

Notas Técnicas do Laboratório Nacional de Astrofísica

CUBES - Phase-A study

Opto-Mechanical Design Report

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CUBES Phase-A Study – Opto-Mechanical Design Report

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Resumo: CUBES é um espectrógrafo proposto por uma parceria entre Brasil e ESO para ser um instrumento visitante do VLT. Este documento apresenta o relatório do Projeto Opto-Mecânico apresentado na revisão de projeto da Fase-A do espectrógrafo CUBES em setembro de 2012 escrito por Macanhan, no qual o projeto ótico foi desenvolvido pelo engenheiro ótico do ESO Bernard Delabre e o projeto mecânico foi desenvolvido pela engenheira mecânica do LNA Vanessa B. P. Macanhan.

Abstract: CUBES is a spectrograph proposed as a Brazil-ESO collaboration as a visitor instrument to VLT. This document presents the Opto-Mechanical Design Report presented at CUBES Phase-A Review in September 2012, written by Macanhan in which the optical design was developed by the ESO optical engineer Bernard Delabre and the mechanical design was developed by the LNA mechanical engineer Vanessa B.P. Macanhan.

Palavras-chave/keywords: CUBES; spectrograph; opto-mechanical design; Phase-A study; espectrógrafo; projeto opto-mecânico.

1. Introdução

Cassegrain Ultra violet Brazilian-ESO Spectrograph – CUBES – is a spectrograph proposed by LNA, IAG and ESO as a visitor instrument for VLT, in a Brazil-ESO

collaboration. In April, 2011, proposal documentation was elaborated by the instrument team and the project was approved by ESO for the next step. On April 1st, 2012 CUBES Phase-A study started. From April to September, 2012 CUBES team developed the conceptual study of the project and the documentation to be presented to the Review Board in the Phase-A Review scheduled to September 27th, 2012.

The documentation elaborated for Phase-A Review includes:

- Science Case – VLT-TRE-ESO-13800-5679
- Technical Specifications – VLT-SPE-ESO-13800-5686
- Operation Concept – VLT-PLA-ESO-13800-5680
- Technical Report – VLT-TRE-ESO-13800-5681
- Opto-Mechanical Design Report – VLT-TRE-ESO-13800-5687
- Project Management Plan – VLT-PLA-ESO-13800-5682
- Top Level Requirements – VLT-TRE-ESO-13800-5683
- Executive Summary – VLT-PLA-ESO-13800-5684

This document presents the Opto-Mechanical Design Report presented at CUBES Phase-A Review, written by Macanhan in which the optical design was developed by the ESO optical engineer Bernard Delabre and the mechanical design was developed by the LNA mechanical engineer Vanessa B.P. Macanhan.



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CHANGE RECORD

ISSUE	DATE	SECTION/PARAGRAPH AFFECTED	REASON/INITIATION DOCUMENTS/REMARKS
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1 Scope

This document presents a preliminary opto-mechanical design of the Cassegrain U-band Brazilian-ESO Spectrograph (CUBES) for the Phase A study. It is referenced in [RD.3] and takes into account [RD.5] and [RD.6] developed during phase A.

The intended audience of this document is formed by the members of the CUBES phase A Review Board, by ESO's management and by the CUBES project team once it will established as a project.

2 Introduction

This document describes the opto-mechanical design of CUBES, divided in pre-slit unit (section 5) and spectrograph (section 6). The mechanical design is based on the optical design developed by Bernard Delabre, VLT requirements for instrumentation [AD.1], [AD.2], [AD.3] and the operational requirements [RD.2].

The current document is an Applicable Document to the Technical Report [RD.3].



3 Applicable and Reference Documents

3.1 Applicable Documents

The following Applicable Documents (AD) of the exact issue form part of the present document to the extent specified herein.

AD Nr	Doc Nr	Doc Title	Issue	Date
AD1	VLT-SPE-ESO-00000-2723	Requirements for Scientific Instruments on the VLT Unit Telescopes	1	18.03.2005
AD2	VLT-DWG-ESO-11430-2052	Unit telescope – Section altitude/azimuth axis	1	10.05.2001
AD3	VLT-DWG-ESO-11430-2055	Unit telescope – Detail of instrument rotator	1	10.05.2001
AD4	VLT-SPE-ESO-10000-1853	Instructions to perform earthquake analysis for VLT instruments and similar equipment	1	09.06.1999
AD5	VLT-SPE-ESO-10000-0004	Environmental specification	6	12.11.1997
AD6	VLT-SPE-ESO-50000-4645	ESO mechanical standards	1	17.06.2009

3.2 Reference Documents

The following Reference Documents (RD) contain useful information relevant to the subject of the present document.

RD Nr	Doc Nr	Doc Title	Issue	Date
RD1	VLT-TRE-ESO-13800-5679	Cubes Phase A Science Report	1	xx.08.2012
RD2	VLT-PLA-ESO-13800-5679	Cubes Phase A Operational Concept Definition	1	xx.08.2012
RD3	VLT-TRE-ESO-13800-5681	Cubes Phase A Technical Report	1	xx.08.2012
RD4	VLT-PLA-ESO-13800-5682	Cubes Phase A Project Management Plan	1	xx.08.2012
RD5	VLT-SPE-ESO-13800-5683	Cubes Phase A Top Level Requirements	1	xx.08.2012
RD6	VLT-SPE-ESO-13800-5686	Cubes Phase A Technical Specifications	1	xx.08.2012

4 Overall structure

CUBES will consist of a self-contained unit, and its flange will be bolted directly to Cassegrain rotator flange, as required by AD1.

CUBES will consist of two main assemblies: pre-slit unit and spectrograph. The pre-slit unit consists of an image slicer, a slit viewer, a calibration unit, and, possibly, an ADC. The spectrograph consists of collimator, VPH grating, camera and detector.

The instrument components will be mounted on frame/cage like structure, denominated frame or main frame, which will support the entire instrument mass. A base on the bottom part of the instrument will allow it to be laid on a surface, which can be the handling cart, a base or even the floor, when CUBES is out of operation.

Special attention will be given to flange installation repeatability in order to allow rapid instrument re-installation. The intention is to align the instrument during first commissioning and lock all adjustments, in order to have none or minimum realignment during re-installation.

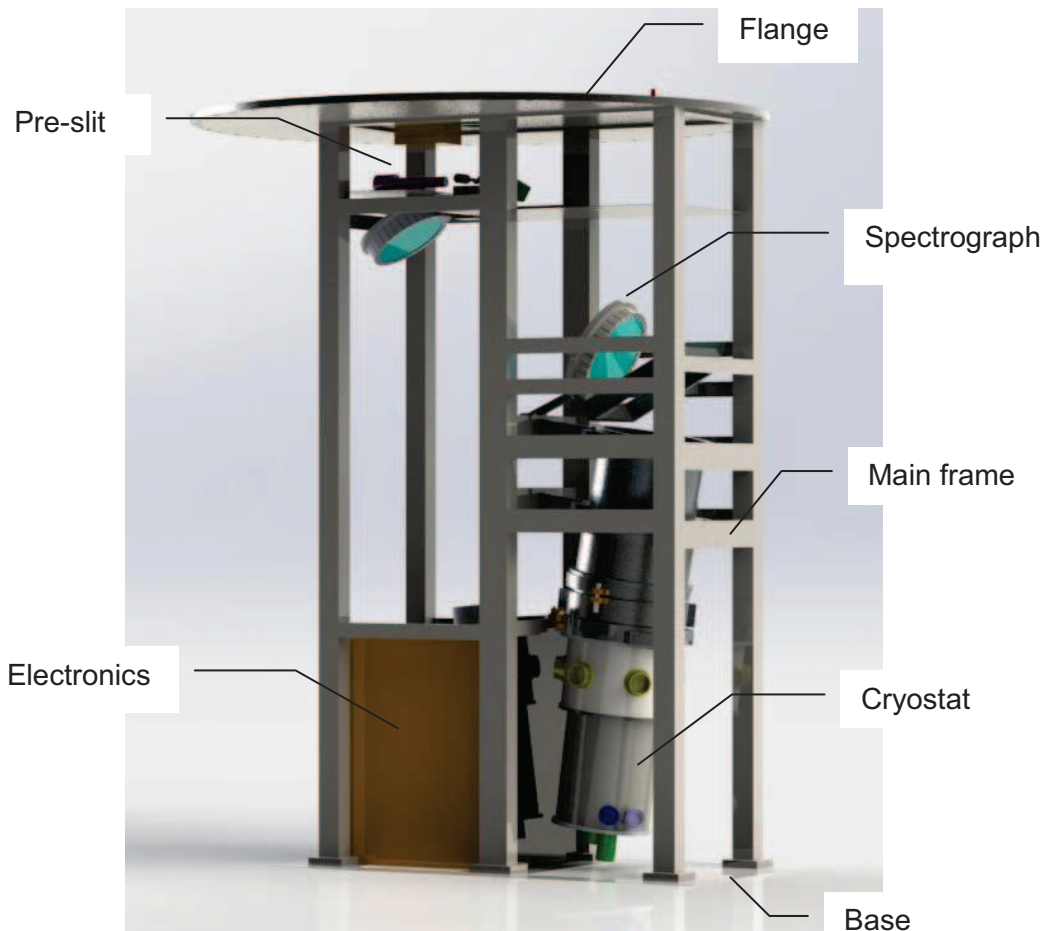


Figure 4.1. CUBES opto-mechanical layout

4.1 Structure concept

The CUBES structure will consist of a main structural frame, which will support all spectrograph mass. Bolted to it there will be the optical components mechanical supports, electronic boxes or components, etc. The main structure will be designed to be stiff enough to ensure that the detector, which is at the end of the spectrograph and also the component which demand the best precision positioning, will never deflect beyond optical tolerance in any spectrograph position within its operating range as defined in RD6, with an addition of an extra safety factor. This extra safety factor (value TBD) will allow future addition of extra components, optical, mechanical or electronic, in case it is desired to improve spectrograph performance. A baffle plate separates pre-slit area from spectrograph area in order to isolate light.

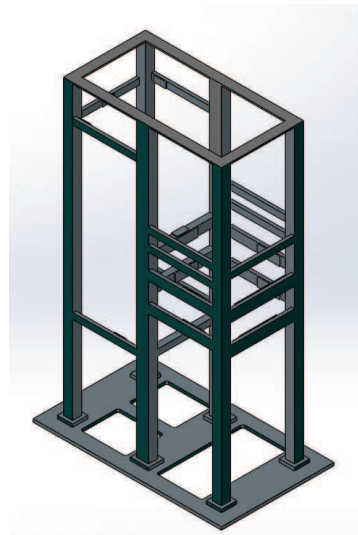


Figure 4.1.1. Main frame with base

On the top of the instrument there will be the interface flange, which will be bolted at the telescope Cassegrain rotator flange. At the bottom of the instrument, there will be a base which allows the instrument to be laid on the Instrument Handling Carriage - IHC, or on a base, or even on the floor. This base will have bolt holes to enable the instrument to be bolted on a base or on the floor when out of operation for safety reasons, especially in case of earthquake. Details are TBD at Paranal.

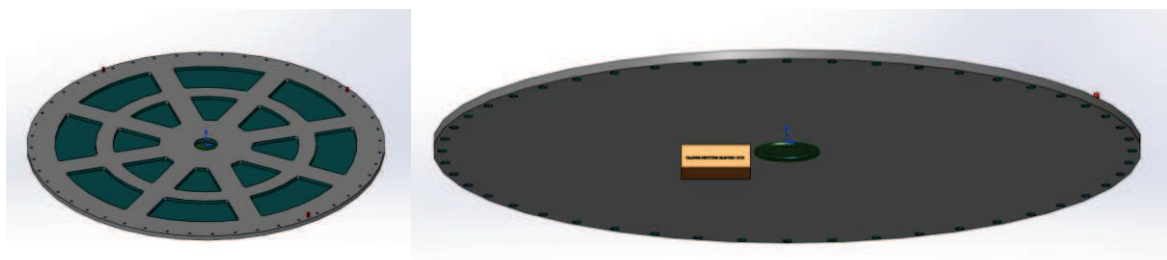


Figure 4.1.2. Top flange isometric views from top and bottom, showing the dowel pins for mounting repeatability and flange shutter for closing the instrument

The main frame, top flange, and base will be fabricated in stainless steel AISI316. As long as the instrument weight is not a critical parameter for CUBES, AISI316 was chosen due to its good mechanical resistance and stability. In addition it has a lower thermal expansion coefficient than aluminium, which provides a much more stable structure and instrument. Optical components mechanical cells and supports will be fabricated in aluminium 6061-T6 or 7075-T6, except for some small pre-slit components which will be glued in Invar[®].

For non-reflective finishing, AISI316 parts will be black electropainted, aluminium parts will be black anodized, and Invar[®] parts will be painted with Aeroglaze[®] Z306 polyurethane coating, which can also be used for AISI316 where necessary.

CUBES can be covered with removable aluminium plates, bolted to its structures. All cover plates will be removable in order to facilitate instrument assembling, alignment, and maintenance. As an alternative option, the cover plates can also be fabricated in Divinycell[®] foam core between two thin plates of fiberglass, in an aluminium frame. This material has been successfully used in SIFS spectrograph cover and will be used in STELES spectrograph cover, for which weight limit is an issue. On one hand, Divinycell[®] advantages are its very light weight and, therefore, easy handling. If necessary, it also provides thermal insulation when fabricated in thicker core dimensions, such as 20 millimetres or more. On the other hand, aluminium can ensure better light insulation, especially for complicated plate geometries, and is also considerably easier and faster to fabricate, that is an advantage in case one plate needs to be replaced in the future, when CUBES is already operating (if a technician drops one plate during maintenance and it is damaged, for example).

All assemblies, sub-assemblies and components will be bolted. Very small parts, such as slicer mirrors, will be glued on Invar[®] supports. There will be no welding in any of CUBES mechanical components.

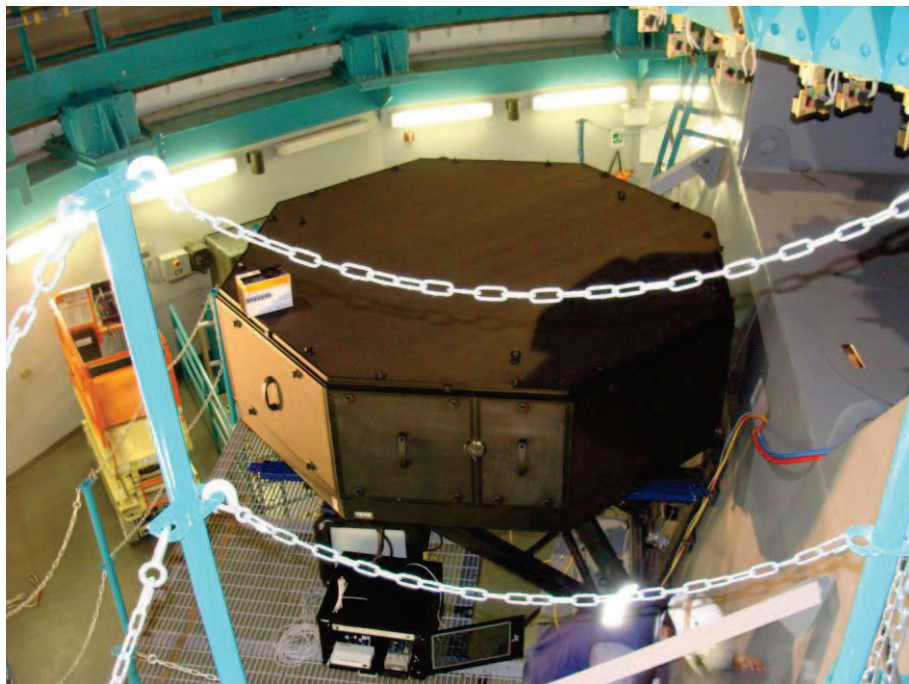


Figure 4.1.3. SIFS spectrograph installed on SOAR Telescope (Chile) – the picture shows the use of fast lockers and handlers on Divinycell[®] plates, facilitating opening/closing instrument cover

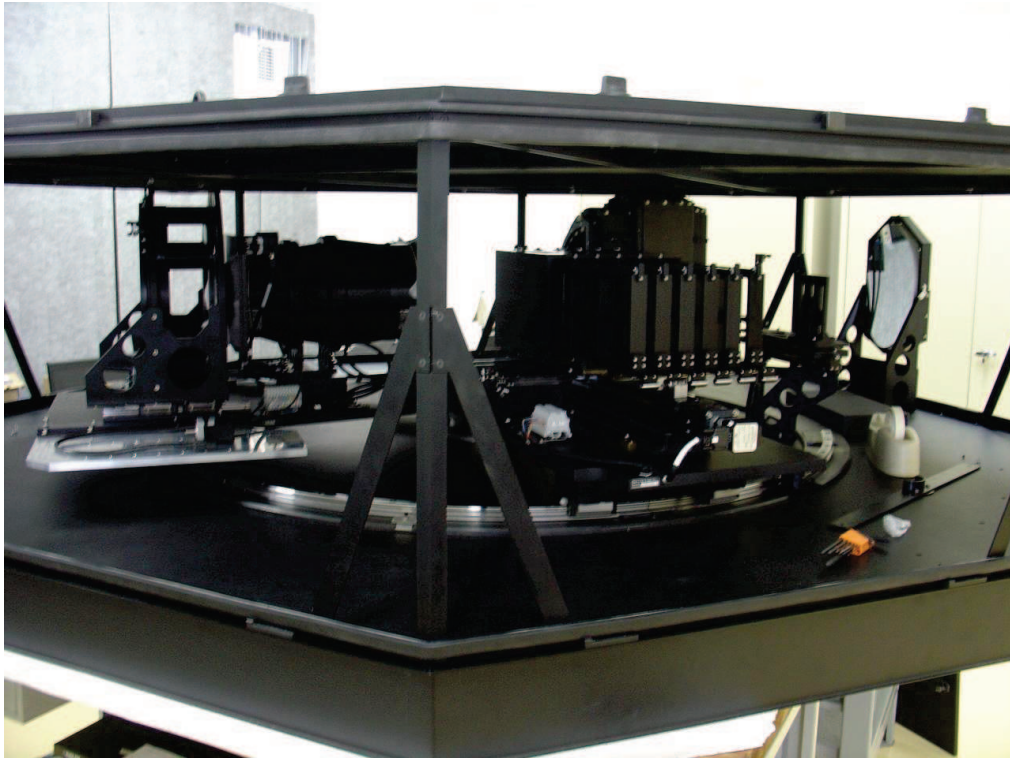


Figure 4.1.4. SIFS being mounted at LNA – The picture shows the same instrument with the Divinycell[®] plates removed from the aluminium frame – full access to all opto-mechanical components. The same principle will be used on CUBES, for Divinycell[®] or aluminium plates.

4.2 Mass and torque

According to AD1, the total mass attached to the Cassegrain rotator shall not exceed 2500 kg. The moment applied to the rotator flange with a moment vector perpendicular to the optical axis, at any telescope altitude, shall not exceed 20 kNm. The moment applied to the rotator flange with a moment vector parallel to the optical axis, at any telescope altitude, shall not exceed 500 Nm in any instrument orientation. The maximum torque component due to friction alone, for example from the instrument cable wrap mechanism, shall not exceed 100 Nm [AD.1]

CUBES estimated mass is 1068 kg. Maximum estimated moment at vector perpendicular to optical axis is 10319 Nm. Maximum estimated moment at vector parallel to optical axis is 1501 Nm, which will be compensated with counterweights.

The flange weight estimation is 220 kg, even adding weight relieves. It has such weight because it has to respect UT rotator flange dimensions. The main frame weight estimation is 570 kg. It has to support the flange weight and, principally, ensure detector position precision to satisfy the optical tolerances. Cryostat and its electronics will achieve close to 100 kg.

Therefore, CUBES mass and moments will satisfy VLT rotator flange limits.



4.3 Overall dimensions

Cassegrain instruments, and any associated ancillary equipment such as electronics cabinets, cooling equipment and thermal enclosures, shall not exceed the space envelope allocated for Cassegrain instruments in ADWG-C1. [AD.1] According to the cited drawing [AD.2], the Cassegrain instrumentation envelope is 4400x7400 millimetres and 3050 millimetres height from rotator flange to floor.

Considering other facilities areas, such as auxiliary telescope hall and its entrance door, control building integration facilities and its entrance door, and telescope entrance doors, the minimum entrance door width is 3100 millimetres. The minimum entrance door height is 3000 millimetres, which becomes 2500 millimetres discounting 500 millimetres for the instrument handling cart. However, clearance under M1 cell is 2500 millimetres, which becomes 2000 millimetres discounting 500 millimetres for the instrument handling cart.

CUBES overall dimensions are 1080 x 580 millimetres, not considering the flange. CUBES itself is smaller than rotator flange screw holes diameter, which is 1500 mm according to [AD.3]. So, CUBES flange will follow rotator flange diameter of 1540 millimetre. In addition, CUBES height is 2000 millimetres.

Therefore, CUBES overall dimensions are under VLT limits.

4.4 Stiffness and earthquake safety

The instrument stiffness will depend mainly on its weight and the main structure elements thickness. The most important requirement is to ensure that the detector, which will be at the end of the spectrograph structure, will satisfy the optical tolerance, with a good safety margin factor. The main structure elements thickness will be calculated to satisfy the requirements without adding excessive mass. It can be done using Finite Element Analysis (FEA) softwares Ansys[®], Nastran[®], or SolidWorks Simulation[®], since all the three of them are available at LNA.

After fabrication, the instrument stiffness will be tested/checked at LNA moving the assembled spectrographic to all critical positions: 0°, ±45° in “x” and “y”, and ±90° in “x” and “y”, and measuring the detector position to check if the tolerances are being kept. The measurements can be done at LNA metrology laboratory using a Coordinate Measuring Machine (CMM), a Metris articulated arm which easily provides this type of measurements with adequate precision. If just after mechanical fabrication any component, optical or electronic, is not still available in Brazil for any reason, at the moment of stiffness test, dummy weights will be used, in order to make the stiffness test as soon as possible.

In case the checking procedure shows the detector position is out of tolerance, which is not supposed to happen, stiffness can be easily improved bolting extra structural elements to the main structure where required.

As long as no overall vibration coming from telescope occurs [AD.5], there will be no need for instrument vibration isolators. No significant vibrations are expected to be generated from CUBES components to the telescope. However, if a vibration problem occurs, coming from an



electrical component that cannot be replaced (very unlikely), it will be locally isolated, since no vibrations are desired in the instrument itself.

Another important issue related to stiffness is earthquake safety. According to [AD.4] an important design goal of the equipment is to provide sufficient rigidity to avoid dynamic coupling and magnification effects with the VLT structure by maximising the structural stiffness and minimising the mass, which is reached when the lowest significant eigenfrequency of equipment structure is above 30Hz along horizontal x- and y-directions and above 70 Hz along vertical z-direction. During the design phase, a modal FEA model will be generated as required in [AD.4] following data available at [AD.5]. After fabrication, a vibration test will be performed with the instrument to ensure its earthquake safety.

After the stiffness test, the instrument will be taken for a vibration test at Integration and Test Laboratory at INPE – Instituto Nacional de Pesquisa Espaciais¹. INPE is another research institution of the Ministry of Science, Technology and Innovation as is LNA, located at São José dos Campos, 150 km from Itajubá. In this laboratory, vibration tests are performed on a variety of products, from notebooks to satellites, in various vibration conditions. The purpose of the vibration test is to simulate how CUBES will perform under an earthquake.

For the vibration test/earthquake simulation, first the main and secondary structures will be tested and evaluated. Once approved, the entire spectrograph will be mounted and tested, except the optics. Aluminium dummy lenses and mirrors will be placed instead of real optical components for the vibration test. This second test is to ensure structural stiffness. Finally, an alignment simulation will be made using the dummy lenses and the instrument will be tested again. This third test is to evaluate the alignment performance after an earthquake. One of the purposes of the opto-mechanical design calculations is that no re-alignments will be necessary after an Operating Basis Earthquake (OBE) and to minimize re-alignment need after a Maximum Likely Earthquake (MLE). The alignment test is to experimentally ensure that this requirement was achieved. If the results are not satisfactory, the design will be reinforced in order to maximize instrument stiffness as necessary.

4.5 Mounting of the spectrograph

CUBES requires a mechanism that allows the instrument to be rapidly dismantled and re-installed [RD.6]. Therefore, special attention will be given to flange installation repeatability to allow that, as shown in Figure 4.1.2. The purpose is to align the instrument during first commissioning and lock all adjustments, in order to have none or minimum realignment during re-installation.

For mounting the spectrograph on the telescope, the instrument will be lifted by CUBES Instrument Handling Carriage (IHC) until the CUBES flange touches the Cassegrain rotator flange, for the flange bolting. Cassegrain rotator flange has 48 M10 tapped holes [AD.3], however due to CUBES relatively low mass there is no need to use all 48 screws. If it is more convenient for VLT technicians, less screws can be used for mounting CUBES flange on the rotator flange in order to facilitate and accelerate CUBES mechanical installation. The number of screws will be

¹ More information about INPE vibration test facilities can be seen at http://www.lit.inpe.br/vibracao_mecanica

calculated considering not only instrument stiffness, but mainly earthquake safety. The IHC and handling procedure are described in section 7.1 in this document.

For UT power supply, fluid supplies and control systems, CUBES will have a well-established procedure for (dis)connecting all cables and hoses. CUBES electronic and cooling requirements are relatively uncomplicated making a “plug and play” design feasible [RD.6].

5 Pre-slit

5.1 Pre-slit concept

The Pre-slit assembly consists of an image slicer, as the main sub-assembly, a slit viewer, and a calibration unit. The inclusion of an ADC is currently part of phase A baseline design, though the need for an ADC will be reconsidered during the next design phase. [RD.3]

Baffle plates are used to separate the pre-slit area from the spectrograph in order to isolate light.

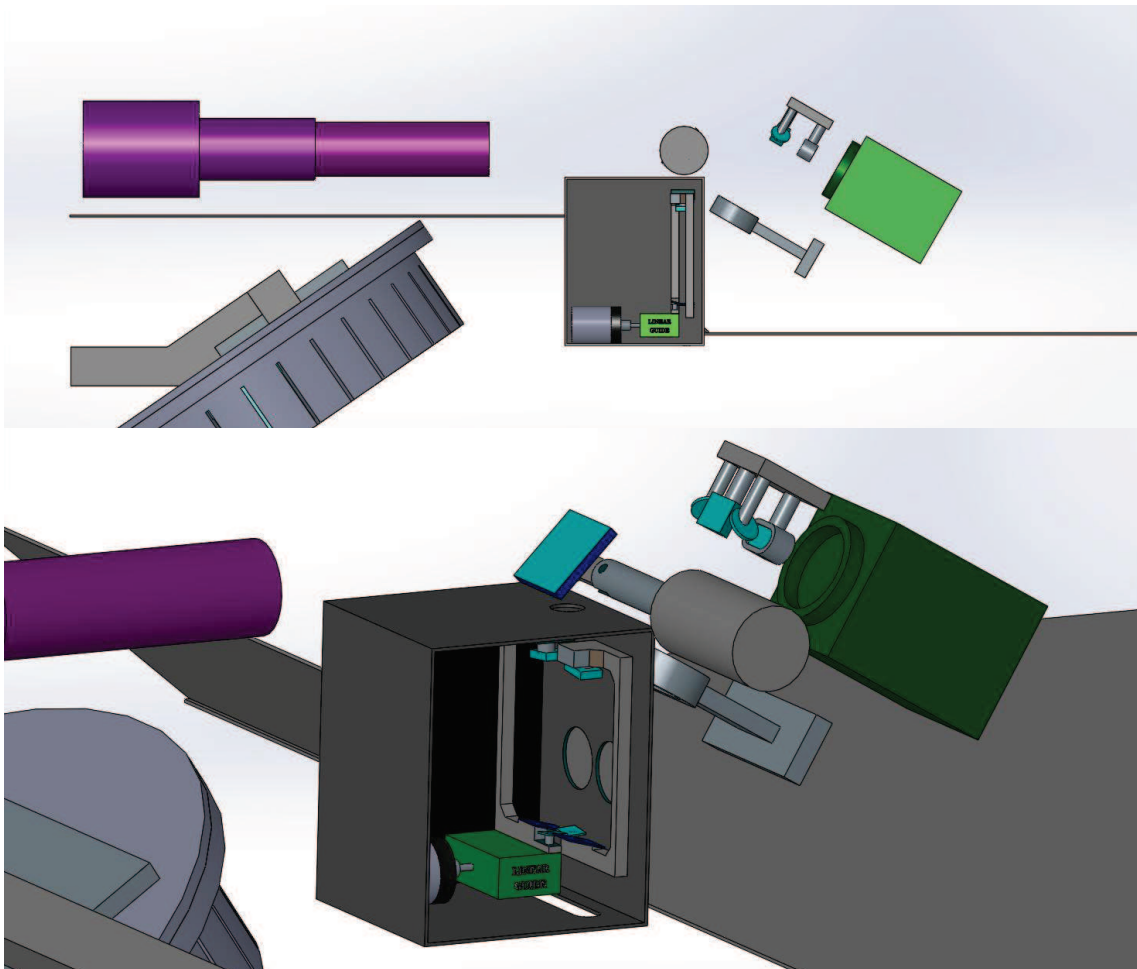


Figure 5.1.1. Pre-slit front and isometric views

5.2 Image slicer and slit viewer

The image slicer is permanently mounted in the telescope focal plane and offers the possibility to select the number of slices between 1 and 3. Its principle is illustrated in Figures 5.2.1 and 5.2.2.

The slicer consists of a fixed part and a moving part.

Each part includes:

- a tilted curved slit jaw
- a reimaging mirror
- a tilted reflective mirror (including a fixed width slit) for the slit viewer.

This complete second unit moves parallel to the first one. The amplitude of the translation determines the number of slices (between 1 and 3)

The slit jaw mirrors are spherical and the reimaging mirrors are toroidal. The curvature of the slit jaw is used to reimage the pupil at the same location than the direct slit. The light reflected by these slit jaws is reimaged at magnification 1 respectively above and below the direct slice by the reimaging mirrors.

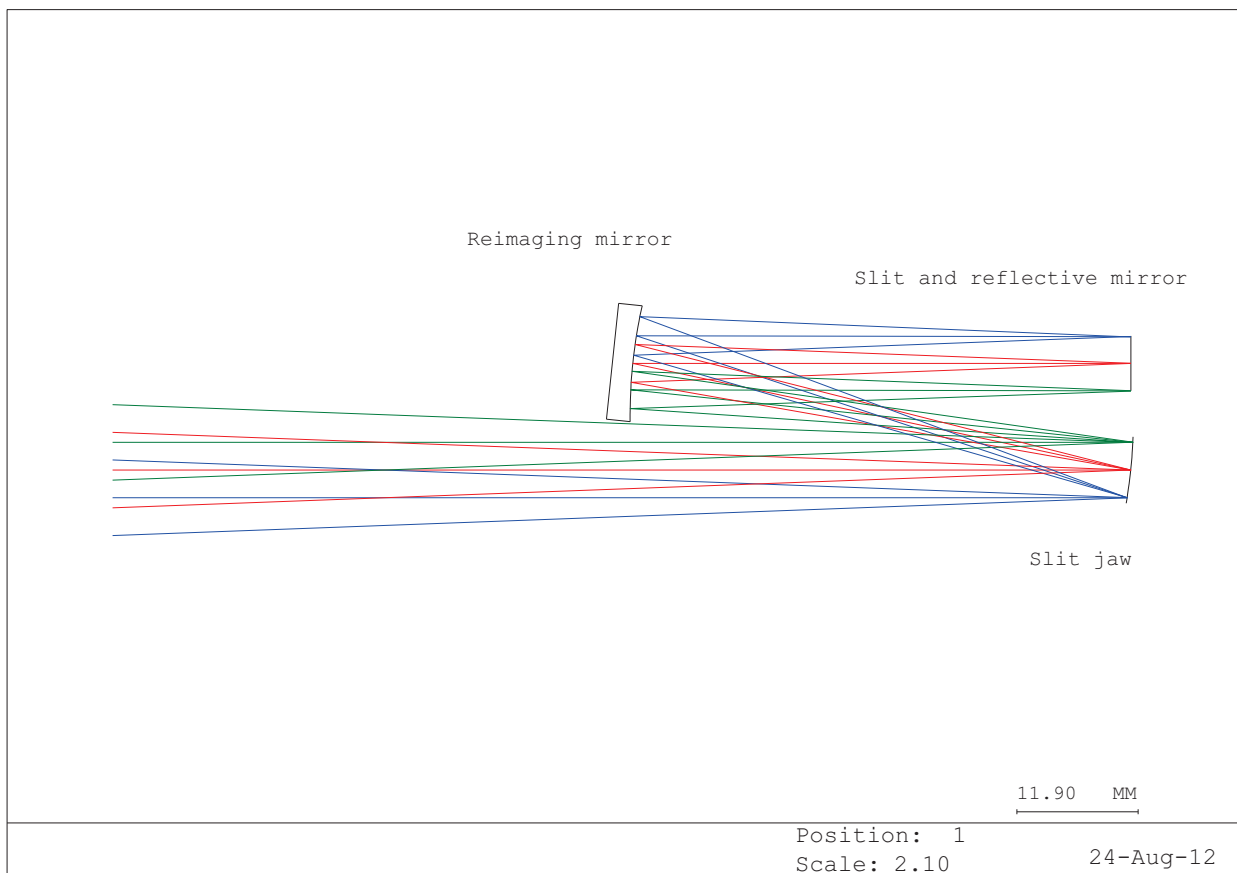


Figure 5.2.1. Image slicer optical fixed unit

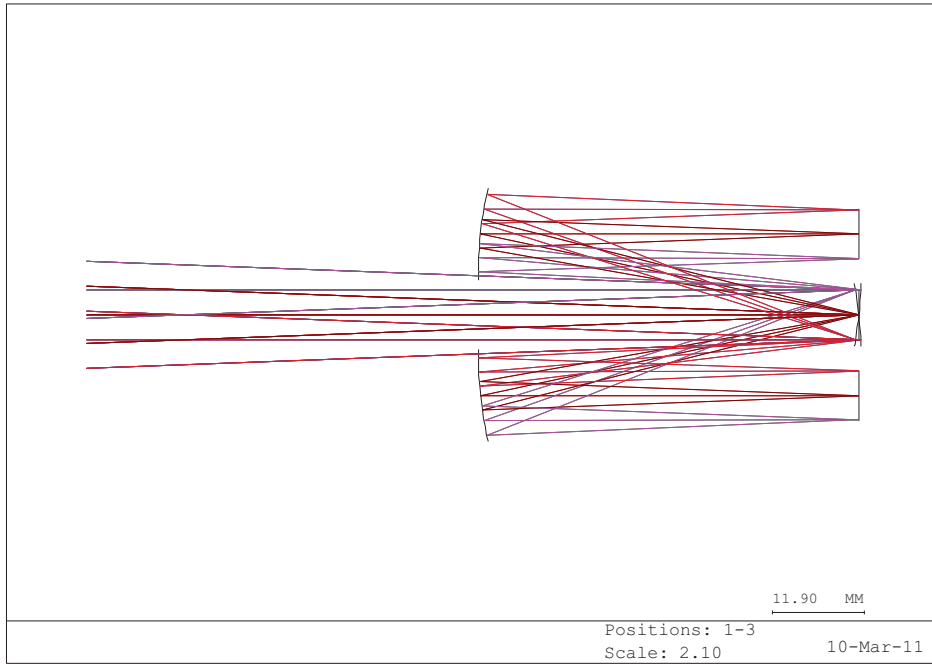


Figure 5.2.2. Image slicer both units (side view)

This slicer has 100 % efficiency for the central slit (no optic is on the light path) and around 98% for the other slits. The slit selection is illustrated in Figure 5.2.3. The top blue circles represent the position of the star before the slicer and the bottom “circle” the aspect of the star after the slicer.

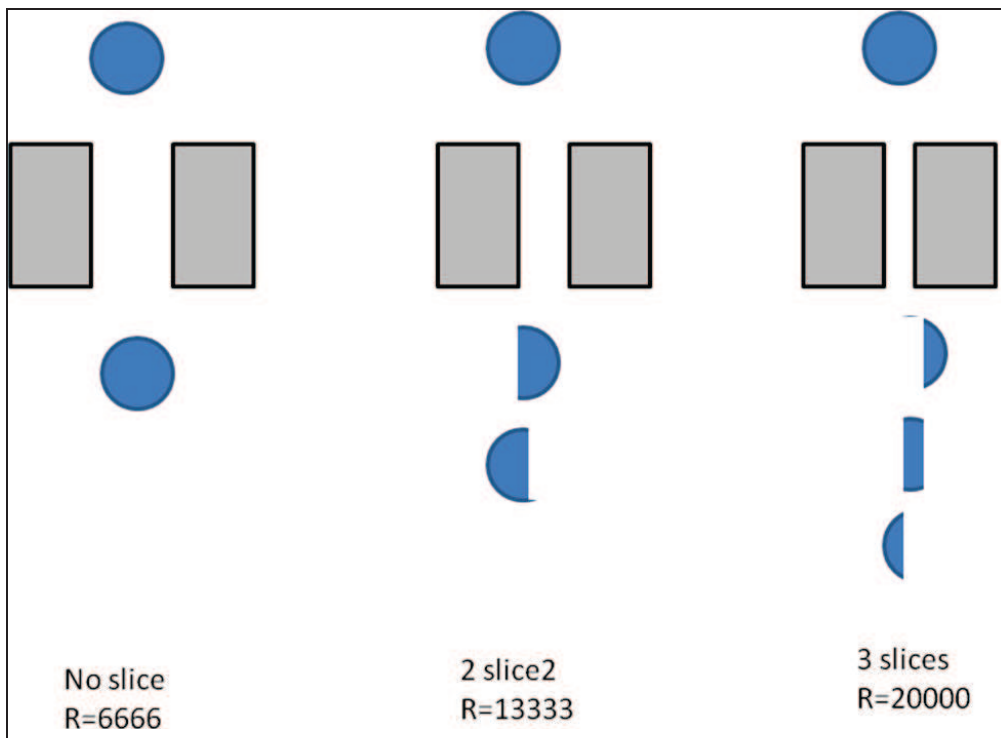


Figure 5.2.3. Slit selection

The amplitudes of the slit translation are:

- 3 slices : 180 μm (minimum distance) the slit is never fully closed
- 2 slices : 270 μm
- 1 slices : 540 μm

The slit viewer will be fully integrated to the slicer device. The complete field of view available on the slit viewer camera is 10 x 10 arc sec. This field will not be continuous but separated in two sub-field of 10 x 5 arc sec. The separation occurs at the level of the slit jaws which are tilted in opposite direction. Each sub-field is reimaged on the upper and lower slits areas and then reflected towards two parallel reimaging systems as shown in Figure 5.2.4.

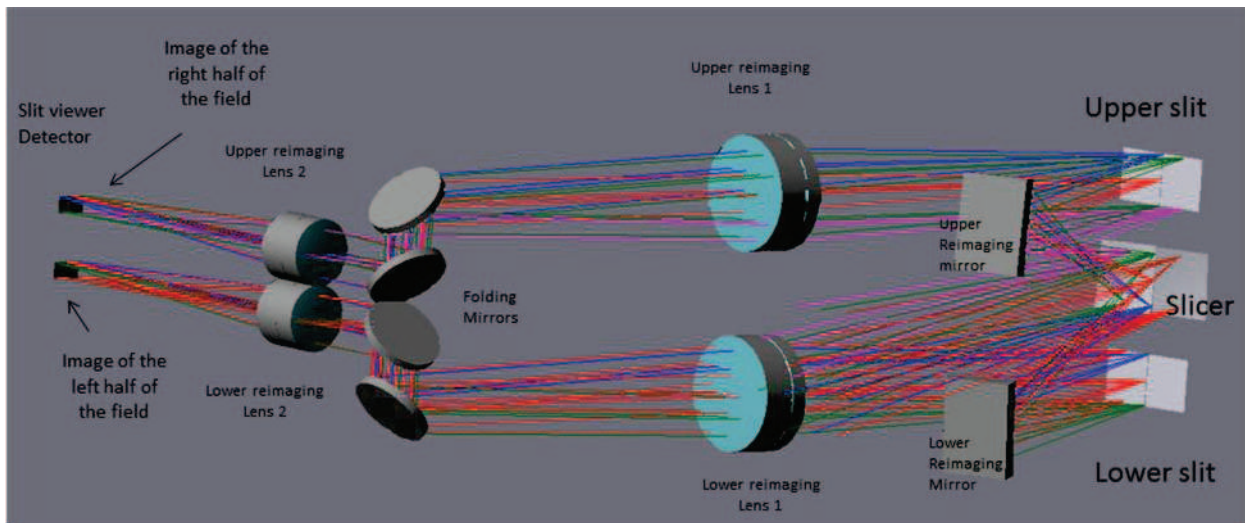


Figure 5.2.4. Slicer and slit viewer optical layout

The reimaging system consists of 2 lenses and 2 folding mirrors. The two half field are reimaged on a single detector. The system presented in the figure reimages each half field on an area of 3.15 x 1.57 mm. A 1K X 1K detector is sufficient to collect the two images (10 microns pixel). Effective area is 3.15 x 8.5 mm. The image scale shown on the figure is 32 mas/pixel. This value can be easily modified down to 100 mas/pixel by changing the focal length of the 2nd reimaging lenses.

The image slicer and slit viewer mechanical concept is shown in Figure 5.2.5. The image slicer will be assembled inside a box for light isolation. Its mirrors and slits will be glued in Invar[®] structures. There will be two Invar[®] structures: one for the fixed components and the other for the movable components. The movable structure will be mounted on a linear guide and attached to a high precision actuator. This actuator will provide the three different positions for the slicer. In the slit viewer, the first pair of lenses will be assembled in Invar[®] cells and the other components will be glued in a Invar[®] structure, close to the detector. The use of Invar[®] in most components is because their small dimensions. The entire system will be approximately 210 x 150 x 70 millimetres, weighting no more than 2 kilograms.

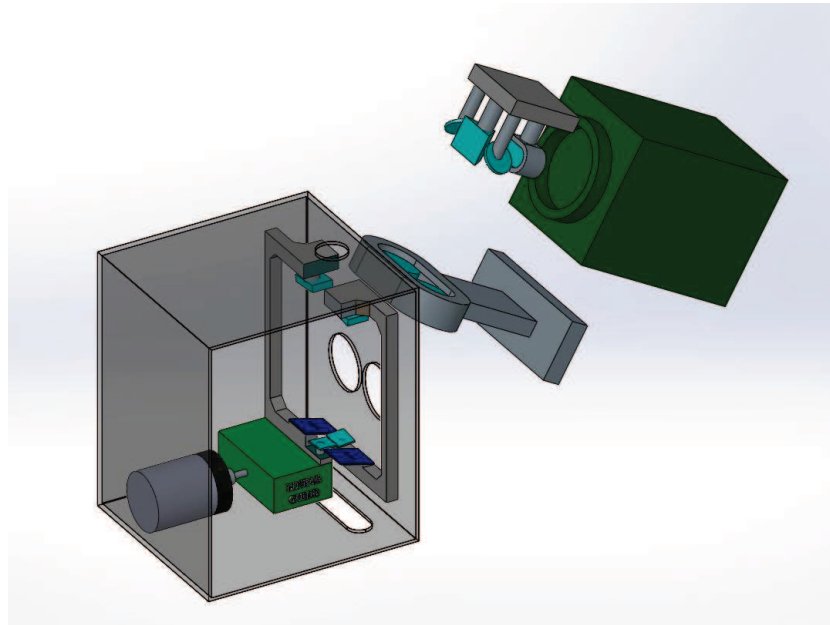


Figure 5.2.5. Image slicer and slit viewer

5.3 Calibration unit

The calibration unit consists of a retractable pick off mirror mounted on an electronic actuator, which positions the mirror in and out the light path. When in the light path, the folding mirror directs the light coming from the calibration lamp, passing through some optics, to the slit and spectrograph. The folding mirror is glued to an Invar[®] base which is connected to the actuator.

The calibration lamp can be attached to the frame with a tap, bolts, or both, such that it is easily replaced when necessary. Mirror actuator electronics will be attached to the frame, independently from lamp+lens mount. Special attention will be given to safety aspects considering the UV source.

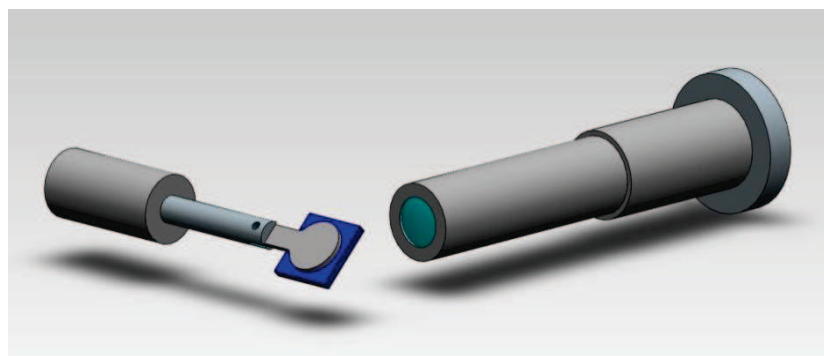


Figure 5.3.1. Calibration unit

5.4 ADC

If an ADC is included in the pre-slit, as a first proposal, ADC prisms can be mounted as shown in Figure 5.4.1. Lenses (1), lens housings (2), pulleys (3), motors (4) and switches will be mounted inside an enclosing box, not shown, which can be fixed to the flange set or tube wall.

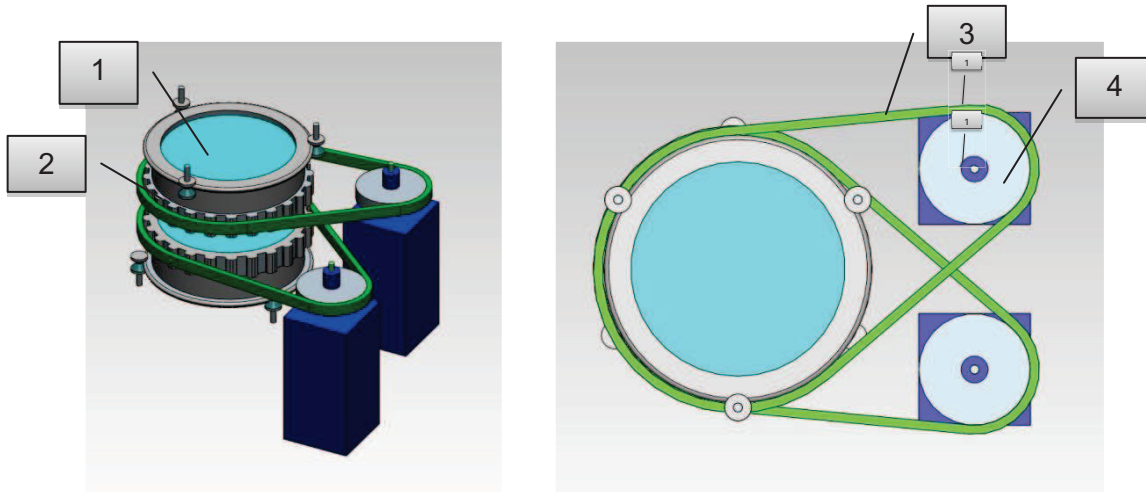


Figure 5.4.1. ADC concept - isometric and top views – first proposal

An alternative proposal is mounting the ADC lenses in commercial motorized rotation stages, instead of using motors and pulleys. This kind substitution was made in STELES rotator prism, where a system using motors and gears was changed for a simpler and smaller Newport[®] rotation stage. Despite of not having been completely tested yet, the rotation stage system has presented itself very satisfactory, simpler, cleaner, and more precise than the motors.

There is enough space for ADC in the pre-slit area.

6 Spectrograph

6.1 Optical design

As the instrument throughput is the main driver of the design, the number of optical element has been reduced to the minimum at a cost of some additional aspheric surfaces. The camera is also not achromatized and can operate only in the defined wavelength range of the instrument. Again for the same reason an Echelle grating has not been considered, preference has been given to a VPH which offers a better efficiency. The price to pay here is a limited wavelength range as no cross dispersion is possible with this kind of grating.

6.1.1 Collimator

As the field of view with 3 slices is relatively large (16 mm) a Cassegrain Collimator is not adequate. A more appropriate solution is an achromatic doublet with two folding mirror. The front surface of the doublet is aspheric. No transfer pupil is required if the VPH is oversized by 16 mm along the grooves length.

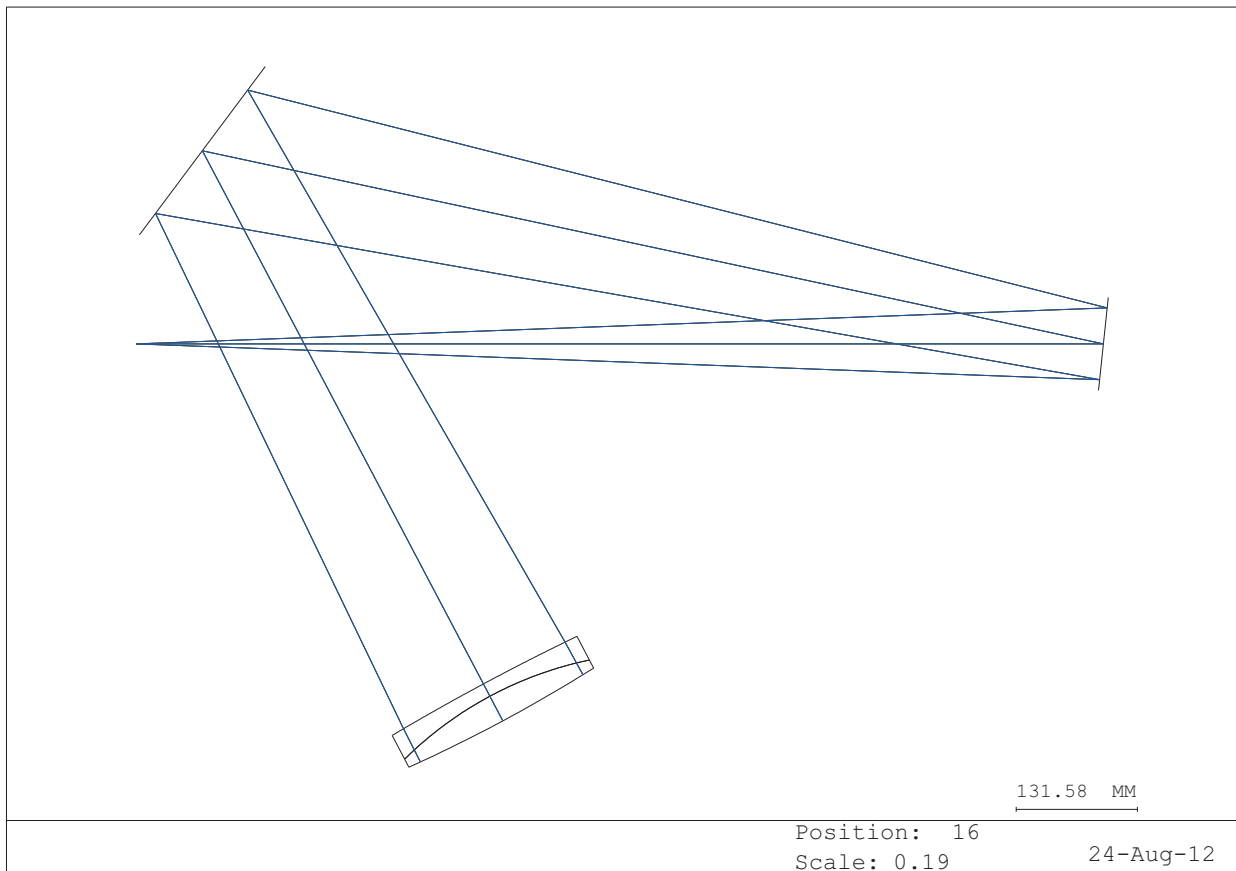


Figure 6.1.1. Collimator optical concept

The collimator delivers a 206 mm parallel beam.

6.1.2 VPH grating

The VPH has a high groove density (3050 gr/mm). To operate in Bragg condition the VPH is tilted by 33.33° with respect to the optical axis of the collimator. The VPH is encapsulated between 2 silica plates. Both external surfaces have a weak radius of curvature (7.7 m). To avoid any vignetting the physical size of the VPH has to be at least 222 x 242 mm.

6.1.3 Camera

The camera is not achromatized. The color correction is achieved by a tilt of the detector along the dispersion direction. Although this camera has a large field of view (18.5°) and operates at a F/Number of 2.67, it consists of only 2 aspheric lenses and a aspheric cryostat window. All 3 elements are made of Silica to avoid any glass absorption. The cryostat is tilted with respect of the camera body.

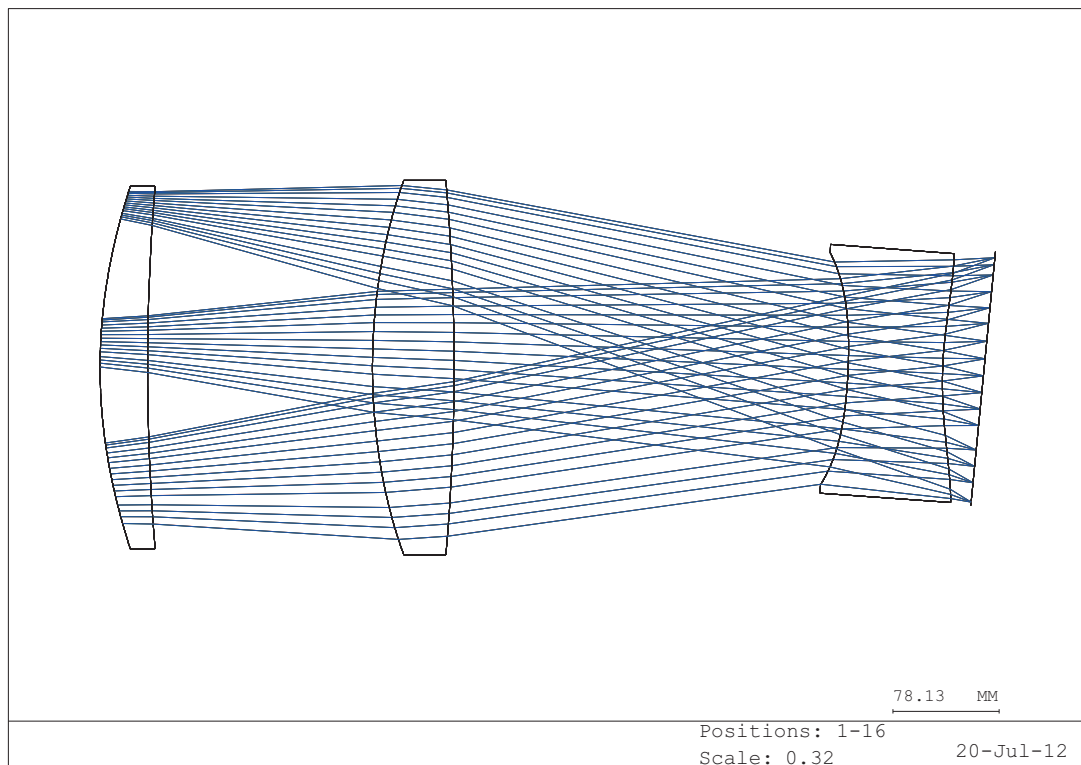


Figure 6.1.3.1. Camera optical concept

The front and the last three surfaces are aspherics. The focal length is 570 mm.

6.1.4 Optical performance

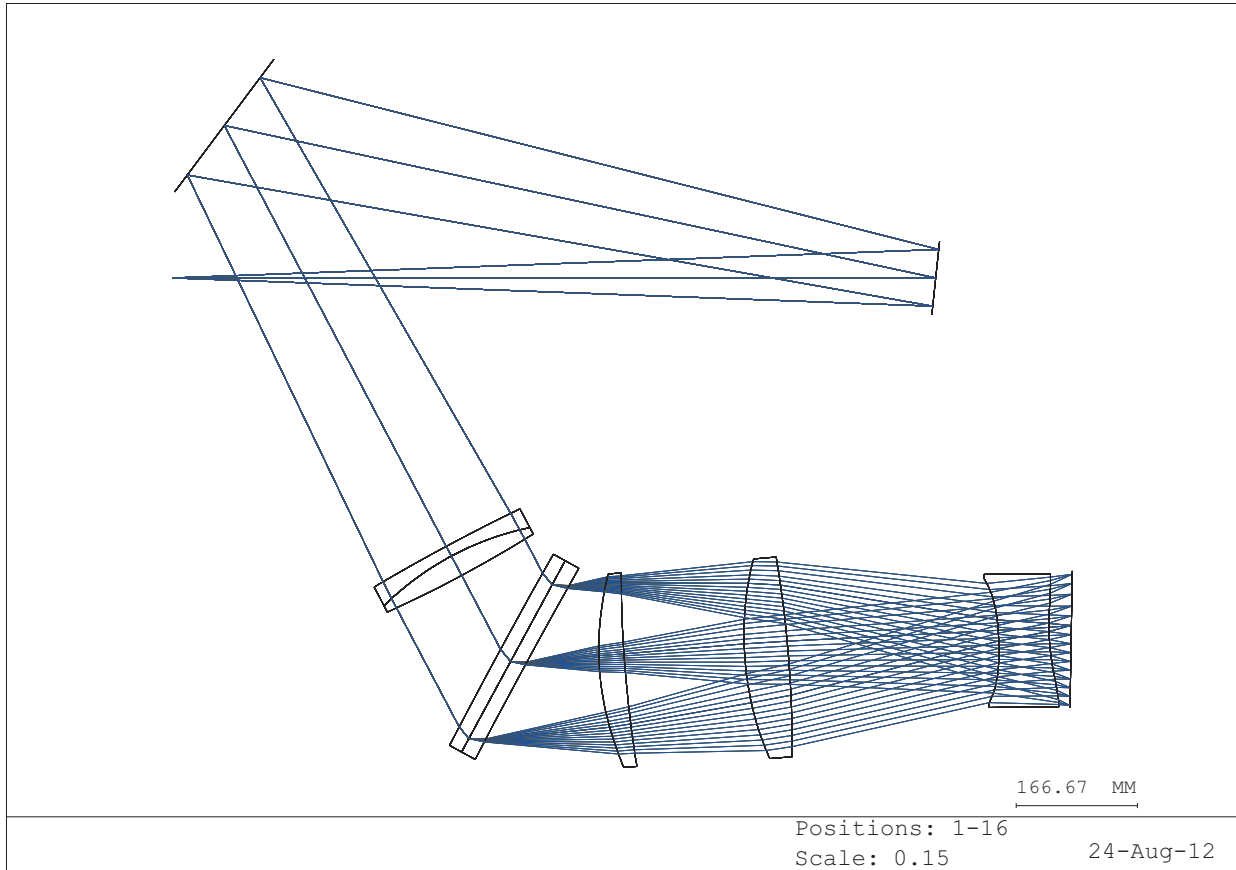


Figure 6.1.4.1. Spectrograph optical layout (side view)

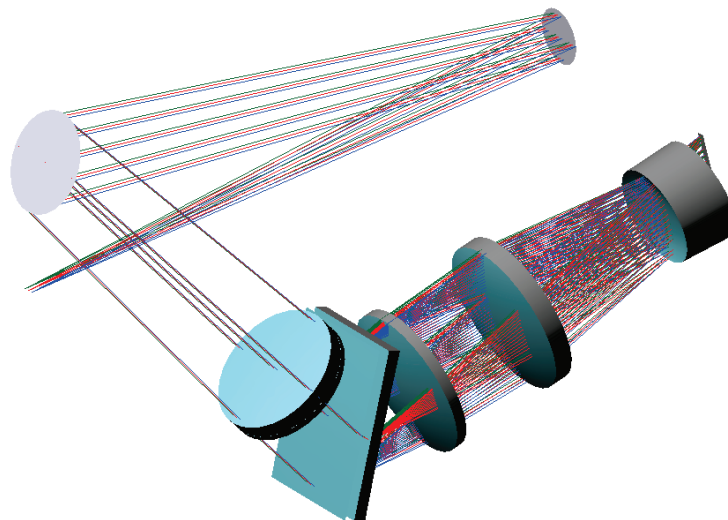


Figure 6.1.4.2. Spectrograph optical layout (3D View)

6.1.5 Image quality

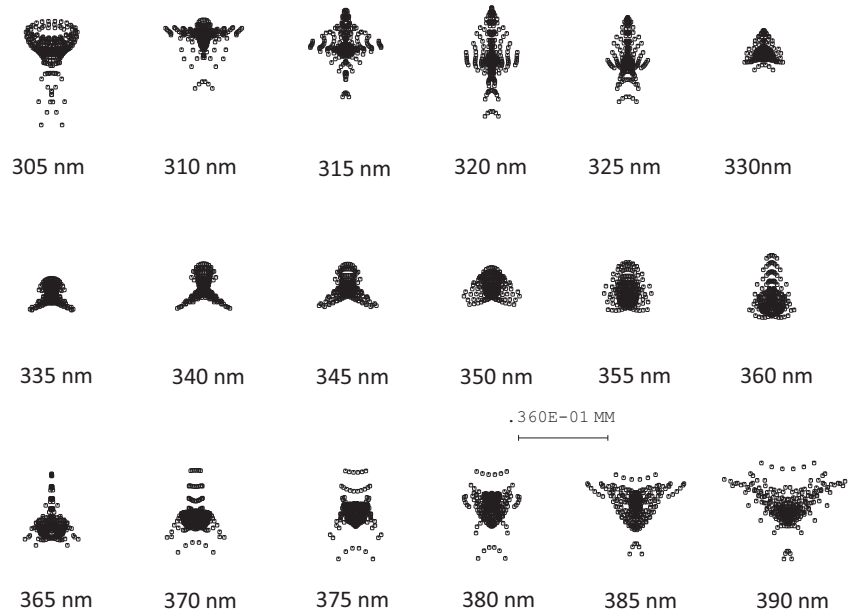


Figure 6.1.5.1. Spot diagrams

6.1.6 Throughput

Assuming an average loss of 0.75 % per surfaces the global throughput of the spectrograph should be around 91% for the central slice and 89 % for the others. (this value includes the VPH external surfaces but not the VPH itself)

6.2 Thermal behaviour

Assuming a structure of steel SS316, lens barrel and camera body made of Aluminium, the focus variation of the spectrograph with temperature is only $2 \mu\text{m}/^\circ\text{C}$.

A focus compensation system does not seem to be needed at least for a temperature change of 10°C . A larger difference (between summer and winter) can be compensated manually by using the cryostat adjustment screws.

6.3 Alternative design for $10 \mu\text{m}$ pixel detectors

This design can be adapted to $10 \mu\text{m}$ pixel detector. The camera is faster ($F/1.9$) but has the same number of components and image quality compatible to the pixel size. The fore optic, the collimator and the VPH are identical.

6.4 Mechanical concept

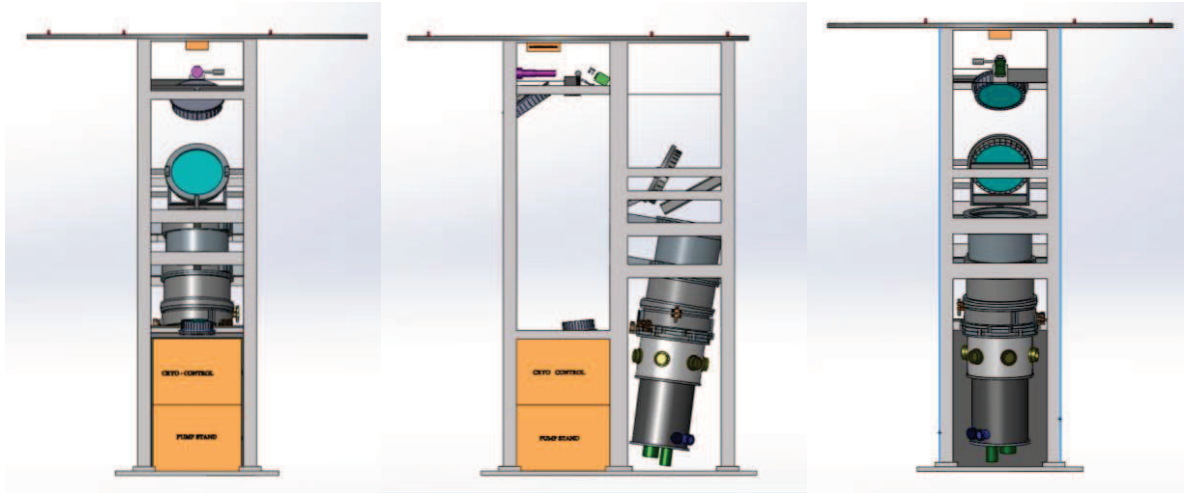


Figure 6.4.1. Left, front and right views of CUBES opto-mechanical concept

The main spectrograph is the largest part of the instrument. Their components: collimator mirrors and lens, VPH grating, camera and detector will be all mounted in supports bolted to the main frame. The support-frame bolting will position the components in place requiring careful tolerances in all frame bolting holes. Isolation plates will be used to separate the spectrograph from the pre-slit area to isolate light.

Collimator mirrors and lens will be assembled in finger-type cells bolted to their supports, which will be attached to the frame, as shown in Figure 6.4.2.

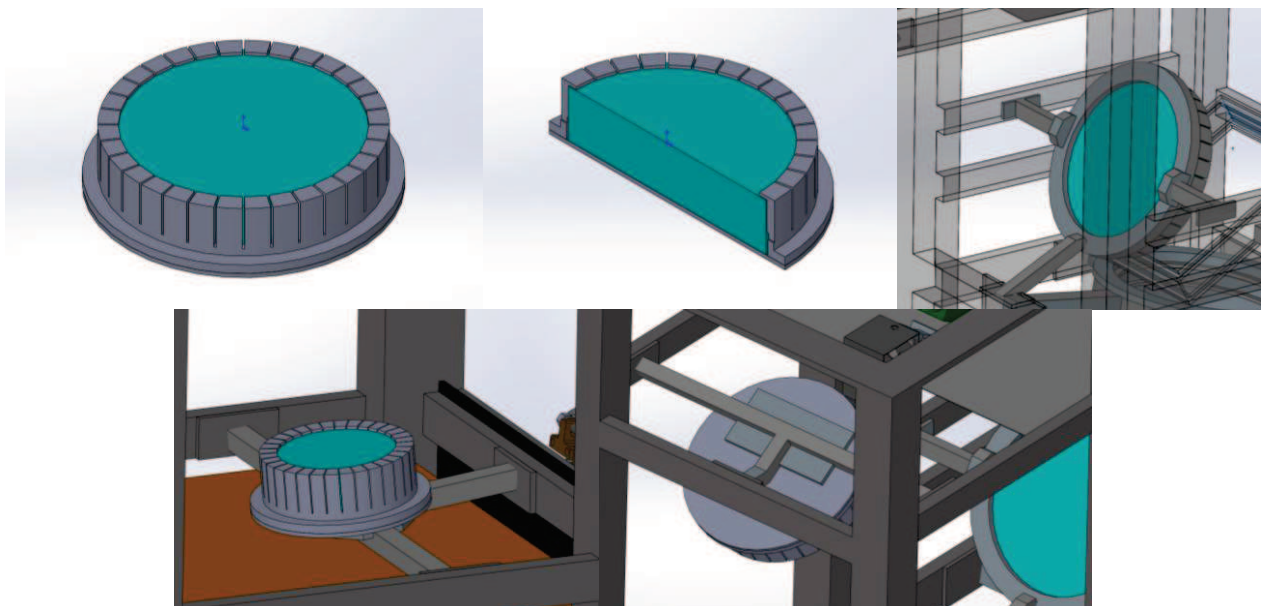


Figure 6.4.2. Cells and supports bolted to the frame

The two first camera lenses will come assembled and aligned in a tube from optics fabricator. The camera tube support will be bolted to the frame, as the previous components. The third camera lens will be the cryostat window, just before the detector, which will be inside cryostat. The alignment between camera and detector is very important, therefore, the cryostat will not be attached to the frame, but attached to the camera.

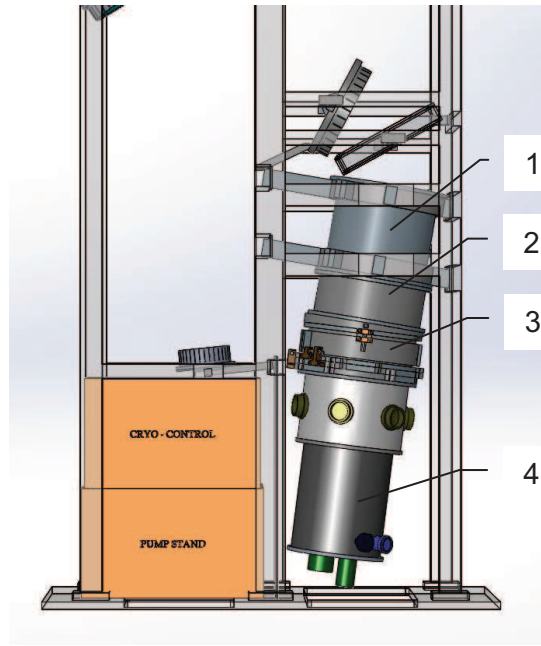


Figure 6.4.3. Camera (1), spacer (2), detector adjustment system (3), and cryostat (4)

Before the cryostat, there will be the cryostat adjustment system, which provides all six-degree of freedom adjustments, to ensure perfect alignment between camera and cryostat – Figure 6.4.4. Differential screws will move the plates guided by grooves to provide fine adjustments in linear x , y and z and angular z . A precision ring will provide angular x and y adjustments. At least four screws will lock each adjustment. This system will be designed and tested to keep aligned after OBEs. A spacer tube will be needed just to hold cryostat in position.

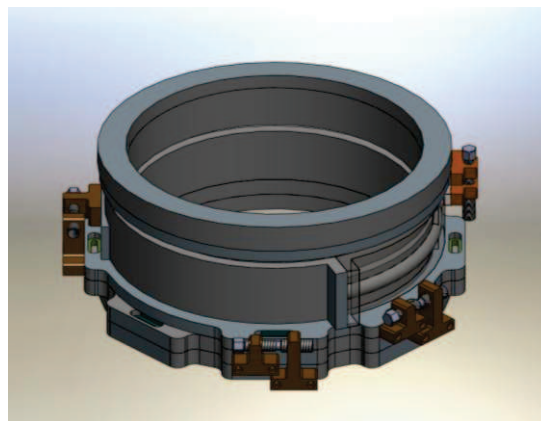


Figure 6.4.4. Detector adjustment system – 6 DOF adjust



The cryostat control and pump stand are positioned next to the cryostat, where the best instrument weight balance will be achieved, and an AISI316 plate is placed between them to protect NL2 spilling. However, if this configuration is not good, there are several alternatives. A very interesting one would be to position the electronic boxes behind the spectrograph, above the cryostat. However, more counterweights might be needed.

6.5 Mechanical design optimization with FEA

The next step is to optimize mechanical design. Work with VLT to understand the flange optimization possibilities and with electronic engineer to list cryostat, actuators and all controllers and electronic accessories weights and position possibilities to have a very realistic table of weights. The enclosure material will have to be defined too, since it has significant influence in the instrument weight. Once having these requirements, the frame structure will be optimized with FEA to have the best weight x stiffness x earthquake safety dimensions. (A preliminary FEA analysis has already been done, however more precise inputs are needed for better results).

The six long frame bars will be divided in two or three bolted bars (never welded) to ensure bolting precision and avoid warping.

7 Handling, maintenance and safety

7.1 Handling procedure

CUBES is designed to be either installed on the telescope or stored when not in use.

As described in section 4.1., on the top of the instrument there will be the interface flange, which will be bolted at the telescope Cassegrain rotator flange. At the bottom of the instrument, there will be a base which allows the instrument to be laid on the IHC, or on a base, or even on the floor. This base will have bolt holes to enable the instrument to be bolted on a base or on the floor when out of operation for safety reasons, especially in case of earthquake.

When not in operation, CUBES will stay bolted on the floor, or on a base if required, in a specific place TBD with Paranal designated for its purpose.

There will be an IHC for safe mounting and dismounting of the instrument from the UT Cassegrain rotator flange, and transportation of the instrument around the facilities. Due to CUBES stable base, it will be possible to use a commercial IHC, such as the existing VLT cart shown in the following pictures. That type of IHC allows instrument transportation and lifting, and is easy to handle and replace if necessary.



Commercial system similar or identical to CUBES IHC

For mounting the instrument on the UT, the IHC will be lifted and CUBES flange will be bolted onto the rotator flange. Repeatability will be ensured by CUBES dowel pins being precisely inserted in rotator flange precision holes [AD.3].

There will be hoisting points for instrument crane lifting when needed, especially when getting CUBES on and off the IHC from and to the floor/base.

No re-alignments will be needed. As mentioned in session 4.5, not all of the 48 rotator flange holes will be needed for CUBES flange bolting. Therefore, if it will make the mounting procedure faster and is desired, calculations can be made in order to minimize the number of bolts, or screws, as long as it will not compromise earthquake safety.

For UT power supply, fluid supplies and control systems, CUBES shall have a well-established procedure for (dis)connecting all cables and hoses. CUBES electronic and cooling requirements will be relatively uncomplicated making a “plug and play” design feasible [RD.6]. All connectors will be assembled and labelled on an interface plate (“Instrument Connection Point”), and cables will follow to the tripod (similar to the solution adopted by FORS) to the service connection point on the M1 cell, making connections as simpler and fast as possible.

7.2 Maintenance

As mentioned in section 4.1., using aluminium or Divinycell[®] plates, all cover plates will be mounted on an aluminium frame, and will be removable using fast lockers (as it was made in SIFS and is being made in STELES spectrographs). It will enable full access to all CUBES opto-mechanical and electronic components.

Connectors will be placed and labelled on cover surfaces. Electronic boxes and racks will be placed with labelled doors towards outside providing easy access.



Because the CUBES optical design is “clean” – without crossing or too close components – it will not be complicated to design its structure and cells in a way to provide access to (dis)assembling all CUBES components. Therefore, any component will be able to be removed from the instrument with no difficulties.

All off-the-shelf components will follow ESO mechanical standards [AD.6], such as, bolts/screws, washers, nuts, etc; or will be of easy access commercial models (Newport[®], Thorlabs[®], etc), such as stages, micrometres, etc.

The cryostat will be placed partly outside of the CUBES enclosure, allowing direct liquid nitrogen refilling, without needing to remove any cover plate, as it is being done with STELES.

7.3 Safety

In addition to following all ESO safety requirements [AD.1] [AD.5] and performing theoretical calculations and experimental laboratory tests to ensure earthquake safety [AD.4],[AD.5], special attention will be paid to nitrogen spilling from cryostat. The opto-mechanical design will ensure that liquid nitrogen from the cryostat will never spill on CUBES cables, for any UT orientation.

8 Manufacturing and procurement

All instruments developed by LNA have had their mechanical parts manufactured in Brazil. LNA has a mechanical shop well-equipped with precision machining centres, an EDM – Electrical Discharge Machine, metrology laboratory, etc. The instruments developed at LNA have been manufactured at LNA mechanical shop or at Brazilian contractors, depending on project demand or schedule.

However, it is of LNA interest to develop new international contractors to increase contractor availability and competition, and the CUBES project can be a good opportunity for that. Therefore, CUBES can be manufactured in Brazil at LNA or open for competition among Brazilian and European companies, as it will be more convenient for project quality and schedule.

As mentioned, all CUBES parts will follow standard materials and sizes, and manufacturing procedures [AD.6].

9 Assembly, integration and verification

Components usually are first assembled at manufacturer’s mechanical shop for fabrication verification. Being manufactured at LNA or contractor, all mechanical components will be (re)assembled at LNA integration laboratory and sent to LNA metrology laboratory for precision and tolerances verification.

To avoid major fabrication non-compliances in case of contracting the manufacturing, close communication between the LNA mechanical engineer responsible for the CUBES mechanical design and the contractor must be established during all fabrication process and at least one in site visit must be scheduled for quality verification during manufacturing process. LNA already



has a contractor manufacturing process verification, which includes material samples testing and quality certificate requirements, in site visits, in site assembly and verification, and remanufacturing of non-compliant parts. If a European is contracted, a similar process must be followed to ensure compliancy of parts with minimum delays arising from non-compliance.

If the LNA metrology test is not satisfied, major non-compliances will be returned to contractor for remanufacturing. Because this is very undesirable due to schedule delay, the verification process described in the upper paragraph aims to avoid remanufacturing returns. Minor compliances can be returned to contractor or adjusted at the LNA mechanical shop. The great advantages of the LNA shop adjustments are avoiding schedule delays, since the part does not have to “travel” to the contractor, and also better precision ensured, once LNA technicians always achieved required quality and precision.

Then, all opto-mechanical components will be tested to verify if the fabricated glasses (mirrors, lenses, grating) fit the fabricated mechanic cells. This is important because it is not rare that optic manufacturers send glasses that do not meet the required external dimensions, such as slight different lens diameters or mirror thicknesses, for example. Therefore, it is not rare to have to adjust the mechanics to the new optics dimensions.

CUBES full assembly and integration will happen at LNA integration laboratory, following ESO and project standards and requirements [AD.6] [RD.3] [RD.5] [RD.6] and writing compliance matrix.

ESO staff will come to LNA for instrument verification, alignment and test. CUBES will be sent to Paranal only after all details are verified and approved, in order to minimize work at VLT plant.

10 Cost, manpower and schedule

Cost manpower and schedule of the entire project are described at section 6 of CUBES Project Management Plan [RD.4].

The product breakdown consists of three main sub-assemblies: the pre-slit, the UV spectrograph, and the supporting frame.

- 0. CUBES SPECTROGRAPH
 - 1. PRE-SLIT
 - 1.1. Image slicer - IS
 - 1.1.1. IS unit
 - 1.1.2. IS adjustment
 - 1.1.3. IS support
 - 1.1.4. IS electronics
 - 1.2. Calibration unit - CU
 - 1.2.1. CU folding mirror
 - 1.2.1.1. CU FM base
 - 1.2.1.2. CU FM electronics
 - 1.2.1.3. CU FM support



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- 1.2.2. CU lamp
 - 1.2.2.1. CU lamp cell
 - 1.2.2.2. CU lamp support
 - 1.3. Slit viewer - SV
 - 1.3.1. SV cell
 - 1.3.2. SV electronics
 - 1.3.3. SV support
 - 1.4. ADC
 - 1.4.1. ADC cell 1
 - 1.4.2. ADC cell 2
 - 1.4.3. ADC electronics
 - 1.4.4. ADC support
 - 1.5. Shutter
 - 1.5.1. Shutter base
 - 1.5.2. Shutter electronics
 - 1.6. Pre-slit support
 - 2. UV SPECTROGRAPH
 - 2.1. Collimator assembly
 - 2.1.1. Collimator mirror 1 – CM1
 - 2.1.1.1. CM1 cell
 - 2.1.1.2. CM1 support
 - 2.1.2. Collimator mirror 2 – CM2
 - 2.1.2.1. CM2 cell
 - 2.1.2.2. CM2 support
 - 2.1.3. Collimator lens – CL
 - 2.1.3.1. CL cell
 - 2.1.3.2. CL support
 - 2.2. VPG grating assembly
 - 2.2.1. VPHG cell
 - 2.2.2. VPHG support
 - 2.3. Camera assembly
 - 2.3.1. Camera tube
 - 2.3.2. Spacer camera-detector
 - 2.4. Detector assembly
 - 2.4.1. Cryostat
 - 2.4.2. Detector adjustment
 - 2.4.3. Detector electronics
 - 3. STRUCTURE
 - 3.1. Frame
 - 3.1.1. Main frame
 - 3.1.2. Secondary frame



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- 3.2. Top flange
 - 3.3. Base
 - 3.4. Cover or enclosure
 - 4. Auxiliary devices
 - 4.1. Handling carriage



APPENDIX: Abbreviations and Acronyms

This document employs several abbreviations and acronyms to refer concisely to an item, after it has been introduced. The following list is aimed to help the reader in recalling the extended meaning of each short expression:

ADC	Atmospheric Dispersion Corrector
CMM	Coordinate Measuring Machine
CUBES	Cassegrain U-band Brazilian-ESO Spectrograph
ESO	European Southern Observatory
FEA	Finite Element Analysis
GUI	Graphical User Interface
HW	Hardware
ICS	Instrument Control Software
IHC	Instrument Handling Carriage
INS	Instrumentation Software Package
I/O	input/output
ISF	Instrument Summary File
IWS	Instrument Workstation
LNA	Laboratório Nacional de Astrofísica
LCC	LCU Common Software
LCU	Local Control Unit
LNA	Laboratório Nacional de Astrofísica
MLE	Maximum Likeli Earthquake
MS	Maintenance Software
N/A	Not Applicable
OBE	Operating Basis Earthquake
PAE	Preliminary Acceptance Europe
P2PP	Phase 2 Proposal Preparation
RAM	Random Access Memory
SIFS	SOAR Integral Field Spectrograph
SOAR	Southern Astrophysical Research Telescope
STELES	SOAR Telescope Echelle Spectrograph
TBC	To Be Clarified
TBD	To Be Defined
TCS	Telescope Control Software
TIM	Time Interface Module
TRS	Time Reference System
TSF	Template Signature File
VLT	Very Large Telescope
VPH	Volume Phase Holographic
WS	Workstation

End of document