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VERY LARGE TELESCOPE

MACAO for VLTI
Detailed mechanical design report of the coudé AO facilities.

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1 Scope

This document describes the final design of the coudé AO facilities [1], performed at ESO, which includes:

- The mechanical elements.
- The optical elements.
- The electromechanical devices.
- The control electronic hardware cabinets.

It summarises the work done since the conceptual design review and it is mainly based on the requirements already stated in AD1, along with new requirement additions and updates. These requirements are cross-checked in section 7 (Verification matrix of the mechanical design.)

2 Applicable Documents

AD1	VLT-TRE-ESO-15600-2059, *MACAO Conceptual Design-Optomechanics*, Issue 1.0, 10.03.2000
AD2	VLT-TRE-ESO-15600-2270. MACAO-VLTI Electronics - LCU
AD3	VLT-ICD-ESO-15600-2057. MACAO-VLTI Interface Control Document
AD4	VLT-ICD-ESO-15000-1826, *Interface Control Document between VLTI and its Instruments,* Issue 1.0, 16/11/99
AD5	MACAO WFS unit. Technical specification and statement of work. Doc. No.: VLT-SPE-ESO-11640-2189 Issue: 1 Date: 12-7-2000
AD6	VLT-ICD-ESO-11670-0699, Issue 3.0, *STRAP Interfaces Control Document*, 28.02.2000
AD7	Small CCD Head interface. Doc. No.: VLT-IDW-DJO-11710-0000. Issue: f. Date: 5-1-96
AD8	Technical report of the coudé Station 4 Rotating Platforms pre-assembly and ESO integration period Doc. No.: VLT-TRE-ESO-11520-0828 Issue: 1 Date: 08.08.1995
AD9	M9-M10 tower, central column. Doc. No.: VLT-DWG-ESO-11535-1771. Issue: 1. Date:
AD10	M9-M10 tower, base frame. Doc. No.: VLT-DWG-ESO-11535-1772. Issue: 1. Date:
AD11	M9-M10 tower. Doc. No.: VLT-DWG-ESO-11535-1773. Issue: 1. Date:
AD12	M8 train coudé assembly. Doc. No.: VLT-DWG-REO-11518-0010. Issue: 00. Date: 12-9-99
AD13	Puits. Doc. No.: VLT-DWG-REO-11518-1001. Issue: 00. Date: 15-2-2000
AD14	Interface volume M8 coudé. Doc. No.: VLT-DWG-REO-11518-0006. Issue: 01. Date: 3-8-99

[1] With exception of the DM and its tip-tilt mount, lenslet array and its mount, which are not designed at ESO

AD15	Coudé tubes box M7 M8. Doc. No.: VLT-DWG-AES-11310-0-102003-2000. Issue: B. Date: 23-5-95
AD16	Mirror position and distances in the VLT UT coudé. Doc. No.: VLT-TRE-ESO-15000-2165. Issue: 2 . Date: 20 June 2000

AD17	Central structure assembly. Doc No: VLT-DWG-DPW-11520-0-010000-2074. Issue D. Date 23-6-94
AD18	Cover grid assembly. Doc No: VLT-DWG-DPW-11520-0-010000-2213. Issue A. Date 27-4-95
AD19	Cover grids loaded areas. Doc No: VLT-DWG-DPW-11520-0-010000-2318. Issue 0. Date 17-6-94
AD20	Channels and conduits installation. Doc No: VLT-DWG-DPW-11520-0-010000-2229. Issue A. Date 27-4-95
AD21	Complete platform assembly. Doc No: VLT-DWG-DPW-11520-0-010000-2673. Issue B. Date 5-5-95
AD22	VLT Environmental Specifications, VLT-SPE-ESO-10000-0004, issue 6

3 Acronyms

ACE	Array Control Electronics
AD	Applicable Document
AIT	Assembly Integration and Test
APD	Avalanche Photodiodes used in photon counting or ‘Geiger’ mode
CWFS	Curvature Wavefront Sensor
DM	Deformable Mirror
ESO	European Southern Observatory
MACAO	Multiple Application Curvature Adaptive Optics system
MLA	Moulded Lenslet Array
MM	Membrane mirror
ND	Neutral Density
RD	Referenced Document
STRAP	System for Tip-tilt Removal with Avalanche Photodiodes
TBC	To Be Confirmed
TBD	To Be Defined
TCCD	Technical CCD
TD	Telecentricity doublet (also called telecentricity lens)
TT	Tip tilt mount
VLT	Very Large Telescope
VLTI	Very Large Telescope Interferometer
WFS	Wavefront Sensor

4 General description

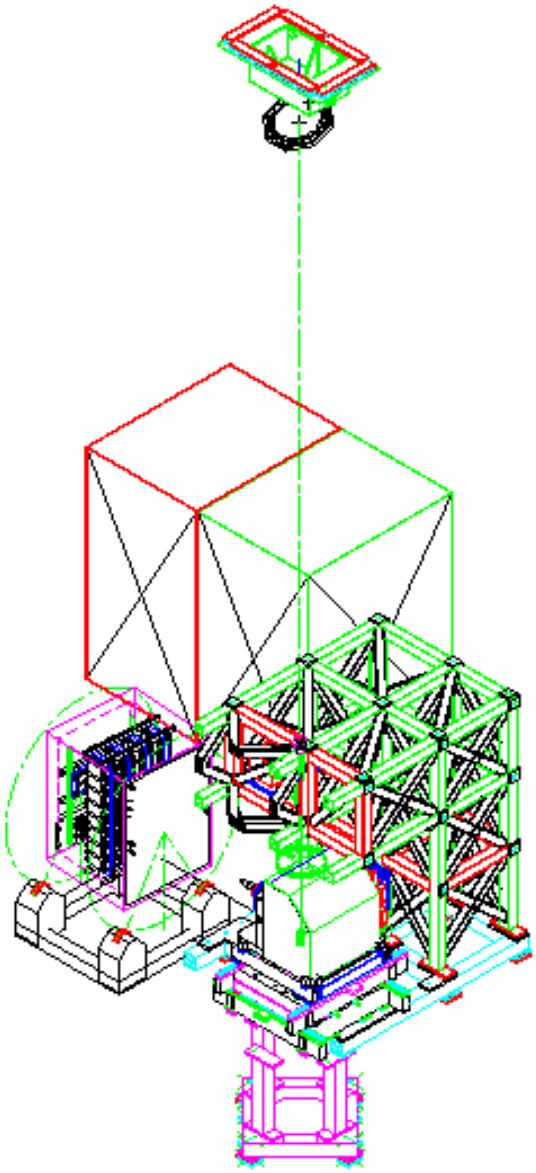
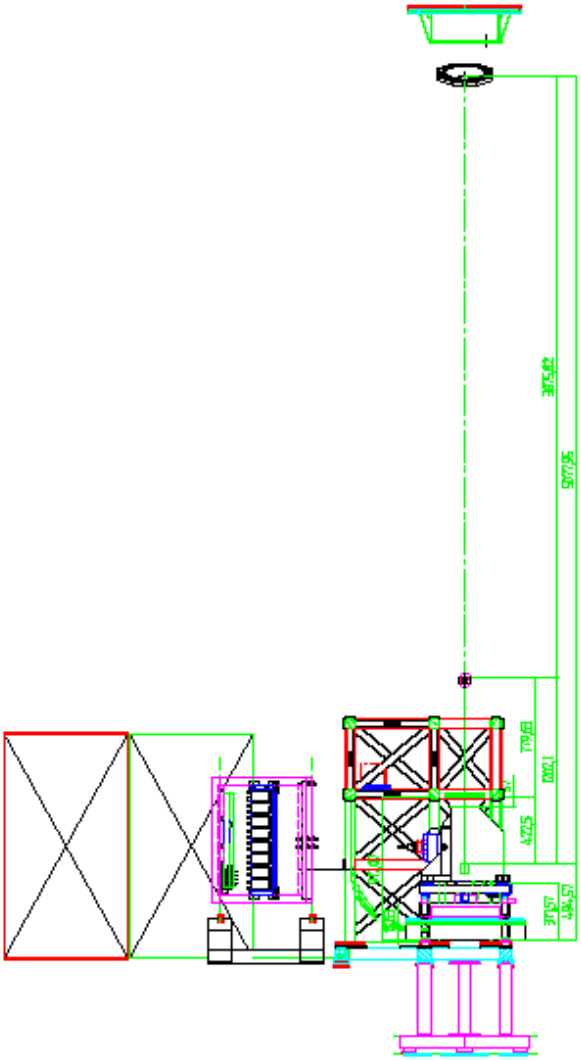


Figure 1: General layout of the coudé AO facilities

Figure 1 shows a general layout of the coudé AO facilities, located at the transmitted coudé focal plane (**13004,973 mm** from M1 AD16) on the top of the coudé rotating platform AD8, AD17, AD18, AD19, AD22, and on the coudé tube (DM). While the rotating

platform is oriented to send the light beam to the interferometer tunnel (fixed position), the DM and its tip/tilt mount is co-rotating together with the telescope azimuth axis. Not shown in Figure 1 is the control electronic cabinet of the Deformable Mirror and Tip-Tilt mount unit located on the telescope azimuth. The TT-DM environment and the mechanical interfaces are described in AD12, AD13, AD14, AD15.



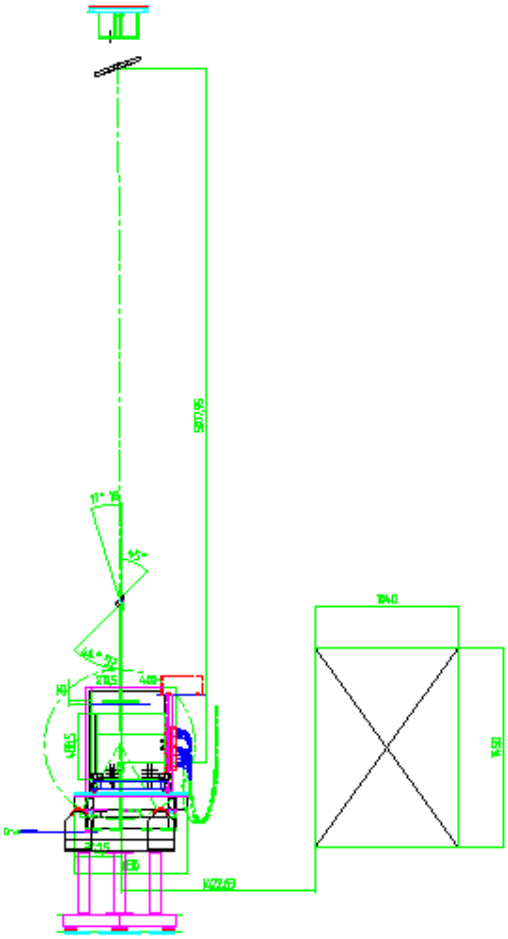


Figure 2: Detail of the AO facilities in the coudé laboratory.

Figure 2 shows details of the AO facilities in the coudé laboratory, viewed from the coudé instrumentation side and integrated with the M9-M10 towers, AD9, AD10, AD11.
The M9-M10 tower is not part of the coudé AO facilities, however its design foresees the following mechanical interfaces dedicated to:

- X-Y table.
- Electrical and fluid supplies
- ACE box
- Integration hoisting and handling devices

4.1 Adjusting ranges

The adjustment range between the coudé rotating platform and the M9 M10 tower is ± 20 mm. This adjustment will be used to reach the nominal position of the M9 M10 mirrors (**11794 mm** from M1 AD16). Therefore the nominal distance between the M9 front surface and the transmitted coudé focal plane is 1210,973 mm.

The adjusting range between the M9 tower base frame and the X-Y table is + **25 mm** – **50 mm** in Z of the AD16 co-ordinate system. This adjustment does compensate the Δ between the nominal and the as built transmitted coudé focal plane.[2]

4.2 Main items

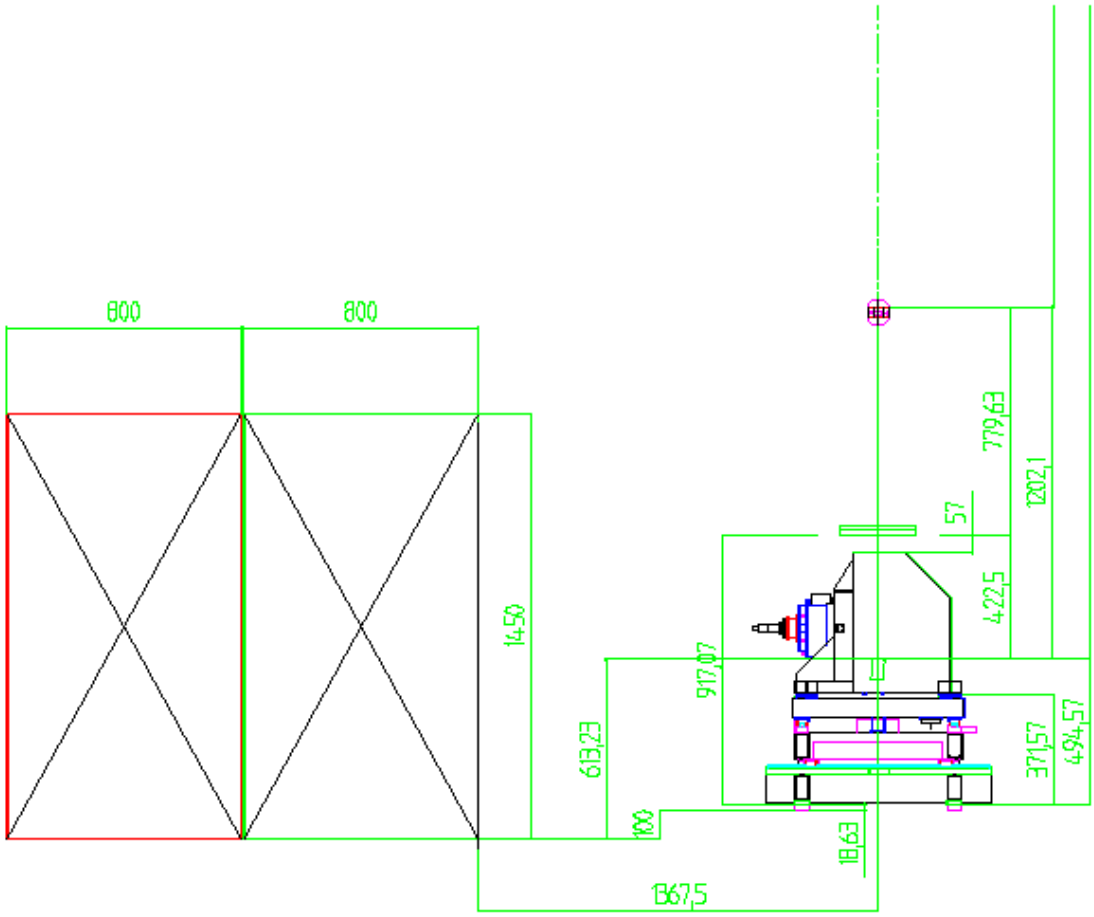


Figure 3: coudé AO subsystems

The above Figure 3 shows the items, which are installed on the Rotating platform.

- WFS box
- Optical fibres link.
- APD rack

[2] Since the coudé back focal length (through the M9 and TD AD16) is fixed to 379 mm. The TD shall also have the same adjusting range of +25mm – 50 mm

- Coudé Lab Electronic cabinets (not shown, refer to **Error! Reference source not found.**)
- X-Y table
- The ACE box (installed on the M9-M10 tower).

The TD lens is shown for completion only, but it is not part of the coudé AO facilities.

4.2.1 WFS box.

The WFS is located in the coudé laboratory and is attached to the X-Y table, at the centre of the coude' platform, below the M9-M10 tower.

The WFS box contains the following sub-units:

1. Notch filters (not part of MACAO).
2. Input shutter.
3. Mode exchanger.
    a) Translation stage.
    b) Several 45° mirrors and beam splitters to redirect the beam to:
        - Membrane Mirror.
        - STRAP.
        - TCCD monitoring camera.
    c) Objective.
    d) Fixed I-band filter.
    e) Mechanical interface for a non-resident alignment device.
4. CWFS module containing :
    a) Membrane mirror, the resonant cavity and the loud-speaker.
    b) The diafragm.
    c) Membrane mirror focus stage.
    d) Membrane mirror tip-tilt stages.
    e) Relay optics
    f) Neutral density filter wheel.
    g) Derotator, including drive system, and alignment provisions.
    h) 60 elements moulded optics lenslet array.
5. Tip-tilt sensor module containing (not part of MACAO):
    a) Neutral density Filter wheel.
    b) STRAP sensor unit
    c) Small format TCCD
6. Cover and buffer:
7. Electrical and fluid supplies:

4.2.2 Optical Fibre link.

The optical fibre link is a 3m long fiber bundle, protected by a flexible hose. It is layed down on a table between the APD rack and the lenslet assembly, providing enough loops, to avoid bending radius smaller of 200mm, to follow the +/-125mm stroke in x-y direction of

the WFS box. In order not to load with tension forces the optics of WFS box the bundle will be connected to a flange, mounted directly on the WFS box structure. It includes:

1. Interface flange to be connected to the WFS box structure.
2. Interface piece attached to the lenslet rotator stage
3. Fibres bundle.
4. Interface flanges to the APD rack.

4.2.3 APD assembly.

The APD rack is located behind the optical fibre link and on-axis with the lenslet, fixed on the coude' platform.

4.2.4 Coudé Lab Electronic cabinets.

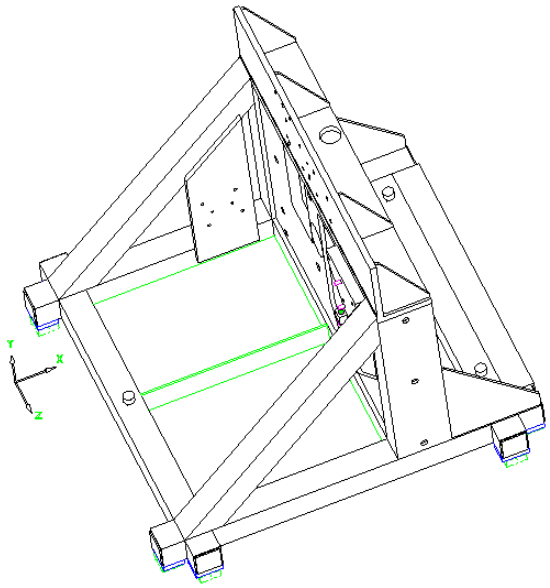
Two electronic cabinets are installed on the coudé rotating platform. The cabinets are insulated to reduce the power emission in the coude' lab area.

5 Subsystems Design

5.1 WFS Box

The design of the WFS box can be characterised in three main parts:

- T shape support structure
- Front compartment.
- Back compartment.



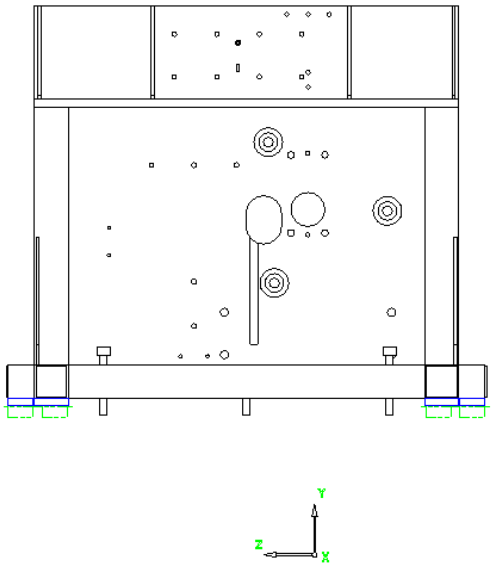


Figure 4: T-shape support structure.

Figure 4 shows the T shape support structure, which supports the front and back compartments of the WFS. It is made of welded, off-the-shelf, aluminium profiles, and by an aluminium plate 30mm thick on which all the function are mounted. It does also mechanically interface the X-Y table, over a surface of 500 mm x 500 mm. All the opto-mechanical elements attached to the T shape support structure will be positioned within ± 0,1 mm referred to their nominal positions with respect to the optical beam entrance axis. This accuracy is obtained by machining and it fulfils the optical alignment requirements. The T shape support structure also includes fixation points for handling during integration and interfaces to non-resident optical alignment devices.

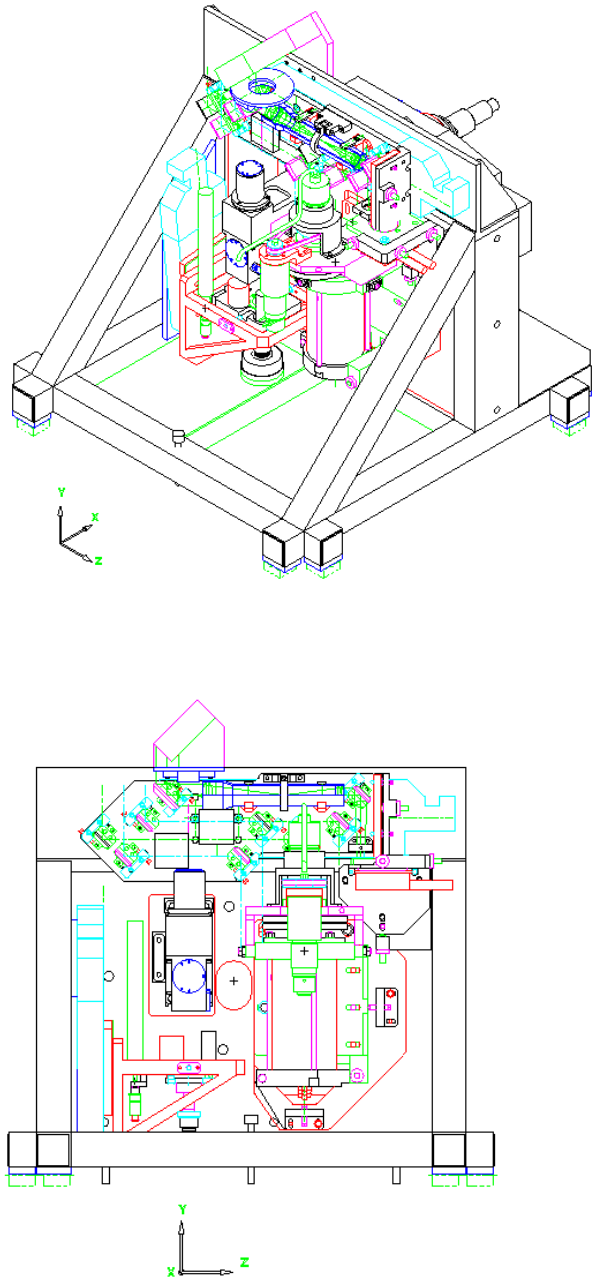


Figure 5: General layout of the WFS box front compartment

Figure 5 shows the WFS box front compartment that is a design volume in which all the opto-mechanical components are located upstream of the T shape support structure, and are confined within a light tight cover.

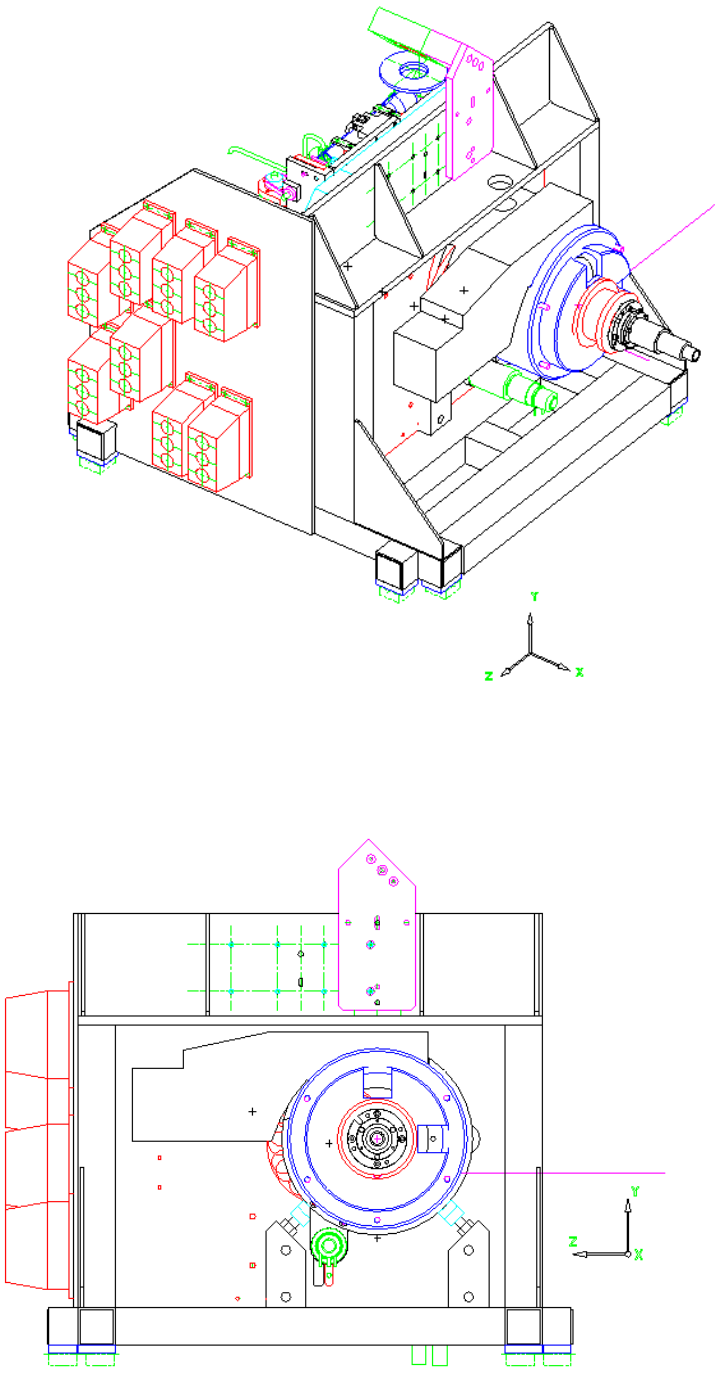


Figure 6: General layout of the WFS box back compartment

Fig. 6 shows the WFS box back compartment, that is a design volume comprising all the opto-mechanical components located downstream of the T shape support structure

The described "*two compartments"* concept has been chosen in order to optimise the following main drives:

- Stiffness.
- Masses.
- Allowable design volume.
- Integration.
- Alignment.
- Operation.
- Maintenance.
- Safety.
- Costs

5.1.1 Notch filter

The notch filters are not part of the coudé AO facilities design. The notch filters are installed on the WFS cover, before the entrance window, inside a frame sliding on two guides 100mm long. Two spring loaded ball screws, open and closed positions, define the position of the filter. The filters are operated manually.

5.1.2 Input shutter

An input shutter is installed inside the WFS box mounted on the T-mount structure. The shutter is a bi-stable type in order not to dissipate power when open. The diameter of the optical beam is 11mm at the entrance point.
Shutter main characteristics:

- Type: Prontor Compur electronic-m shutter size 0, total height 20mm.
- Shutter speed (max): 1/125 s
- Maximum aperture: 24 mm.
- Double coils supply 24V, current consumption 3A.

5.1.3 Mode exchanger.

The main function of the mode exchanger, shown in Figure 7 and Figure 5 is to direct the light to the membrane mirror, STRAP and to the TCCD.

5.1.3.1 Translation stage

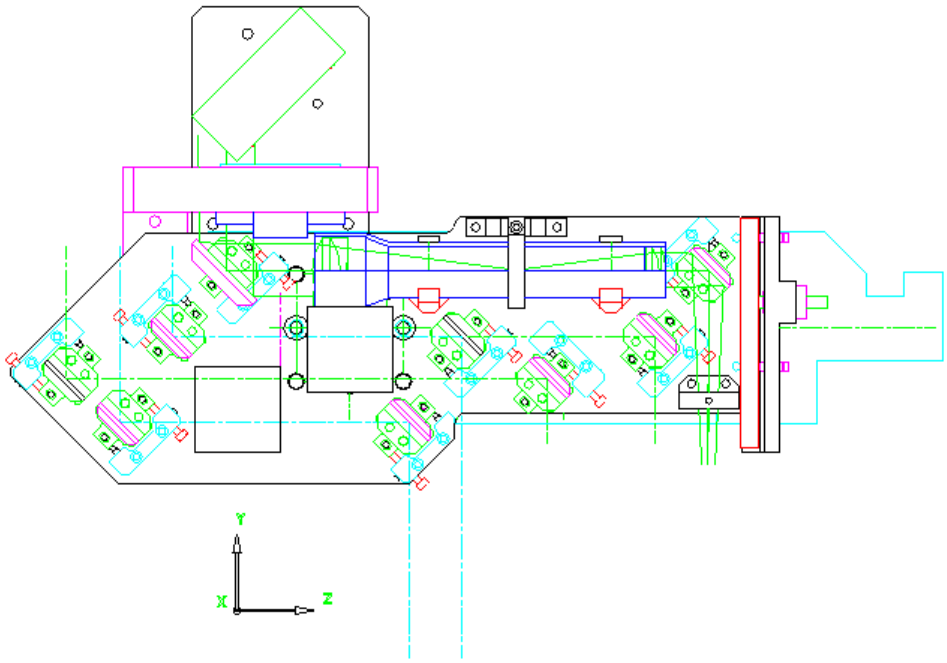
In order to minimise the number of functions necessary to achieve the required operation modes, several 45^o mirrors and beam splitters have been installed on a plate and aligned on 4 rows. All the opto-mechanical elements attached to the plate can be positioned within $\pm$ 0,1 mm referred to their nominal positions. This accuracy is obtained by machining and it fulfils the optical alignment requirements. Each 45^o mirror and beam splitter is mounted on a tip-tilt base with the possibility to adjust within +/- 4˚ range with 19' resolution.
The interface attachments for the alignment lens and the I-band filter are provided.

The plate is driven by a translation stage with the following main characteristics.

- Type: OWIS LIMES 90
- Travel: 100 mm
- Maximum speed: 40 mm s^{-1}
- Material: Black anodised aluminium alloy.

- Motorization: DC-motor
- Resolution: 0.5µm
- Repeatability (no load): 2 µm
- Accuracy (no load on 100mm travel): yaw 30”, pitch 20”, vertical deviation 3 µm, lateral deviation 4 µm.

These translation stage characteristics fulfil the functional requirements specified inAD1 and AD2.



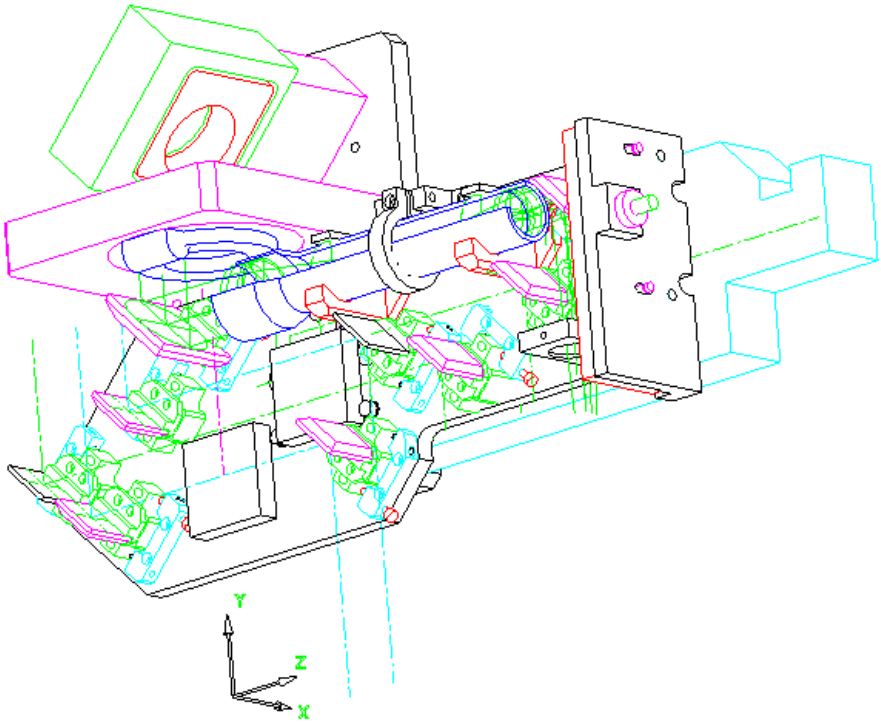


Figure 7: Mode exchanger

5.1.3.2 Operation modes

The following operation modes can be realised switching from one position to another of the mode exchanger.

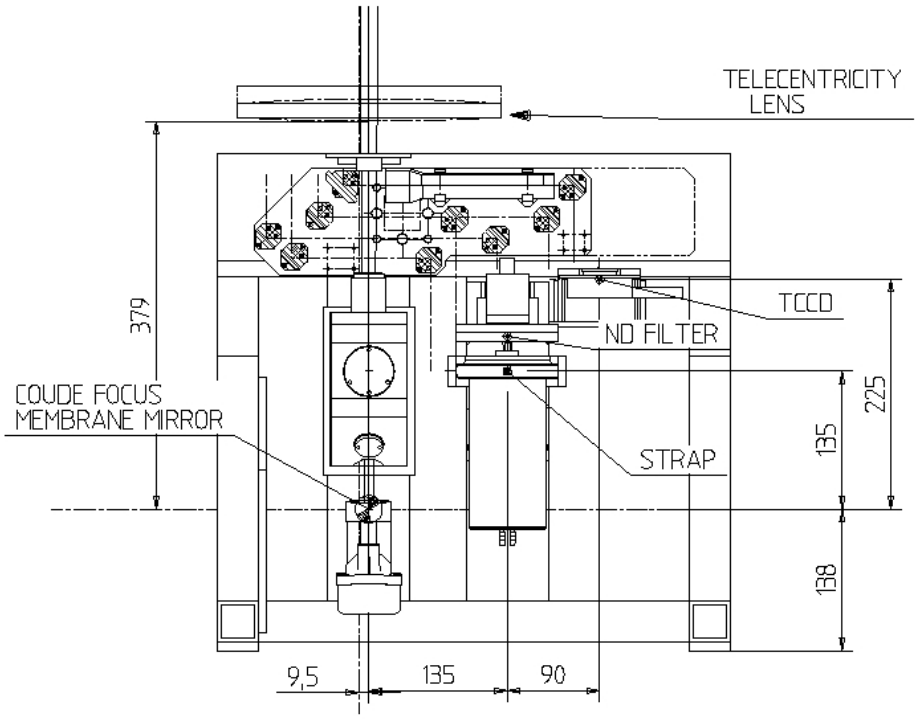


Figure 8: First operation mode. Light to the membrane mirror only.

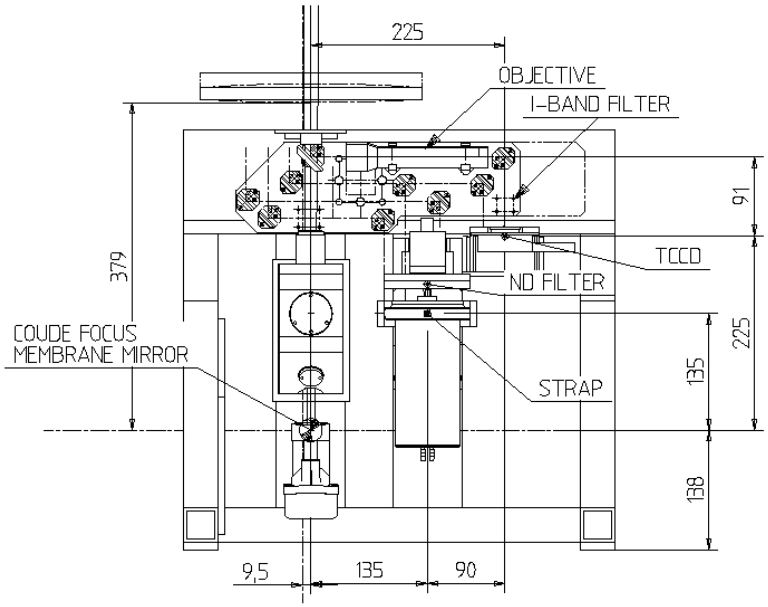


Figure 9: Second operation mode. Light to the TCCD only with objective and fixed I-band filter (10 arcsec circular field of view).

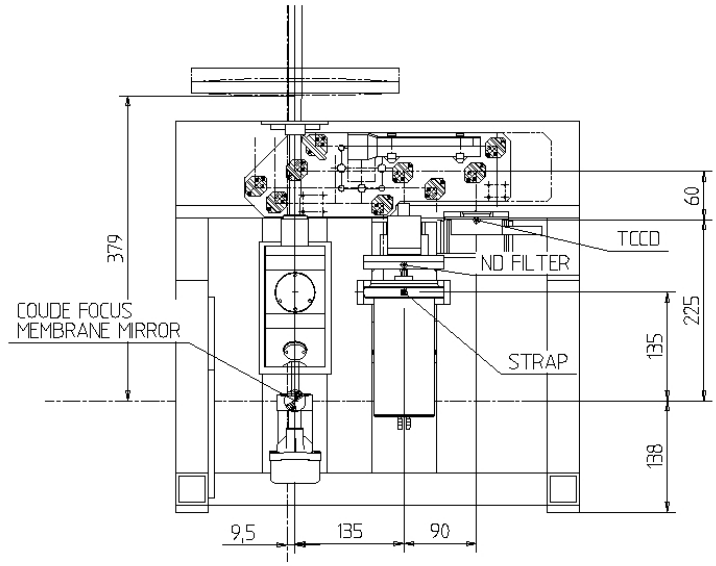


Figure 10: Third operation mode. Light to STRAP and TCCD.

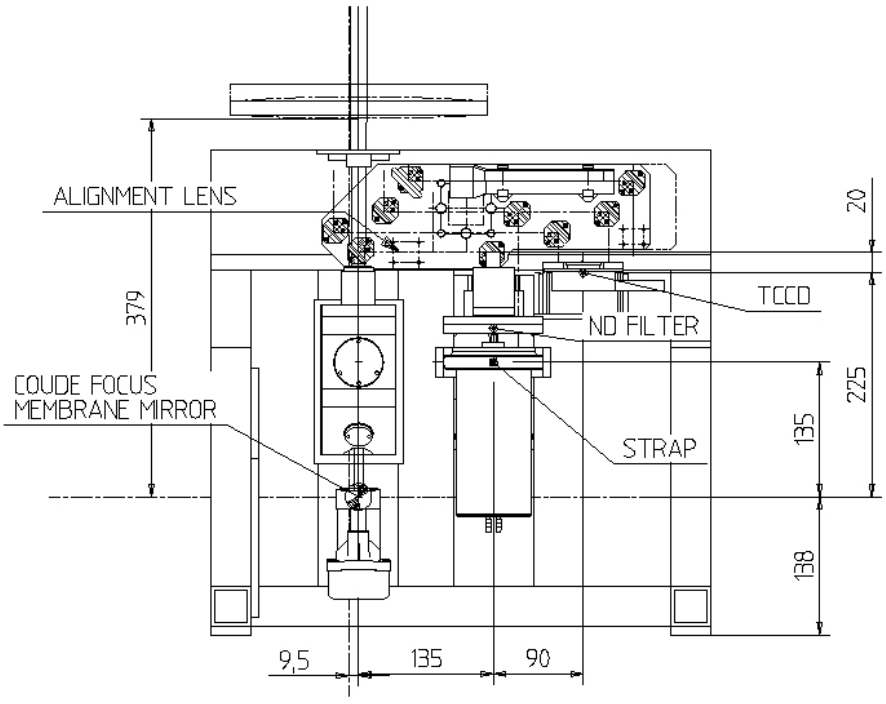


Figure 11: Fourth operation mode. Light to STRAP only.

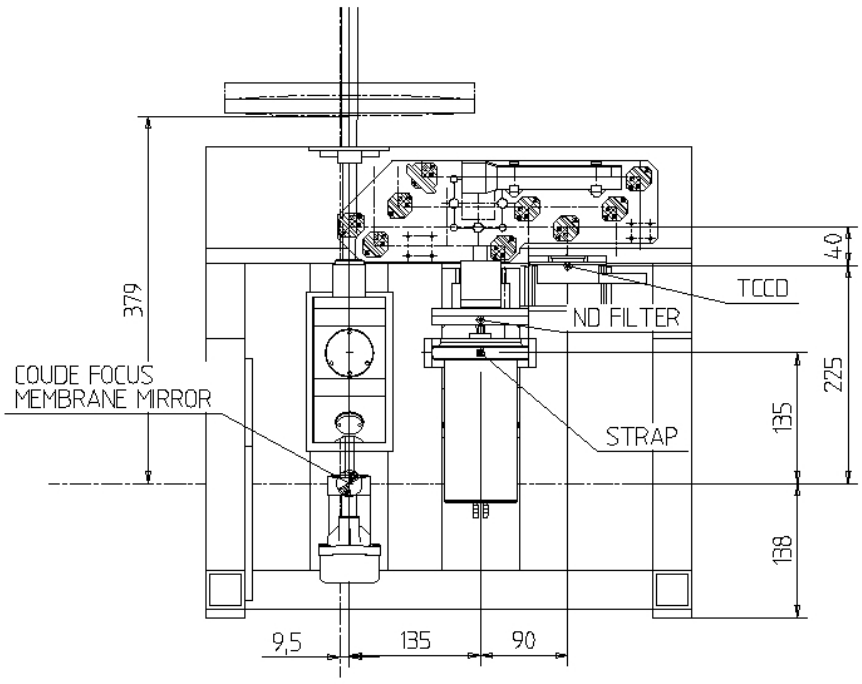


Figure 12: Fifth operation mode. Light to the membrane mirror and TCCD.

5.1.4 CWFS.

The CWFS is a shared design with SINFONI, thus assuring the interchange ability of the sub-system among the 2 instruments. It is composed of

- Membrane mirror.
- Circular diafragm, motorised.
- Tip-tilt stage.
- Focusing stage.
- Relay optics/beam expander.

5.1.4.1 Membrane mirror

The membrane mirror unit is composed of

- The membrane mirror
- The resonant cavity
- The loudspeaker.

The 10 mm diameter membrane mirror is made of a 4 μm thick aluminium coated Mylar, pre-tensioned on a cylindrical support 16mm in diameter, with a tweeter loudspeaker at the other end of the cylinder. One of the cavity longitudinal modes is tuned at 2.1 kHz. The cavity length is 79mm long, and it is adjustable in the +/- 4mm range.
The membrane is used at an angle of incidence of 3°. Its mechanical mount has motorised tip and tilt control, as well as a linear motion (focus stage) along the reflected optical axis.

5.1.4.2 Circular variable diaphragm

A variable aperture diaphragm, type Melles Griot max aperture 18mm minimum aperture 1mm, is placed in front of the membrane, and attached to its mount. It is used to limit the effects of the sky background on the CWFS signal. It is centred to within 0.1mm on the membrane centre. The diaphragm is motorised and remotely controlled using DC motor Faulhaber 1624 with no-play gear, the position is controlled using an encoder Heidenhain ROD 424M with 3600 pulses per turn. The encoder is mounted not on the same axis of the motor, and is coupled to the diaphragm via pinion and gear with multiplication ratio of 4. The resolution step is then of about 0.025˚. The play between pinion and gear will be of about 0.1mm, giving an uncertainty in the position of the pin, which actuates the diaphragm, of about 0.5˚. Assuming the aperture linearly dependent with the angular position of the diaphragm's pin, the incertitude on the aperture diameter will be of 0.1mm. The diaphragm is placed at 2mm from the membrane mirror surface. Assuming to operate the DC motor at 5000 rpm and using a gear ratio of 485 and considering the further reduction of 4 the 90˚stroke is covered in little less than 6s. Two limit switches define the fully open and fully closed position of the diaphragm.

5.1.4.3 Focus stage

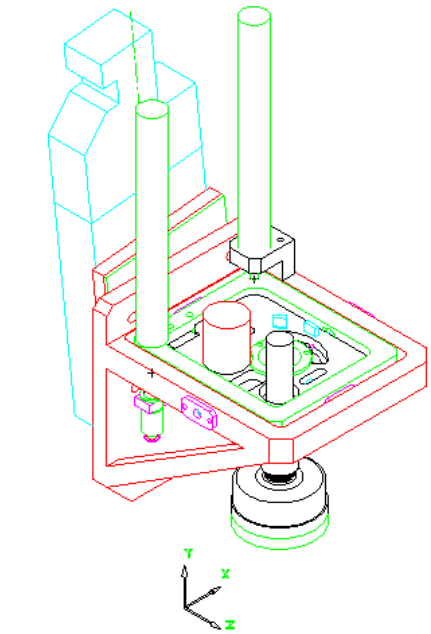
Membrane mirror and its tip-tilt stage are mounted on a translation stage with the following main characteristics.

- Type: OWIS LIMES 90
- Travel: 30 mm
- Maximum speed: 40 mm s^{-1}
- Material: Black anodised aluminium alloy.
- Motorization: DC-motor
- Resolution: 0.5µm
- Repeatability (no load): 2 µm
- Accuracy (no load on 100mm travel): yaw 30", pitch 20", vertical deviation 3 µm, lateral deviation 4 µm.

The translation stage is fixed onto the interface plate on the T-mount with an angle of 6˚, that is, the focusing motion is along the direction of the reflected beam. The fixation is defined by two positioning holes diameter 3mm H7 placed within +/-0.1mm with respect to the surface on which the beam relay is mounted, that is within 25' angle with respect to the vertical surface of the T-mount plate. The repositioning of the focusing module is assured with 2 pins 3mm diameter j5 at 30mm distance that is within the 3' tolerance.

5.1.4.4 Tip-tilt stage

The membrane mirror tip-tilt stage is a shared design with SINFONI. This electromechanical device is attached to the focus stage.
The tip tilt movement is obtained using a square gimbal mount, motorised with two PI linear motors with gear and encoder, counteracted by a spring loaded screw each.
The angular range is +/- 6˚.
For stability reason the gimbals are supported on the two sides of the rotation axes with a couple of pre-stressed roller bearings each.



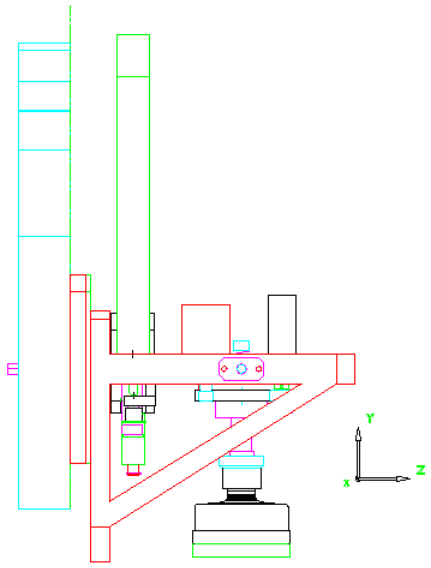


Figure 13: Tip-Tilt stage.

5.1.4.5 Relay optics

Collimates the beam and image the pupil on a lenslet array. The mechanical housing AD5 of the relay optics (designed by R. Conzelmann) is a shared design with SINFONI. The mechanical housing is attached to the T-mount.

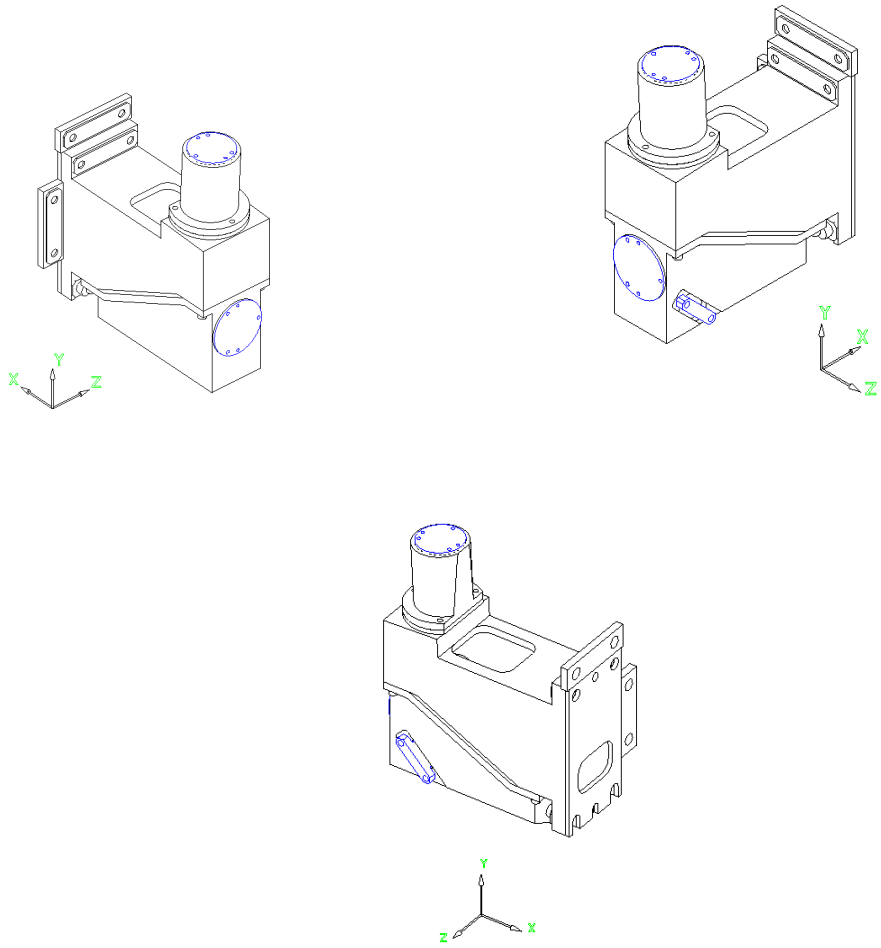


Figure 14: Relay optics.

5.1.4.6 CFWS neutral density filter wheel

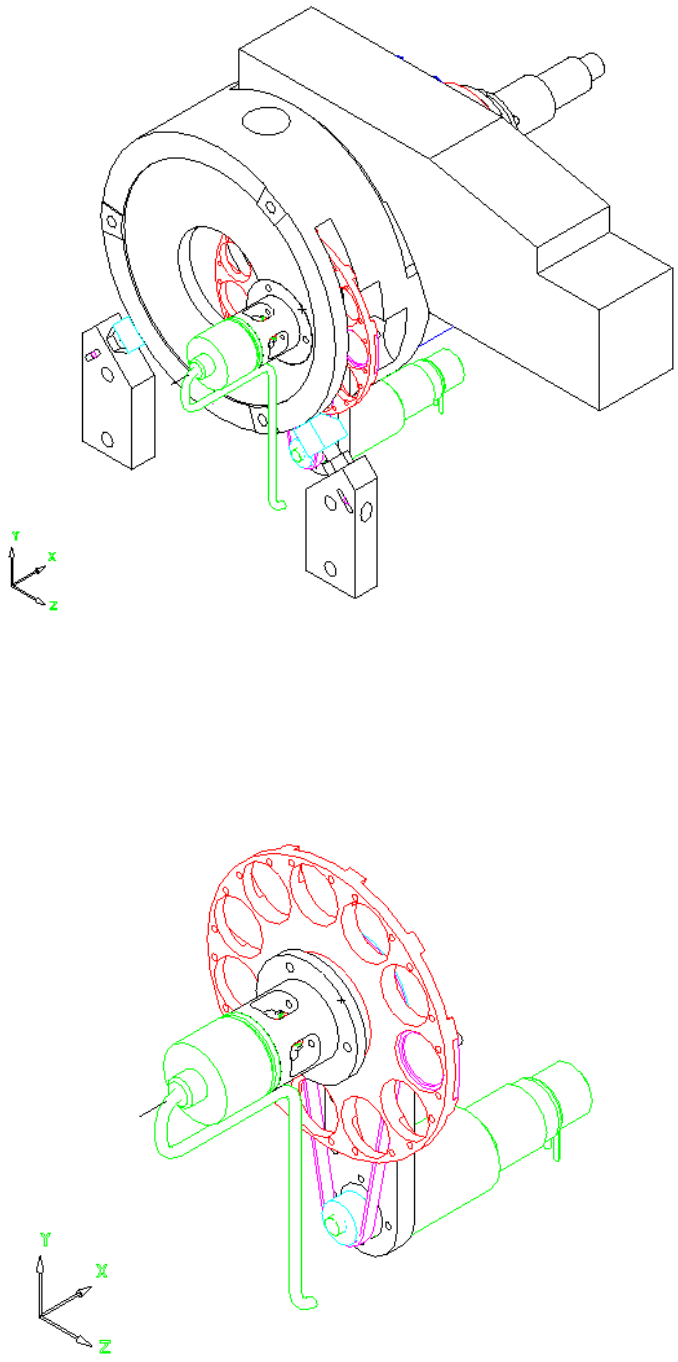


Figure 15: Neutral density filter wheel.

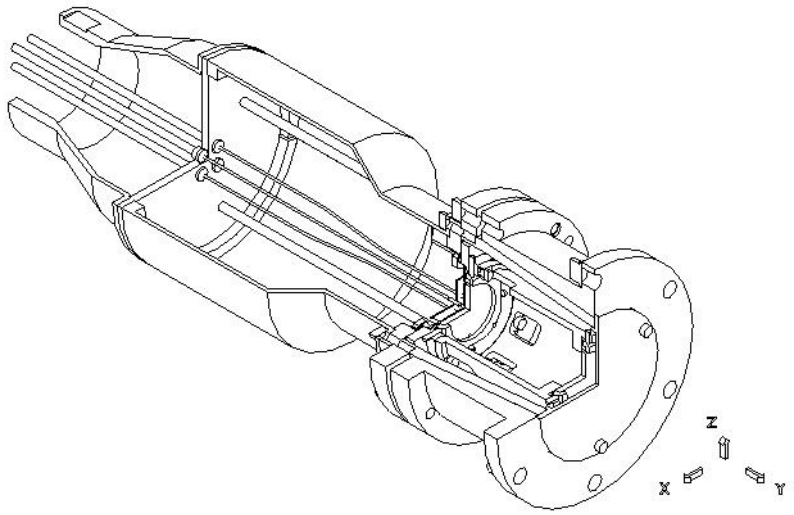
The neutral density filters wheel unit is composed of:

- Filter wheel (11 positions)
- Filters mounting frame (filters mounted tilted 1°)
- Filters (10) diameter 25.4mm.
- Home Limit switch
- Holding plate with attachment items
- Encoder Heidenhain 3600 pulses per turn, mounted on the wheel axis, different from drive axis.
- Pulleys and toothed transmission belt, reduction ratio 2 between wheel and drive pulley.
- Drive Faulhaber 3042 with gearbox, reduction ratio 276, and tachometer.

The unit is mounted on the structure, which houses also the field de-rotator and the micro-lenslets assembly.
The set of an observing configuration starting from farest position, operating the drive at 5000 rpm, will last about 6 s.
The positioning resolution is 0.1° that is, at radius of 70mm, centre of the filter, the resolution is about 0.12mm.

5.1.4.7 Lenslet array

The lenslet array, 14mm diameter, 60 elements is fixed in its mount and interfaced to the same structure which houses the field de-rotator and the ND filter wheel.
The fibres bundle outgoing from the backside of the assembly is fixed onto an independent structure, discharging the loads rising during the motion of the WFS box while tracking, because of the tension rising dragging the fibre bundle, directly on the WFS box T-mount.



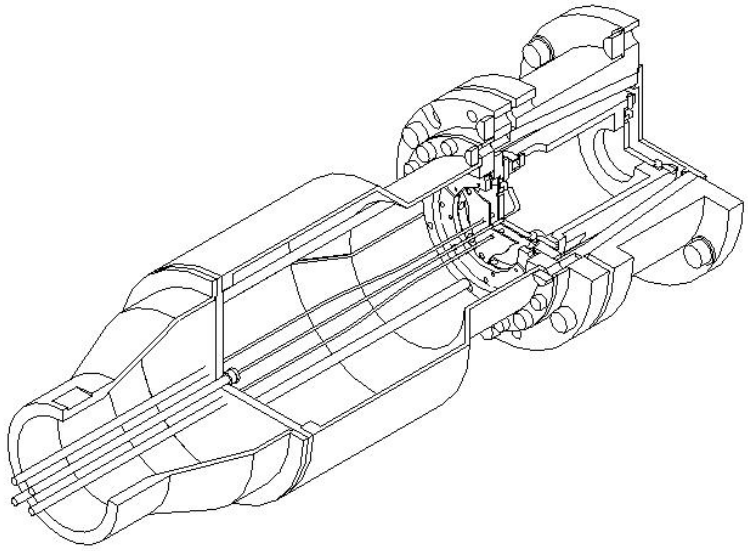


Figure 16: Lenslet array, mechanical interface.

5.1.4.8 Field de-rotator

The field of view de-rotator takes care to counter rotate the image coming from the alt-az telescope. It is composed of:

- Drive unit
- Outer tube
- Inner tube
- Prism
- Lockable Adjustment screws
- Pre-loading devices.

The drive unit is a DC motor type Newport. RV 160 CCHL, with the following characteristics:

- Maximum Rotation: $\pm 360^{o}$.
- Maximum angular speed: 16 ^{o}/sec
- Maximum torque: 20 Nm
- Wobble: $\pm$ 15 µrad
- Concentricity: $< \pm$ 2 µm
- Repeatability: 0,002 ^{o}.
- Material: monolithic tool-steel body.

The outer tube is fitted into the motor hub, and fixed onto its interface flange. A pin defines the mounting orientation. On the outer tube the lockable adjusting screws and the counteracting spring-loaded ball-pins are mounted. The inner tube, on which the prism is glued and positioned, is positioned with respect to the optical axis using two adjusting screws with the metric pitch of 0.35mm, at 90° from each others and counter acted on the same axis by two spring loaded ball-pins at each end. In order to avoid instability the balls are machined flat, to create a contact on a surface instead of on a point. Also the axial

movement is adjustable in the same way. The preload obtained via the springs is such that in the most unfavourable position the preload is not less that 30N (the prism is secured against acceleration up to 3g).
The adjustment range is +/- 3mm in step of about 0.05mm (considering a sensitivity of 1/7 turn). In angular terms it is equivalent to about +/- 2.3° in step 1.2'.

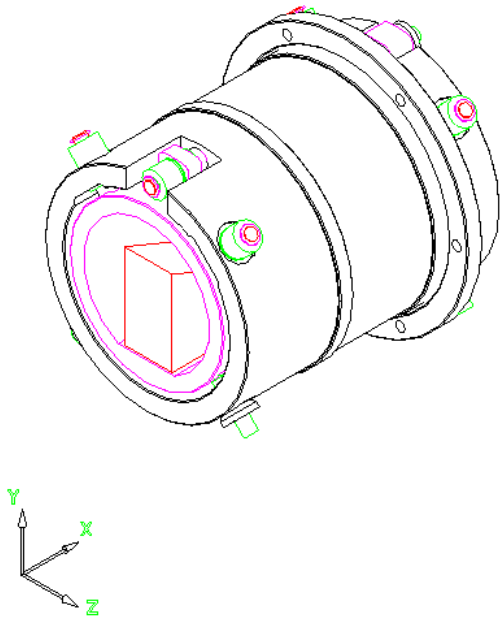


Figure 17 De-rotator assembly

5.1.5 Tip-tilt sensor.

The tip-tilt sensor unit is composed of:
- STRAP neutral density filters wheel
- STRAP with its adjusting mount.
- Small format TCCD

5.1.5.1 STRAP neutral density filter wheel

The neutral density filter wheel is a commercial wheel VISION type 10MWA168 with two wheels with 8 filter diameter 25.4mm, mounted inclined and fixed in their seat with spring. The wheels are mounted on plate in axis with a Heidenhain encoder with 3600 pulses per turn. The wheels are driven with a pulleys-toothed belt system via a Faulhaber DC motor with gearbox and tachometer.
Operating the motor at 5000 rpm and using a gear box with reduction ratio 276, setting an observation, from the farest position, will last about 6s (twice 3s).
The position resolution is 0.1°, which, at 40mm radius, translates into about 0.07mm resolution.

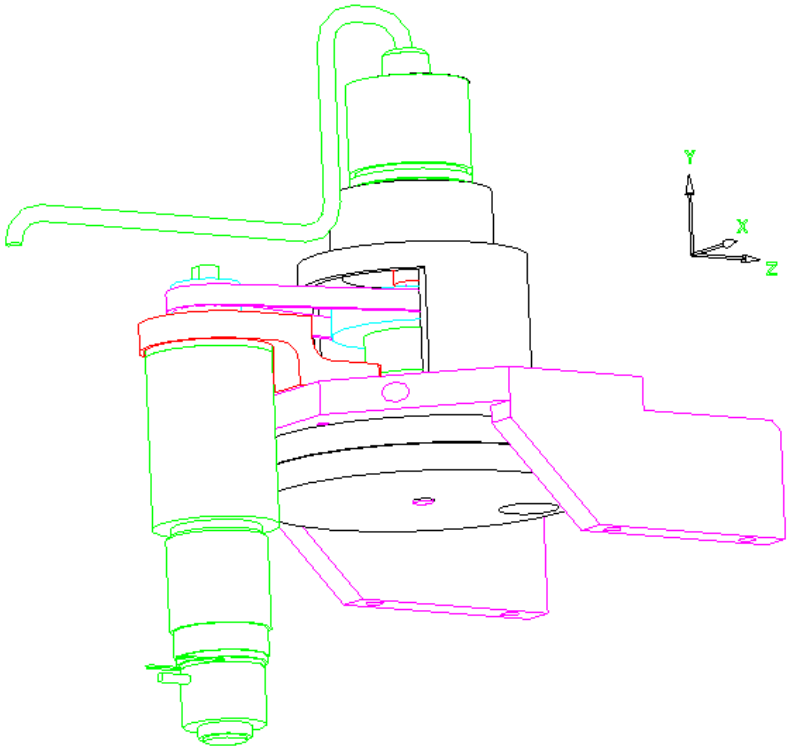


Figure 18: STRAP neutral density filter wheel

5.1.5.2 STRAP sensor unit

The STRAP AD6 sensor is assembled on the plate in the front compartment of the WFS box, in a manual operated adjustment mount. STRAP will be positioned by machining tolerance to ± 0,1 mm, referred to its nominal position.
STRAP is installed inside an adjusting mount, which provides x-y-z adjustment as well as tip-tilt.
In order to allow for a finer adjustment and at the same time to provide a stable mounting of STRAP the detector has been fitted into a mount which holds the cylinder both at the top and at the bottom, and actuate the adjustment at the bottom.
The tip-tilt adjustment is performed with metric screws with a pitch of 0.35mm. The range is of +/- 4.2° with step of 1.4'.

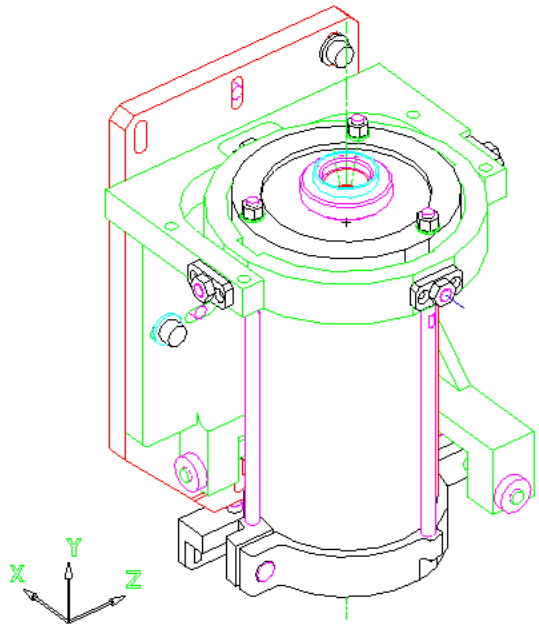


Figure 19: STRAP alignment device

5.1.5.3 Small format TCCD

An ESO technical CCD AD7 camera is used for MACAO VLTI performance monitoring, field viewing and maintenance purposes. A standard I-band filter is mounted on the mode exchanger plate and positioned in front of the TCCD. The TCCD comes with its control electronics and ESO standard control SW. It has a sensor head, which is located in the WFS box front compartment, and an ACE control electronic box, located in the M9-M10 tower (see also Figure 2 and Figure 3).
The small format CCD, 290x386 pixel, is used with 22 µm pixels. Placed directly at coudé the plate scale is 11.07mas/pxl. The field of view without additional optics is 4”x3”. The sensor head containing the TCCD has a Peltier cooler, which keeps the CCD at –35 °C. The TCCD is mounted on an adjustable mount interfaced to the plate of the T-mount. It has linear adjustment capability in x-y-z directions, using adjustment screws metric with a pitch of 0.35mm.

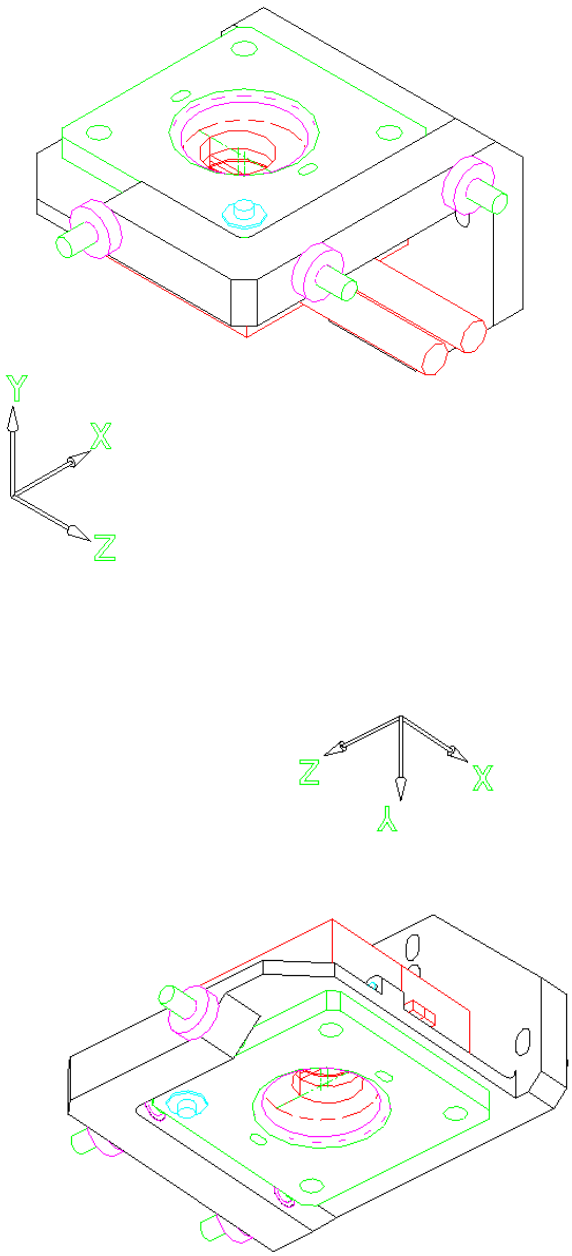


Figure 20: TCCD assembly

5.1.6 Cover and buffer.

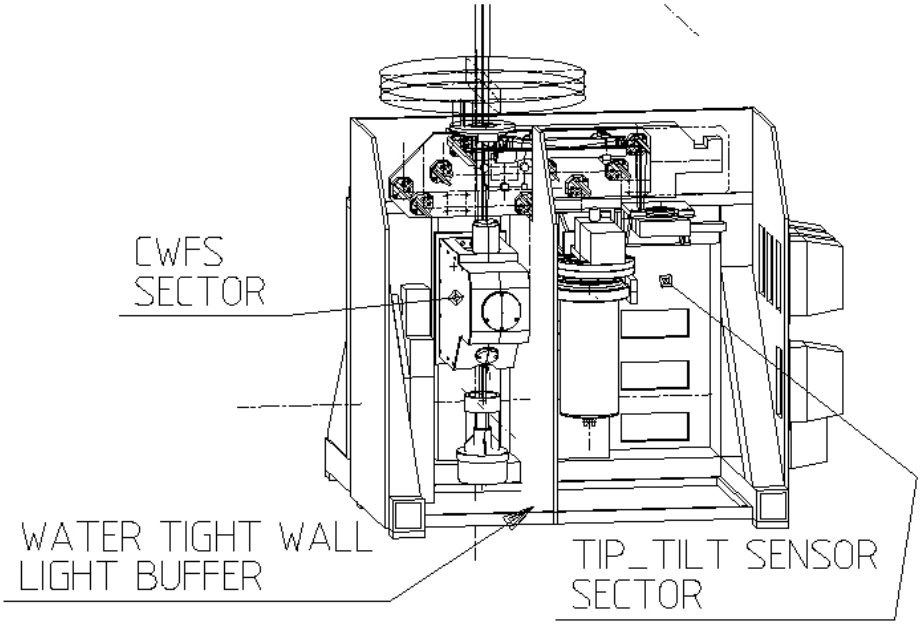


Figure 21: Front compartment sectors

The front compartment is enclosed in a light tight aluminium cover; the inner wall of the cover can be furbished with dumping material, thus reducing the noise level generated by the membrane mirror. In the fond of the compartment a level sensors can be installed to provide safety-shutting capability on the liquid lines of STRAP and TCCD.
A watertight wall is inserted between the CWFS sector and the tip-tilt sensor sector, thus avoiding CWFS contamination due to coolant liquid leakage. The same wall can also serve as light buffer to minimise the stray light between the 2 sectors.

5.1.7 Electrical and fluid supplies.

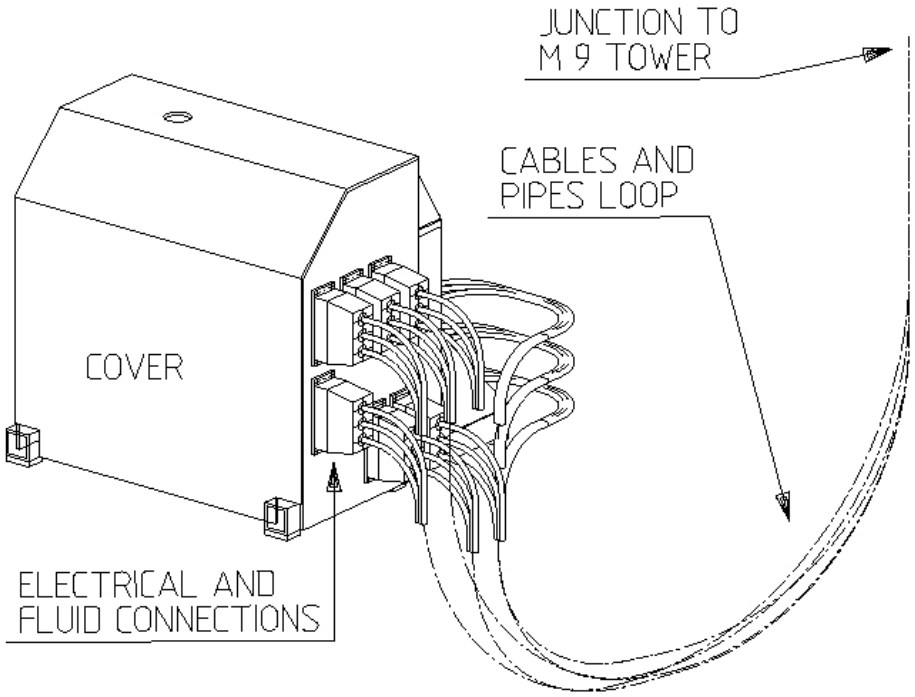


Figure 22: Electrical and fluid routing.

The electrical and fluid supplies are routed from the M9 – M10 tower to the WFS box. The cables and pipes are selected to maximise their flexibility and they are hanging on a constrain-free configuration, thus minimising fluctuating reaction forces on the WFS box. The WIELAND connectors can be made light tight. This “loop” design may require corrective actions and optimisation during the first installation and testing.

5.2 Optical Fibres link.

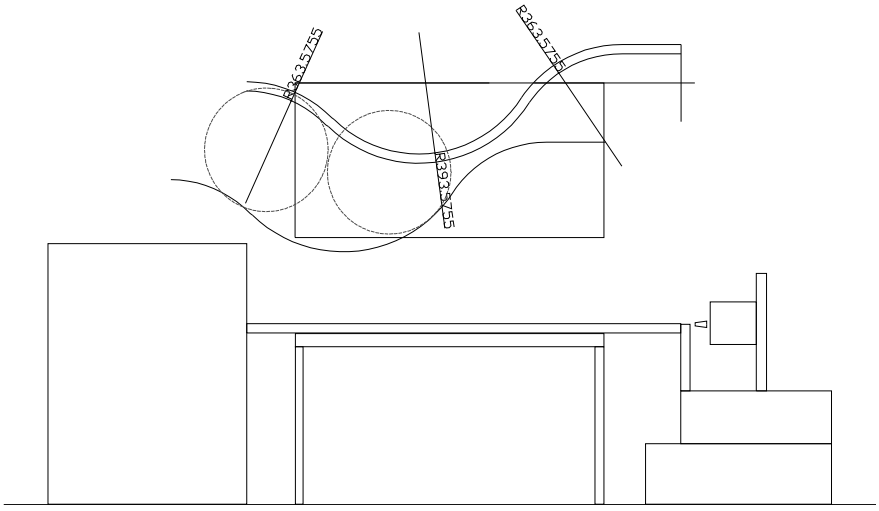


Figure 23: Optical fibers link

60 optical fibres are routed from the lenslet array to the APD modules. The bundle has the following characteristics:

- Effective maximum length 2400 mm (plus 600 mm inside the APD rack).
- Minimum bending radius: 200 mm

In order to minimise the reaction forces on the WFS box the bundle will be laid down on table covered with Teflon. The bundle of fibres will be protected in a cladding and the loops will care for never having a bending ratio less than 200mm.
This arrangement allows fixing the APD rack on the platform, eliminating the need for active follow up of the rack.

5.3 APD rack.

The APD rack shelters the detector arrays.
It is a standard 60” cabinet. The cooling plates care for the cooling of the arrays. It is mounted on the coude’ platform.

5.4 Deformable mirror structure

The deformable mirror is mounted in box like structure, which is mounted on the coudé tube of the telescope.
The box provides the adjustment provisions of the deformable mirror in the plane perpendicular to the optical axis and tip-tilt using 4 screws M20x0.75.
The box is closed by a lit after alignment, and is provided with a hole in its bottom to access the electrical connectors of the deformable mirror.

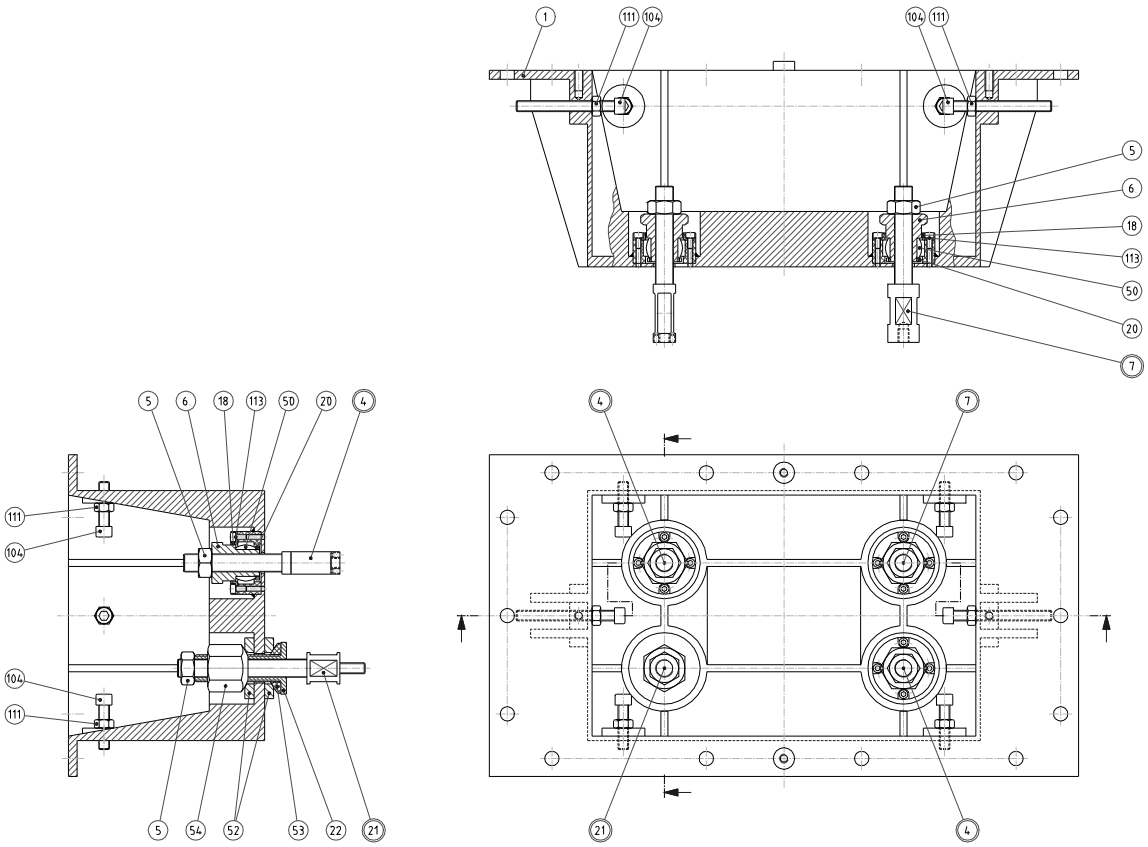


Figure 24 Deformable mirror structure

5.5 Coudé Lab Electronic cabinets.

Two electronic racks are installed on the rotating platform and attached to its cover grids AD18, AD19. The cable routing to and from the cable twist and SCP tower is done via the rotating platform conduits located underneath the cover grids AD20.
The cabinets are insulated, and have dimensions of 1450 Hx1040 Wx800 D (mm).

6 WFS box X-Y table

The WFS box is mounted on a x-y table to track during observation.
The x-y table is defined in the drawings

- WFS X-Y table assembly. Doc. No: VLT-ESO-DWG-15600-0-010000-0004. Date: 16-11-2000. Issue:0
- X-Y table first stage. Doc. No: VLT-ESO-DWG15600-0-010000-0005. Date: 16-11-2000. Issue:0
- X-Y table second stage. Doc. No: VLT-ESO-DWG15600-0-010000-0006. Date: 16-11-2000. Issue:0
- X-Y table third stage. Doc. No: VLT-ESO-DWG15600-0-010000-0007. Date: 16-11-2000. Issue:0
- X-Y drive unit. Doc. No15600-0-010000-0003. Date: 16-11-2000. Issue:0
- Pneumatic spring operated brake of the X-Y table. Doc. No: VLT-ESO-15600-0-010000-0002. Date: 16-11-2000. Issue:0
- Brake unit blade. Doc. No: VLT-ESO-DWG-15600-0-010000-0008. Date: 16-11-2000. Issue:0

The X-Y table will be built according to the following planarity accuracy

- 3 μm over 10 mm stroke, measured everywhere on the 250 mm x-y range
- 10 μm over the total 250 mm x-y range.

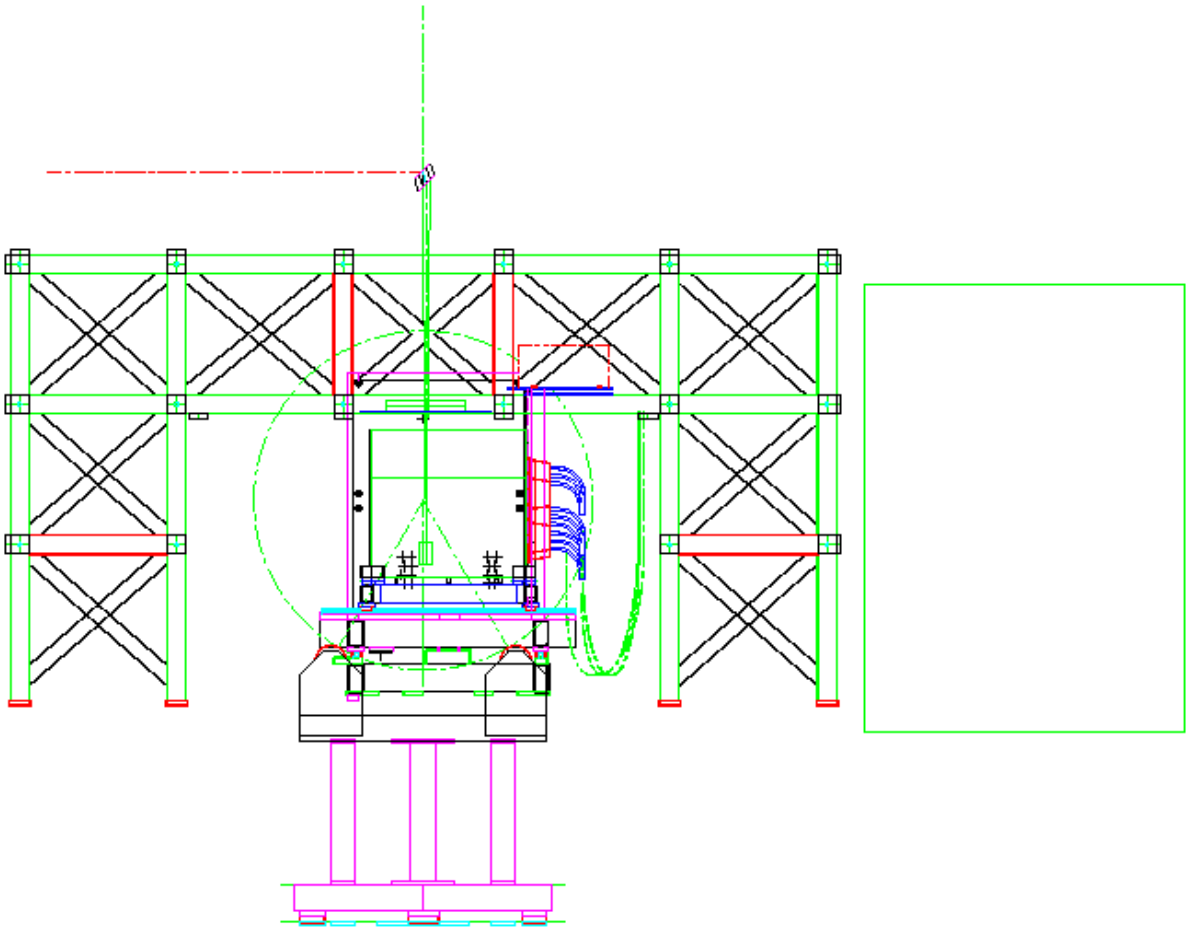


Figure 25: X-Y table (view from coudé instrumentation side).

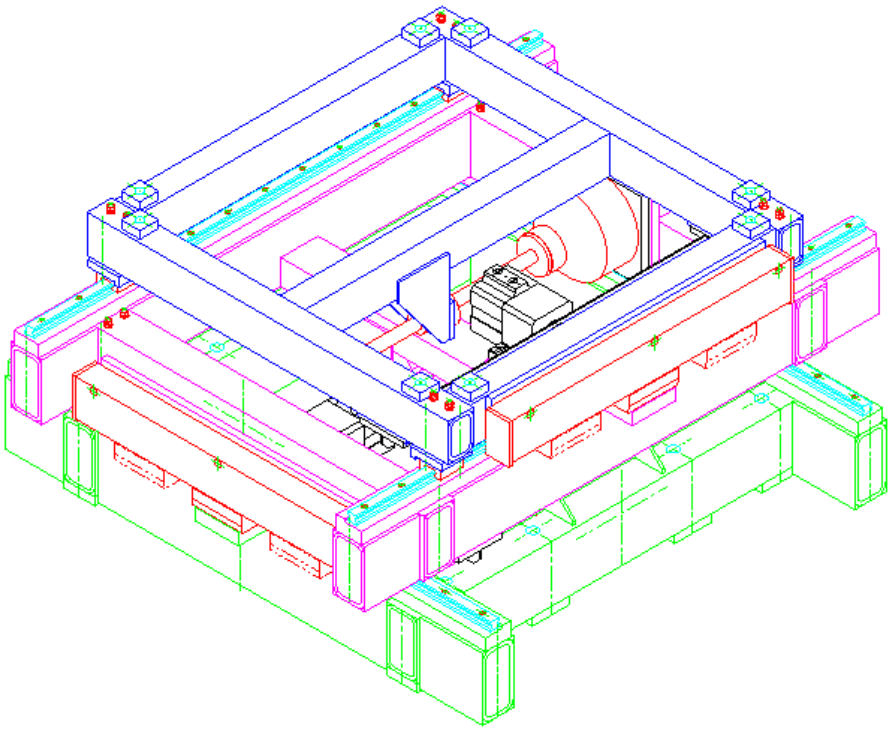


Figure 26: X-Y table

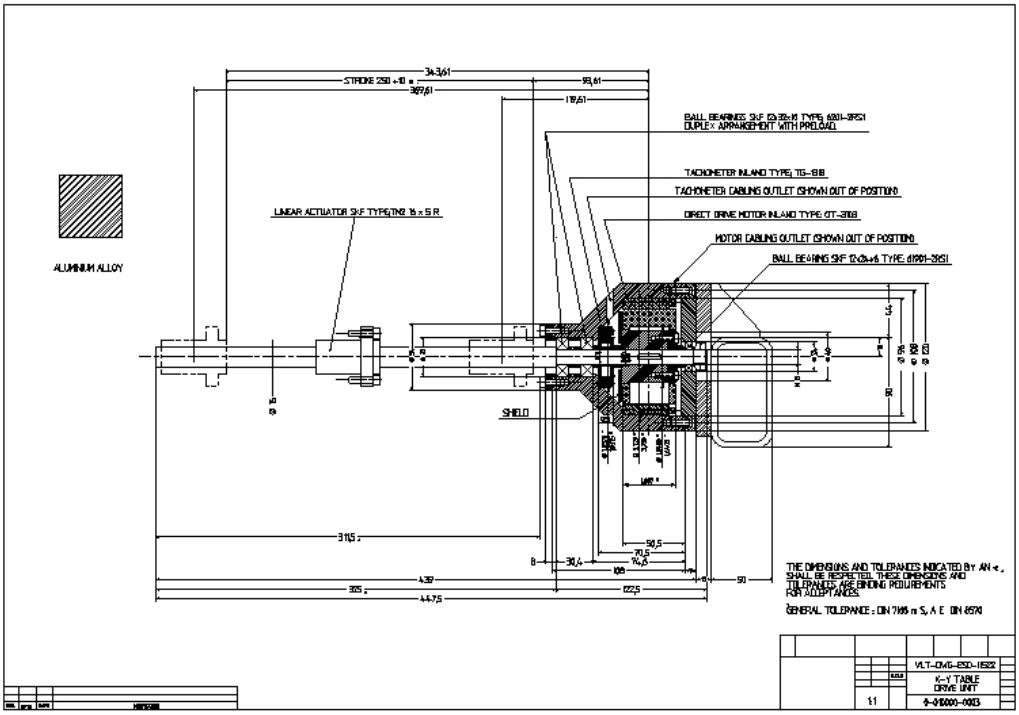


Figure 27: X-Y table, drive assembly.

6.1 X-Y table Main components list

Direct drive motor : Inland QT – 3103 Tachometer: Inland TG – 1318
Encoder Heidenhain LS 107
Linear actuator: SKF TN2 16 x 5R
LM Rail THK with pads SR15S
Miscellaneous (brake unit, switches, connectors etc.)
Structural parts

6.2 FEM analysis

6.2.1 Modal analysis and seismic considerations

A modal analysis of the X-Y table plus WFS box has been run showing a first eiegenfrequency unchanged with respect to the PDR. The lowest mode is defined by the stiffness of the X-Y table itself and is about 70Hz. With such a high eigenfrequency the WFS box + X-Y table can be considered like a 1 d.o.f component mounted on a spring with a first eigenfrequency given by the lowest mode of the coude' platform, at 15 Hz. Based on this consideration, and using the MLE acceleration spectrum in AD22, the maximum acceleration will be of 0.9g. Being less that gravity, the lateral seismic acceleration will not endanger the components. In vertical the Eurocode 8 norms specify that only 70% of the lateral acceleration shall be applied, Therefore the total acceleration will be 1.63g. Again this load will not endanger the mechanical parts, neither the lectronic components. Bolting connection will b e tighten to a torque, which will support this load.

None the less It has to be reminded that after MLE ESO policy accepts a complete realignment of the Observatory equipment.

6.2.2 Static analysis under gravity load

A static analysis has been performed to calculate the deflection of the components under gravity load. The results are reported here below.

Table 1: WFS main components translation and rotation under gravity load

Applied Force: gravity	UX [μm]	UY [μm] Vertical axis	UZ [μm]	ROTX [arcsec]	ROTY [arcsec]	ROTZ [arcsec]
Lenslet entrance plane	0	-1.6	0	0	0	0.6
STRAP	0	-0.85	0	0	0	0.6
C.o.G. Beam expander box	0	-0.85	0	0	0	0.67

6.2.3 Static analysys under 1N force along the fibre bundle direction

The following Table 2 summarises the translation and rotation displacements of the main components under a lateral force of 1N along the fibres bundle direction.

Table 2: Displacements under 1n force along the fibre bundle axis

Applied Force: gravity	UX [μm]	UY [μm] Vertical axis	UZ [μm]	ROTX [arcsec]	ROTY [arcsec]	ROTZ [arcsec]
Lenslet entrance plane	0.017	0.014	0	0	0.004	0.015
STRAP	0.017	-0.003	0	0	0.004	0.015
C.o.G. Beam expander box	0.017	-0.002	0	0	0.010	0.010

Using these values one can evaluate the deflection caused by the strain of the fibre bundle during the tracking travel, +/- 125mm in both directions, of the X-Y table.

The fibres bundle will lay on a table covered with Teflon. Assuming a weight of 10kg the dragging force will be about (friction coefficient conservatively assumed 0.2) 50N. Therefore the largest deflection will be 0.85 μm or 0.75”

7 Verification matrix of the mechanical design.

The matrix below lists the major requirements of the WFS box and their fulfilment.

Performance verification for	**Verification by**			**Technical specification**	**Performance responsible**	**Requested value**	**Measured value**	**Document number**
	D.	**A.**	**T.**					
WFS box	X		X	5 operation modes, mutually exclusive.	ESO		5 operation modes, mutually exclusive	
WFS box	X		X	Light tight	ESO		yes	
WFS box	X		X	Acoustic dumping	ESO		yes	
WFS box	X			Dust protection	ESO		yes	
WFS box	X			Turbulence protection	ESO		yes	
WFS box	X		X	NO Light pollution	ESO		yes	
WFS box	X			Sectors separation	ESO		yes	
WFS box	X		X	Removable covers	ESO		yes	
WFS box	X			STRAP ND wheel	ESO	2x8positions and closed off position	2x8positions and closed off position	
WFS box	X			CWFS ND wheel	ESO	11 positions including Closed off position with mirror	11 positions including Closed off position with mirror	

WFS box	X		X	Rotation of de-rotator (around the optical axis).	ESO	+/- 180 ^{o}	+/- 360 ^{o}	
WFS box	X			WFS field selection	ESO	$\pm$ 120 mm range $\pm$ 2 μm		
WFS box	X			Membrane mirror at coudé focal plane, F 47,6	ESO		yes	
WFS box	X			Membrane mirror focus	ESO	30 mm	yes	
WFS box	X			Membrane mirror slow steering rotations	ESO	+/- C	+/- 5°	
WFS box	X			STRAP tip-tilt	ESO	+/- 4.2°	+/- 4.2°	
WFS box	X			X-Y and tip-tilt rotation of the lenslet array	ESO		yes	
WFS box	X			Interface to non resident alignment devices	ESO	Folding mirror mount/alignment tool on beam selector	yes	

8 Conclusions

The detailed electro-mechanical design of the MACAO for VLTI fulfils the requirements set by system and AIV functions

9 Annex A:

Technical data sheets of commercial available components