MEGARA Science and instrument performance

Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

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Introduction

MEGARA (*Multi-Espectrógrafo en GTC de Alta Resolución para Astronomía*) is an optical fiber-fed spectrograph with two Integral-Field Units (IFU) and a set of robotic positioners for Multi-Object Spectroscopy (MOS) that will be installed at one of the Folded-Cassegrain foci of the GTC 10.4m telescope in La Palma.

MEGARA is being developed by a Consortium lead by Universidad Complutense de Madrid (UCM; Madrid, Spain). The co-partners are the Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE; Puebla, Mexico), Instituto de Astrofísica de Andalucía (IAA-CSIC; Granada, Spain) and Universidad Politécnica de Madrid (UPM; Madrid, Spain). The instrument is in the Detailed Design Phase, with a CDR planned for late 2013 and first light at GTC in 2016.

The use of state-of-the-art optical-fiber and VPH technology yields a total throughput unsurpassed by instruments working at these spectral resolutions.

The combination of this superb efficiency with its versatility (IFU and MOS capabilities in a wide range of spectral resolutions between R=6,000-21,500) along with the collecting area of GTC will make of MEGARA+GTC a unique facility for years to come.

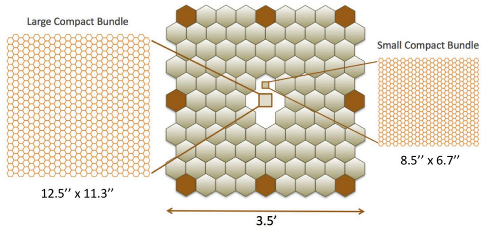
MEGARA will provide an unprecedented scientific return for astronomers within the GTC community. MEGARA data cubes shall have more than 600 spectra taken simultaneously from a given region of the sky. One of the main scientific goals of MEGARA is the study of the age, chemical abundances and kinematics of stellar populations in nearby galaxies. Other topics that drive the design of the MEGARA instrument include the study of low-mass stars and pre-Planetary Nebulae in the Milky Way, massive blue stars in the Local Group, high-redshift dwarf galaxies and proto-galaxy clusters, and the Cosmic Web from the analysis of redshifted UV line-emission from the Intergalactic Medium (IGM).

IFU bundles	12.5x11.3 arcsec^2 (LCB), 8.5x6.7 arcsec^2 (SCB)
MOS	92 objects in 3.5x3.5 arcmin^2 (+8 for sky subtraction)
Spaxel (fiber) size	0.62 arcsec (LCB & MOS), 0.42 (SCB)
Wavelength range	3650-10000 ÅÅ
Spectral resolution	LCB/MOS: R=6000-18700 SCB: R=7000-21500
# of spectrographs	1 (IFU or MOS) (650 simultaneous spectra)
GTC station	Folded-Cass [spectrograph @ Nasmyth]

MEGARA factsheet

MEGARA Main characteristics

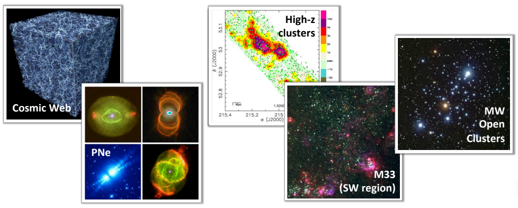
The instrument has two components, the **focal-plane unit** placed at one of the Folded-Cass foci that includes the two IFU bundles and the system of robotic positioners (see figure on the right) and the MEGARA **spectrograph**, which is located at one of the Nasmyth platforms of GTC (see below). The main characteristics of MEGARA in terms of FoV, spatial and spectral resolutions and wavelength range of operation are shown on the left.



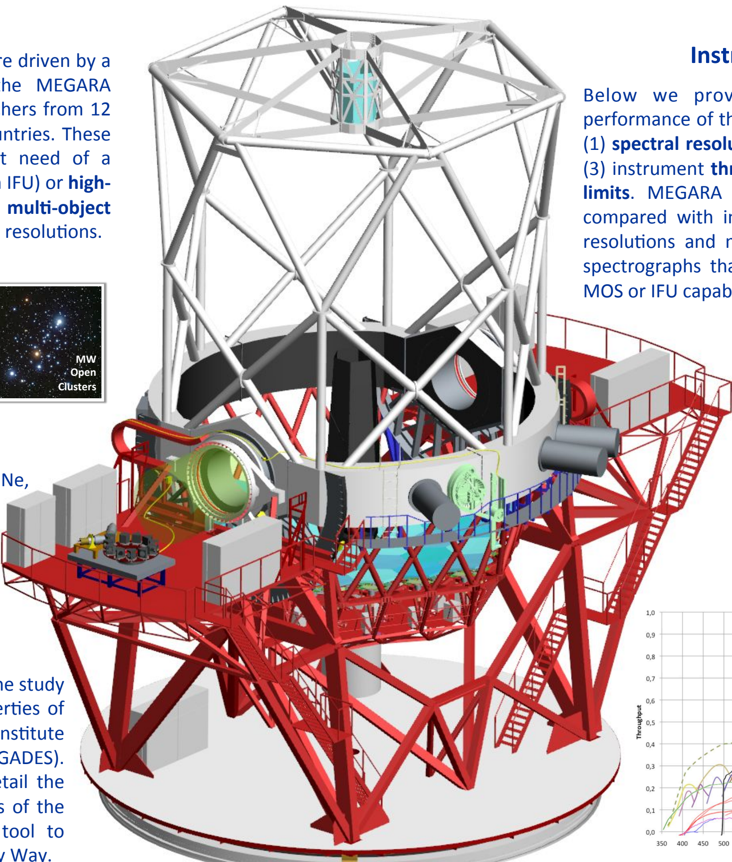
MEGARA focal-plane layout

Science

The characteristics of the MEGARA instrument are driven by a number of scientific projects designed by the MEGARA Science Team, which is composed by 54 researchers from 12 different institutions from the GTC partners' countries. These projects can be grouped in either those that need of a **contiguous field in spectroscopy** (by means of an IFU) or **high-density** (several objects per square arcmin) **multi-object spectroscopy** (MOS) both with intermediate-high resolutions.

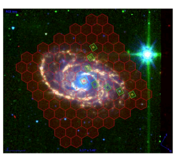


The former group includes the study of Galactic PNe, nearby galaxies (see below) and spectroscopy of the high-z IGM in UV resonant lines. As part of the latter we aim at analyzing the properties of low-mass stars in Galactic open clusters, stars in Local Group galaxies and high-z proto-clusters.



MEGADES

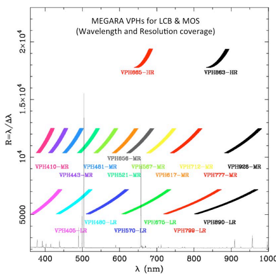
One of the main interests of our team focus on the study of the stellar populations and ionized-gas properties of nearby disk galaxies. Our efforts in this field constitute the *MEGARA Galaxy Disks Evolution Survey* (MEGADES). This survey wil explore with unprecedented detail the distribution of ages, abundances and kinematics of the stars in external galaxies, being the perfect tool to extend ESA Gaia's future results beyond the Milky Way.



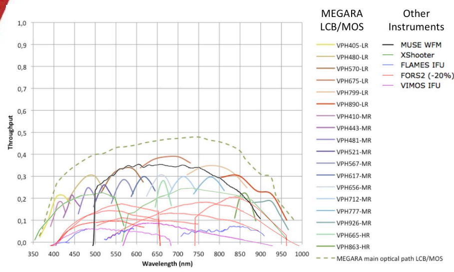
One of the MEGADES proposed observations

Instrument performance

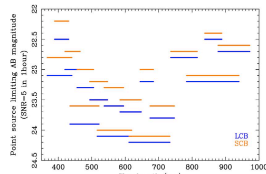
Below we provide a graphical summary of the performance of the MEGARA instrument with regards to (1) **spectral resolution** ($\lambda/\Delta\lambda$), (2) **wavelength coverage**, (3) instrument **throughput** & (4) **point source detection limits**. MEGARA provides a 3x increase in efficiency compared with instruments working a similar spectral resolutions and matches that of other state-of-the-art spectrographs that work at lower-R and lack of either MOS or IFU capabilities.



(1) Spectral resolution & (2) λ-coverage



(3) Instrument throughput ↑ & (4) PS detection limits ↓



Summary

MEGARA is an intermediate-resolution optical IFU & MOS for GTC that will be available to the community in 2016 thanks to combined efforts of the MEGARA Consortium and GRANTECAN. The unprecedented efficiency of MEGARA at these spectral resolutions combined with the collecting area of GTC will allow pursuing research goals that were inaccessible to date, such as the detailed (spectrophotometric and chemical) analysis of stellar populations in nearby galaxies and the study of the high-redshift IGM.

All the MEGARA posters presented at this meeting available at …

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CONSORTIUM

Participating companies

MEGARA Fiber Bundles

Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

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Abstract

MEGARA is the future optical Integral Field Unit (IFU) and Multi-Object Spectrograph (MOS) for the 10.4-m Gran Telescopio CANARIAS (GTC). This poster summarizes the design of the MEGARA Fiber Bundles, from the GTC focal plane, to the entrance at the spectrograph pseudo-slits. MEGARA passed the Optics Detailed Design Review in May 2013 organized by GRANTECAN. The poster summarizes also the prototypes that are being tested at laboratory and the strategy of the installation at the GTC.

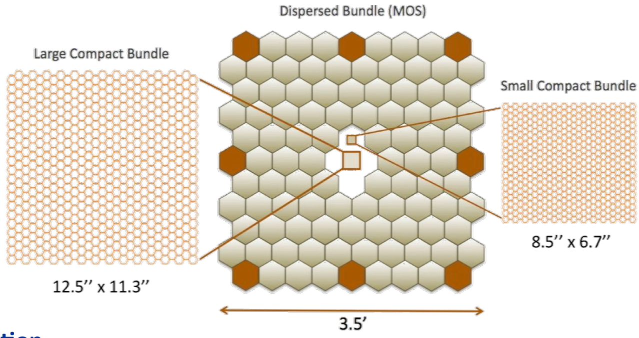
MEGARA modes: Fibers arrangement at the Folded Cassegrain Focal Station

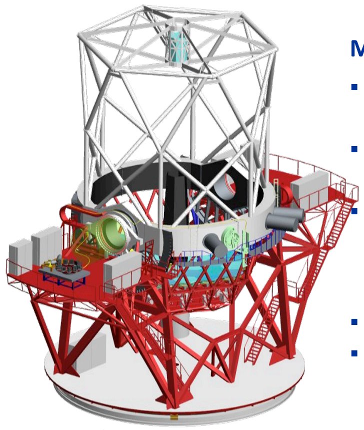
MEGARA shall provide three different modes, which corresponds with the three fiber bundles available: the Large Compact Bundle IFU (**LCB**), the Small Compact Bundle IFU (**SCB**) and the Multi-Object Spectrograph (**MOS**) mode (also called the Dispersed mode).

The **LCB** is composed by **567 fibers of 100 µm** core displayed on a square area of about **12.5'' x 11.3''** near the optical axis of the instrument **plus 8 positioner robots** (orange hexagons in the figure) located in the outer edge of the instrument FOV used for measuring the sky background simultaneously with the observations with the LCB.

The **SCB** is composed by **500 fibers of 70 µm** core distributed in a square image area of **8.5'' x 6.7''**, whose center is offset approximately 19' from the center of the LCB.

The fibers belonging to **MOS** mode are in total **644 fibers of 100 µm** core and can be positioned anywhere in the central **3.5' x 3.5'** around the two IFU bundles thanks to the positioner robots, which support a **minibundle of 7 fibers each (1.6'' in diameter)**.

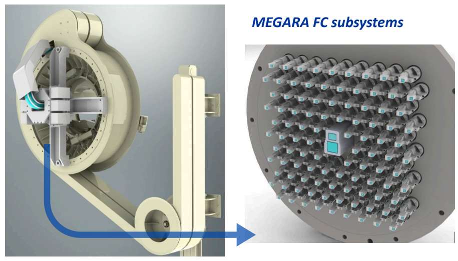




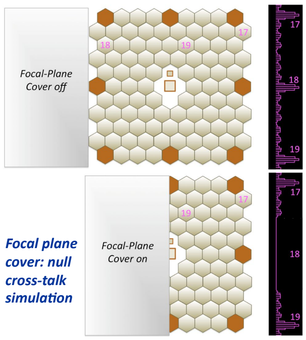
Estimated fiber length is 32 m

MEGARA at the Folded Cassegrain Focal Station

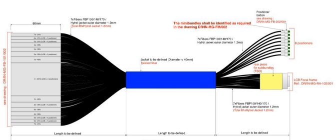
- The **field lens** shall correct the lack of telecentricity of the GTC focal station providing a field curvature below 0.1'' in the whole FOV.
- The **focal plane cover** shall allow to occult part of the fibers (LCB and MOS) for performing null-cross-talk observations.
- The 2D refractive **microlens arrays** shall couple the science light at the telescope focal plane into the fibers, defining the FOV and adapting F# from f/17 to f/3 to minimize FRD. The spaxel size shall be fixed to 0.62'' for LCB and MOS and 0.42'' for SCB.
- **Fibers cables** are FBP 100/140/170 and FBP 70/140/170 from Polymicro.
- The **Fiber MOS** shall consist of 100 robotic positioners (8 of them for LCB sky subtraction). Each fiber minibundle patrols a circular area of diameter Ø23.21 mm thanks to the two rotations provided by the positioner robot.
- Finally, the fibers of each bundle shall be arranged in a row at the **pseudo-slit**, which shall be divided in boxes to simulate the focal plane curvature at the spectrograph entrance (ROC 1075 mm, size 119 mm).



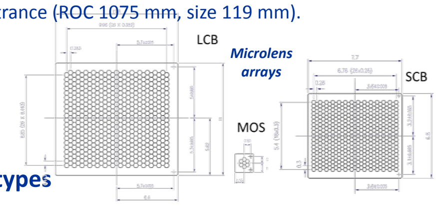
MEGARA FC subsystems



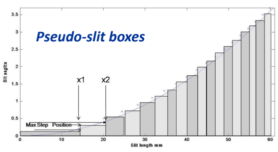
Focal plane cover: null cross-talk simulation



LCB fiber bundle schematic from the focal plane to the pseudo-slit



Microlens arrays

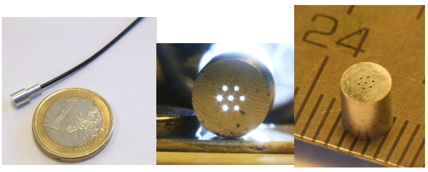


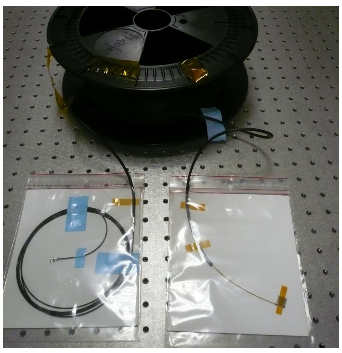
Pseudo-slit boxes

Fiber MOS and Fiber bundles prototypes

Two prototypes have been manufactured during the preliminary design: the Fiber bundle prototype and the Fiber MOS positioner prototype. In both prototypes the fiber link is 40 m to simulate the most pessimistic estimated length (at PDR) at GTC (between Folded Cassegrain focus and the Spectrograph location).

The Fiber Bundle prototype includes a minibundle of 7 fibers. This prototype ends on one side (the Folded Cassegrain Focal Station end) by a standalone positioner button (without the positioner) over which the microlens array shall be mounted and, on the other side (the spectrograph position), by a replica of a pseudo slit box.

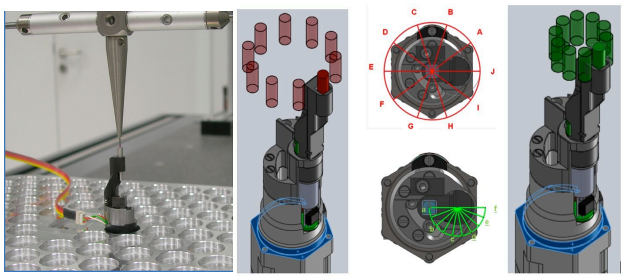




This prototype will be used to carry out several optical tests, as FDR measurements, in order to check the real optical behaviour of the entier fiber system (fibers and microlenses). These tests will be performed at LICA laboratory at the Complutense University (LICA-UCM). We have also proposed to integrate this prototype at GTC in order to repeat these measurements on the GTC when F/C rotator will be installed.

The Fiber MOS positioner prototype includes a complete Fiber MOS positioner and the 7-fiber minibundle attached to the positioner.. The positioner was designed and manufactured at AVS and then was sent to SEDI, where the fiber minibundle was integrated.

Geometrical tests have been carried out to determine the behavior of both rotations (R1 and R2) concluding that the positioner prototype achieves the requirements and provides high repeatability and high positioning accuracy.



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CONSORTIUM

Participating companies

MEGARA Multi-Object Spectroscopy robotic positioners

Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

Arrillaga, X.[1], Larman, A[1], Ocerin, E.[1], Carrera M.A.[1], Gil de Paz, A.[2], Gallego, J.[2], Carrasco E.[3], Sánchez, F.M.[4], Vílchez, J.[5], Iglesias, J.[5], García-Vargas, M.L.[6], MEGARA Science and Instrument Teams

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Abstract

MEGARA is the future optical Integral Field Unit (IFU) and Multi-Object Spectrograph (MOS) for the 10.4-m Gran Telescopio CANARIAS (GTC). This poster summarizes the design of the MEGARA Fiber MOS and the positioner robot prototypes built and tested. The fiber positioner of the MOS are considered a critical part of the instrument due to the high positioning accuracy required and its micro mechanics. Therefore, a fiber positioner prototype has been manufactured for the PDR stage of the project. Its reliability and performance have been tested and manufacturing process optimized for the mass production of the positioner.

Fibers arrangement at the Folded Cassegrain Focal Station

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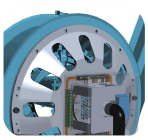
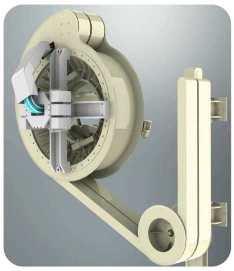
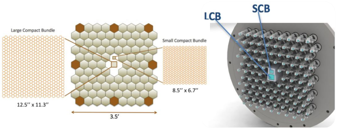
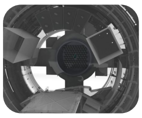
IFU bundles	12.5x11.3 arcsec^2 (LCB), 8.5x6.7 arcsec^2 (SCB)
MOS	100 objects in 3.5x3.5 arcmin^2
Spaxel (fiber) size	0.62 arcsec (LCB & MOS), 0.42 (SCB)
Wavelength range	3650-10000 ÅÅ
Spectral resolution	LCB/MOS: R=6000-18700 SCB: R=7000-21500
# of spectrographs	1 (IFU or MOS) (650 simultaneous spectra)
GTC station	Folded-Cass [spectrograph @ Nasmyth]

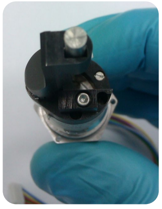
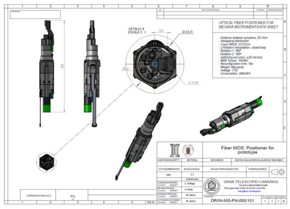






MEGARA fiber MOS positioner prototype

The positioner system consists of 100 identical positioners distributed on the focal station. 3.5 x 3.5 arcmin2 (on sky) area around the two IFU bundles. The technological challenge associated to the development of the positioner system lies on the reduced size and precision required for positioning the fibers with the fiber positioners.

The Fiber MOS positioner prototype includes a complete Fiber MOS positioner and the 7-fiber minibundle attached to the positioner.

Positioner prototype datasheet

Fiber positioner at natural scale 1:1

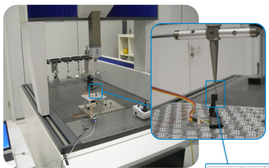
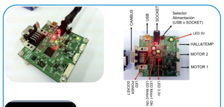
Positioner performance tests

Geometrical tests have been carried out to determine the behavior of both rotations (R1 and R2) concluding that the positioner prototype achieves the requirements and provides high repeatability and high positioning accuracy. The tests carried out at AVS included Probe force tests, Geometrical tests, Zero Protocol tests, Step uniformity and resolution, Backlash, Target repeatability and Lifetime test.

To perform all mentioned tests, a specific set up has been developed. Such set up consists of a focal plate used as a jig in which the positioner is fixed as it would be in the final focal plate, a CMM (Coordinate Measuring Machine) to get the positioning of the reference button of the positioner and a basic electronics card with specific software to easily govern the positioner movements from a PC.

A reference button has been manufactured and placed in the positioner arm in order to have a part with reference surfaces to take reliable measurements. The used reference button dimensions are Ø3mm ± 2.5µm.

MEASURING CONCEPT: The probe takes the position of the reference button by measuring 6 points equally distributed around its diameter. These 6 measurements allow positioning the center of the button in the space. Another measurement is made with the probe on the top surface of the button in order to measure its height. These 7 points are translated into geometrical points for its further data comparison.

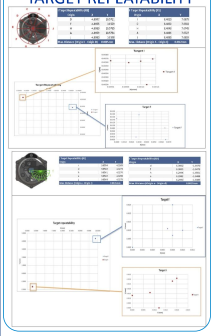
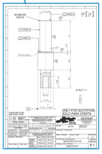



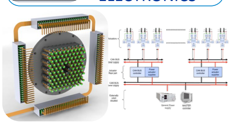
CAN BUS speed	125Kbps
Motor 1 speed	250step/sec
Motor 2 speed	500 step/sec
Motor 1 mode	Full step
Motor 2 mode	Full step
Rsense Motor 1	1 ohm , Max current 0.2A
Rsense Motor 2	1 ohm , Max current 0.2A
Motor 1 rotation sense	Clockwise
Motor 2 rotation sense	Counter clockwise

ELECTRONICS

SOFTWARE

TARGET REPEATABILITY

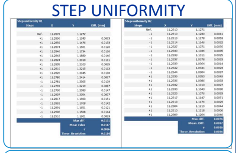


Zero protocol R1					
Measurement	X	Y	Z	Diff. (Ref. point)	Diff. (Meas. 1)
1	11.2852	1.1583		0.0032	0.0000
2	11.2877	1.1487		0.0072	0.0099
3	11.2865	1.1600		0.0042	0.0021
4	11.2885	1.1489		0.0071	0.0100
5	11.2867	1.1613		0.0054	0.0034
6	11.2892	1.1583		0.0030	0.0040
Ref. Point:	11.2873	1.1559	σ=	0.0017	0.0038
			Mean value=	0.0050	0.0049
			Max value=	0.0072	0.0100

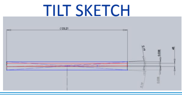
Zero protocol R2					
Measurement	X	Y	Z	Diff. (Ref. point)	Diff. (Meas. 1)
1	11.2903	1.1318	0.0000	0.0025	0.0000
2	11.2909	1.1269	0.0000	0.0025	0.0049
3	11.2905	1.1318	0.0000	0.0025	0.0002
4	11.2909	1.1271	0.0000	0.0023	0.0047
5	11.2906	1.1317	0.0000	0.0024	0.0003
6	11.2911	1.1268	0.0000	0.0026	0.0051
Pto. Referen	11.2907	1.1294	σ=	0.0001	0.0024
			Mean value=	0.0024	0.0025
			Max value=	0.0026	0.0051

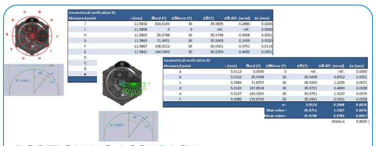
ZERO PROTOCOL

STEP UNIFORMITY



TILT SKETCH





POSITIONING ACCURACY

Backlash R1			
Steps	X	Y	Diff. (mm)
	-1.4056	11.5007	
+1	-1.3950	11.5008	0.0106
+1	-1.3860	11.5012	0.0090
-1	-1.3987	11.4998	**0.0128**
+5	-1.3641	11.5038	0.0348
-1	-1.3739	11.5027	**0.0099**
-1	-1.3854	11.5006	0.0117
+1	-1.3783	11.5047	**0.0082**

Backlash R2			
Steps	X	Y	Diff. (mm)
	5.0541	6.1475	
+1	5.0526	6.1548	0.0075
+1	5.0524	6.158	0.0032
-1	5.0534	6.1505	**0.0076**
+5	5.0501	6.1713	0.0211
-1	5.0500	6.171	**0.0003**
-1	5.0513	6.1636	0.0075
+1	5.0506	6.1679	**0.0044**

BACKLASH

CONCLUSIONS /TESTS SUMMARY

GEOMETRICAL TESTS

R1 RADIUS value :23.176mm (23.21mm nominal) → OK (Position manually set. Not reached max. R1)
Flatness R1 : 3 µm → OK
R2 RADIUS value :5.810mm (5.8025mm nominal) → Larger than theoretical: OK
Flatness R2 : 4 µm
- Parallelism R1/R2 plane: 36µmm → OK
- Parallelism R1/ reference surface: 29 µm → OK
- Parallelism R2/ reference surface: 23 µm → OK
- Eccentricity R1/R2 center: 9 µm → OK
- MAX POSITIONER TILT required 3mrad (0.19º) → OK Positioner points are between -5/+43

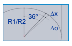
Positioner geometry Z MAX Defocus error ±200 µm → **fulfilled OK**

POSITIONING ACCURACY

R1 Positioning accuracy: Δx with respect to the absolute positioning (outer Ø worst case)
- Max value: 11.4 µm
- Mean value: 5.4 µm
- σ(standard deviation):4 µm

R2 Positioning accuracy Δx with respect to the absolute positioning (outer Ø worst case)
- Max value: 7.6 µm
- Mean value: 5.7 µm
- σ(standard deviation):2.6 µm

±25 µm X/Y positioning accuracy → **fulfilled OK**



ZERO PROTOCOL TESTS

High repeatability → **OK**

R1 Difference with respect to the 1st measurement:
- Max value: 10 µm
- Mean value: 4.9 µm
- σ(standard deviation):3.8 µm

R2 Difference with respect to the 1st measurement:
- Max value: 5.1 µm
- Mean value: 2.5 µm
- σ(standard deviation): 2.4 µm

STEP UNIFORMITY (RESOLUTION)

R1 Difference with respect to the theoretical step (Δx= 11.4 µm):
- Max value: 15.1 µm
- Mean value: 7.3 µm
- σ(standard deviation): 11.7 µm

R2 Difference with respect to the theoretical step (Δx= 3.6 µm):
- Max value: 7.6 µm
- Mean value: 0.6 µm
- σ(standard deviation): 3.7 µm

BACKLASH → Negligible for both motions

TARGET REPEATABILITY
- R1 Max difference with 1st measurement: 16.2 µm
- R2 Max difference with 1st measurement: 2.7 µm

LIFETIME TESTS(10 DAYS of continous movements)
- Measured difference: 22 µm
- No significant mechanics wear detected

COATING TESTS

The mechanical behavior and the coating length have also been validated during the prototype testing stage. The cable length (300mm) and torsion range were initially discussed and validated by the fiber manufacturer.

Summary

The results summarized show that the positioner **requirements are fulfilled**. The manufactured prototype has been a good mock up in order to identify aspects to be taken into account for series manufacturing verification phase.

High repeatability with high resolution offers high positioning accuracy

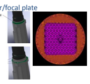
MEGARA fiber MOS FEM & Thermal analysis

FEM and thermal analysis of the different subsystems at the focal plane have been performed to asses the design and selected materials.

Boundary conditions → Simulate Interface and fitting positioner/focal plate

Materials: F114, AISI 420 and Al 7075

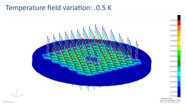
Load Cases:
- Heat emitted by 2 motors.
  - M1:0.433 W
  - M2: 0.1856W
- Gravity perpendicular to positioner axis (considered as worst case)
- Reconfiguration time: 15s of transient athermal analysis of emitted heat
- Displacement constraint: x, y and z displacements constrained in the interface between focal plate and its supporting structure.
- Increment of environmental temperature: (Day/night temperature change)
  - ΔT21: Max T=292K; Min T=271K
  - ΔT10: Max T=286.5K; Min T=276.5K   Reference T=281.5K
  - ΔT5: Max T=284K; Min T=279K
- FEM Model: Solid and bar elements



Thermal results:

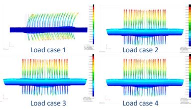
Heat emitted→Heat conduction and nodal sources at BC

Temperature field variation: .0.5 K

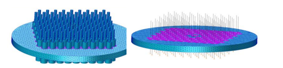
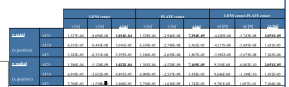


Structural results:

Displacements calculated for 4 different load cases:
1. Motors heat + gravity + displ. Constraint → Max. disp.: 0.26µm
2. Motors heat + gravity + displ. Constraint + ΔT21→ Max. disp.: 25.9µm
3. Motors heat + gravity + displ. Constraint + ΔT10→ Max. disp.: 12.4µm
4. Motors heat + gravity + displ. Constraint + ΔT5→ Max. disp.: 6.34µm



Conclusions:
- Parameter inducing larger displacements: Environmental temperature change.
- Gravity load effect and emitted heat effect very mild in comparison
- Effect of interface between focal plate and adapter: The bigger the interface surface, the milder the Max. displacement value

FOLDED CASSEGRAIN ADAPTER

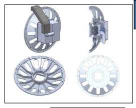
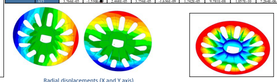
CAD Model:

Adapter with different concentrated masses to represent the lens, the plate with actuators, electronics and rest of components.

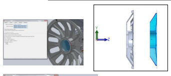
Each mass represents the real mass value located at the corresponding gravity center.

FEM Model: Shell elements of type quad 4

Materials: St52 proposed and compared with Al 7075

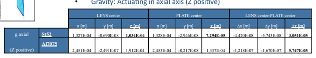
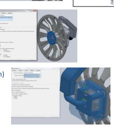



Load Cases:
- Gravity: Axial gravity (Z positive direction) and radial gravity (X positive direction)
- Exterior increment of temperature:
  - ΔT21: Max T=292K; Min T=271K
  - ΔT10: Max T=286.5K; Min T=276.5K   Reference T=283K
  - ΔT5: Max T=284K; Min T=279K
- Concentrated mass:
  - Lens: 8.58398Kg, CoG(x=0, y=0, z=64.18mm)
  - Plate and actuators: 17.75626Kg, CoG(x=0.7mm, y=0.08mm, z=-1.64mm)
  - Electronics: 47.37499Kg, CoG(x=49.29mm, y=72.98mm, z=-187.83mm)



Material justification:

Displacements comparison for St52 and AL7075.
- Temperature increment: 21 degrees
- Gravity: Actuating in axial axis (Z positive)

Conclusions:
- St 52 material derives in better results due to its lower coefficient of thermal expansion
- Gravity effects: Units of microns
- Temperature response
  - Field lens and focal plate: Position tolerances ±100µm with respect to the interface
  - Focal plate absolute displacement: +73µm
  - Positioner displacements: +25µm (worst case)   Δ100µm → Admissible √
  - Field lens absolute displacements: +103 µm and -4 µm→ 107 µm → Admissible √
  - Relative displacement between focal plate center and field lens center (conservative): 30 µm +4 µm +25 µm = 59µm

THESE RESULTS VALIDATE THE PRELIMINARY DESIGN OF THE FOCAL PLATE / ADAPTER

MEGARA fiber MOS positioner for mass production

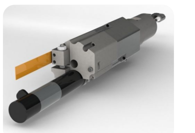
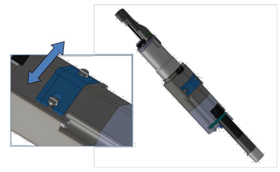
The design changes performed to the Fiber MOS positioner prototype presented at the PDR are related to the adaption of the design to solve maintenance issues and the addition of improvements taking into account the handling, manufacturing and adjustment of the mass production series of the final positioners.

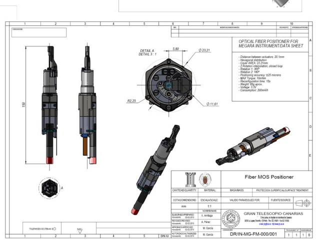
The main changes are listed bellow:

Increase of the central fiber path from Ø1.3mm to Ø3.65mm: This larger central path allows an easy fiber system handling for the assembly and disassembly phase improving the maintenance of the positioner. The fiber unit will be assembled from the rear part of the positioner.

Adjustable hard stops for R1 and R2: The mechanical hard stops limiting R1 and R2 have been updated and the new design allows adjusting both hard stops at each positioner. With these adjustable hard stops, the zeros of both rotations can be adjusted identically for each positioner. All positioners are interchangeable.

R1 preloading system simplicity: Which allows using lower torque motors due to the efficiency enhancement of the positioner.



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Participating companies

MEGARA Optics Design

Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

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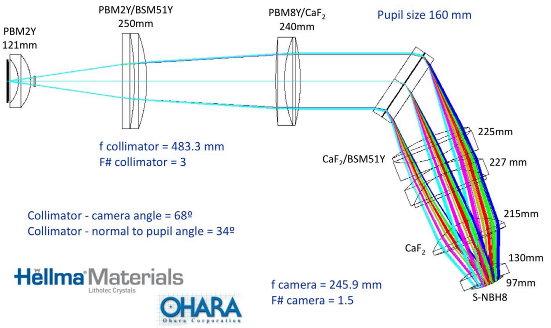
Abstract

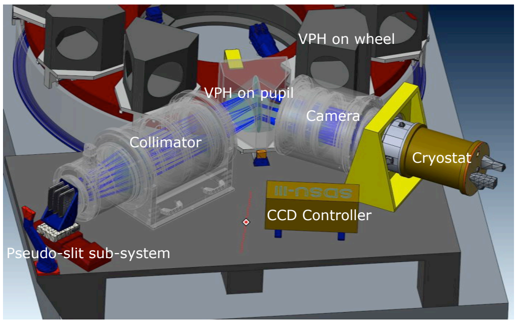
We summarizes the main aspects of the optics detailed design for MEGARA spectrograph. The spectrograph is a fully refractive system composed by a Pseudo-slit, where the fibers are placed like in a long slit and that it is mounted on a focusing mechanism; the Collimator, 1 singlet and two doublets; a set of 18 large and high-performance VPH-gratings at the 160mm Ø pupil position (11 of them being mounted simultaneously in the instrument); the Camera (two doublets and 3 singlets), with the last lens being the cryostat window; and the 4k x 4k Detector. The shutter and the order sorting filters, placed inside the collimator barrel, complete the optical system. MEGARA passed the Optics Detailed Design Review in May 2013, some of the blanks have been already ordered, and the Optics manufacturing phase has already started at INAOE and CIO in México.

Main optics: Collimator and Camera

The Optical CDR package has included all the analyses needed to proceed with MEGARA Optics fabrication. This includes the thermal analysis, ghost analysis, complete image quality evaluation; image stability, image quality and throughput error budgets and the production of the complete set of manufacturing drawings.



Optical Layout of MEGARA spectrograph



Collimator Optical Elements

Element	Material	R1 (mm)	R2 (mm)	Central Thick. (mm)	Blank ∅ (mm)
COLL-S1	PBM2Y	-91.0 (x)	-113.3	35.0	160.0
COLL-D2	PBM2Y	flat	-728.1	35.0	277.0
COLL-D3	BSM51Y	- 728.1	-398.8	35.0	277.0
COLL-D4	PBM8Y	+1259.9	+344.5	25.0	265.0
COLL-D5	CaF2	+344.5	-542.5	45.0	255.0

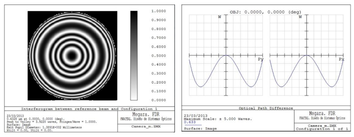
Camera Optical Elements

Element	Material	R1 (mm)	R2 (mm)	Central Thick. (mm)	Blank ∅ (mm)
CAM D-1	CaF2	+435.9	-231.7	60.0	241.0
CAM D-2	BSM51Y	-231.7	Flat	25.0	245.0
CAM D-3	BAL15Y	+269.2	+145.1	25.0	245.0
CAM D-4	CaF2	+145.1	Flat	60.0	225.0
CAM S-5	CaF2	+156	-1143	62.0	225.0
CAM S-6	S-LAH55V	+176.4	365.8	40.0	145.0
CAM S-7	S-NBH8	-162.5	219.5	30.0	115.0

Image Quality Error Budget Summary

ITEM	Σ (μm) MR-B	σ (μm LR-Z	σ (μm) LR-U	Comment
Nominal performance	**8.50**	**9.81***	**8.20***	Nominal design in one representative mode
Collimator fabrication (lens thickness, wedge, surface irregularity, curvature)	**2.26**	**2.03**	**1.86**	200 (PDR) and 1000 Monte Carlo runs in normal distribution, respectively.
Camera fabrication (lens thickness, wedge, surface irregularity, curvature)	**2.96**	**4.79**	**4.74**	200 (PDR) and 1000 Monte Carlo runs in normal distribution, respectively.
Collimator AIV (axial and lateral decentration, tilts).	**1.95**	**2.08**	**1.99**	200 (PDR) and 1000 Monte Carlo runs in normal distribution, respectively.
Camera AIV (axial and lateral decentration, tilts).	**3.10**	**3.98**	**3.11**	200 (PDR) and 1000 Monte Carlo runs in normal distribution, respectively.
Uncompensated	**3.60**	**2.18**	**3.02**	200 (PDR) and 1000 Monte Carlo runs in normal distribution, respectively.
Thermal	**2.10**	**2.10**	**2.10**	Worst case. Analytical model
Glass homogeneity	**3.60**	**3.60**	**3.60**	Analytical model
Pupil elements	**5.00**	**5.00**	**5.00**	Allocated Estimation
Detector Flatness	**1.32**	**1.32**	**1.32**	Considering flatness ± 5 μm
Pseudo-slit curvature	**3.20**	**3.20**	**3.20**	
Atmospheric Effect	**0.14**	**0.14**	**0.14**	Performance Difference between 0.77 and 1at
TOTAL (rms squared)	**12.92**	**14.23**	**13.05**	**Target value: 19.22**

Predicted values for the different Image Quality EB contributors at the time of optical CDR.



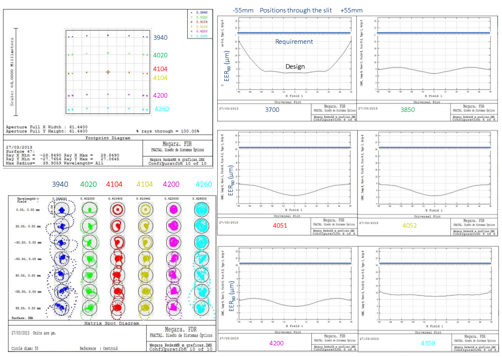
All the interferograms for final tests at the level of the collimator and camera have been simulated. The figure shows a nominal interferogram for central field (0º AOI), tilt/piston removed. The lower figure is the OPD plot.

Pupil Elements

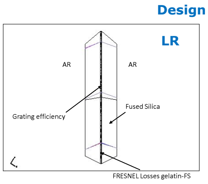
MEGARA gratings: scientific requirements

VPH Name	Setup	R_{FWHM}	λ_1-λ_2 (Å)	Λc (Å)	Δλ (@ λc), Å	Δv km/s	lin res Å/pix
VPH405-LR	LR-U	6028	3653 – 4386	4051	0.672	50	0.17
VPH480-LR	LR-B	6059	4332 – 5196	4800	0.792	49	0.20
VPH570-LR	LR-V	6080	5143 – 6164	5695	0.937	49	0.23
VPH675-LR	LR-R	6099	6094 – 7300	6747	1.106	49	0.28
VPH799-LR	LR-I	6110	7220 – 8646	7991	1.308	49	0.33
VPH890-LR	LR-Z	6117	8043 – 9630	8900	1.455	49	0.36
VPH410-MR	MR-U	12602	3917 – 4277	4104	0.326	24	0.08
VPH443-MR	MR-UB	12370	4225 – 4621	4431	0.358	24	0.09
VPH481-MR	MR-B	12178	4586 – 5024	4814	0.395	25	0.10
VPH521-MR	MR-G	12035	4963 – 5443	5213	0.433	25	0.11
VPH567-MR	MR-V	11916	5393 – 5919	5667	0.476	25	0.11
VPH617-MR	MR-VR	11825	5869 – 6447	6170	0.522	25	0.13
VPH656-MR	MR-R	11768	6241 – 6859	6563	0.558	25	0.14
VPH712-MR	MR-RI	11707	6764 – 7437	7115	0.608	26	0.15
VPH777-MR	MR-I	11654	7382 – 8120	7767	0.666	26	0.17
VPH926-MR	MR-Z	11638	8800 – 9686	9262	0.796	26	0.20
VPH665-HR	HR-R	18700	6445 – 6837	6646	0.355	16	0.09
VPH863-HR	HR-I	18701	8372 - 8882	8634	0.462	16	0.12

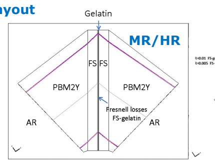
Image Quality Analysis



Design Layout

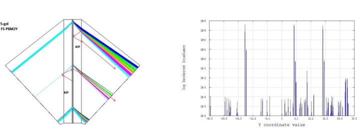


Model of R=5,500 type grating. The VPH hologram is sandwiched between two flat Fused Silica windows. INAOE will include specific coatings designed for each grating.



Model of an R(EED80) = 10,000 type grating and 20,000 type grating. The VPH hologram is sandwiched between two Fused Silica windows that are glued (with RTV141 silicon) to 2 prisms made of PBM2Y. INAOE will include specific coatings designed for each grating.

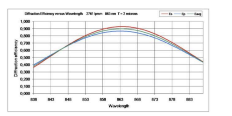
Ghost Analysis



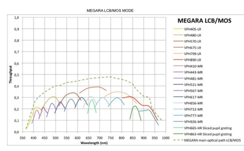
A complete ghost analysis for each pupil element has been carried out taken into account all relevant bounces among collimator, camera, detector and pupil elements. The baffle positions of all opto-mechanical elements have been set up. The figure shows the model for a MR grating. The ghost analysis including a 3 arcmin wedge window. The resulting ghost/image ratios are lower than 5x 10^{-5}.

Throughput Analysis

We have carried out a detailed throughput Error Budget for each MEGARA set-up.



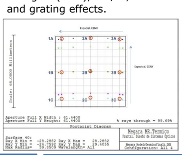
Diffraction Efficiency (by Wasatch) for VPH863-HR



Total throughput provided by MEGARA for the LCB and MOS modes evaluated at the different gratings.

Thermal Analysis

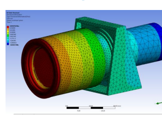
We have carried out a complete thermal analysis for collimator and camera separately to guarantee the optical performance between -4ºC to +20ºC (nominal range is -2ºC to +19ºC). The results have fed the opto-mechanical design. We have derived the image stability for each grating by measuring the change in the centroids position on the detector between -4º and 20ºC as shown in figure. This model contains collimator and camera changes (ROC), dn/dt, thickness and camera athermalization and grating effects.



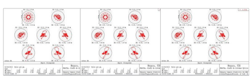
CENY(-4º) - CENY(20º) (mm)		
1A/2A/3A	1B/2B/3B	1C/2C /3C
-2	-2	-2
-3	-3	-3
-3	-3	-3

The main conclusion has been the introduction of a flat window between the prism and the hologram for MR and HR gratings.

Gravitational displacements analysis



Gravitational displacements. Camera-cryostat assembly



From left to right. Non-tilted camera (no mechanical deformation), LN2 empty and LN2 full. Circle is the fiber size. Each spot contains its centroid coordinates in x,y.

As expected, gravity deformation does not introduce degradation in image quality. The LN2 change does not introduce any relevant change in the centroids that might affect the instrument performance.

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Participating companies

MEGARA Spectrograph Mechanical Detailed Design

Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

Maldonado, Manuel[1]; García-Vargas, M.L.[1]; Sánchez-Blanco, E.[1]; Pérez-Calpena, Ana[1]; Cuellar, A.[2]; Carrasco, E.[2]; Gil de Paz, A.[3]; Gallego, J.[3]
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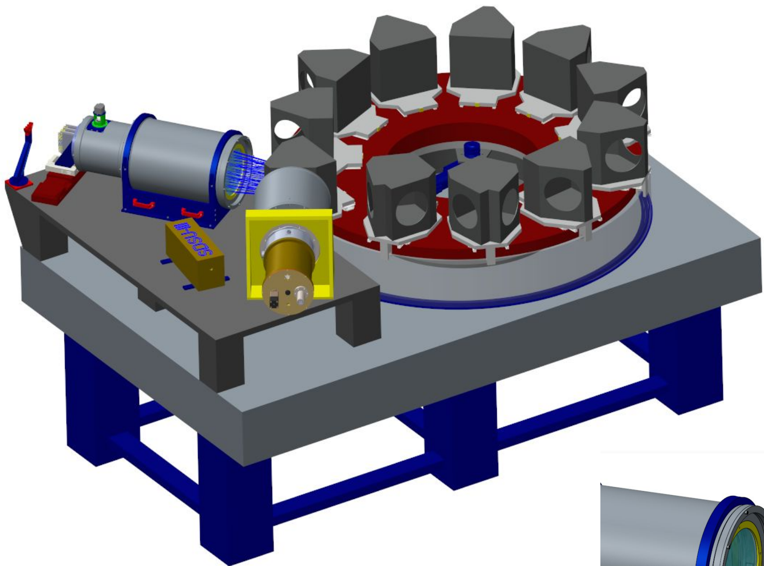
[1]FRACTAL SLNE (Madrid, Spain), [2]INAOE (Puebla, México), [3]UCM (Madrid, Spain), [4]UPM (Madrid, Spain), [5]IAA (Granada, Spain)

Abstract

We describe the current mechanical design and the adopted solutions for the Mechanisms and the opto-mechanical components of MEGARA spectrograph. MEGARA is the future optical Integral Field Unit (IFU) and Multi-Object Spectrograph (MOS) for the 10.4-m Gran Telescopio CANARIAS (GTC). MEGARA is in the final design phase.



VPH GRATINGS WHEEL AND INSERTION MECHANISM

The spectrograph includes the capability of the **automatic interchange of 11 VPH gratings** that are placed on a Ø1880 mm aluminum alloy wheel. The mechanical mount of each VPH is screwed to a platform that has a pair of guideways screwed on its downside. These guideways are inserted on their corresponding carriages that are screwed to the wheel. VPH mounts are to be seated in a kinematic system.

The insertion mechanism consists of an electro-mechanical actuator that translates a stud type track roller that moves on a railway. As the wheel rotates, platform protrusions are passing by the roller during grating selection. Once the desired VPH is located on position, this track roller engages the protrusion of the VPH mount platform and pushes it to the optical path or pulls it out of it. The **actuator** will be a precision electro-mechanical actuator comprised of a stepper motor, a high precision preloaded ballscrew with an absolute encoder on the motor. The actuators proposed for driving the wheel are a pair of servomotors with planetary reducers preloaded on a crossed rolled bearing gear by pinions in order to remove backlash.

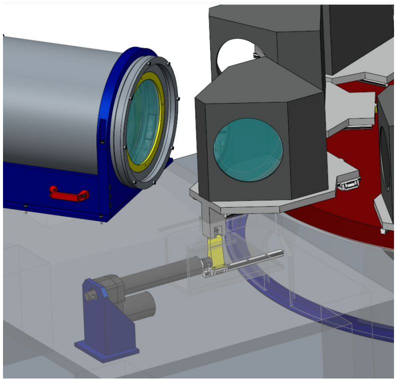


Fig: The linear actuator displacing a VPH platform

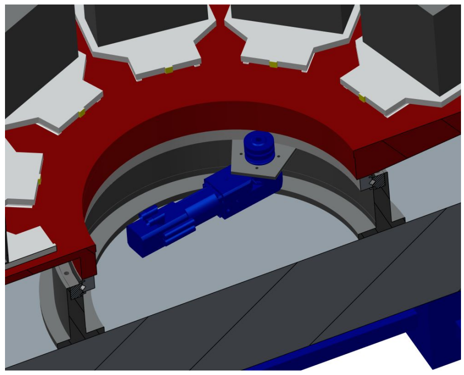
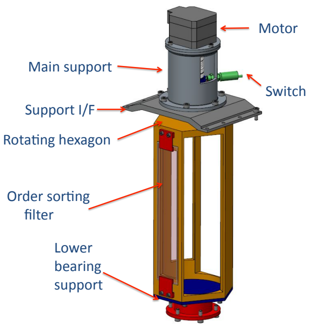


Fig: Cross section showing one actuator and the bearing

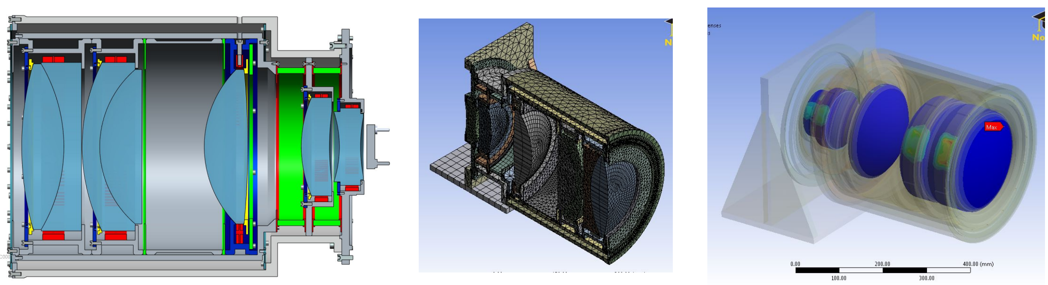
PSEUDO SLIT AND SHUTTER MECHANISMS

At pseudo-slit position, two orthogonal translation stages are included; one for fiber bundle selection and the second one to allow fine focusing for improving image quality in the different grating configurations. The translation stages proposed are commercial components. A **rotary shutter** is inserted in the collimator barrel. It has a mini-motor that rotates an hexagon. By rotating 60º, the cylinder allows light passing by. Another 60º allows light passing thru an order sorting filter that is placed in the hexagon. Another 60º turn blocks completely the light.



OPTO-MECHANICS: MAIN OPTICS AND VPH GRATINGS MOUNTS

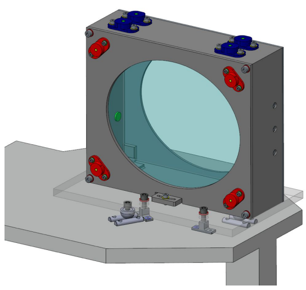
The lenses are inserted on the collimator and camera barrels inside subcells with several flexible elements to compensate for diameter thermal dilatation. Intensive Finite Elements analysis (FEA) has been done to simulate the behavior of the barrel, subcells and other mechanical elements, verify that the expected stress fields and the gravitational displacements on the lenses are compatible with the optical quality tolerances and validate the design of the passive athermalization of the camera.

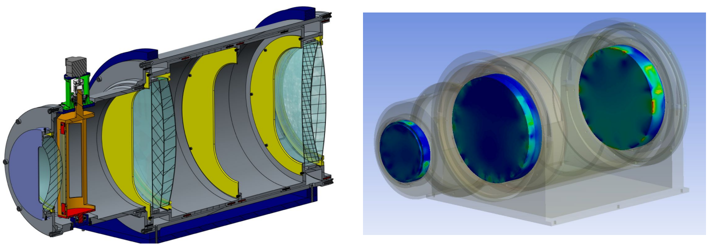


THE CAMERA BARREL : Cross section - FEM mesh – stress on lenses

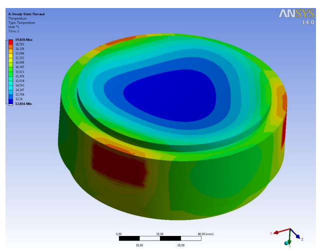
LR VPH MOUNT

Current detailed design of the LR VPH mount. The VPH mount is attached to an intermediate platform which has 3 semi-spheres that are seated on 6 cylinders that are attached to the platform.





COLLIMATOR BARREL : Cross section - stress on lenses



Temperature map of CAM-S7 lens (cryostat window)

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MEGARA Cryostat advanced design

Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

Ferrusca Rodríguez, D.[1]; Castillo-Domínguez, E.[1]; Velázquez de la Rosa, M.[1];
Gallego, J.[2]; Carrasco E.[1]; Sánchez, F.M.[3]; Iglesias, J.[4]; Vílchez, J.M.[4] & MEGARA Team
[1]INAOE (Puebla, México), [2]UCM (Madrid, Spain), [3]UPM (Madrid, Spain), [4]IAA (Granada, Spain)
dferrus@inaoep.mx

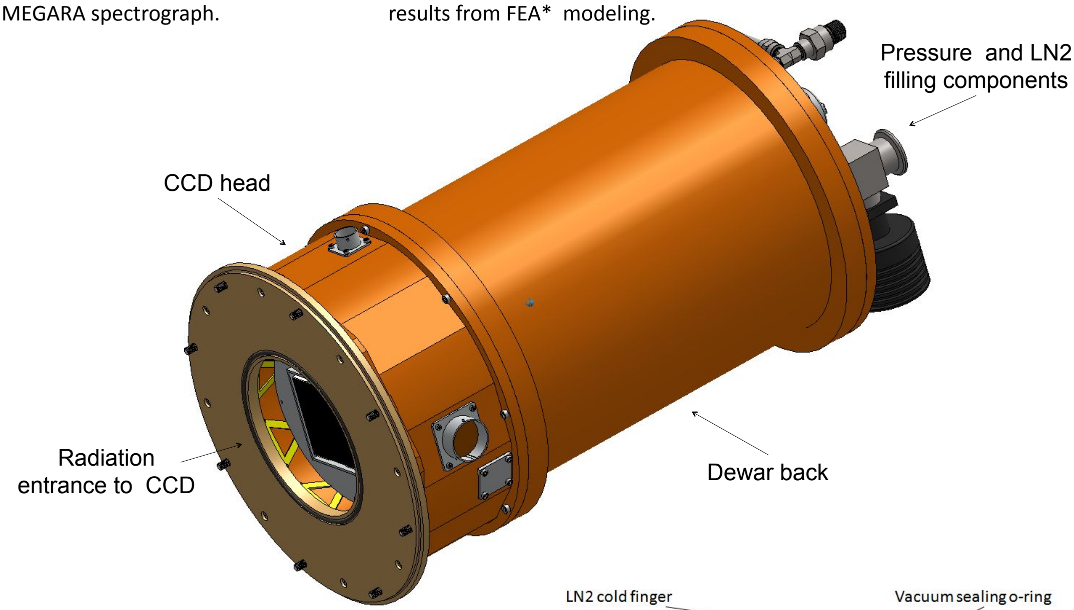
September/2013

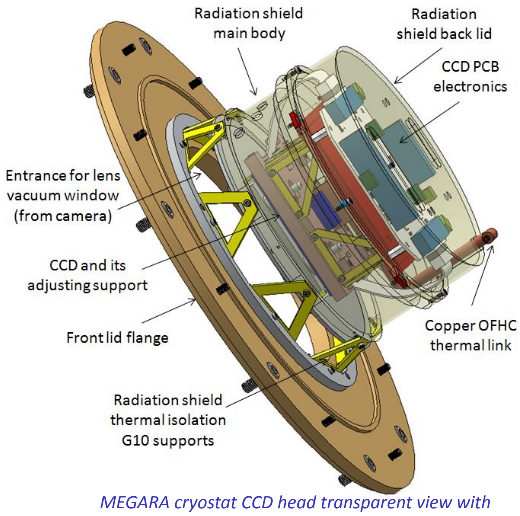
We present in this poster the advanced design of the MEGARA cryostat which is a custom made cryogenic device developed at the "Astronomical Instrumentation Lab for Millimeter Wavelengths" at INAOE[5], Mexico; it will harbor the scientific CCD detector for the MEGARA spectrograph.

The proposed cryostat is an open cycle liquid nitrogen system, which offers flexibility and modular stages that allows easy adjusting for detector mounting. We show the parts involved in the design as well as results from FEA* modeling.

MAIN CHARACTERISTICS

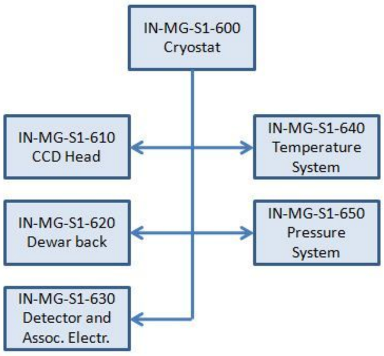
SPECIFICATION	VALUE
Cryostat provider	INAOE, Astronomical intrumentation lab for mm-λ
Cryostat type	Open cycle, filled with liquid nitrogen
Mass	23 kg
Dimensions	300 mm diameter / 570 mm max. length
LN2 tank volume	7.3 lts (7 lts usable)
Estimated LN2 hold time	>40 hours
Vacuum requirement	≤ $4{\cdot}10^{-6}$ mbar
Vacuum flanges	Commercial KF 25 flanges, fittings and valves
Sorption pump	Custom design / Active charcoal

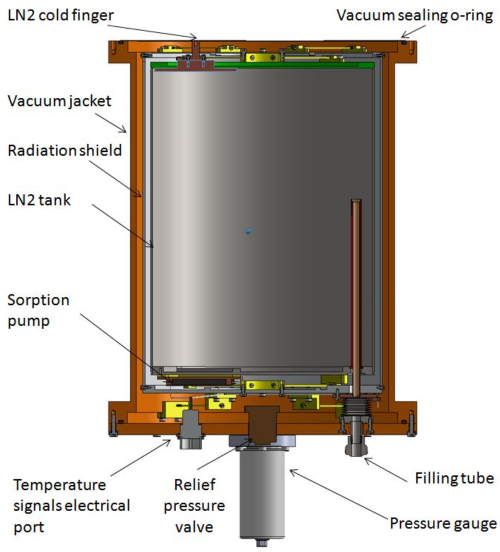




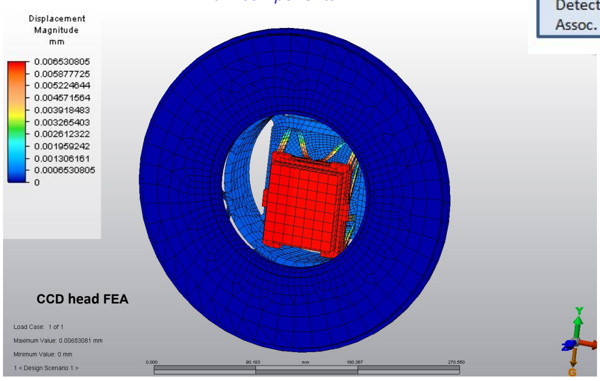
MEGARA cryostat CCD head transparent view with main components

MEGARA cryostat is integrated by five sub-systems: CCD head and Dewar back are the cryostat main body components; temperature and pressure systems includes all sensors and associated controllers. Detector & assciated electronics includes the CCD and the in-vacuum electronics to protect the CCD.

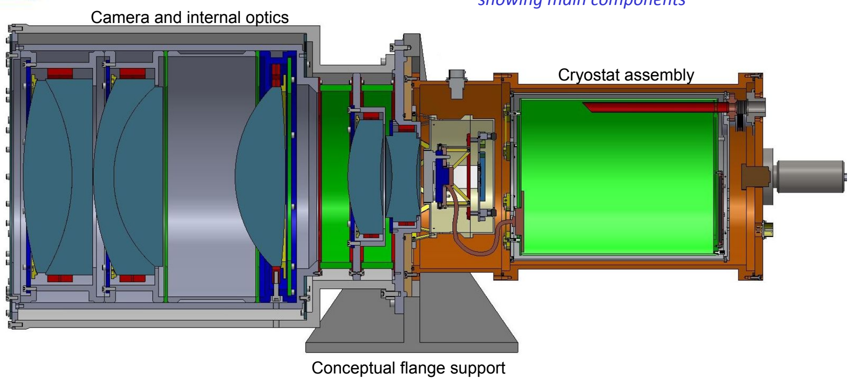




MEGARA cryostat dewar back cross section view showing main components



**Finite element analysis (FEA) has been performed on the CCD head to find maximum displacements of the detector. For the case of an stationary cryostat, as it is the case of MEGARA, the analysis results show that the maximum displacement magnitude is 6 μm .*



MEGARA cryostat mounted in support attached to spectrograph camera (cross section view)

[5] Instituto Nacional de Astrofísica, Óptica y Electrónica
www.inaoep.mx

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MEGARA Optics manufacturing

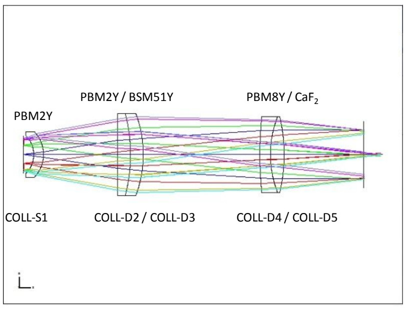
Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

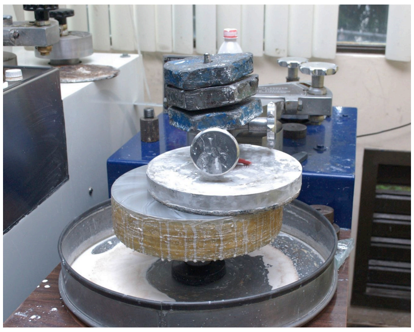
Carrasco, E.[1]; Páez, G.[2]; García-Vargas, M.L.[3]; Sánchez-Blanco. E.[3]; Gil de Paz, A.[4]; Gallego, J.[4]; Iglesias, J.M.[5]; Sánchez, F.M.[5] & MEGARA Team
[1]INAOE (Puebla, México), [2]CIO (Guanajuato, México), [3]FRACTAL SLNE (Madrid, Spain), [4]UCM (Madrid, Spain), [5]IAA (Granada, Spain)
[6]UPM (Madrid, Spain)

Abstract

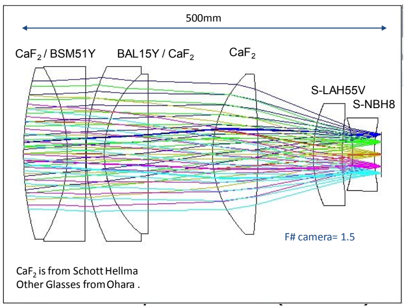
We illustrate the optics manufacturing process for MEGARA the next optical Integral Field Unit (IFU) and Multi-Object Spectrograph (MOS) for the 10.4-m Gran Telescopio Canarias (GTC). INAOE is part of MEGARA Consortium and it is in charge of the Optics Manufacturing work package. MEGARA passed the Optics Detailed Design Review in May 2013, and some of the blanks have been already ordered, being in the point of starting the Optics manufacturing phase. Except for the optical fibers and microlenses (manufactured in Europe), the complete MEGARA optical system will be manufactured in Mexico, between the workshops of INAOE and CIO. This implies a field lens, a 5-lenses collimator, a 7-lenses camera and a complete set of VPHs with 36 flat windows and 24 prisms, being all these elements very large and complex. Additionally, the optical tests and the complete assembly of the camera and collimator subsystems will be carried out in Mexico.

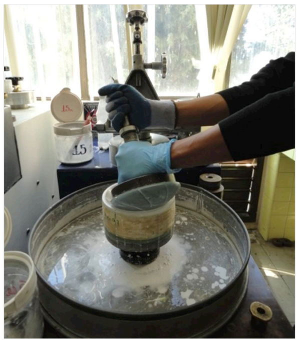
Main optics



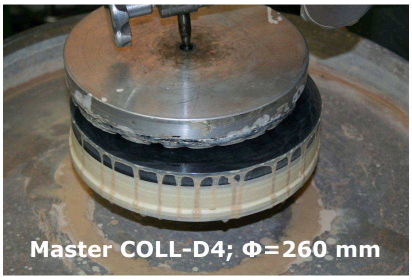


Diameter: 272mm



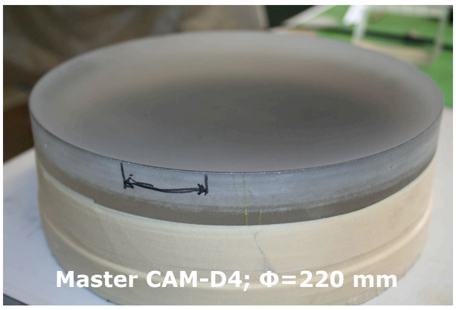


Dummy of COLL-S1 (aspheric)
Diameter: 155mm



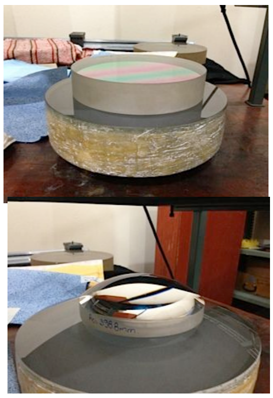
Master COLL-D4; Φ=260 mm

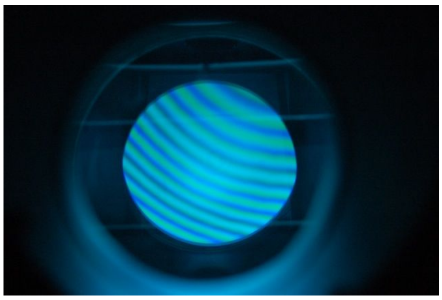
End of main optics: Sep-2014



Master CAM-D4; Φ=220 mm

Dummy of a VPH window @ CIO
(210 mm x 190 mm)





Testing by zones of a flat and a cx surfaces. Diameter: 272 mm

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MEGARA

Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

Instrument characterization facilities at LICA-UCM in preparation for MEGARA

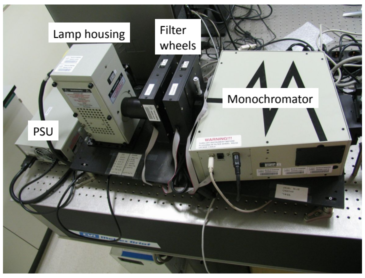
Zamorano, J. [1]; Gil de Paz, A. [1]; Tulloch, S.[2]; Tapia, C.[1]; Nievas, M. [1]; Gallego, J. [1]; Carrasco E.[3]; Sánchez, F.M.[4]; Vílchez, J.M.[5]; Iglesias, J.[5] & MEGARA Team

[1]UCM (Madrid, Spain) , [2]FRACTAL SLNE (Madrid, Spain), [3]INAOE (Puebla, México), [4]UPM (Madrid, Spain), [5]IAA (Granada, Spain)

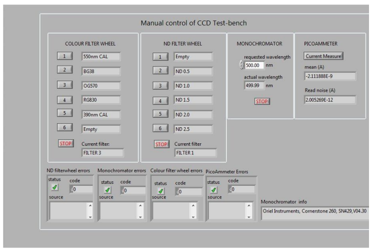
A CCD test-bench has been built at the UCM LICA laboratory. It is initially intended for the characterization of the MEGARA instrument but can be considered as a general purpose scientific CCD test-bench. The test-bench uses an incandescent broad-band light source in combination with a monochromator and two filter wheels to provide programmable narrow-band illumination across the visible band. Light from the monochromator can be directed to an integrating sphere for flat-field measurements or sent via a small aperture directly onto the CCD under test for high accuracy diode-mode quantum efficiency measurements. Point spread function measurements can also be performed by interposing additional optics between sphere and the CCD under test.

The whole system is under LabView control via a clickable GUI. Automated measurement scans of quantum efficiency (QE) can be performed requiring only that the user replace the CCD under test with a calibrated photodiode after each measurement run. A 20cm diameter cryostat with a 10cm window and Brooks Polycold PCC closed-cycle cooler also form part of the test-bench. This cryostat is large enough to accommodate almost all scientific CCD formats has initially been used to house an E2V CCD230 in order to fully prove the test-bench functionality. This device is read-out using an Astronomical Research Camera controller connected to the UKATC´s UCAM data acquisition system.

Completed test-bench light source

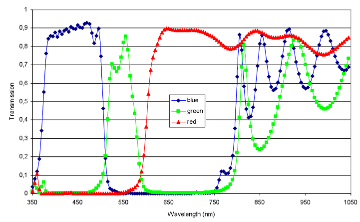


The test-bench is under full LabView control



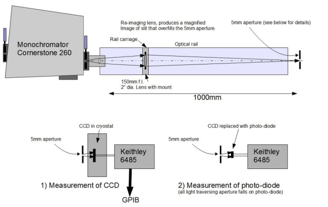
Example data from the test-bench: QE of warm CCD230

Example data from the test-bench: Bayer filter set



Test-bench operation

Quantum Efficiency measurement mode

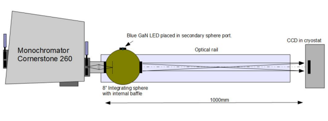


The monochromator slit is re-imaged onto a 5mm aperture located 1m downstream. The CCD detector is placed behind this aperture and connected to a picoammeter. The CCD diode-mode current is logged as the monochromator is stepped in wavelength between 360 and 1000μm. The CCD is then removed and a 10mm diameter calibrated photodiode placed behind the aperture. The wavelength scan is then repeated. The CCD QE can be calculated from simple ratioing of the CCD and photodiode currents.

[E2V CCDs can be operated as photodiodes by connecting a picoammeter between the DD and SS pins.]

Hamamatsu S2281-04 photodiode calibrated by NPL

Flat-field measurement mode

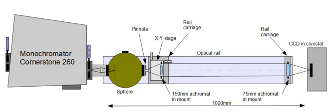


A Newport oriel 8" 70677 integrating sphere was mounted at the exit port of the monochromator. A 4k x 4k x 15μm CCD placed at the end of the optical rail experienced an illumination non-uniformity of <0.5%.

The sphere contained an internal baffle to block straight-through illumination.

The sphere also contained a blue-LED for rapid flat-field and linearity measurements.

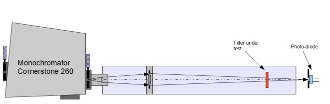
PSF measurement mode



A 25μm pinhole was placed at the output port of the sphere and imaged onto the CCD detector under test via two doublet lenses. One of these lenses was mounted on a manually adjustable X-Y translation stage to aid with focusing and centering the pinhole image.

This mode was useful for diagnosing charge transfer and charge-spreading problems in CCD detectors.

Filter measurement mode



In this mode the configuration was similar to the QE measurement mode except that the photodiode was left permanently mounted behind the aperture. An additional filter mount was placed on the optical rail just upstream of the diode. Two wavelength/current-logging scans were performed the first with the filter and the second without the filter. Simple current ratioing then gave the filter transmission.

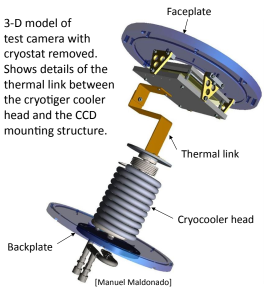
Available Test-bench facilities

related to MEGARA

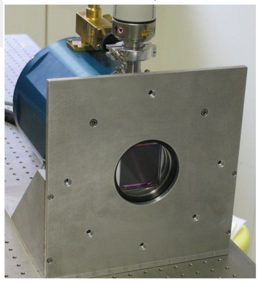
- Fibers characterization Needed for MEGARA 100 mini-bundles (with and without microlenses)
- Detector characterization for MEGARA detector and for the data acquisition system.
- Optical and alignment tools for mounting and characterizing MEGARA VPH gratings.

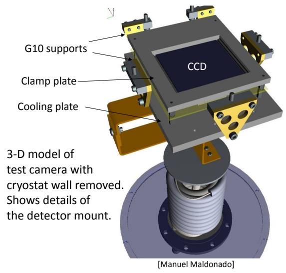
CCD230 test camera.

Built in conjunction with the test-bench.

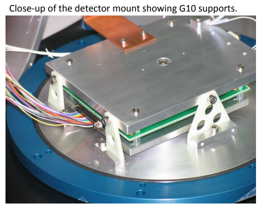


The finished camera in its IR-Labs cryostat on the test-bench.

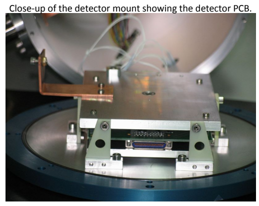


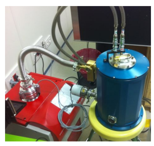


Close-up of the detector mount showing G10 supports.



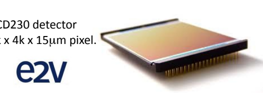
Close-up of the detector mount showing the detector PCB.



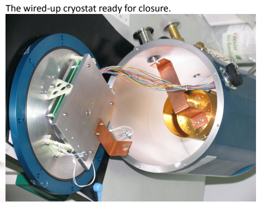


Finished camera on pump. The cryocooler gas hoses are also visible.

CCD230 detector 4k x 4k x 15μm pixel.



The wired-up cryostat ready for closure.



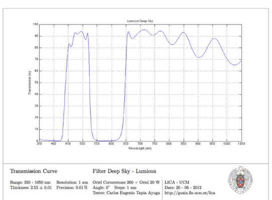
Teaching and training activities

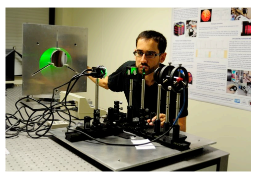
UCM physics students are being trained in the techniques of optical tests and detector calibration. Laboratory work for master students is being designed and is planned to begin this academic year.

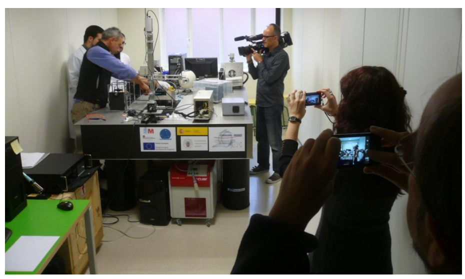
A result of their training work at LICA is the database of astronomical filters used in amateur astronomy that have been characterized using the optical bench described above.

Finally, some students are developing their own instruments using LICA facilities:

- A Fizeau-Michelson interferometer for optical test of surface mirrors from f/2 with accuracy better than lambda/15
- Portable night sky photometers for light pollution studies.







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MEGARA Control System

Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

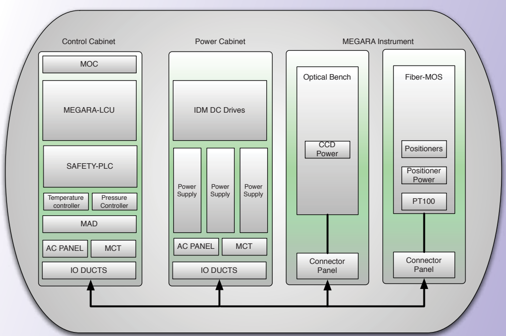
A. Castillo-Morales[2], B. Lefort[1], M. C. Eliche-Moral[2], S. Pascual[2], V. Villar[2], I. Morales[5], E. González[4], R. A. Marino[2], N. Cardiel[2], J. Gallego[2], F. Sánchez[4], J. Vílchez[5], J. Iglesias[5], E. Carrasco[3], A. Gil de Paz[2] and MEGARA Team.

[1]FRACTAL SLNE (Madrid, Spain), [2]UCM (Madrid, Spain), [3]INAOE (Puebla, México), [4]UPM (Madrid, Spain), [5]IAA (Granada, Spain).

Abstract

MEGARA (Multi-Espectrógrafo en GTC de Alta Resolución para Astronomía) is an optical Integral-Field Unit (IFU) and Multi-Object Spectrograph (MOS) designed for the GTC 10.4m telescope in La Palma. The MEGARA Control System is responsible to move the different mechanisms of the instrument, to save and process the readout of the detector controller and to provide the necessary inputs for the MEGARA Observing Preparation Software Suite (MOPSS), the Data Factory and the Sequencer.

Control Hardware Overview



The MEGARA hardware is divided into two physically separated cabinets. The Control cabinet will gather all the interfaces to the GTC control system and the MEGARA logical controllers. The Power Cabinet will gather all the power electronic, mainly DC motor drivers and power supplies.

MOC: Module used to opto-isolate the control cabinet hardware: it gathers the transceivers required to adapt the different signals and communication protocols to the fiber links.

MAD: Module used to remotely switch ON / OFF the cabinets hardware. The MAD is controlled via CANOpen from the *Inspector* GUI.

AC PANEL: Module responsible for the electrical protection (surge suppressor, filtering, overload breakers..). This module distributes the 230 V AC to the electronic equipment.

MCT: Module used to control the cabinets temperature. Thermal data and alarms are transmitted to the GTC supervision software.

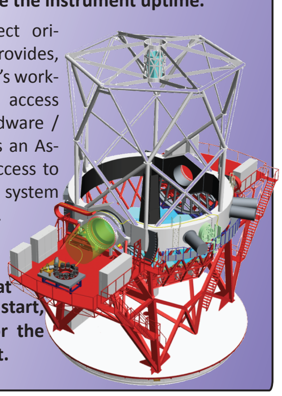
SAFETY-PLC: an industrial PLC with failsafe inputs/outputs that handles interlocks signals.

MEGARA-LCU: VME rack fitted with a Motorola MVME5100 running VxWorks that hosts the MEGARA Control System and the DAS control system.

System Highlights

MEGARA control system hardware re-use GTC hardware to benefit from the technical teams "know-how", to reduce the spare parts needs and, consequently, to maximize the instrument uptime.

The distributed object oriented architecture provides, from any observatory's workstation, engineering access to the low level hardware / commands as well as an Astronomer oriented access to the MEGARA control system high level commands.



The *Inspector* Java GUI is a multi-users control interface that allows to configure, start, control and monitor the MEGARA instrument.

MEGARA Observing Preparation Suite

The MOPSS consists of three software components designed to assist observers to plan their observations.

Exposure Time Calculator estimates the SNRs and limit magnitudes for a given observational setup.

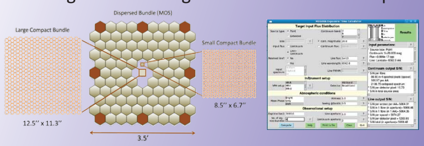
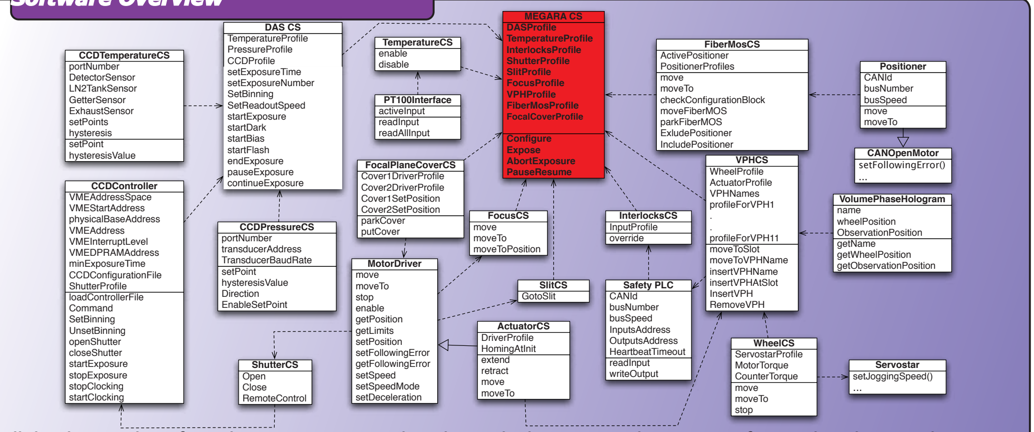


Image Simulator creates images simulating the output of the instrument depending on the observational strategy adopted for observing a given source.

Fiber MOS Positioning Tool allows to generate the best combination of Fiber MOS pointing parameters and spatial configuration of the RPs, to observe a list of user-selected sources.

Software Overview

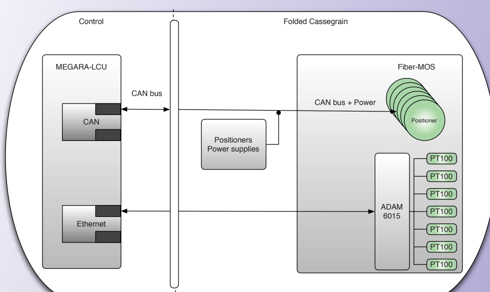


All the classes inherit from the GCS Device *superclass that embed: a state machine, an interface to the telescope alarms Manager and to the data Monitor Manager. The CORBA based communication layer allows to deploy the system on several servers, to communicate with all the other* Device *components and to access classes' public methods from the* Inspector *GUI.*

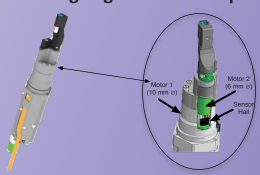
Fiber MOS

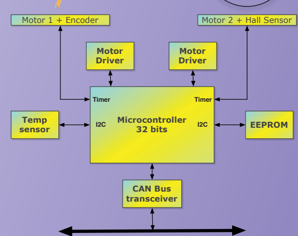
The Fiber MOS allows placing fiber mini-bundles anywhere in the central 3.5 x 3.5 arcmin² FOV around the two IFU bundles.

The Fiber MOS is composed by 100 two axis micro positioners moving mini-bundles made of 7 fibers each. A positioner has an embedded Freescale microcontroller running a CANOpen library that implements the CANOpen Device Profile Drives and Motion Control Standard (DSP 402).



MEGARA fiber positioner robots use independent positioning for each fiber bundle. The objective is to maximize the flexibility of the system offering a great deal of spatial configurations.





Positioners achieve the required positions using a combination of 2 rotation movements. The system precision is critical and must fit the science requirements.

MEGARA Data Factory (MDF)

MDF outputs are data corrected from the instrument signatures that can be used at the different levels of either data acquisition or analysis (See poster by S. Pascual et. al about DRP).

During an observation the images produced by MEGARA are displayed on the Inspector Panel. The user has also the possibility to load and visualize images and other data processed by the DFP.

Data Reduction Pipeline (DRP)

The DRP provides data in physical units as required by scientific analysis. The DRP is not integrated with the GTC Control System. The user has the possibility to modify the data processing parameters.

Data Factory Pipeline (DFP)

This GTC component will be used exclusively to compute data products required to complete data acquisition. It will not produce any scientific quality data. The results of a particular run of the DFP can be browsed and loaded from the Inspector GUI.

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MEGARA

Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

MEGARA Observing Preparation Software Suite (MOPSS)

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Abstract

We describe the software components of the **MEGARA Observing Preparation Software Suite (MOPSS)**. MEGARA is an optical Integral-Field Unit (IFU) and Multi-Object Spectrograph (MOS) designed for the GTC 10.4m telescope in La Palma. The MEGARA IFU mode will offer both IFU and MOS capabilities.

The MOPSS will provide observers the necessary tools to plan their observations with GTC/MEGARA in an optimum way. It includes the **MEGARA Exposure Time Calculator**, the **MEGARA Image Simulator**, and the **Fiber MOS Positioning Tool**. The three tools shall be stand-alone, multi-platform, and easy-to-install software packages. Web-based GUI versions that will not require any previous installation to be run by the user are under consideration too.

The MEGARA ETC allows obtaining in a straight-forward way an estimate of the required observing time with MEGARA to achieve a specific scientific objective. This tool is best suited for the Phase I preparation of observing proposals. The MEGARA Simulator is intended for astronomers planning on doing an intensive use of the instrument or working very close to the sensitivity limits of the instrument. It will fully simulate the 2D frames to be generated by the instrument. Finally, the FMPT allows estimating the optimal configuration and use of the MEGARA MOS starting from a list of sources with different priorities.

An updated view of the current status of each tool (at a level of Critical Design Review) is provided. MEGARA first light is scheduled in 2016.

A brief MEGARA description

The MEGARA IFU mode will offer two different fiber bundles, one covering 12.5x11.3 arcsec^2 (**Large Compact Bundle; LCB**) and another covering 8.5x6.7 arcsec^2 (**Small Compact Bundle; SCB**), with different spaxel sizes (0.62 and 0.42 arcsec, respectively). The **MOS mode** consists of a total of 92 additional mini-bundles with 7 fibers each that will be positioned by Robotic Positioners (RPs) in a region 3.5x3.5 arcmin^2 in size around the central IFUs. Eight additional RPs in the outer edge of the field-of-view will be used for sky background measurements.

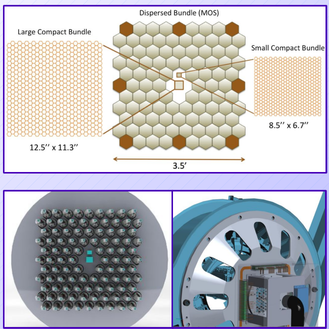

Figure 1: ***Top:*** Diagram of the MEGARA geometrical layout for the three observing capabilities of the instrument (LCB, SCB, and MOS). The hexagons in the LCB and SCB represent the section of the micro-lens appended to each fiber. The hexagons in the MOS correspond to the spatial region that is patrolled by each RP. ***Bottom:*** Design of the MEGARA Positioner system at the GTC Folded-Cassegrain (FC) focal plane. A RP locates a 7-fibers mini-bundle on the target position combining the interpolation of two rotations.

MEGARA will use Volume Phase Holographic (VPH) grisms as dispersive elements. The wavelength coverage will be 3,650-10,000 Å with a spectral resolving power from 6,000 to 18,700 in the LCB and MOS modes and from 7,000 to 21,500 in the SCB mode, depending on the selected VPH. The whole optical spectrum will be covered both at low (R~6,000) and medium (R~11,000) resolutions. At R~19,000, both the Hα and CaT would be also accessible

Exposure Time Calculator

The MEGARA Exposure Time Calculator (ETC) is a tool intended to simulate the signal-to-noise (S/N) ratios that will be obtained for the continuum and a spectral line of a target for a given light distribution in the source, exposure time, MEGARA setup, and night atmospheric conditions at La Palma Observatory.

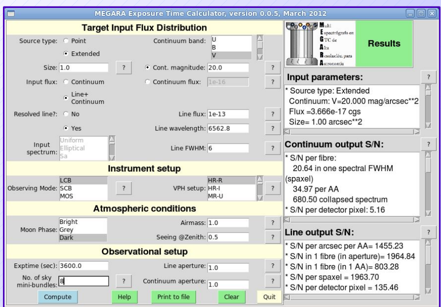

Figure 2: Graphical user interface of the ETC prototype. Future versions will also provide estimates of the exposure time required to achieve a given S/N on a target, and limiting fluxes for a given S/N and exposure time under certain conditions.

The limiting magnitudes of MEGARA for continuum in point sources at high, medium, and low resolutions are V=24.0, 24.3, and 24.6 mag respectively in the whole wavelength ranges covered by B, V, and R bands, for S/N=5 per spaxel in 1 h of exposure time.

Limiting line fluxes of 2.8x10^{-19}, 3.0x10^{-19}, and 2.7x10^{-19} c.g.s. units can be achieved at S/N=5 per spaxel at the center of the R band at high, medium, and low resolutions respectively, for 1h of exposure time.

Image Simulator

The Simulator tool creates a set of data frames simulating the output of the MEGARA instrument depending on the observational strategy adopted for observing a given source. The Simulator creates a sky+object model, including the different noise sources in the CCD frame. It also includes the effects associated to the observation that are removed through a typical reduction process: bias, flat, geometrical distortion, non-linear dispersion, cross-talk, cosmetic defects, and cosmic rays. To date, only 2D-gaussians with different FHWM can be used as light distributions for the sources. Sersic profiles will be soon implemented.

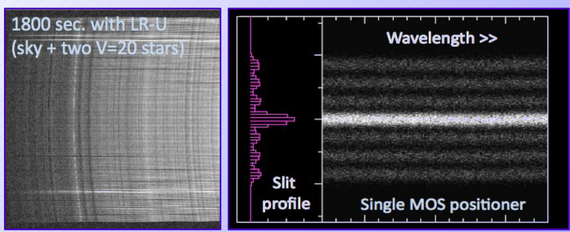

Figure 3: **Left:** Simulated MEGARA CCD frame of two stars with V=20 mag, with the Low Resolution U-band VPH and a exposure of 0.5h. **Right:** Simulated MEGARA light distribution of a point source in the 7 fibers of a MOS mini-bundle.

This tool accounts for the flux distribution of the input source, the instrument configuration, the atmospheric conditions of the run, and the observational strategy used to simulate the CCD frame.

Fiber MOS Positioning tool

The Fiber MOS Positioning tool (FMPT) shall define the optimal assignment of the 92 Robotic Positioners (RPs) for a set of targets in the MOS field-of-view. It shall generate a series of Configuration Blocks (CBs), designed to cover as many sources as possible.

Each CB contains information to:
- point the telescope and set the Fiber-MOS position angle with the FC rotator;
- assign a RP to each target;
- move the RPs from safety positions to observing positions avoiding dynamical collisions, and viceversa;
- optimize the sequence of RP movements to minimize the configuration time.

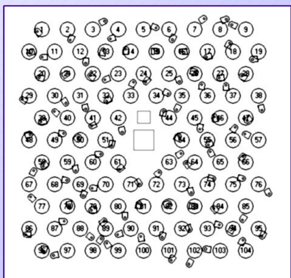

Figure 4: An example of CB placing the RPs onto 100 targets on sky. The CBs will be used to configure the MOS in observing runs and to allow the Data Reduction Pipeline to identify the RP used to observe each specific target.

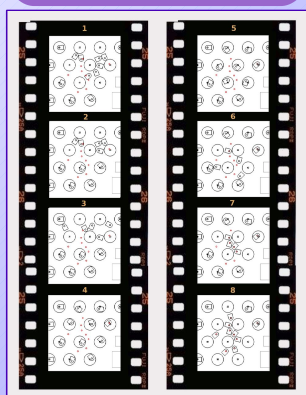

Figure 5: Example of sequence of coordinated simultaneous movements (in 8 phases) required by a set of RPs in the MEGARA MOS to place the fiber mini-bundles onto 9 objects on the sky, starting from another pointing configuration. The target positions are marked with red circles in all panels.

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