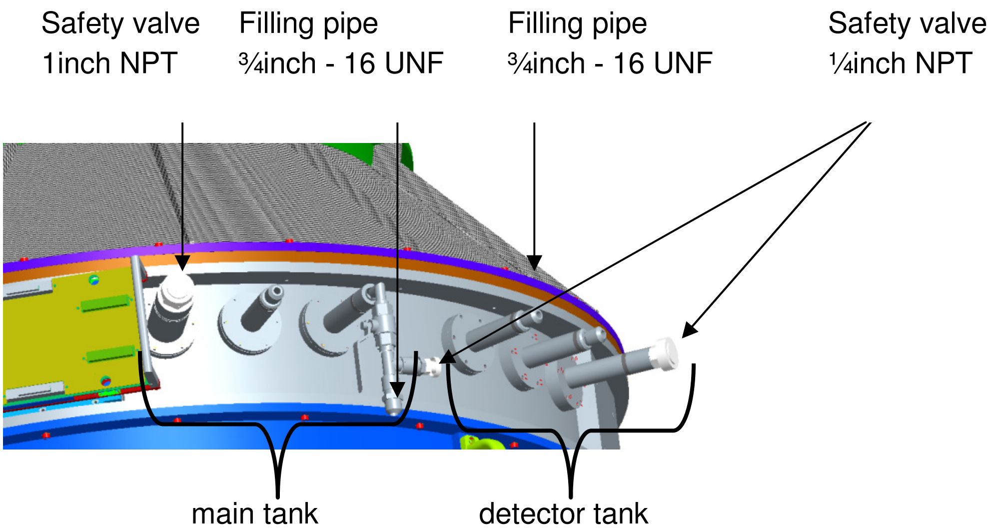


Figure 63: Connections to the tanks for the cryogenic liquids

4.5.4 Warm-up

Warming-up is performed with the built-in warm-up heaters. First the remaining liquid nitrogen must be removed. The exhaust pipe must be closed to remove the liquid nitrogen. So the evaporated gas generates pressure inside the tank. This pressure presses the remaining liquid nitrogen through the filling pipe into an external nitrogen vessel.

Again the detector should always be kept warmer than the surrounding cryostat. This can be achieved by using the heating system and the control loop.

5 PANIC AT THE TELESCOPE

PANIC is mounted to the telescope with a special adapter, which is the link between the rear side of the telescope and the cryostat. Its task is to support the Instrument in the correct place and orientation at the Cassegrain focus. PANIC is built for the 2.2 m telescope with an option to mount it to the 3.5 m telescope as well. If not otherwise stated the subsequent chapters describe the situation for the 2.2 m telescope.

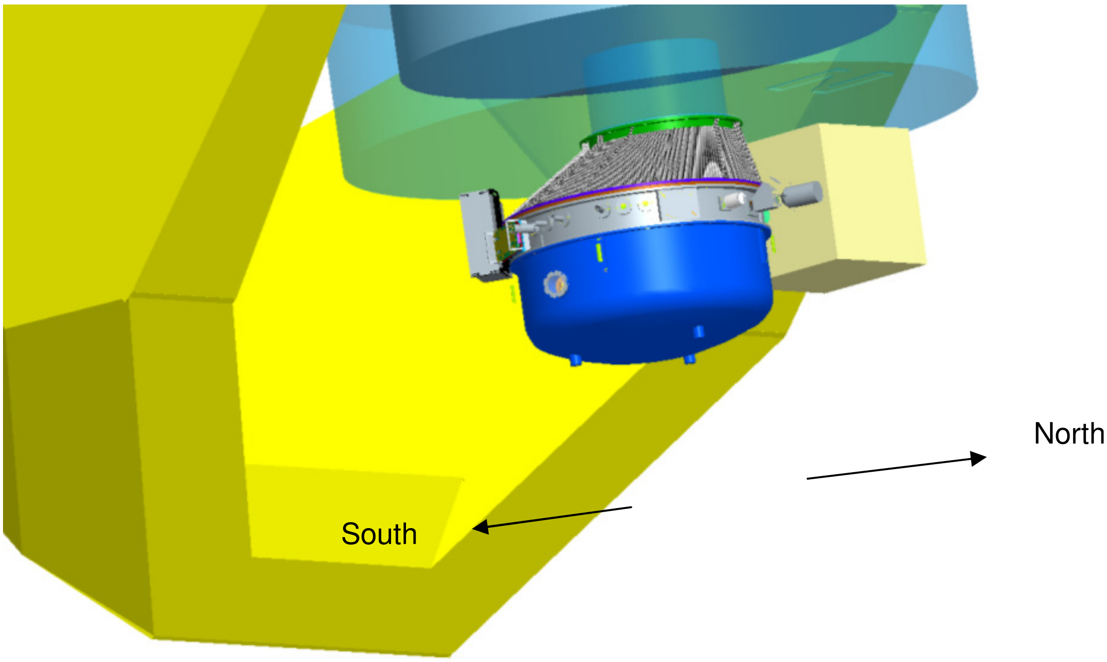


Figure 64: Orientation of PANIC at the 2.2 m telescope

5.1 Telescope Adapter

The telescope adapter connects the optical telescope with the cryostat. The surface between the circular mounting rings in-between both interfaces forms a cone shell (see Figure 65).

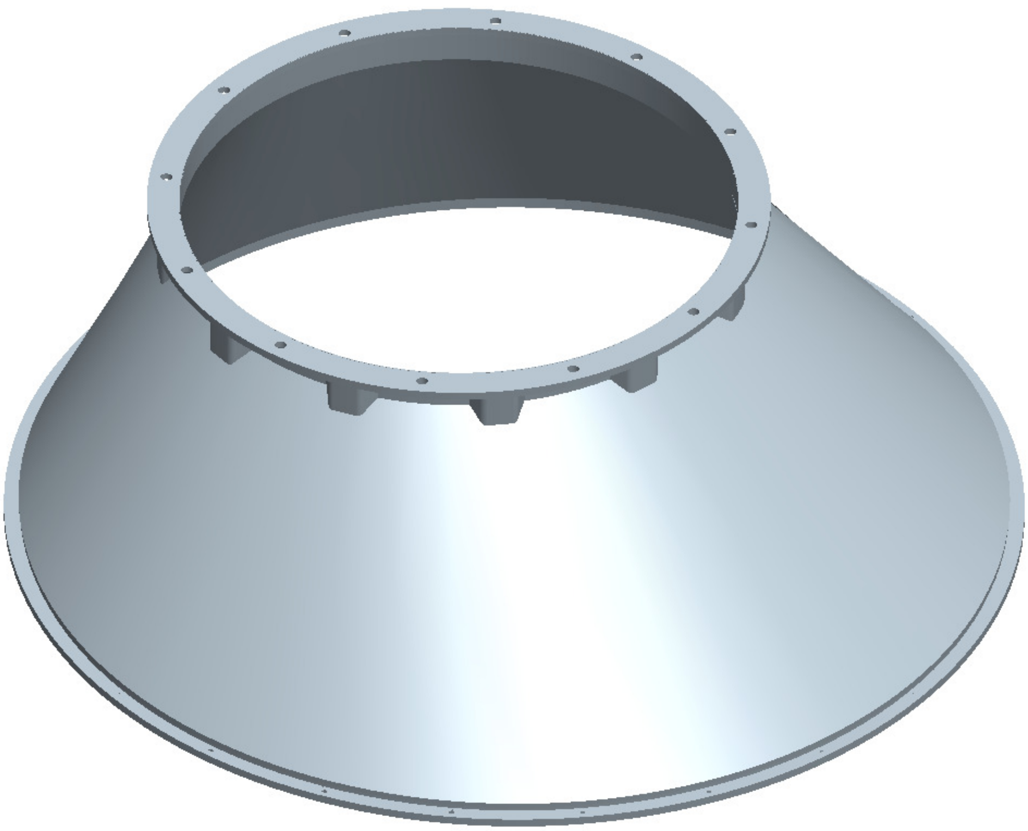


Figure 65: Telescope Adapter

In order to reduce significantly the weight of the telescope adapter, the structure is made from Carbon Fiber Reinforced Plastic (CFRP). The benefit in mass reduction will be approximately 14.0 kg, which represents a weight reduction of 47 % vs. a design made from steel. Beside the mass reduction, the stiffness of CFRP-structure shall be large enough to ensure limited displacements at the cryostat mounting surface.

CFRP Structure

The CFRP structure is composed of two solid 10 mm mounting rings for mounting the optical tube and cryostat and a cone shell in-between. All CFRP components are laminated in a single mould. The moulding is made as a positive contour in which the moulding surface representing the inner surface of the adapter.

The cone structure consists of a honeycomb shell composed of a carbon skin with a thickness of 2.50 mm on each side and of a non-woven core made from polyether fibers.

The skins are made from a carbon twill weave fabric with 245 gr/m² embedded into an epoxy resin matrix. Eight layers of carbon fabrics with a thickness of 0.31 mm each are laid down with a preferred orientation. The core has a total thickness of 6 mm and is composed of 3 individual layers to ease draping.

The manufacturing process is hand lay-up technique. Due to the complexity of the geometry it is necessary to lay down interfering strips of fabrics which have approximately a width of 1/12 of total circumference of the cone. After all the layers of carbon fabrics and the core are laid down, a vacuum is applied during the cold curing process (= curing at ambient temperature).

The mounting rings are made as a monolithic carbon structure with tapered layers in the interface surface to the cone shell. To increase bending stiffness at the mounting ring on the optical tube side, a rim of 100 mm thickness is added on the outer shell surface. The rim is made from 6 mm non-woven core of polyether fibres with two layers of carbon twill weave fabric. Furthermore 12 ribs are equally distributed along the mounting rings to provide additional stiffness. The ribs have a trapezoidal cross section and are made from carbon fabrics with a foam core. The ribs are adapted individually in length to the cone shell.

FEM Analysis

A linear static analysis was made with NASTRAN to determine deflection, stresses and strain. The shell and mounting ring surfaces are idealized with shell elements to reproduce the layered design of the composite's structure. The ribs are represented with solid elements. A nodal load of 3000 N, representing the mass of the instrument, is distributed through a rigid beam element to the hole locations in the mounting ring. tThe load is applied separately in each co-ordinate direction. At the tube mounting ring the structure is constrained by the mounting holes in all transversal directions. Figure 66 shows the FE-model.

Results

Besides ensuring sufficient strength the main objective was a limited maximum displacement in all load cases and for all directions less than 0.3 mm.

A summary of displacements at the reference node are shown in the table below:

	Displacements in mm		
Load	X	Y	Z
Fx = 3000 N	0,08	-0,01	-0,11
Fy = 3000 N	-0,01	0,27	0,03
Fz = 3000 N	-0,11	0,03	0,29

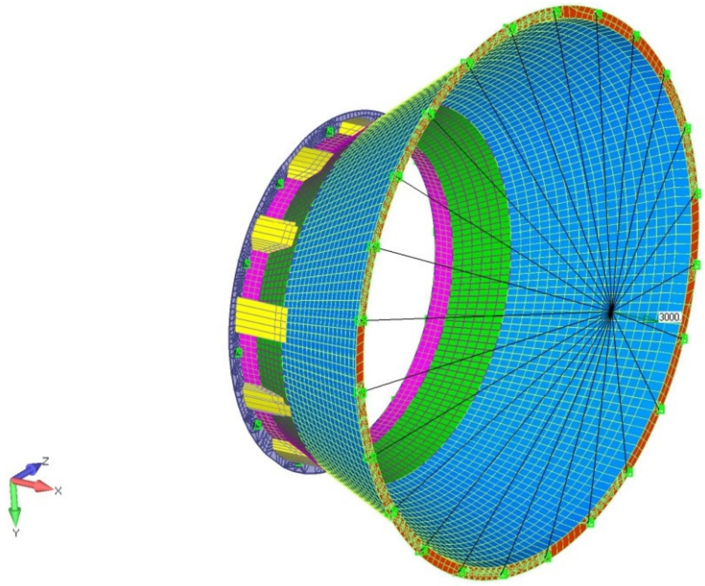


Figure 66: FE-Model of the telescope adapter

5.1.1 Option to Mount PANIC to the 3.5 m Telescope

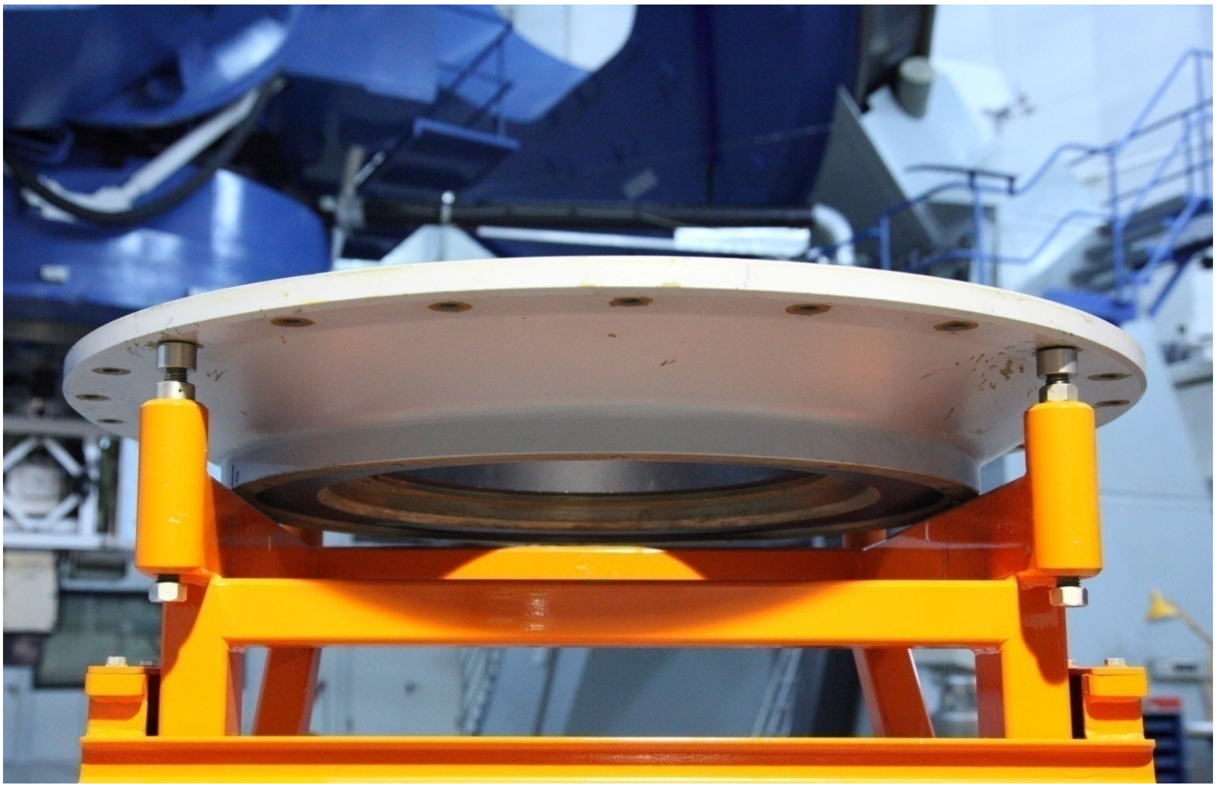


Figure 67: An adapter flange allows instruments designed for the 2.2 m telescope to be used at the 3.5 m telescope

Figure 67 shows the ring which must be mounted between the 3.5 m telescope and the instrument to ensure the correct focal distance for instruments that were designed for the 2.2 m telescope. Attaching PANIC to the 3.5 m telescope would double the spacial resolution of the imaging.

6 DETECTOR

The detector module consists of a mosaic of four 2k x 2k HAWAII 2RG arrays from Teledyne.

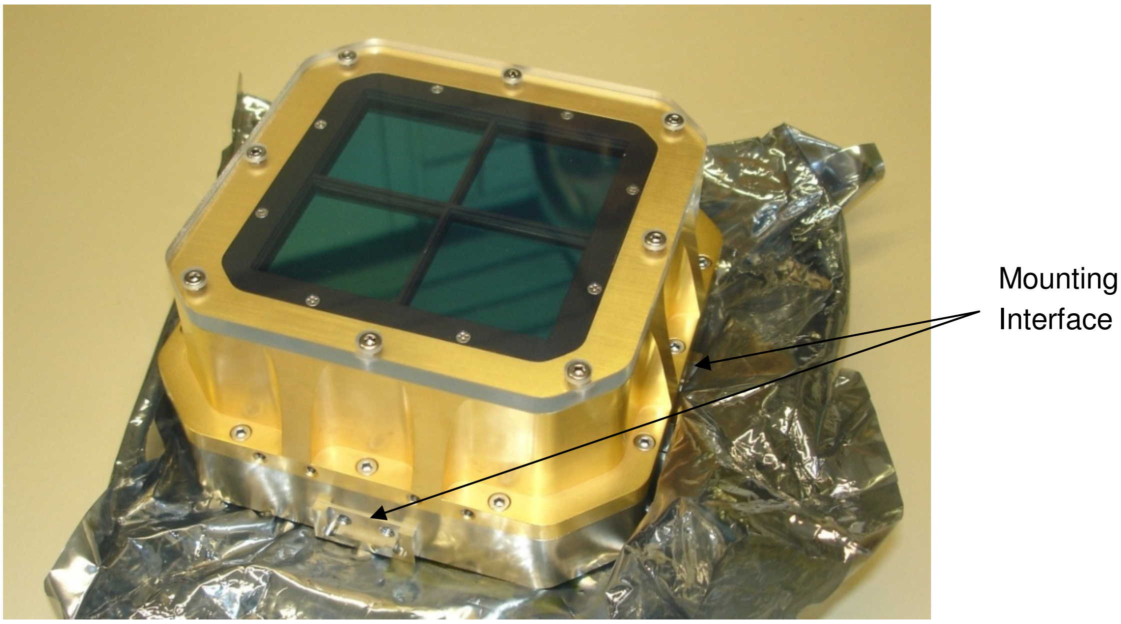


Figure 68: The detector module as delivered from Teledyne

6.1.1 Detector Mount

The detector is mounted via four G10 struts to the mounting interface. These struts insulate the detector module thermally and electrically from the cryostat and the cold optics. A labyrinth between the interface and the detector prevents light entering the inner part of the detector module.

The stiffness of the G10 spacers has been verified by FE-Analysis. Figure 70 shows the result. If the telescope is pointing to zenith the maximum deflection is 22 µm. The simulation shows further that there is no tilt due to the spacers.

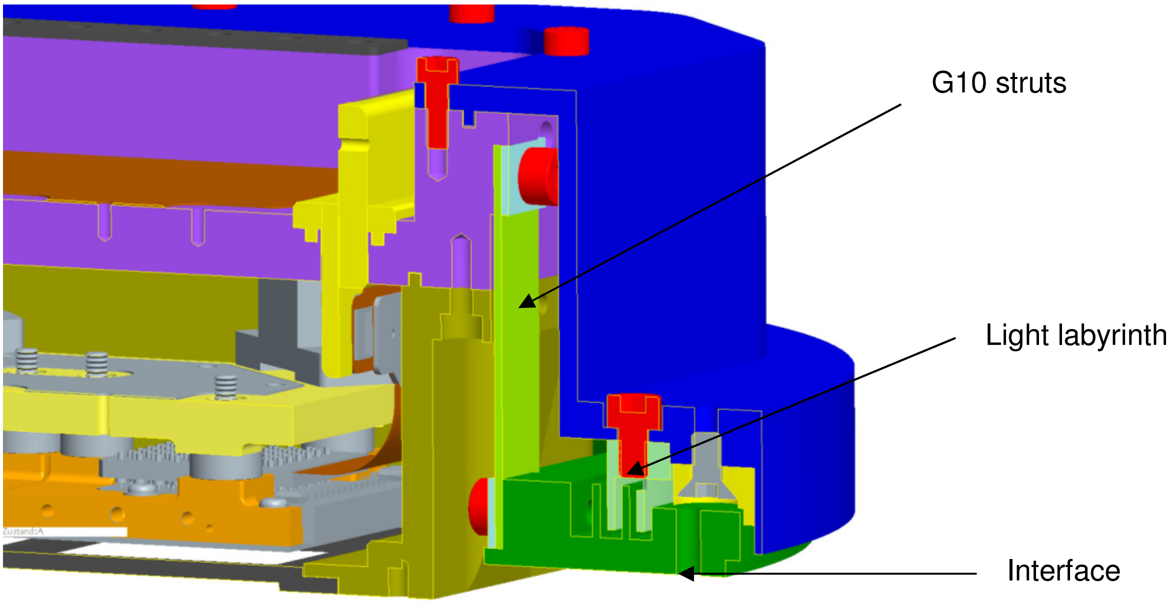


Figure 69: Detector mount

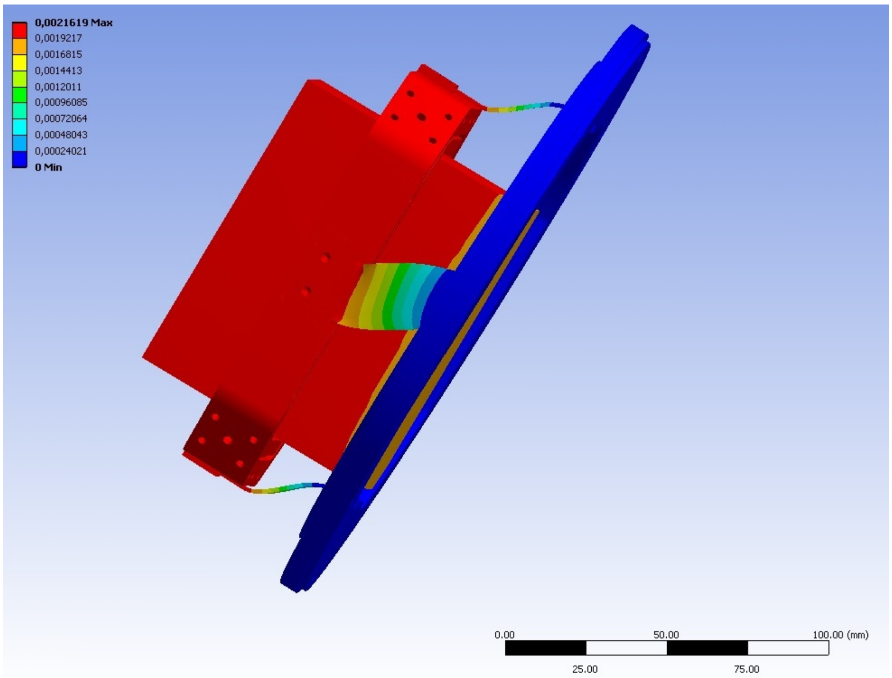


Figure 70: FE-Simulation due to self weight deflection of the detector mount

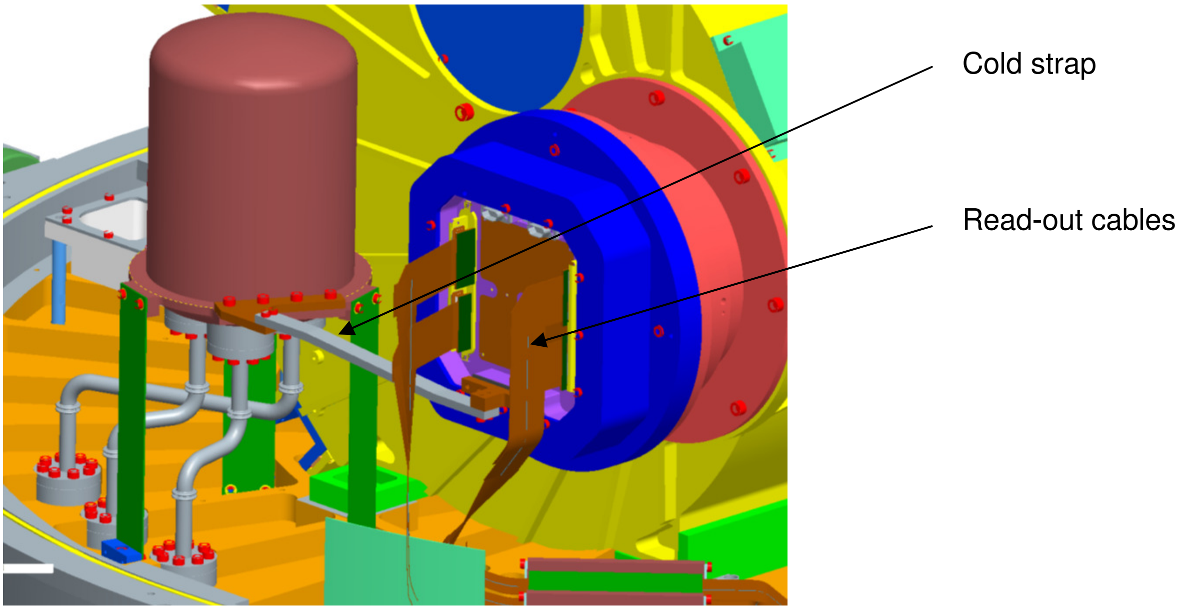


Figure 71: Detector assembly

6.1.2 Read-out Cabling and Preamplifiers

The read-out-system uses its own cabling and feed through. Since the detector consists of four identical modules the connection to the read out electronics is routed in four almost identical harnesses. In the cryostat each harness is a flexible circuit board that also contains the preamplifiers. The preamplifiers are identical for all four detector segments.

The read-out electronics are directly attached to the vacuum vessel at the outer circumference of the vacuum vessel ring. It is a big advantage of this design that the electronics can be permanently installed.

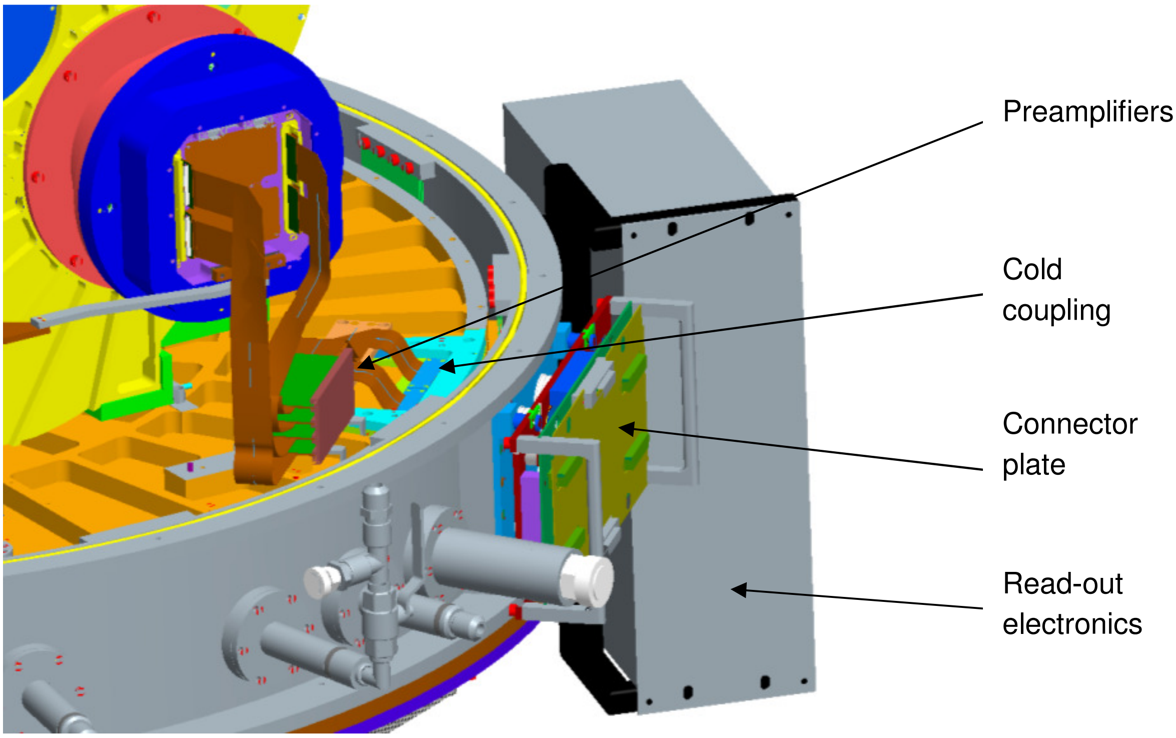


Figure 72:Read-out cabling

7 TROLLEY

This chapter describes the handling of the PANIC instrument in the integration facility at MPIA and at the Calar Alto Observatory.
We decided to have two handling trolleys due to the space restrictions in the 2.2m telescope building (limited space in elevator).
The integration and test trolley (trolley A) allows a 360° rotation of the instrument for integration work in the labs whereas the transport trolley (trolley B) allows vertical lifting for mounting at the telescope flange. A crane is necessary to place the cryostat into the trolleys. Crane hooks can be mounted at the PANIC telescope adapter or at the mounting ring at the cryostat.

7.1 Trolley A

Figure 73 and Figure 74 show the rotation trolley for the PANIC instrument. Rotation is carried out manually with a self-locking belt drive.

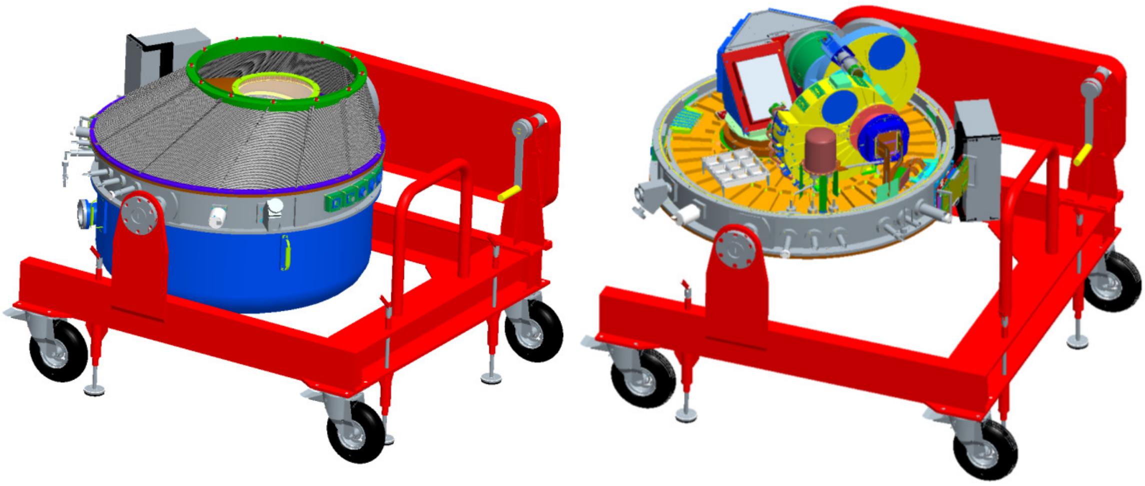


Figure 73: 3D-model trolley A (rotation)

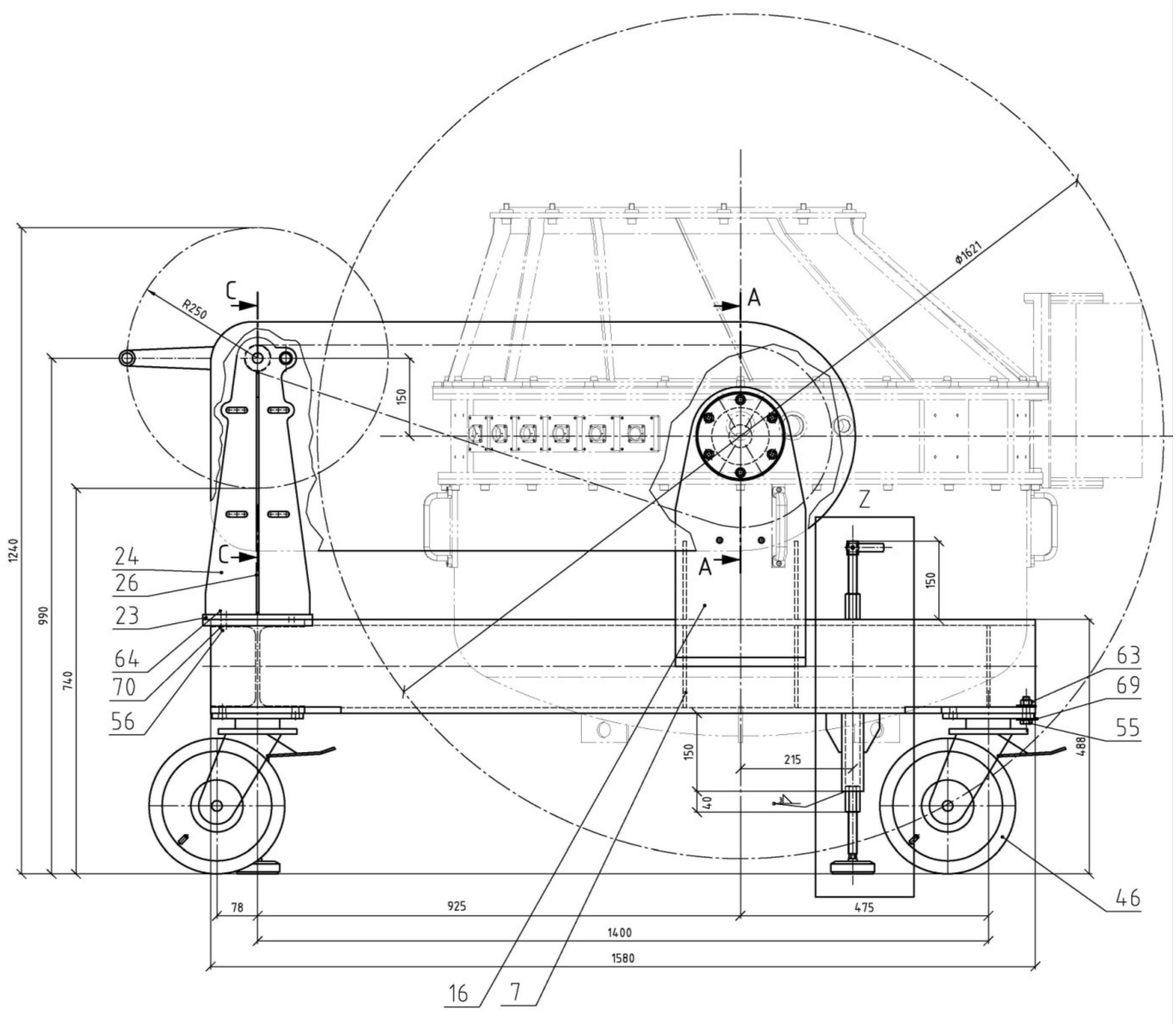


Figure 74: Dimensions of trolley A

7.2 Trolley B

Figure 76 shows the 3D-model of the lifting trolley which serves to mount the instrument at the telescope. This trolley is based on a standard unit with slight modifications (company: Kaiser + Kraft, Figure 75). The handrail has to be dismounted to fit the trolley into the 2.2 m-telescope elevator (Figure 77).

Figure 78 and Figure 79 show PANIC on trolley B with reference to the 2.2 m-telescope mirror cell and the instrument lifting platform.

The lifting of the last 50 mm during the mounting procedure at the telescope flange is done by trolley B.

Figure 75: Lifting trolley from Kaiser + Kraft

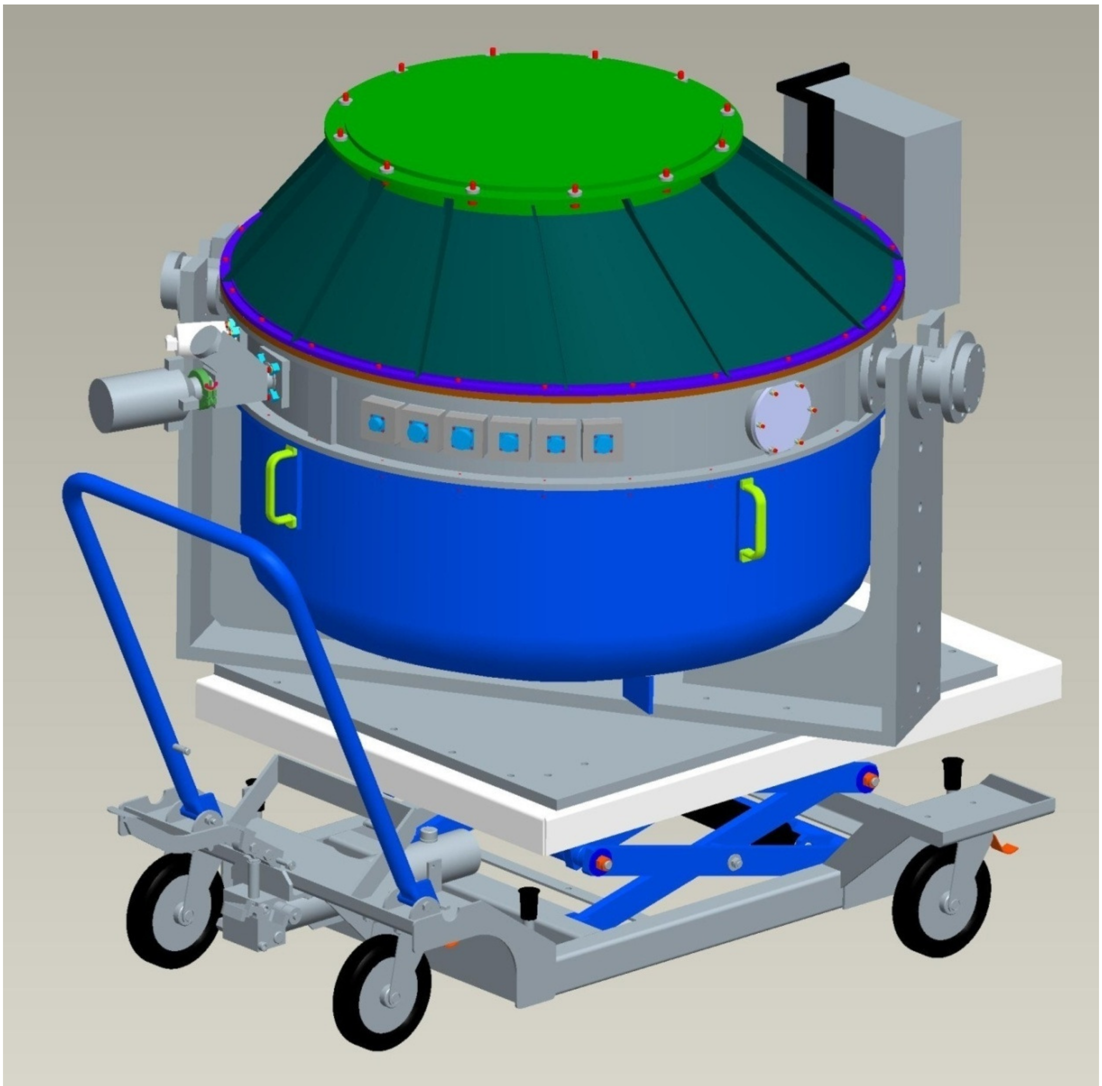


Figure 76: 3D-model lifting trolley B

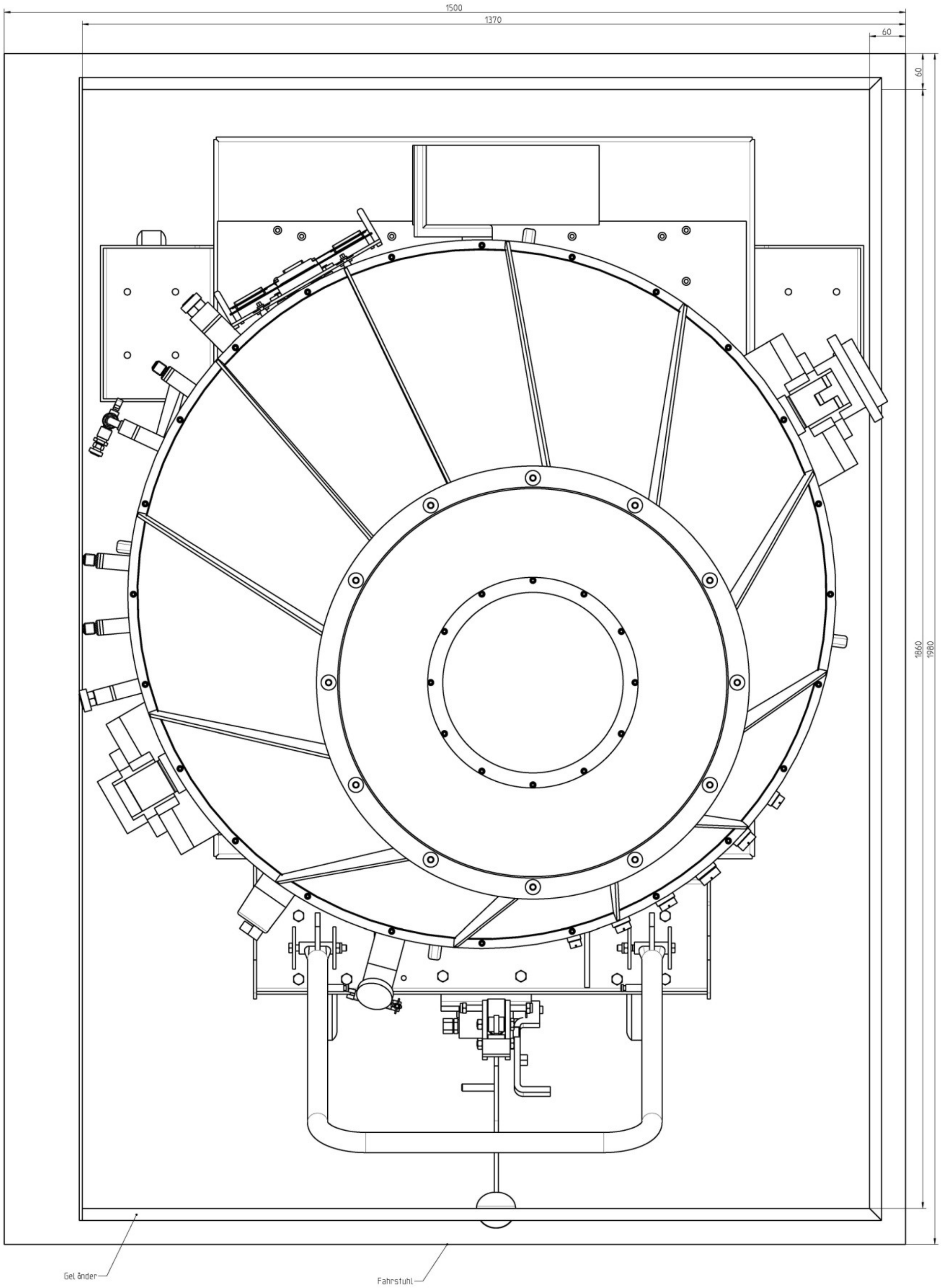


Figure 77: Cryostat lifting trolley B in 2.2m telescope elevator

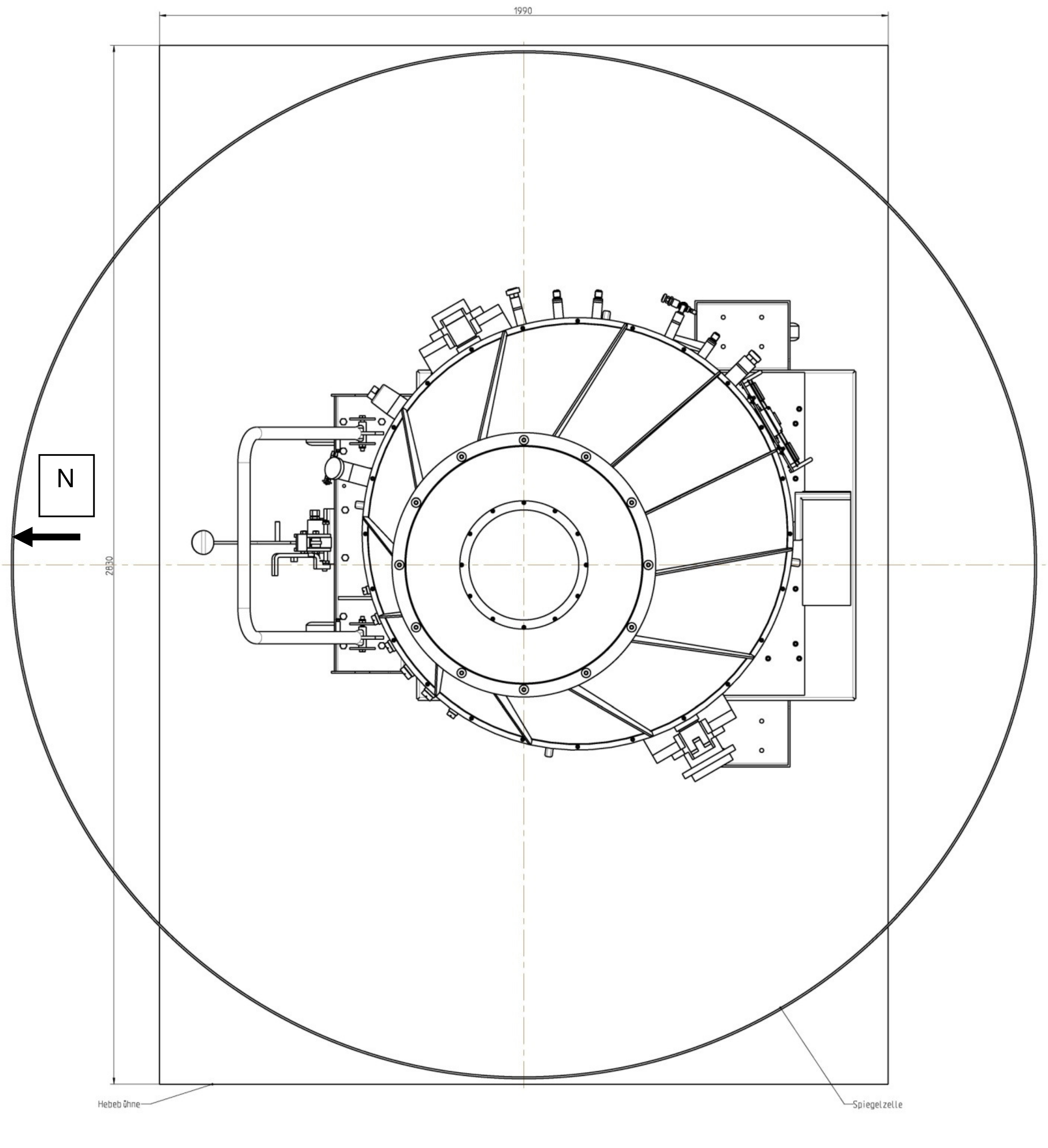


Figure 78: PANIC with reference to the 2.2m-telescope mirror and the instrument lifting platform

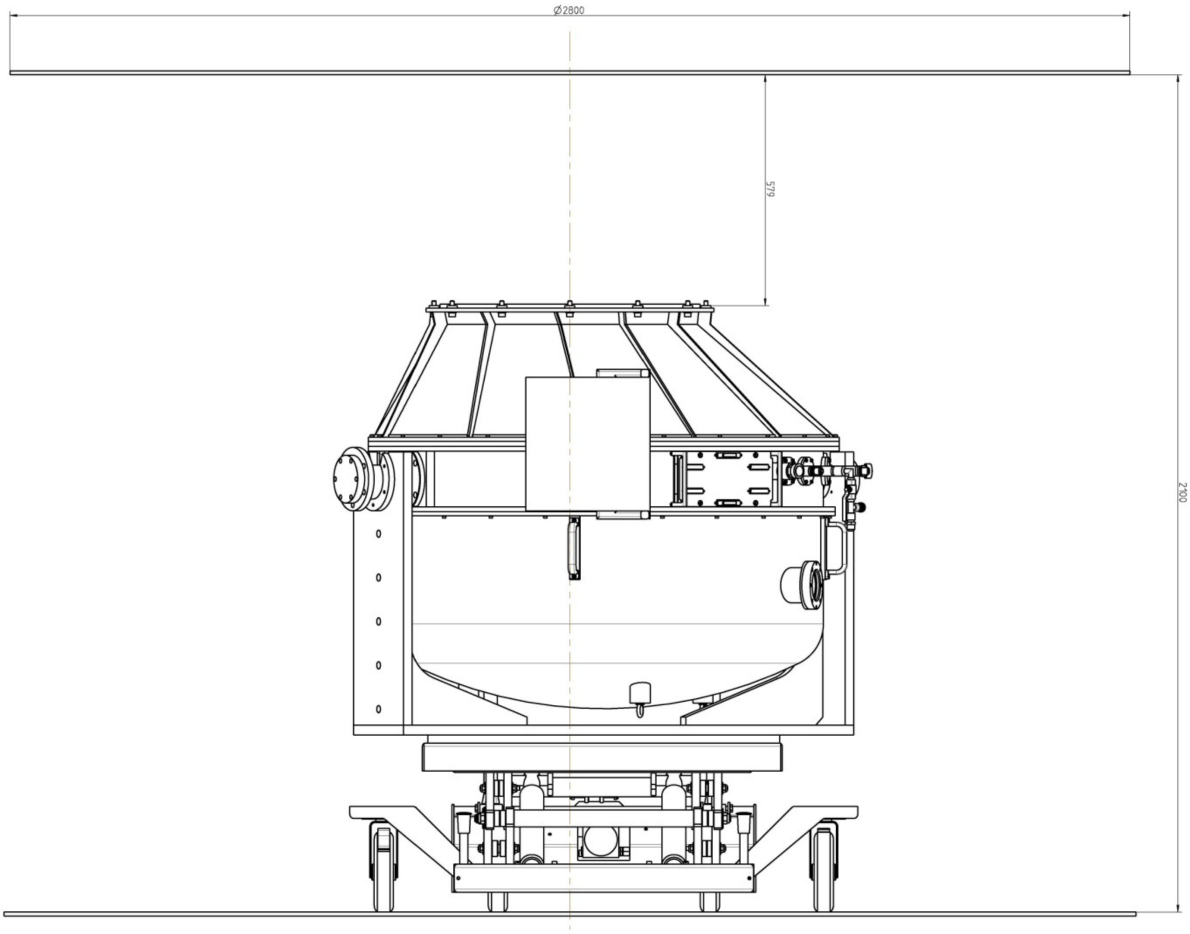


Figure 79: PANIC with reference to the 2.2m-telescope instrument mounting flange

8 OTHER TOPICS

8.1 Mass Estimation

One critical requirement is the maximum allowed weight of the instrument, which must not exceed 400 kg.

Item	Mass [kg]	Remarks
Optics and opto-mechanics	90.9	See chapter 8.1.1
Cryostat	208.4	See chapter 8.1.2
Telescope flange	13.0	
Detector package	2.9	
Electronics	53.0	See chapter 8.1.3
Miscellaneous	15.0	
Total	383.2	

8.1.1 Optics

Item	Mass [kg]			Remarks	Source
Optics and opto-mechanics	**90.9**				
Optics mount 1		**52.8**			
Lens mount 1			**5.5**		CAD-Model
Mirror structure (incl. mirrors)			**21.6**		CAD-Model
Lens mount 2			**9.9**		CAD-Model
Cold stop wheel			**8.4**		CAD-Model
support			**5.4**		CAD-Model
piece parts			**2**		estimated
Optics mount 2		**38.1**			
Lens mount 3			7.4		CAD-Model
Filter wheel			23.1		CAD-Model
Lens mount4			2.9		CAD-Model
support			2.7		CAD-Model
piece parts			2		estimated

8.1.2 Cryostat

Item	Mass [kg]			Remarks	Source
Cryostat	**208.4**				
Vacuum vessel		**84.1**			
Vacuum can ring			**19.8**		CAD-Model
Vacuum can upper part			**20.6**	towards telescope	CAD-Model
Vacuum can lower part			**33.2**		CAD-Model
Window			**3.8**		CAD-Model
Vacuum gauge			0.7		data from supplier
Vacuum valve			1		data from supplier
piece parts			5	feed troughs, seals, O-Rings	estimated
Cold bench		**47.9**		incl shield	
cold plate			31.3		CAD-Model
LN2 shield			11.2		CAD-Model
getter cage			1.1		estimated
cable feed throughs			1.3		estimated
MLI / Superisolation			2		estimated
piece parts			1		estimated
Nitrogen vessel		**45.6**		incl filling pipes	CAD-Model
Nitrogen vessel detector		**2.8**		incl filling pipes	CAD-Model
LN2 (half filling)		**28**		one day hold time with MLI	

8.1.3 Electronics

Item	Mass [kg]			Remarks	Source
Electronics	**53**				
RoE		**7**			data from electronic workshop
Control unit (motors, temperature ...)		**24**			data from electronic workshop
Cabling, rack		**22**			data from electronic workshop

9 MILESTONES, CURRENT STATUS AND SCHEDULE

PANIC has reached the following milestones:

1. PDR in October 2007
2. Delivery of the detectors in January 2009
3. FDR for the optics in September 2008
4. Order of optics in May 2009

Current status:

1. The detector FPA has been delivered. First tests have shown that all read-out channels work. Measured noise values are close those measured by Teledyne.
2. The 3 plane mirrors M1-M3 have been delivered, they are currently being tested with their mounts.

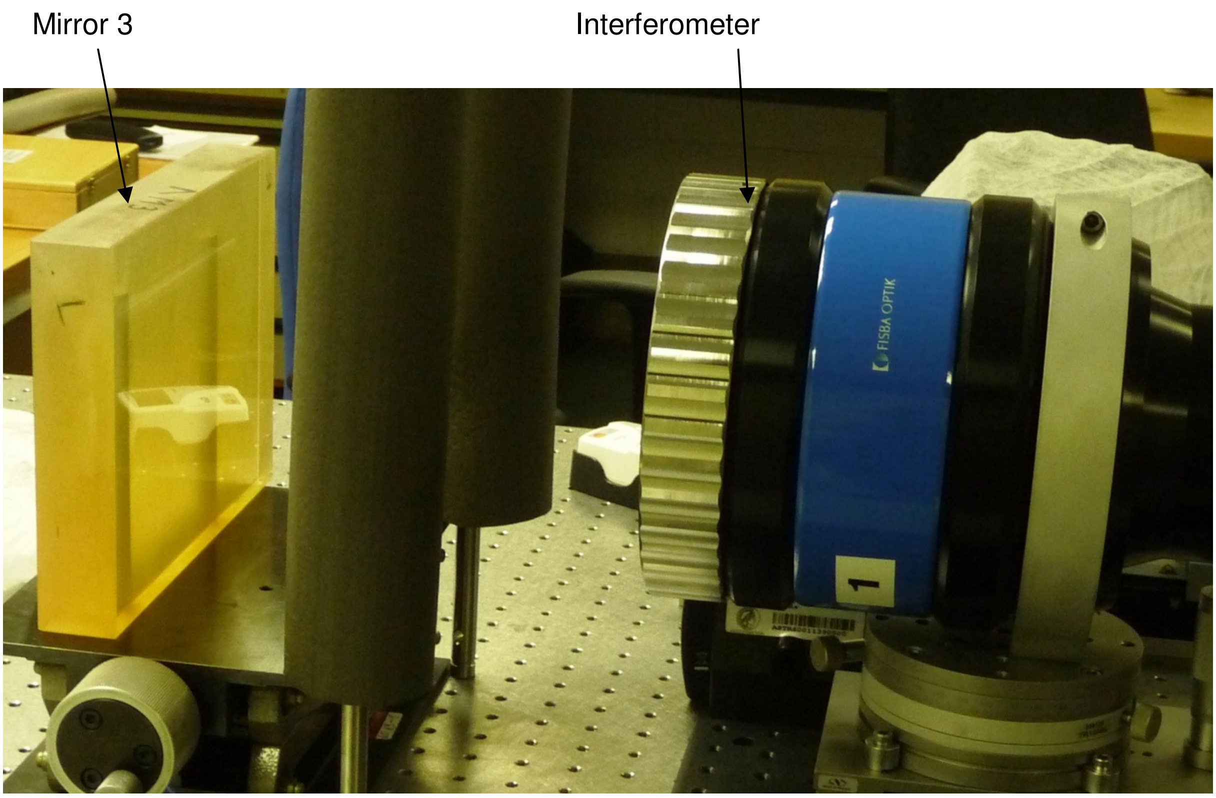


Figure 80: The uncoated mirror 3 is tested with an interferometer before integration into its mount.

3. The manufacturer has purchased all raw materials, delivery of the lenses and entrance window is promised until May 2010.
4. The read-out electronics is working very well and is stable. Firmware upgrades will allow to read-out in all required modes.
5. In order to minimize connections to the warm outside printed circuits have been designed to connect motors and sensors.
6. The control electronics have been built.
7. The read-out software GEIRS has been modified for first tests, work must continue to incorporate various modes. The observation tool, quick-look and data pipeline have been designed and approved by CAHA and IAA and are under development.

Schedule:

1. The next steps are the start up of the cryostat, i.e. internal wiring, vacuum tests, cooling tests. We expect to finish this by March 2010.
2. SESO will deliver the lenses in May 2010. Cryogenic survival tests of the lenses to ensure that stress will not destroy them during cooling down. SESO delivers only the lenses and entrance window. Assembly and alignment of the lenses into modules and aligning these modules into one optical system will then follow This procedure has been worked out in detail in RD 6. We expect to finish this by the end of 2010.
3. In parallel we will start operating the wheels, i.e. functional tests at cold temperatures and tests of positional accuracy.
4. We will continue to work on the read-out, implement read-out modes, and optimize the read-out and the software.
5. Laboratory tests to show the full functionality of PANIC are foreseen for January-May 2011. These tests include quality of images, flexure and stray-light.

Figure 81 shows the schedule for complete assembly and integration of PANIC.

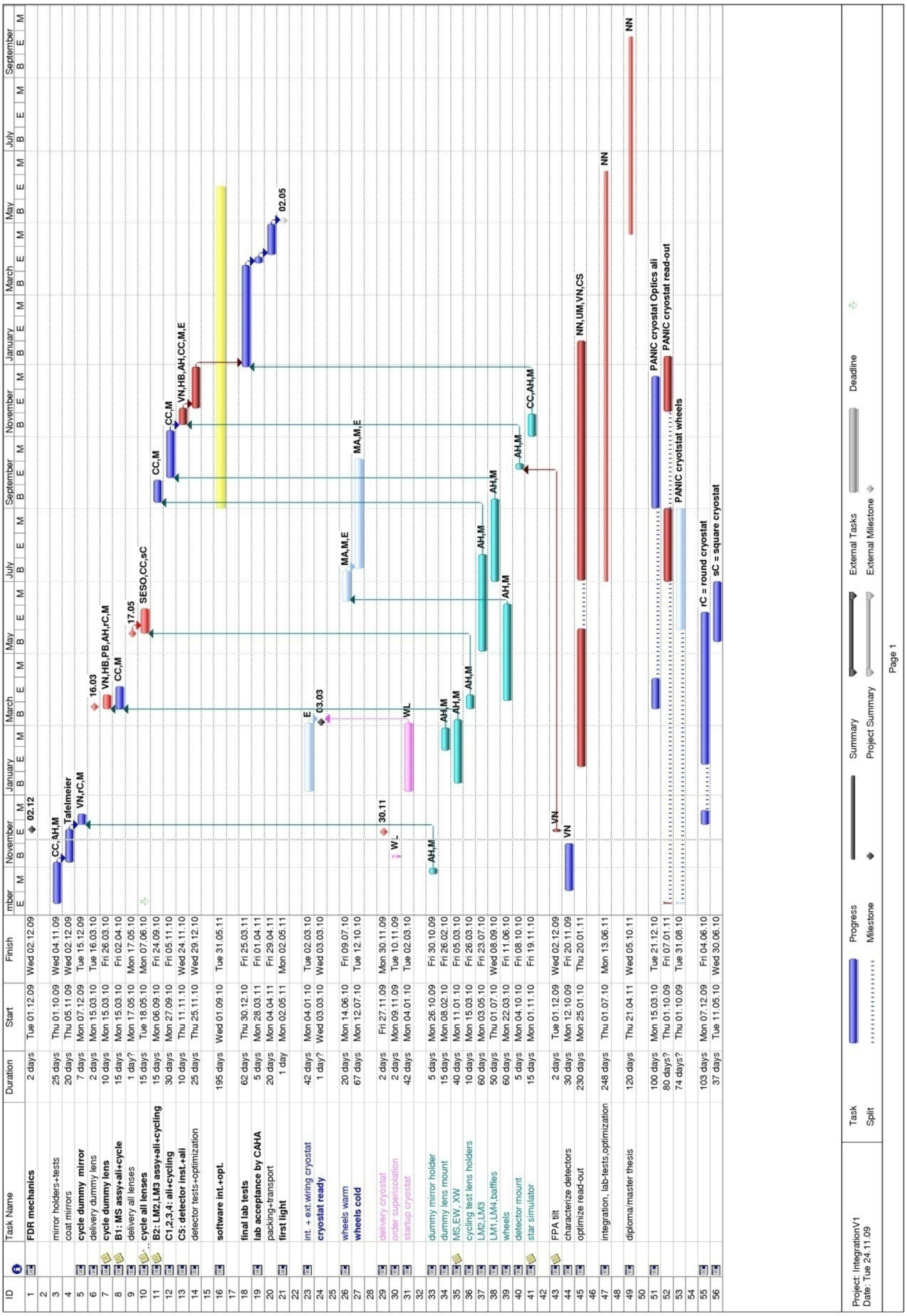


Figure 81: Schedule for assembly and integration of PANIC.