

# LINC-NIRVANA

The **L**BT **I**Nterferometric **C**amera and  
**N**ear-**I**nfra**R**ed / **V**isible **A**daptive  
**i**Nterferometer for **A**stronomy

A collaborative project of the MPIA Heidelberg, INAF-Arcetri,  
Universität zu Köln, and MPIfR Bonn

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## LINC-NIRVANA

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### Fringe and Flexure Tracking System

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## 1 Scope

Description of the FFTS hardware and the outline of the principle of operation.

## 2 Applicable documents

No.	Title	Number & Issue
AD1	Design Report of the FFTS Detector	LN-MPIfR-FDR-ELEC-001
AD2	Interferometry Simulations	LN-KOELN-FDR-GEN-001
AD3	MCAO Simulations	LN-INAF-FDR-AO-003
AD4	Interface Cryostat-FFTS Detector Electronics	LN-MPIFR-FDR-INT-205
AD5	Interface FFTS- FFTS detector electrical	LN-MPIFR-FDR-INT-232

## 3 External Interfaces

Item	Short description
LN Cryostat	Electrical
LN Heat exchanger	Mechanical

## 4 Acronyms and abbreviations

DPU	Detector Positioning Unit
FoV	Field of View
OPD	optical path length difference

## 5 Introduction

Being a Fizeau-Interferometer, the LBT provides a FoV which is much larger than the region that can be exploited by the science detector due to financial constraints. The FFTS can make use of the large FoV (cf. Sect. 6) and increase the sky coverage of the overall instrument, if it is able to acquire the light of a suitable fringe tracking reference star. For this purpose, the FFTS detector needs to be moved to the position of the reference star PSF in the focal plane.

The FFTS will acquire images of this PSF at frame rates of up to several hundred Hz. These frame rates can only be achieved for a small subwindow of the FFTS detector. In order to be able to continuously acquire the light of the guide star, the FFTS detector subwindow needs to follow the trajectory of the PSF in the focal plane. A recurring repositioning of the detector followed by a continuous shifting of the subwindow on the stationary detector itself was considered to be unfeasible for many reasons (such as detector size, readout speed, clock-pattern upload). Therefore, the detector chip with a fixed subwindow has to continuously be moved along the PSF trajectory (note that it can stay fixed for an on-axis reference).

The fringe tracking performance (cf. AD2) is dependent on the level of precision to which the position of the PSF on the subwindow is known. Therefore, it is desirable to keep deviations from the actual position of the PSF due to positioning inaccuracies of the detector as small as possible.

Subpixel (1pixel = 18.5 $\mu$ m) positioning accuracy of the detector is a challenge for any positioning device with a large travel range like in this application. But much stronger are the constraints imposed by the need of a cryogenic environment for the detector. After intense studies and negotiations with companies that have experience in the field of micro positioning, building a cryogenic positioning device that provides the required accuracies was again considered to be unfeasible in the framework of this project. As a consequence, the detector has to be mechanically connected to, but thermally isolated and shielded from, the positioning device, which needs to be kept at ambient temperature. In this way, standard off-the-shelf micro positioning stages can be implemented, and accuracy can be purchased without extra engineering cost.

In the following, we describe the mechanical design which we see as solution for the FFTS mechanics. All of the critical components of the FFTS mechanics are currently undergoing intense prototyping and testing at the I. Physikalisches Institut in Köln.

## 6 Usable Field of View

In general, the size of the FFTS FoV is limited by:

1. The differential piston angular anisoplanatism. The size of the isopiston patch is mainly influenced by the seeing and the performance of the Mid/High layer MCAO system. Please cf. to AD2 for an analysis of the size of the isopiston patch.
2. The influence of optical errors on the interferometric PSF. The degree of misalignment of the two LBT single eye Airy patterns depends on the position in the FoV. It varies with the distance to the optical axis and with the direction with respect to the baseline. The alignment of the two Airy patterns is better parallel to the direction of the baseline than perpendicular to the baseline. This results in an elliptical shape of the usable FoV

Requirements on the FFTS FoV:

1. The FFTS FoV should be as large as possible. With increasing usable FFTS FoV size, the sky coverage of LN increases. (Cf. AD3 for details on sky coverage)
2. A co-alignment of the optical axes of the single eye telescopes of better than 1 Airy radius. According to numerical simulations, the fringe contrast will drop significantly at an Airy pattern misalignment larger than 1 Airy radius. The piston determination algorithm requires a reasonable fringe contrast.

Parameter	Sym.	Value	Unit	Comment
LN optical design				
Focal ratio.	$F/\#_{22.8m}$	31.5		f/ratio of the envelope
Focal plane curvature		spherical		
Focal plane curvature radius	$r_{FoV}$	-217	mm	still preliminary, cf. LN-MPIA-FDR-INT-222, center above focal plane
FFTS FoV $\emptyset$				
Baseline		90	''	angular diameter
$\perp$ Baseline		60	''	angular diameter
Baseline	$D_Y$	300	mm	90'' correspond to 313 mm with $F/\#_{22.8m} = 31.5$ .
$\perp$ Baseline	$D_X$	200	mm	60'' correspond to 209 mm with $F/\#_{22.8m} = 31.5$ .
opt. axis	$D_Z$	64	mm	

## 7 Hardware

The FFTS Hardware consists of the following components

- **Detector Head** with FFTS Detector, detector fanout board, and filter wheel. Cf. AD1 for details of the FFTS Detector system.
- **Moving Baffle.** Comprises the boundary between the cryogenic environment of the detector head and the ambient temperature environment of the Detector Positioning Unit.
- **Detector Positioning Unit.** A remote controllable 3D-stage with high positional reproducibility that allows us to position the detector anywhere within the usable FoV and follow fringe tracking guide star trajectories.
- **Interlock protection.** This prevents mechanical damage of the Hardware in case of unplanned asynchronous motion of the Moving Baffle and the Detector Positioning Unit.
- **Support structure.** The mechanical skeleton of the FFTS to which the Moving Baffle and the Detector Positioning Unit are mounted.
- **Controlling and image analysis computer.** All realtime tasks such as detector positioning, PSF image processing and analysis, and differential piston determination will be carried out by a 4 CPU Linux workstation.

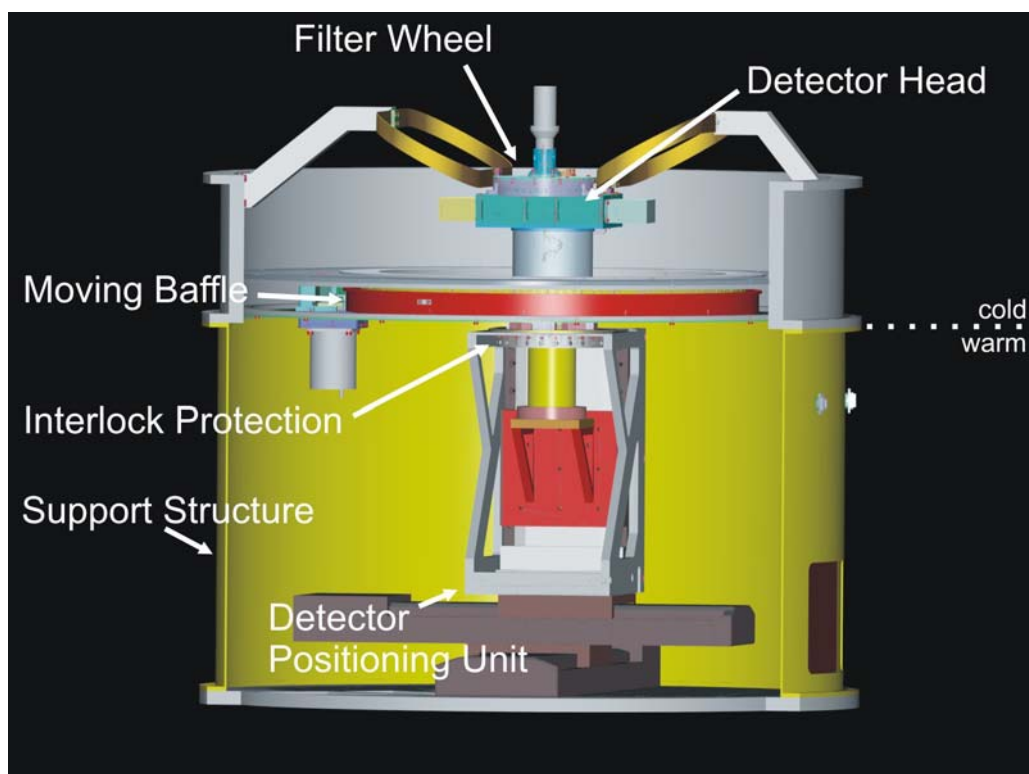


Figure 1: Overview of FFTS components

## 7.1 Detector Head

### 7.1.1 Purpose

The Detector head contains the FFTS detector with its fanout board and the filter wheel (cf. Sect.7.2). It is mounted on top of the fiberglass tube of the Detector Positioning Unit and can be moved anywhere within the volume specified in Sect. 6.

### 7.1.2 Requirements

- Freely placeable along the focal plane in the range of the usable FoV.
- Flexible thermal contact to LN heat exchanger. Total constant heat load on Detector Head: < 1W. Temporary increase of heat load through filter wheel motor.
- Light-tight enclosure of detector and fanout board to shield stray light.
- Fanout board mount should allow use of any of the 4 quadrants of the detector.
- Fixed orientation of the detector with respect to the direction of maximum resolution (long side of the fanout board perpendicular to the baseline of the interferometer, cf. AD5). In this orientation, the direction of fast readout of the detector coincides with the direction of minimum resolution. Possible spill-over effects in between individual pixels at high readout frequencies are then constrained to this direction.
- Easy to remove. The Detector Head must be removable in order to access the warm part of the FFTS mechanics.
- Compact, lightweight design to reduce mechanical flexure of DPU.
- Center of gravity of Detector Head with filter wheel in the center of the fiberglass tube of the DPU.
- Baffling tube for input (being designed)

### 7.1.3 Parts

1 Fanout board, provided by MPIfR, cf. AD1, AD4, AD5

1 Hawaii I detector, single quadrant science grade performance from MPIfR

4 copper cooling straps

### 7.1.4 Layout

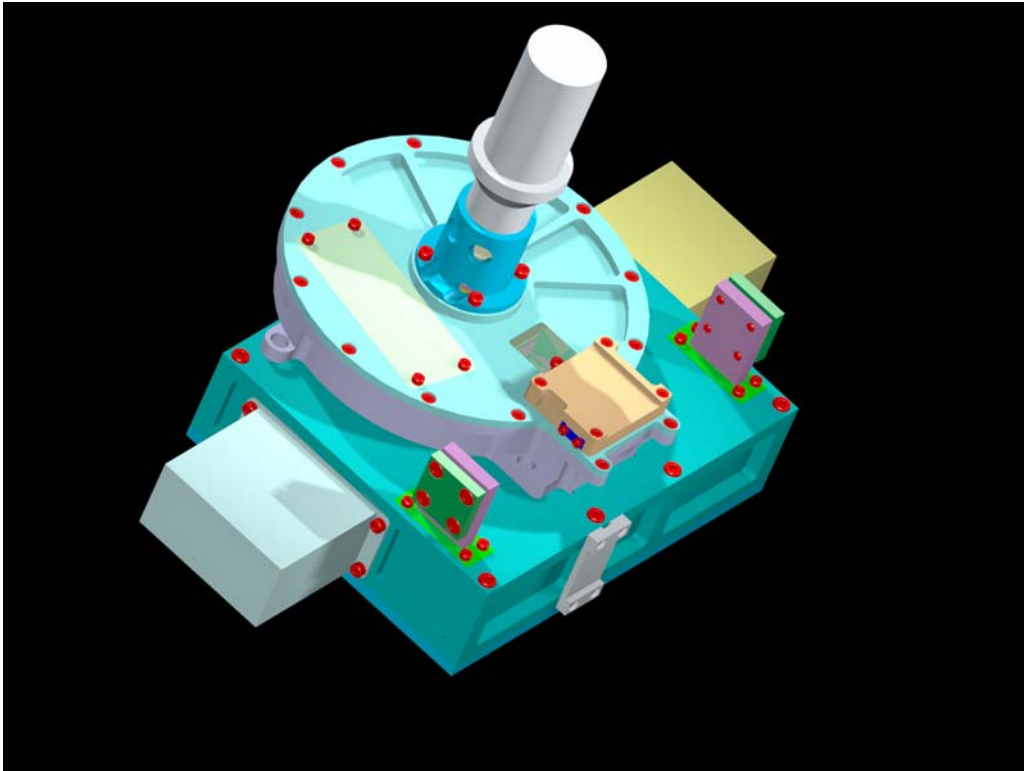


Figure 2: Detector head with filter wheel

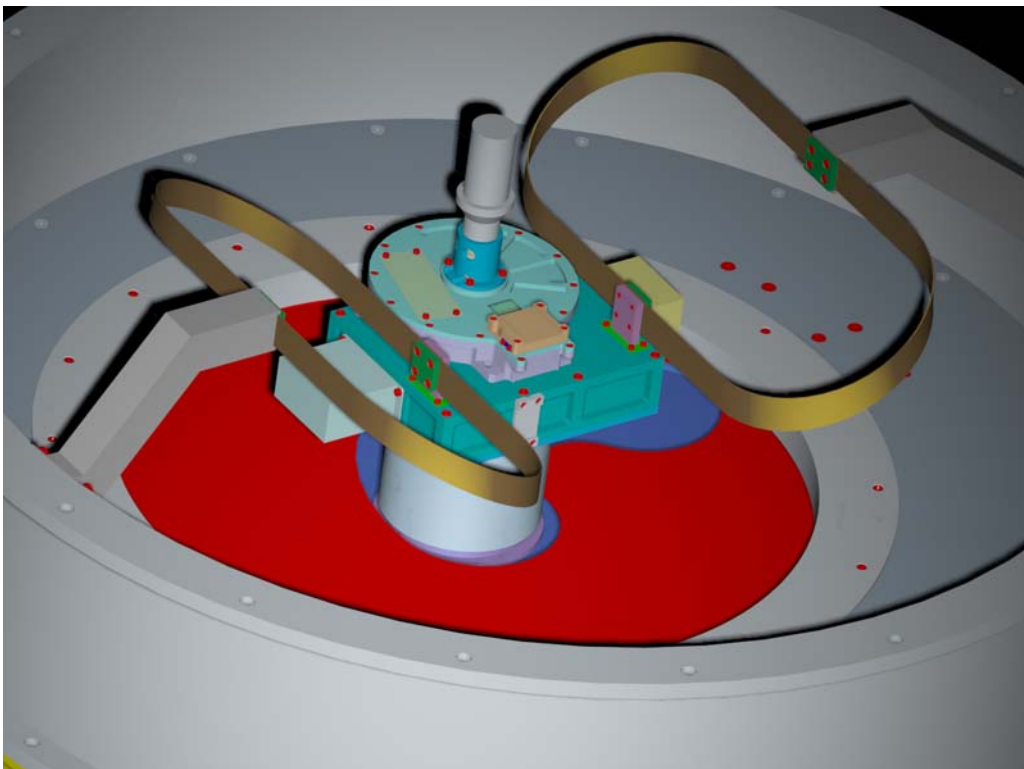


Figure 3: Flexible copper bands provide thermal connection of the detector head with the heat exchanger

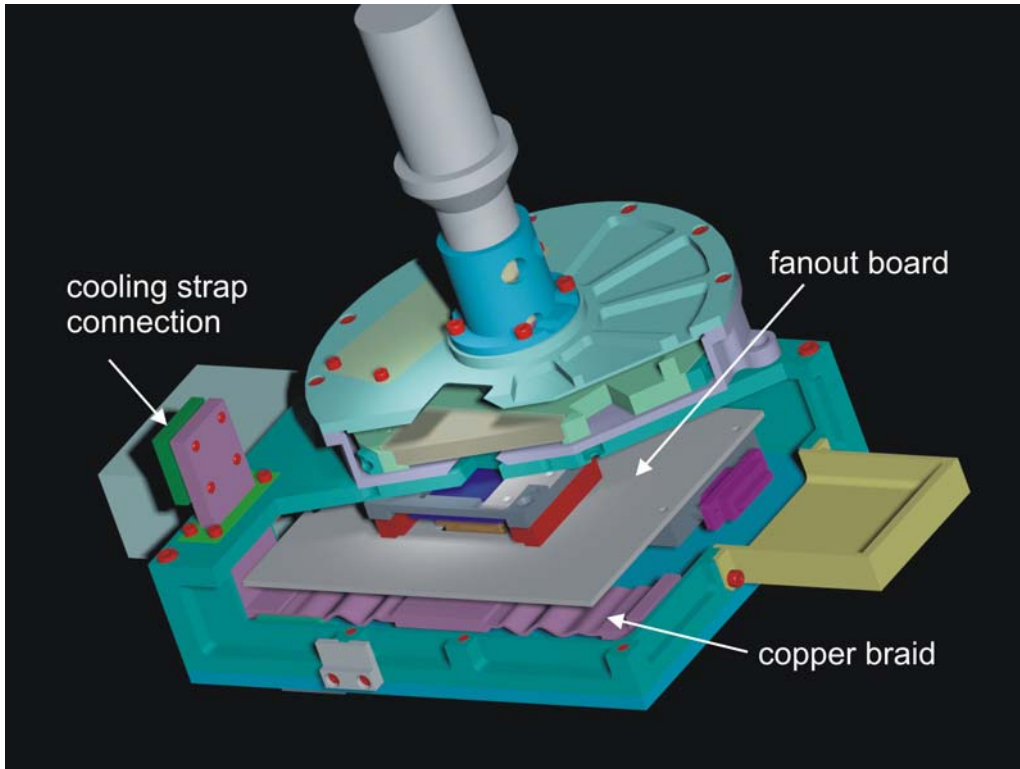


Figure 4: Fanout board with Hawaii I detector underneath filter wheel.

### 7.1.5 Functionality

As shown in Figure 3, thermal contact to the LN heat exchanger is provided via 4 flexible copper cooling straps made of many thin layers. The sandwich sheet structure (no braids are used) prevent the straps from hanging down, their length allows the detector head to access any point in the specified volume. Within the housing, a copper braid directly connects the cooling block at the bottom side of the fanout board with the cooling straps and provides direct heat transfer from the fanout board to the LN heat exchanger (cf. Figure 4).

The size of the housing allows us to mount the fanout board in four positions, hence allowing selection of the quadrant of the detector chip which is to be placed underneath the opening to the filter wheel.

All cables enter the box through the fiberglass tube of the DPU. Dismountable covers allow easy access to the cable connectors of the fanout board. Once the cables are unplugged, the whole Detector Head assembly, including the fanout board, can be removed from the base plate.

### 7.1.6 Specification

Parameter	Sym.	Value	Unit	Comment
Heat load through detector cables		0.162	W	cf. LN-MPIFR-FDR-INT-205
Heat dissipation fanout board		0.5	W	cf. LN-MPIFR-FDR-INT-231
Length of cooling straps		410	mm	

### 7.1.7 Availability

The fanout board and the Hawaii I detector are provided by MPIfR. The Hawaii I detector is already in Bonn.

## 7.2 Filter Wheel

### 7.2.1 Purpose

The filter wheel should provide 9 filter positions with filter central wavelengths of J,H and K and 3 different bandwidths.

### 7.2.2 Requirements

- Rapid filter change between filters of identical central wavelength but different bandwidths. During the alignment of the instrument, once the OPD is smaller than the coherence length of a filter, the filter will be changed to one with a broader bandwidth, to increase throughput and reduce coherence length. The time of vignetting of the detector readout window during such a change should be less than the coherence time  $\tau$  of the atmosphere.
- Filter position detection and additional reference position is required.
- Blank and blind position
- Linear variable bandwidth filter being investigated

To allow for a minimum time of vignetting, filter assemblies are used. 3 Filter assemblies are required. Each includes 3 filters with identical central wavelength but different bandwidths. Within each assembly, the filters have to be ordered with ascending bandwidth (say from left to right). Each assembly consists of rectangular filters which are connected in a row (cf. Figure 5). All three assemblies will be part of a common filter wheel. The overall dimensions of the assembly are chosen such that the clear aperture of the left and right filter still covers the detector area, since the centers of these filters do not have the same radial distance to the filter wheel rotation axis as the central filter.

An important design issue is the dead zone width between adjacent filters. The shadowing effect by the dead zone in between adjacent filters while switching to the next filter bandwidth should be as small as possible.

The dead zone width  $d$  and the angular velocity  $\dot{\phi}$  of the filter wheel determine the time in which part of the subwindow on the detector in which the PSF is acquired is blocked.

$$\dot{\phi}_{\min} = \frac{180}{\pi \cdot \tau} \arctan\left(\frac{(d+D)}{r}\right) \approx \frac{180}{\pi} \frac{(d+D)}{\tau \cdot r}$$

where  $D$  is the subwindow size ( 32 Pixel \* 18.5  $\mu\text{m}/\text{Pixel}=592 \mu\text{m}$ ),  $r$  the effective radius of the filter wheel (33mm), and  $\tau$  (e.g. 0.05s) the coherence time of the atmosphere. A dead zone width of 100  $\mu\text{m}$  then yields

$$\dot{\phi}_{\min} = 24^\circ / \text{s}$$

### 7.2.3 Parts

- 3 Filter assemblies
- 1 cryogenic stepper motor Phytron VSS26
- 1 Harmonic Drive HD05, gear ratio 80:1
- 2 SAIA micro switches
- 1 GRW ball bearing

### 7.2.4 Layout

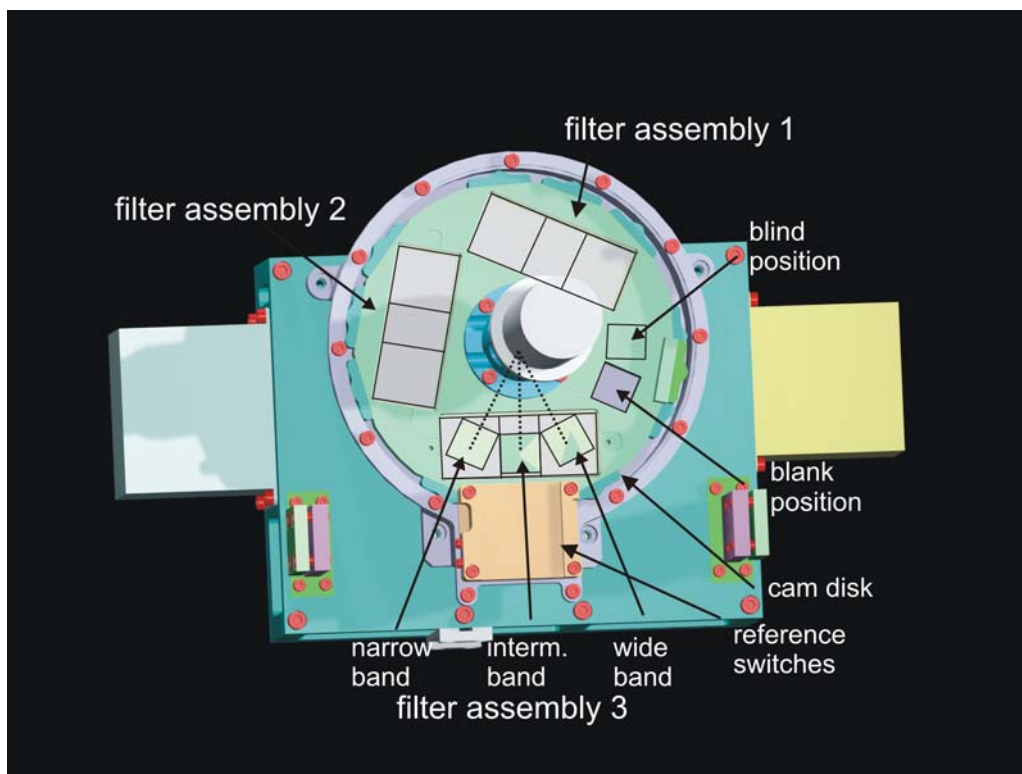


Figure 5: Filter assembly arrangement and position encoding by cam disks and micro switches

### 7.2.5 Functionality

The filter wheel is optimized in terms of weight and compactness. A cam disk and limit switch combination is implemented for filter position reference. In order to minimize weight, the option of absolute position encoding was abandoned. Instead, an additional reference position is defined by a second cam-switch combination. Filter positions will be counted from this reference.

### 7.2.6 Specification

Parameter	Sym.	Value	Unit	Comment
Rotational velocity of filter wheel	$\dot{\phi}_{\min}$	24	$^{\circ}/s$	

For filter assembly specifications cf. Figure 6.

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**Quotation Number:** 0411-5014BE  
**Date:** 12.11.2004

**Quotation**

**For:** Thomas Bertram  
 Universitat zu Koln (University of Cologne)  
**Address:** I. Physikalisches Institut  
 Zulpicher Str. 77  
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**Fax:** +49 221 470 5162  
**E-Mail:** bertram@ph1.uni-koeln.de

**From:** Evelyn Downey  
**Phone:** 978-392-3859  
**Fax:** 978-392-3802  
**E-Mail:** edowney@barrassociates.com

[See Attached](#)

Item	Description	Qty	Unit Price	Total Price
1	J region filters CWL = 1.249um			
1A	FWHM = 0.0125um	1	\$ 6,000.00	\$ 6,000.00
1B	FWHM = 0.125um	1	\$ 5,100.00	\$ 5,100.00
1C	FWHM = 0.3194um	1	\$ 5,100.00	\$ 5,100.00
2	H region filters CWL = 1.652um			
2A	FWHM = 0.0165um	1	\$ 5,500.00	\$ 5,500.00
2B	FWHM = 0.165um	1	\$ 4,600.00	\$ 4,600.00
2C	FWHM = 0.3600um	1	\$ 4,600.00	\$ 4,600.00
3	K region filters CWL = 2.195um			
3A	FWHM = 0.0220um	1	\$ 5,700.00	\$ 5,700.00
3B	FWHM = 0.220um	1	\$ 4,800.00	\$ 4,800.00
3C	FWHM = 0.5785um	1	\$ 4,800.00	\$ 4,800.00
4	J region mosaic assembly Including ALL three bandwidths from Item1 edge bonded together as per customer specifications dated Oct 21, 2004	1	\$ 18,080.00	\$ 18,080.00
5	H region mosaic assembly Including ALL three bandwidths from Item2 edge bonded together as per customer specifications dated Oct 21, 2004	1	\$ 16,580.00	\$ 16,580.00
6	K region mosaic assembly Including ALL three bandwidths from Item3 edge bonded together as per customer specifications dated Oct 21, 2004	1	\$ 17,180.00	\$ 17,180.00
<p><b>COMMON SPECIFICATIONS:</b>                      Peak T% for Item 1A, 2A, 3A &gt; 65%                      In-band T% for all others &gt; 80% average                      CWL and BW tolerance for Items 1A, 2A, 3A = +/- 20% of FWHM                      CWL and BW tolerance for all others = +/- 10% of FWHM                      Out-of band blocking OD4 from 0.7-3.0um                      Operating temp: 80-100K (test witness ONLY) - fixed value TBD                      Transmitted wavefront &lt; 1/10 wave P-V @ CWL over 0.5" dia (TWF measured prior to coating)                      Parallelism &lt; 30 arcsec                      Scratch/Dig: 60/40                      For Mosaic options (Items 4,5,6): Dead Zone Width &lt; 100um                      AOI &lt; 7 degrees (Fixed number TBD)                      All measurements will be taken in f/8 beam                      Clear apertures as defined on specifications sheet dated Oct 21, 2004 from Thomas Bertram.</p> <p>Please note that Cold Test measurements will be performed on a witness piece ONLY for each band. The cold test will likely be at 77K. The shift to the determined operating temp will be correlated from this measurement.</p> <p>Please note that all deliverable bands will be measured at room temp ONLY and the shift to Cold will be calculated from shift data of the witness piece.</p>				
<b>pricing valid for 90 days</b>				
<b>Delivery:</b> 10-14 weeks ARO				
<b>Terms:</b> Net 30 days, FOB Westford, MA 01886 U.S.A.				
<b>Signed:</b> _____ Evelyn Downey, Design Engineer			<b>Date:</b> 12.11.2004	

Figure 6: Quotation for filter assemblies

### 7.2.7 Availability

Delivery time:

- Filter Assemblies: 10-14 weeks
- Phytron cryo motor: 12-16 weeks
- Harmonic drive: ~ 12 weeks
- Dicronite coating of gear: ~1 week
- GRW ball bearing: ~ 6-8 weeks

In stock at MPIA:

- SAIA micro switches

## 7.3 Moving Baffle

### 7.3.1 Purpose

The Moving Baffle separates the cryogenic environment of the dewar from the ambient temperature environment. It prevents intrusion of thermal radiation into the camera's interior. Furthermore, it has to allow the DPU to access the cryogenic environment via a hole, which can be moved to any position within the region of the focal plane projected to the baffle plane that corresponds to the usable FoV.

### 7.3.2 Requirements

- Light tight baffle. The shield has to suppress the intrusion of NIR photons into the camera environment.
- Moving access hole. The area of the FFTS FoV (cf. Sect. 6) projected onto the XY reference plane of the baffle has to be accessible by the moving access hole. This hole allows the DPU to access the cryogenic environment.
- Baffle and DPU mechanically decoupled. The baffle system should not add additional gravitational force or vibrations to the fiberglass tube of the Detector Head.
- Synchronous motion of DPU and Moving Baffle.
- Comovement tolerance between DPU and Moving Baffle.
- Interlock protection.
- Cold shield. The shield has to prevent the intrusion of thermal photons into the cryogenic environment of the dewar. This includes photons radiated from the shield itself. The science detector is oriented in a way that it is facing the moving shield. Emitted or unshielded photons will directly increase the detector noise. Therefore the shield itself has to be cooled.
- Compact design. The baffle should not define the radius of the dewar.

### 7.3.3 Parts

- 1 KAYDON Slimring ball bearing KC 160 XP0
- 1 Phytron cryogenic stepper motor VSS 52.200.5
- 1 Saia micro switch
- 3 GRW ball bearings
- 1 custom made fiberglass tube

### 7.3.4 Layout

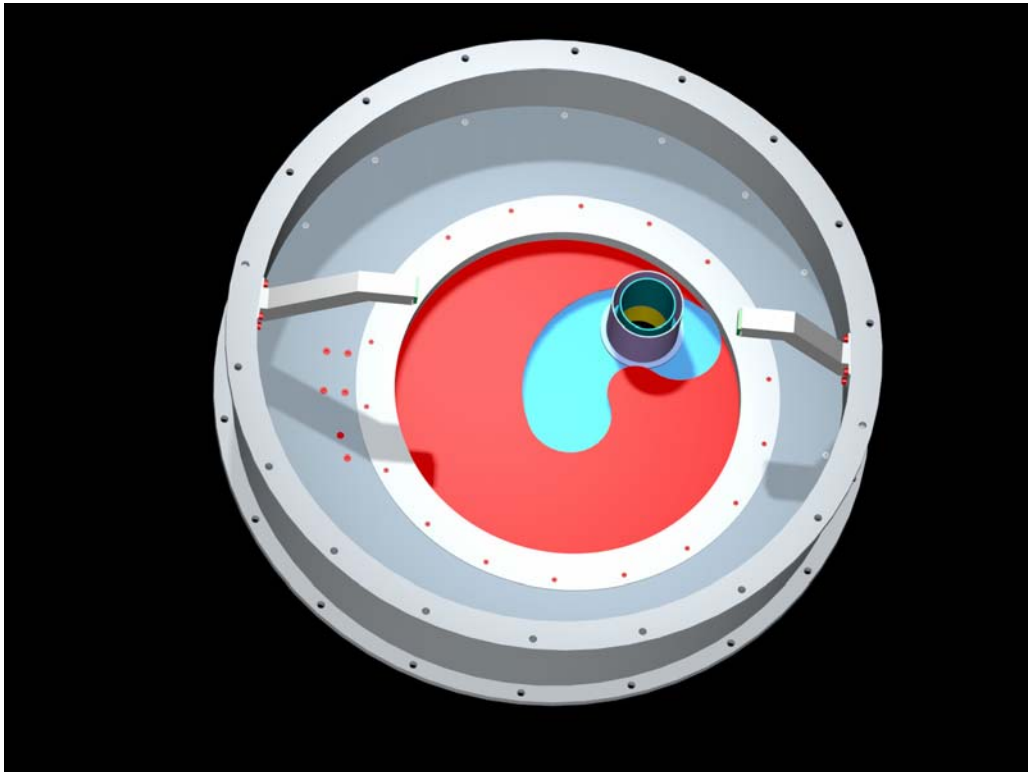


Figure 7: Moving Baffle, view on cold side.

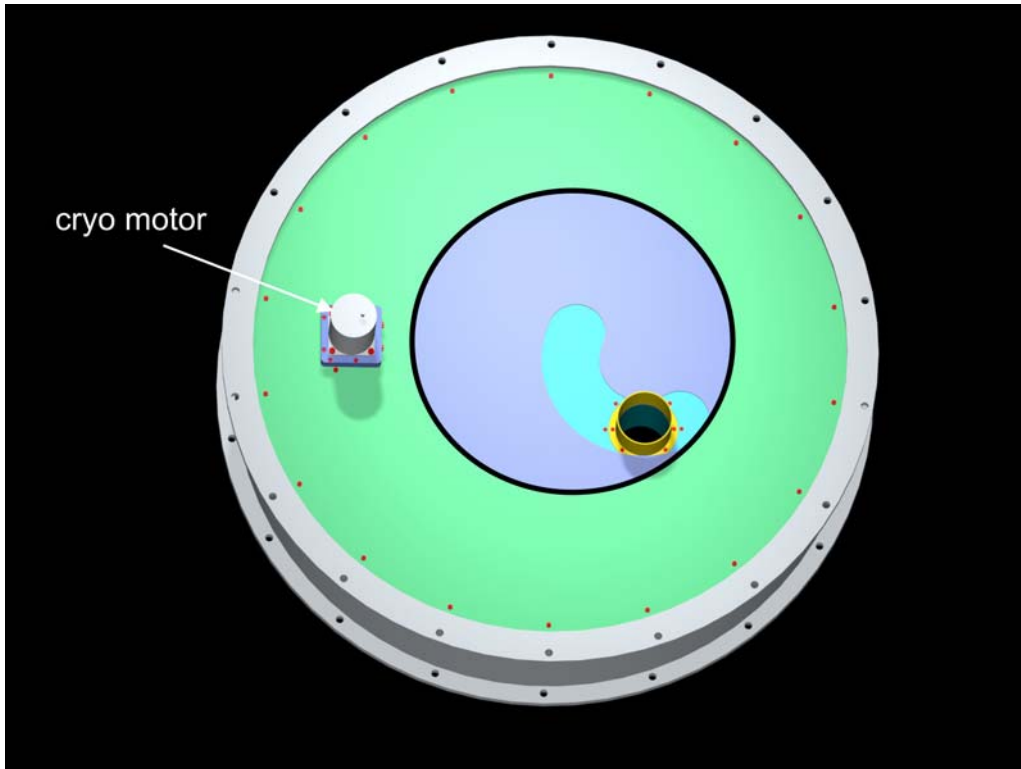


Figure 8: Moving Baffle, view on warm side. The outer annulus is in thermal contact with the heat exchanger. Radiation heat transfer on the rotating disk is restricted to the encircled surface in the center.

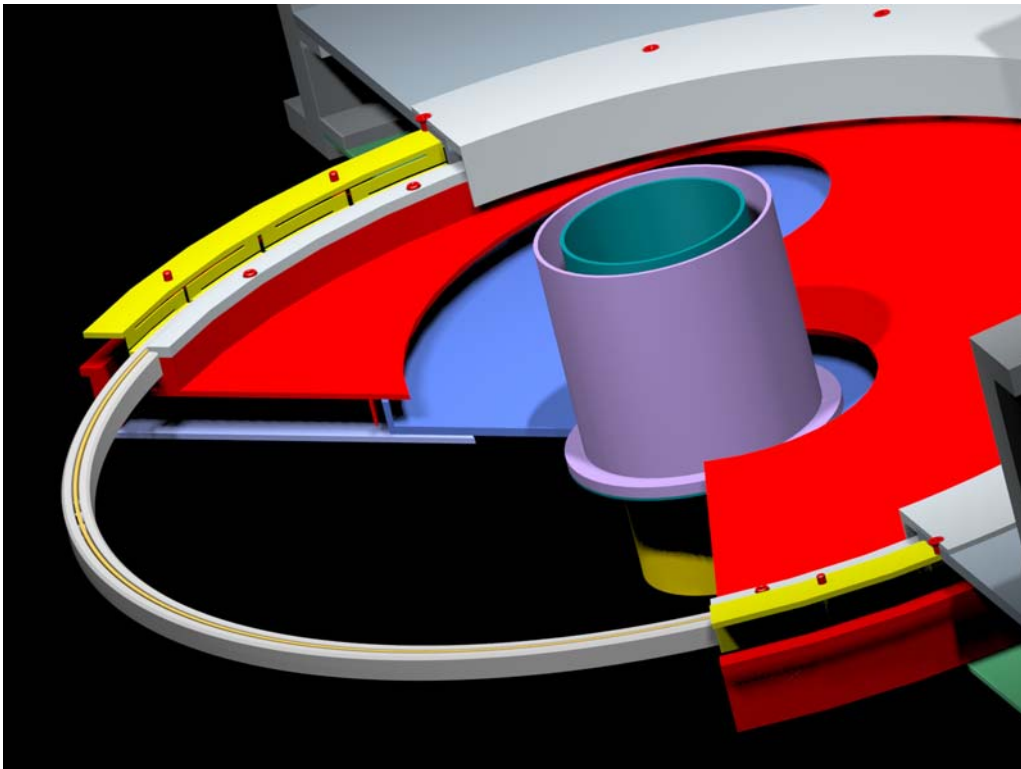


Figure 9: A bearing with an inner diameter of 406.4 mm guides the outer disk. A flexible mounting allows for differential contraction in radial direction.

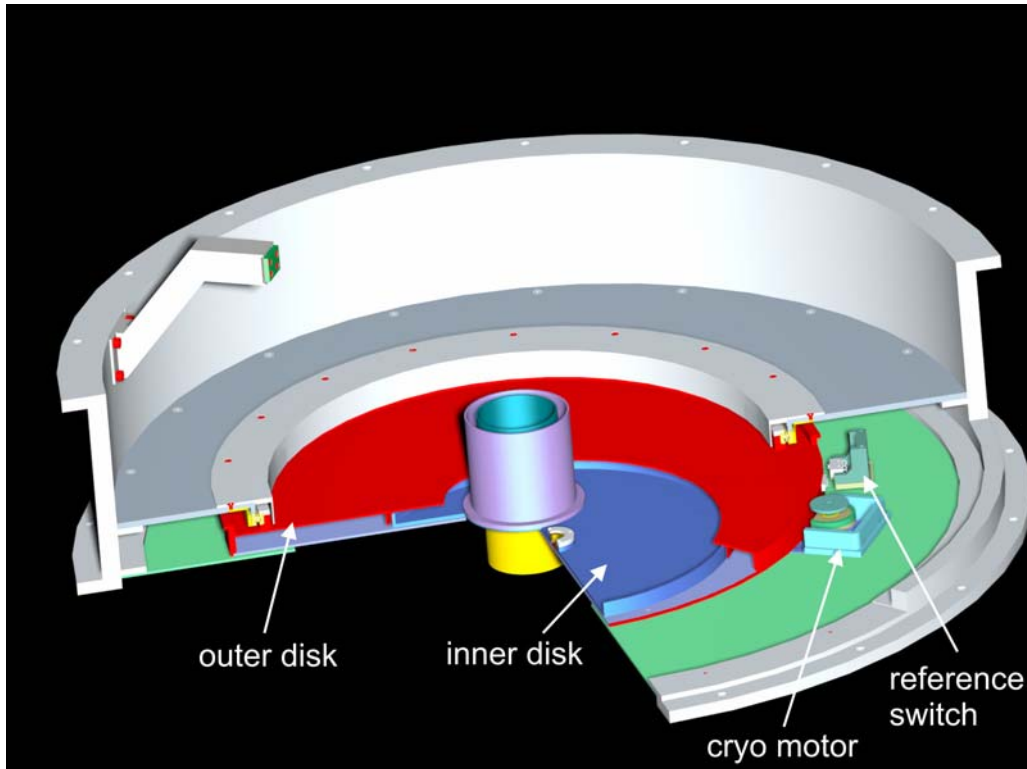


Figure 10: Two nested disks shield the cold part from the warm. The vertical tube can be positioned everywhere within a radius of 150 mm from the center of the baffle by rotating the two disks.

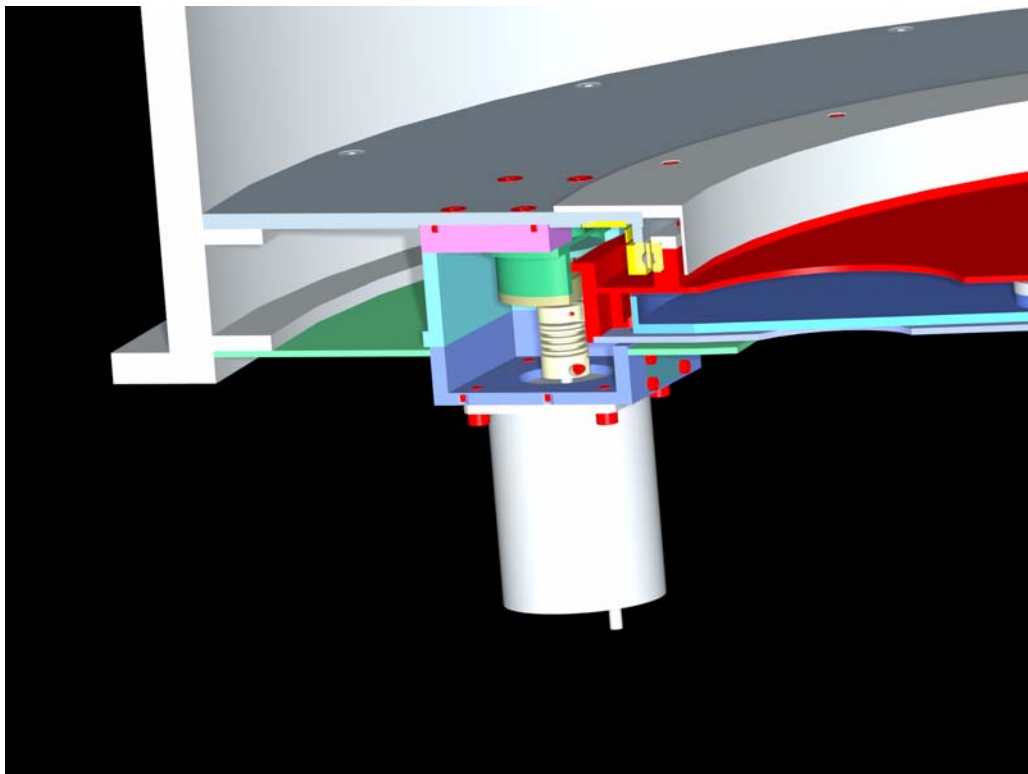


Figure 11: A Phytron stepper motor moves the outer disk of the baffle.

### 7.3.5 Functionality

The Moving Baffle consists of two nested disks. The outer disk is centered on the symmetry axis of the DPU. It is guided by a Reali-Slim ball bearing that provides a central clearance with a diameter that is larger than the positioning range of the DPU (cf. Figure 9). This disk needs to be comoved with any tangential motion component of the DPU. It covers the full area which needs to be accessible, except for a narrow circular arc shaped opening.

This opening is covered by the second disk, which is located within the outer disk (cf. Figure 10). The inner disk allows for radial positioning of the DPU. The inner disk can be moved by the DPU itself without active drive mechanism (cf. Figure 13, a balanced mass distribution and a constant distance to the disk's center results in a constant torque which is dependent only on the friction of the ball bearing). The outer disk, however, needs to be driven by a cryo motor (cf. Figure 11), since the torque is dependent on the radial position of the DPU.

The Baffle motion has to be synchronized with the DPU motion. The design permits a positional discrepancy of 3 mm before triggering an interlock of the system.

With this concept, any X-Y motion of the DPU is decomposed into two simple rotations. In the most common case of tracking a guide star, only circular trajectories centered on the DPU symmetry axis are followed, hence the number reduces to one rotation. The constraints upon the precision of the baffle motion is low due to the +/- 3 mm tolerance. In contrast to translational motion at cryogenic temperatures, rotational motion is easier to realize in such an environment.

The current design assumes sufficient heat transfer via the ball bearing. Initial tests with a scaled model have suggested that this approach is reasonable. Further tests with a prototype will be carried out for final confirmation.

To secure the heat transfer in the cool-down period, the outer and not the inner rim of the bearing is attached to the heat exchanger. Differential contraction in radial direction therefore needs to be compensated to prevent the destruction of the bearing (cf. Figure 9).

To minimize the radiation heat load onto the outer disk, all parts that do not interfere with the DPU are covered by a cold plate. Also, the surface of the disk facing the warm side will be coated to reduce absorption.

### 7.3.6 Specification.

Parameter	Sym.	Value	Unit	Comment
Interlock tolerance		3	mm	
Inner $\varnothing$ of bearing		406.4	mm	

### 7.3.7 Availability

On stock

- KAYDON Reali-Slim ball bearing KC 160 XP0
- Phytron cryogenic stepper motor VSS 52.200.5
- Saia micro switch

Delivery time:

- GRW ball bearings: ~ 6-8 weeks
- custom made fiberglass tube

## 7.4 Detector Positioning Unit

### 7.4.1 Purpose

The DPU allows motion of the Detector Head along the focal plane to the position of the fringe tracking PSF and to follow its trajectory.

### 7.4.2 Requirements

- Travel range 200 mm x 300 mm x 70 mm.
- Maximum velocity for guide star tracking: 2.6 mm/s. This corresponds to the radial velocity of the sky rotation at a radius of 150 mm from the optical axis and telescope pointing with zenith distance of only 1°.
- Maximum time for repositioning: 90 sec
- Absolute positioning accuracy: <math><50\mu\text{m}</math> (for initial PSF position acquisition).
- Position reproducibility:  $\pm 4\mu\text{m}$  for PSF trajectory tracking. The quality of fringe-tracking depends on the uncertainty of the PSF position. Knowing the central position of the PSF to sub-pixel precision allows us to reduce the number of free parameters that have to be fitted to the PSF profile, which in turn increases the performance of the fringe tracking algorithm significantly (cf. AD2).
- Qualified for vacuum conditions ( $10^{-6}$  mbar).
- Reference sensor positions in the centres of the travel range of the X- and Y- Axes (location of the reference sensor position of Z Axis not critical).
- Motor control electronics “MoCon” of MPIA to be used.
- Routing of all cables to the Detector Head through the DPU.
- Shielding of the Z-direction travel range below the detector head.
- Self-locking gears to prevent slip of the stages when motors are switched off and a gravitational force component acts along the direction of the axes (low elevation angle of the telescope).

### 7.4.3 Parts

- 1 Micro positioning stage M531K037, travel range: ~300mm
- 1 Micro positioning stage M521K048, travel range: ~200mm
- 1 Micro positioning stage M511K056, travel range: ~70mm
- 1 custom made fiberglass tube

#### 7.4.4 Layout

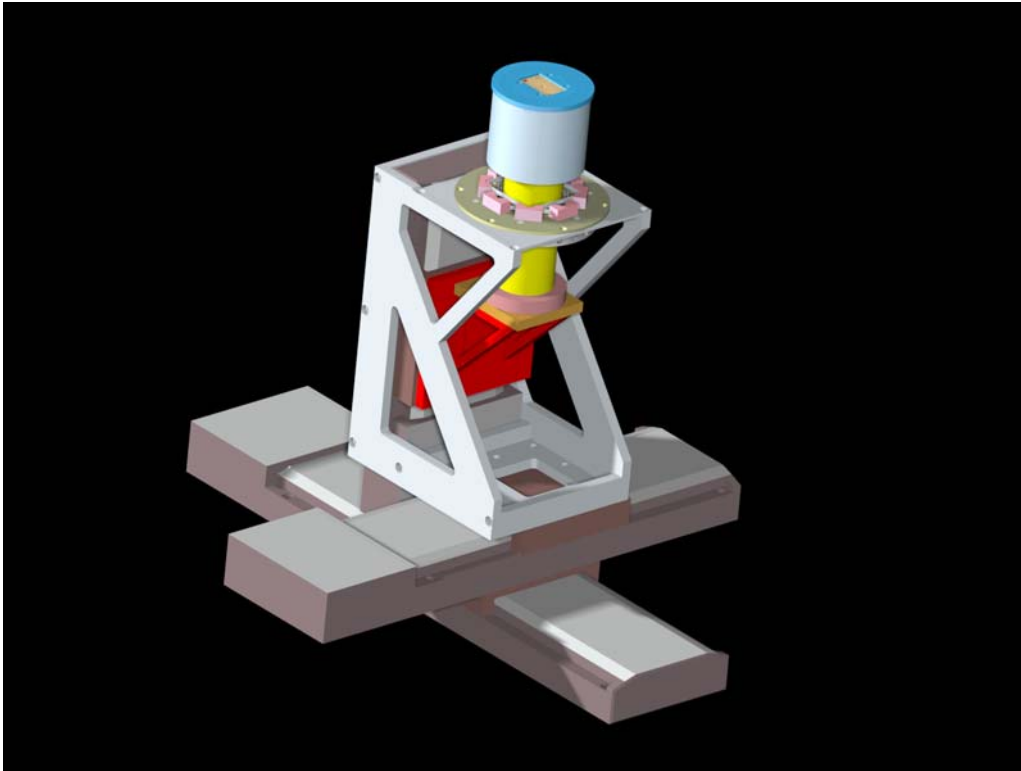


Figure 12: The Detector positioning unit consists of 3 linear stages which allow positioning of the detector head (not shown) on top of a tube anywhere within a volume of  $200 \times 300 \times 70 \text{ mm}^3$ .

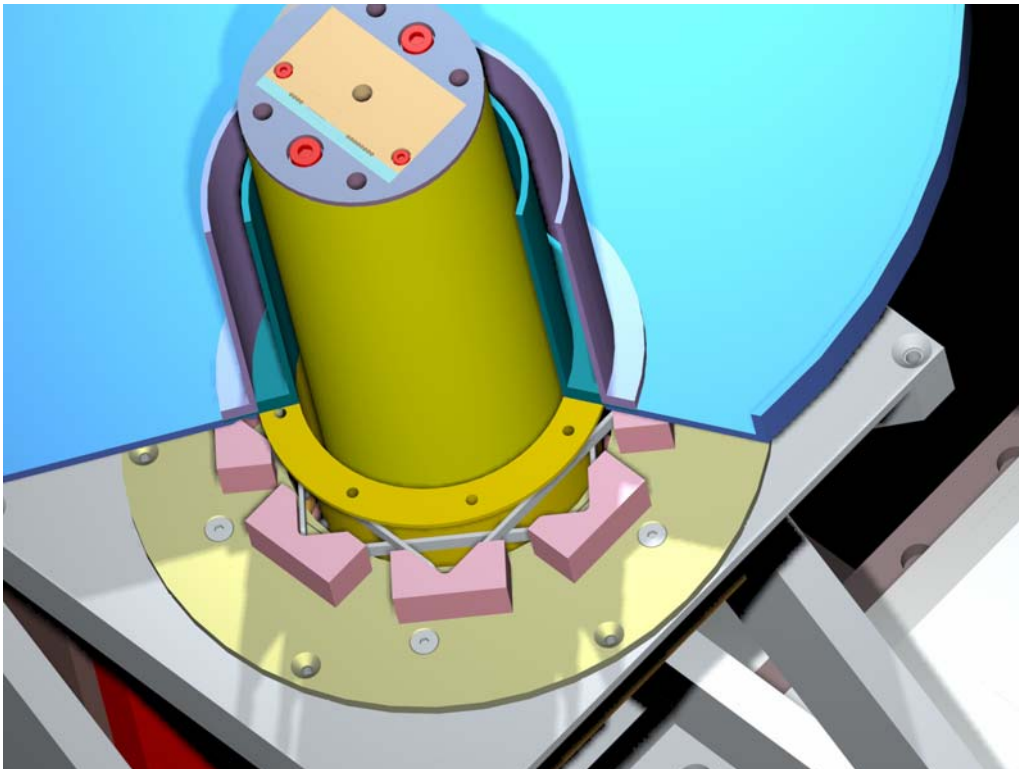


Figure 13: Flat springs attached to the Detector Positioning Unit center the inner disk of the moving baffle on the tube axis.

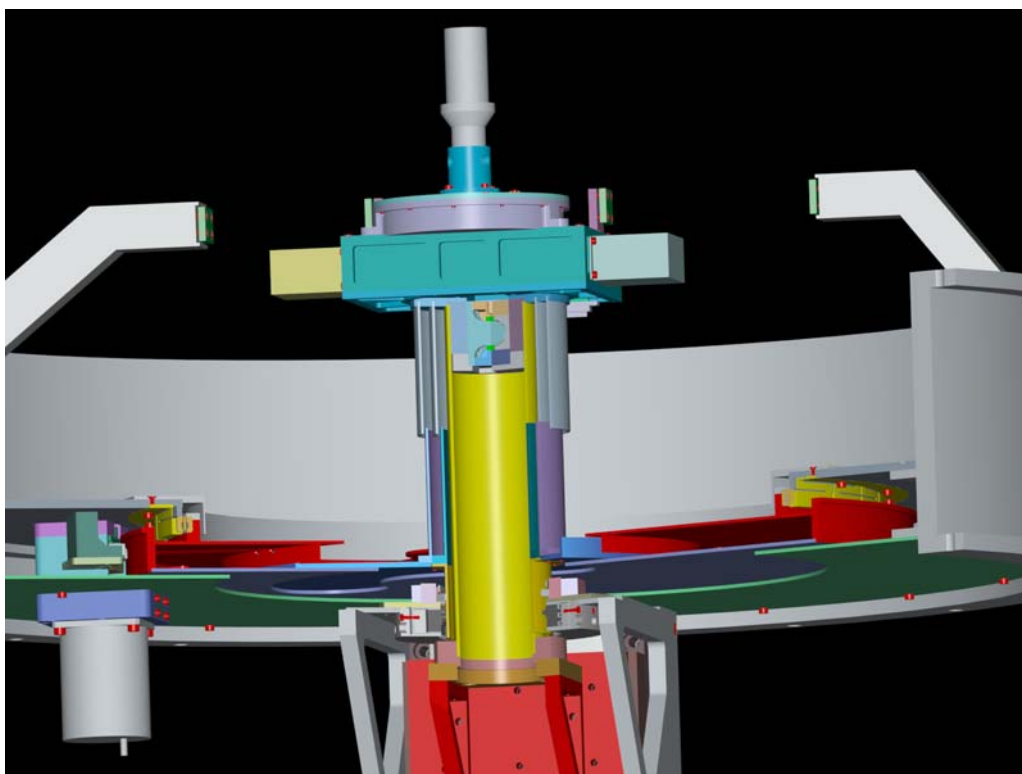


Figure 14: A fiberglass tube supports the detector head in the cryogenic part and connects it with the linear stages in the warm part of the dewar. Here the maximum Z-position is shown.

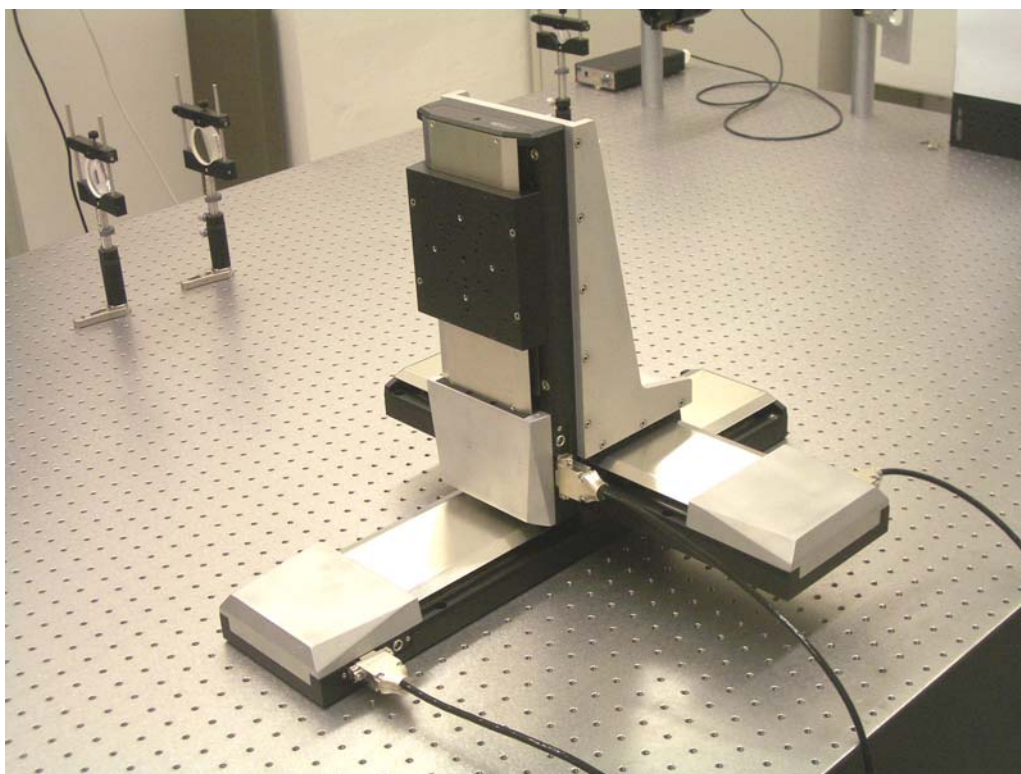


Figure 15: 3 linear stages from PI are assembled in a test setup for the Detector Positioning Unit

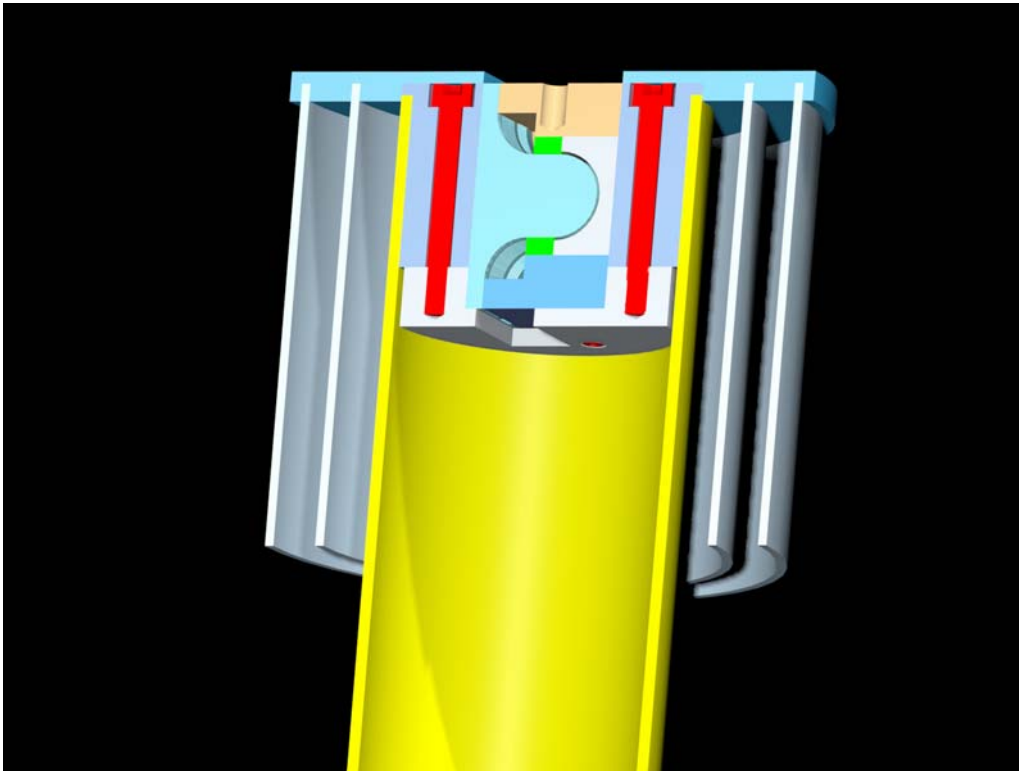


Figure 16: Cut through the detector head mount. All cables to the cryogenic environment are routed through a photon-tight feedthrough

#### 7.4.5 Functionality

The DPU consists of 3 vacuum qualified micro positioning stages from PI with travel ranges corresponding to the volume that has to be accessible by the detector (cf. Figure 12 and Figure 15). A fiberglass tube mounted to the Z-stage points through the moving hole in the baffle and carries the Detector Head (cf. Figure 14). The travel range in Z-direction is shielded by a double layer shield of axial tubes. Tangential flat springs attached to the top of the Z-stage center the inner disk of the moving baffle around the fiberglass tube (cf. Figure 13 and Figure 17). A photon-tight cable feedthrough is integrated into the fiberglass tube (cf. Figure 16) This has the advantage that all cables and the feedthrough itself can remain assembled when disassembling the Moving Baffle.

#### 7.4.6 Specification

Parameter	Sym.	Value	Unit	Comment
Micro positioning stage M531K037				
travel range	$D_Y$	305	mm	Standard travel range of linear stage: 12 inch = 305 mm.
max. velocity	$v_{max}$	3	mm/s	
Gear ratio		29.6:1		
Resolution		0.033	$\mu\text{m}$	spindle pitch and encoder
Micro positioning stage				

MK521K048				
travel range	$D_x$	203	mm	Standard length of linear stage: 8 inch = 203 mm.
max. velocity	$v_{max}$	1.5	mm/s	(2mm/s for duration < 10min)
Gear ratio		69.2:1		
Resolution		0.014	$\mu\text{m}$	spindle pitch and encoder
Micro positioning stage MK521K048				
travel range	$D_z$	70	mm	Custom made size to reduce overall length of FFTS unit.
max. velocity	$v_{max}$	1.5	mm/s	(2mm/s for duration < 10min)
Gear ratio		69.2:1		
Resolution		0.014	$\mu\text{m}$	spindle pitch and encoder
Fiberglass tube				
length		207	mm	
inner diameter		50	mm	

### 7.4.7 Availability

In the lab at Köln:

- 3 micro positioning stages

Delivery time:

- custom made fibre glass tube

## 7.5 Interlock Protection

### 7.5.1 Purpose

The interlock protection is foreseen to prevent damage to the hardware in case of uncoordinated motion of DPU and Moving Baffle.

### 7.5.2 Requirements

- Two levels of activation:
  - a soft limit, which is coupled with the limit switches of the linear stages and connected to the motor control electronics.
  - a hard limit, which directly switches off the motor current.

### 7.5.3 Parts

24 Marquardt Series 1056 enclosed snap action switches

### 7.5.4 Layout

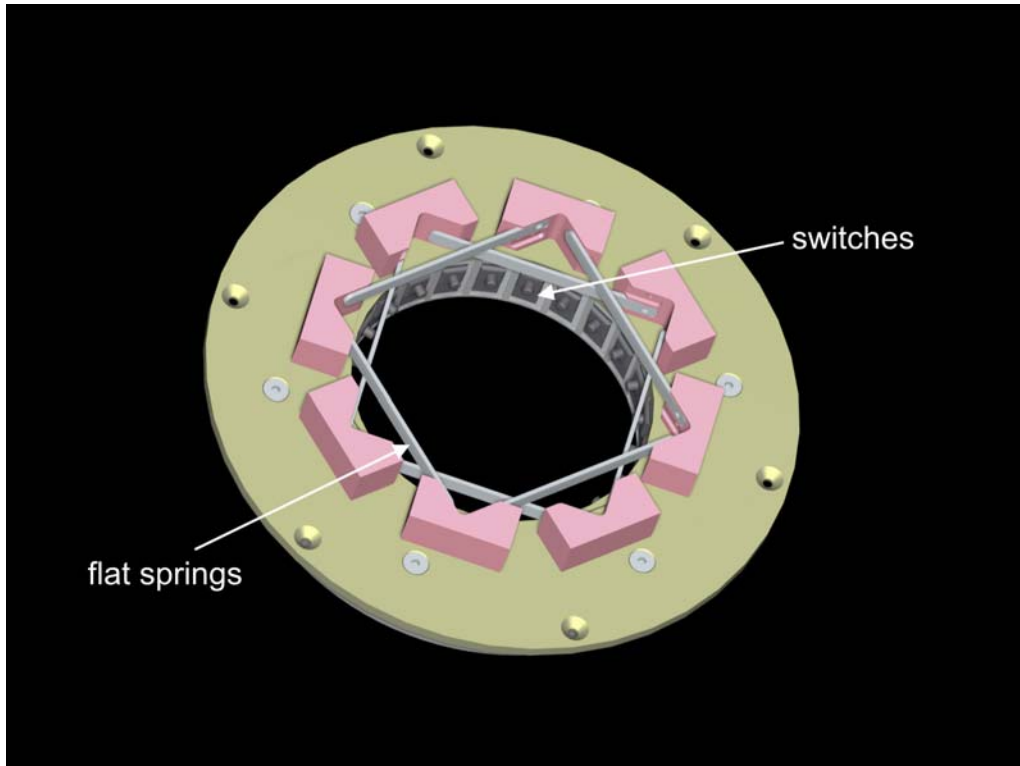


Figure 17: Altogether, 24 Marquardt switches form a two level interlock protection. The flat springs are used to center the inner disk of the Moving Baffle around the DPU fiberglass tube.

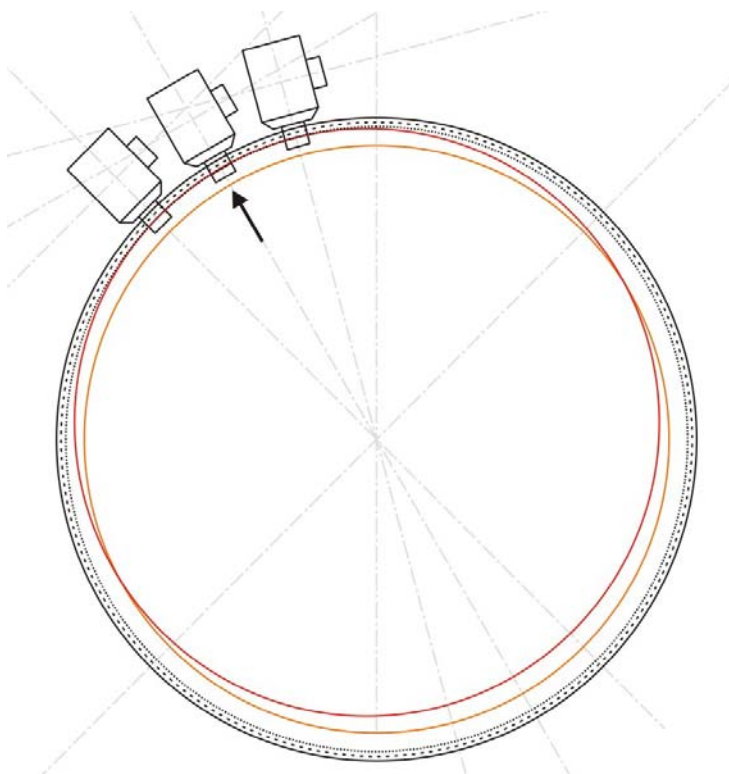


Figure 18: The spacing of the switches keeps geometrical response delays to a minimum ( $<0.1$  mm). The switch in the center will be used for the hard limit, and will therefore have a slightly larger radial distance than shown here.

### 7.5.5 Functionality

The interlock protection consists of a concentric circle of 24 micro switches (Figure 13 and Figure 17) around the fiberglass tube of the Moving Baffle. Every second switch is dedicated to the hard limit level. The radial position of the switches can be adjusted. Both protection levels have to be realized within the 3mm mechanical tolerance between DPU and Moving Baffle. The specified switches have a relatively large over-travel range past the activation position, which allows a second limit switch level (hard limit) in the radial direction before the physical limit of the switches is reached.

The orientation of the limit switch circle is fixed with respect to the linear stages. A total of 12 switches per protection level allows assignment of 3 switches to each direction of the X- and Y-linear stage. These have their own limit switches implemented. A serial wiring of the 3 interlock protection switches and the linear stage limit switch allows us to always interrupt motion into the corresponding direction, regardless of the cause (asynchronous motion or physical limit) which triggered the actuation.

With the spacing of 30° between neighboring soft limit level switches, a geometrical response delay is reduced to 0.1mm (cf. Figure 18).

### 7.5.6 Specification

Parameter	Sym.	Value	Unit	Comment
Marquardt switch				
operating position tol.		0.3	mm	
min over-travel		1.2	mm	

### 7.5.7 Availability

Marquardt Series 1056 enclosed snap action switches are off-the-shelf products. Delivery time: 1 week.

## 7.6 Support Structure

### 7.6.1 Purpose

The support structure is the mechanical skeleton of the FFTS. In the upper part, it forms the boundary between the cryogenic environment and the ambient temperature environment of the LN dewar. Its design has to include thermal shielding in between these two environments. It also includes the mounting and thermal interface to the LN heat exchanger. Its main purposes are:

- mounting platform for the ambient temperature DPU
- thermal bridge between cryogenic FFTS components and the LN heat exchanger
- mechanical interface to LN dewar (heat exchanger)

### 7.6.2 Requirements

- compact design

- Thermal separation of the cold thermal and mechanical interface to the LN heat exchanger on one side, including the moving shield, and the ambient temperature DPU support structure on the other side.
- Heat sink for cryogenic parts of FFTS.
- opening and connectors for cabling

### 7.6.3 Parts

custom made fiberglass structure

### 7.6.4 Layout

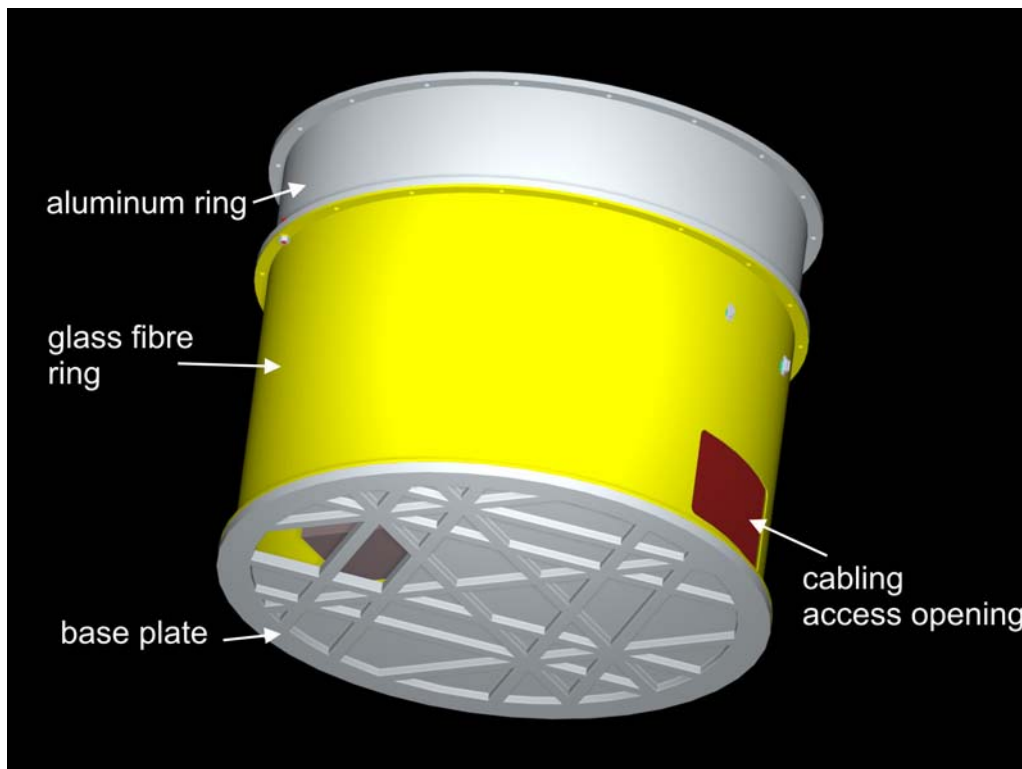


Figure 19: The support structure consists of a aluminum ring in the top, cold part, a fiberglass ring in the warm, bottom part, and a base plate.

### 7.6.5 Specification

Parameter	Sym.	Value	Unit	Comment
Interface to Heatexchanger				
inner $\varnothing$		670	mm	
outer $\varnothing$		740	mm	