E-ELT Instrument study for first light. OPTIMOS-DIORAMAS: mechanical concept study for Slit Masks System.

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ABSTRACT

The Seeing-limited, large multiplex, optical/near-IR spectrograph, Optimos-Dioramas, currently under study by a Consortium of Institutes from France, Italy, and Switzerland, is one of the possible candidates for first light on the E-ELT Telescope. The spectograph is designed to maximize the field of view and cover in one-shot the spectral range (0.37micron - 1.6micron). This paper describes the studies performed to establish a base-line conceptual design of the Slit Masks System for the Optimos-Dioramas spectrograph. This unit has been designed in order to better satisfy the limits of the allowed volume on the Nasmyth E-ELT platform, and it is also able to guarantee all the optical specifications needed to cover the overall field of view (7x7arcmin). In order to take and position the masks in the focal plane, the performed system is fully robotic and able to load/unload the masks in the proper quadrant. A central cross structure, about 8.33arcsec wide, is needed. Each mask will necessarily be larger than 719x719mm, i.e. 780x780mm. The system based on four 0.6mm thick (black painted steel) masks is fully feasible and complies with all specifications. Vignetting due to the focal plane curvature is minimized and the slits (cut via a stencil-laser machine) can have all shapes and sizes.

Keywords: Multi-object spectroscopy, spectroscopy, E-ELT instrumentation.

1. INTRODUCTION

The Optimos-Dioramas study, proposed in response to ESO's "Call for Proposals for a Phase A study for E-ELT Programme Study", is aimed to analyzing the feasibility of a wide field imaging multi object spectrograph for the E-ELT, covering an extended spectral domain from visible to NIR. In the multi-slits approach, the Optimos-Dioramas concept is based on slit masks at the focal plane. This study takes advantage of the experience of the VLT VIMOS and other multi slit spectrographs. DIORAMAS would be installed at the Nasmyth focus of the E-ELT. It rest on the platform, with a support structure enabling co-rotation with the telescope field. The beam from the telescope first encounters focal plane multi slit masks, collimating optics, filters or gratings, then visible or near IR cameras focusing onto detector arrays.

This paper describes the global preliminary mechanical design and the technical solutions of the MEUS and MMUS that are systems of the Optimos-Dioramas instrument. The function of this system is to perform the off-line, remotely controlled, mask manufacturing, identification and preparation of the mask reservoirs for the observing run.

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2. INSTRUMENT CONCEPT AND LAYOUT OVERVIEW

The Optimos-Dioramas overall instrument, shown in Figure 1., has the following characteristics:

- Imaging and multi slit spectrograph, with excellent image quality and total throughput;

- Field of view: 44 arcmin2;

- 4 channels: 2 visible ([0.37]0.38 to 1µm) channels and 2 near infrared (0.6 to 1.6µm) channels. Each channel makes use of a 4096x12288 pixels array, of CCDs for the visible and HgCdTe for the NIR, with a pixel scale of 49 mas;

- Spectral resolution is ranging from R=300 to R=2125 in the VIS, and from R=425 to R=3100 in the NIR, for a 0.5arcsec slit. Slits of 200 mas are well sampled, and enable to increase the spectral resolution up to ~5300 in the VIS and R~7500 in the NIR.

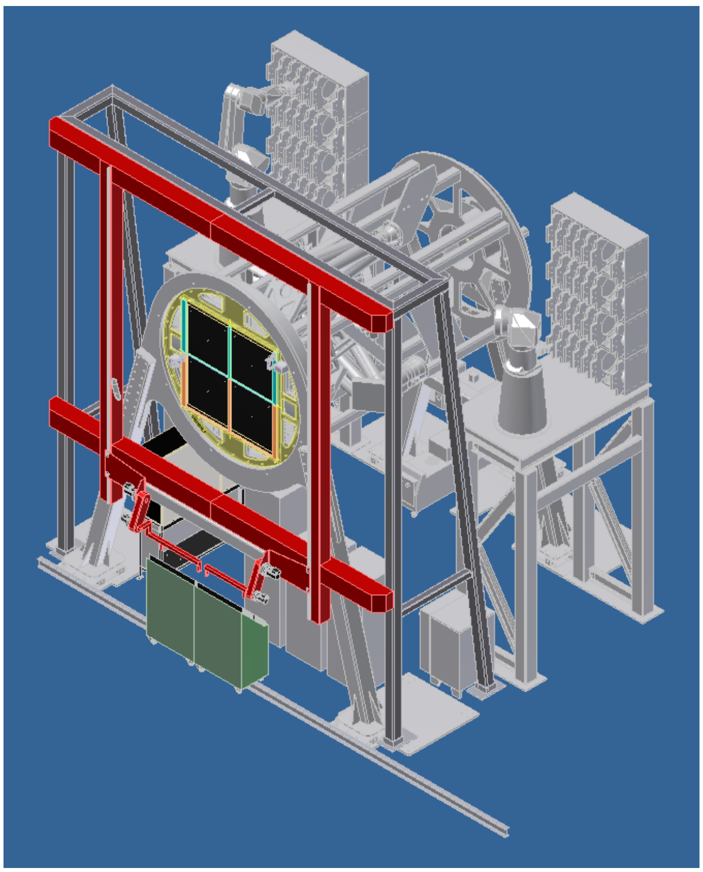

Figure 1. Optimos-Dioramas: overall view.

Two main operation modes are identified:

- Imaging

Full field imaging over 44 arcmin^2 in the same band in the wavelength range 0.6 to 1microns Simultaneous imaging in any VIS filter over 22 arcmin^2 and in any NIR filter over 22arcmin^2.

- Multi slit spectroscopy

Full field multi slit spectroscopy over 44 arcmin^2 in the same band, at same spectral resolution. Simultaneous multi slit spectroscopy in 22 arcmin^2 in VIS and 22 arcmin^2 in NIR.

3. FoV AND MASK: REQUIREMENTS AND SPECIFICATIONS

3.1 FoV

The Optimos-Dioramas instrument (see Fig. 2 - left side) field of view measures 1468x1468mm - will be divided in 4 quadrants. In order to hold and position the masks in the field of view, a central dead cross of 30mm is needed. The numbering and position of the 4 quadrants in the instrument field of view assumed it is shown in Fig. 2 - right side, which assumes a view of the "backbone cross mask" (see chapter 4.) looking towards the sky from the spectrograph side.

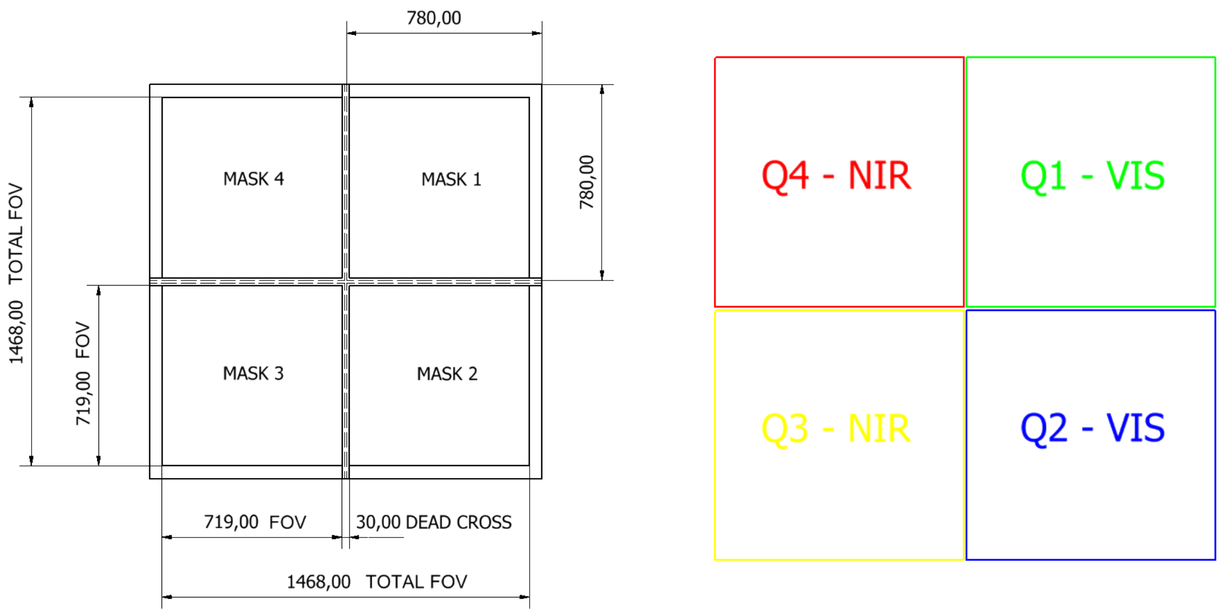

Figure 2. Optimos-Dioramas: overall view.

3.2 Mask

Each mask size will necessarily be larger than the useful quadrant FOV of 719x719mm, i.e. 780x780mm, as schematized inFig. 2 - left side. Part of the free 49mm border of each mask will contain the mask identifiers.

The selected material for the masks is AISI steel 1015 – thickness 0.6mm. The overall requirement on the slit absolute positioning accuracy is 180µm: the design meets this requirements and can be improved at the expense of a higher cost for the laser cutting machine.

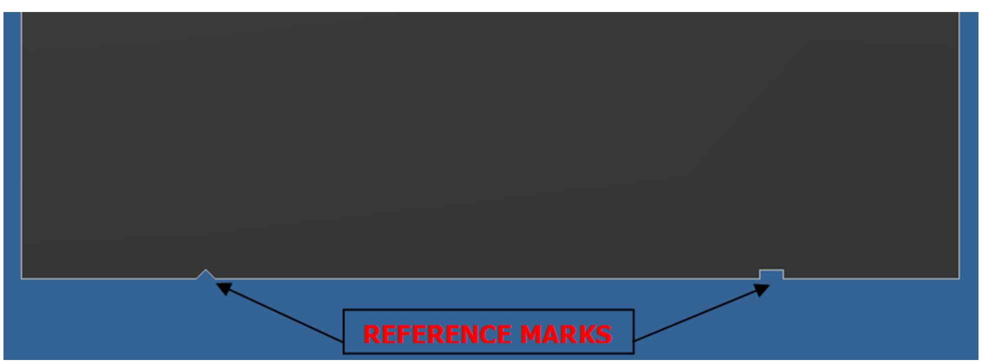

Figure 3. Illustrative drawing of reference marks on the mask.

Assuming to have a number of different masks available for each night, and, possibly, the possibility of storing manufactured masks for later usage, the problem of mask identification must be addressed. Identification of the mask shall not only identify the quadrant (to prevent insertion of masks in the wrong place), but also identify the observation to which a mask belongs.

When the mask is in the laser machine, we can identify it by cutting a barcode (as done for VIMOS). Barcodes (at least in the simple code used for VIMOS) can store only numeric sequences (for VIMOS it used 1+5 digits, where the 1 digit was used for quadrant identification).

Each mask will also be cut along the bottom edge with two reference marks (e.g. a rectangular and a triangular one – see Fig. 3) used to align the mask during final insertion into the Mask Locking Devices, and other marks, around the lateral edges, in order to block the mask inside the locking system.

3.3 Slit physical requirements

In each mask shall be cut a number of slits between an indicative minimum of about 40 (0 for the dark mask), and a maximum of about 300, as dictated by the Instrument Science Requirements.

The requirements on the slits are shown in Table 1:

	OPTIMOS / DIORAMAS
RMS quality on edge Slit (roughness)	30μm
Typical Slit width (minor size) Minimum slit width (minor size)	1.8mm ± 15μm 0.9mm ± 15μm
Typical Slit length (major size)	18mm ± 50μm
Typical Slit shape	rectangular

Table 1. Slit physical requirements.

The requirements about curved or tilted slits will be detailed in the next phase (but the case of VIMOS demonstrates they are possible to be cut with a laser machine). In each mask shall also be cut a number of square apertures for reference objects (in a number between 2 and 5) as dictated by the operational requirements for target acquisition.

4. MASK EXCHANGE UNIT SYSTEM

Once slits and reference apertures have been cut and masks are identified, they will be placed in two reservoirs/transporters, each serving two quadrants. Once the reservoirs/transporters are carried to the Nasmyth platform and placed below the instrument focal plane via a conveyor belt-rail, robotic arms will load/unload the masks in the proper quadrant. The mask exchange unit system will be composed of three main mechanical subsystems:

- FOCAL PLANE MASKS SUPPORT SUBSYSTEM;
- MASKS EXCHANGE ROBOTS;
- MASKS RESERVOIRS.

4.1 Focal Plane Masks Support Subsystem (Backbone Cross Mask - Masks Locking Devices)

The Backbone Cross Mask, shown in Fig. 4 - left panel, will be directly screwed into the crown of the Dioramas Instrument Rotator. The Masks Locking Devices (shown in Fig .4 - right panel) will be mounted on the previous sub-system.

The locking devices will have 2 positions/state:

- open which allows insertion of a mask;

- closed/locked when the mask is inserted.

When all the masks have been carried in their proper position by the robots, electromagnets, mounted on the Mask Locking Devices, will block the masks in position and the Locking devices will be closed. The time needed to exchange a full mask set is estimated in 2 minutes, once the instrument has reached the “home” (reference) position.

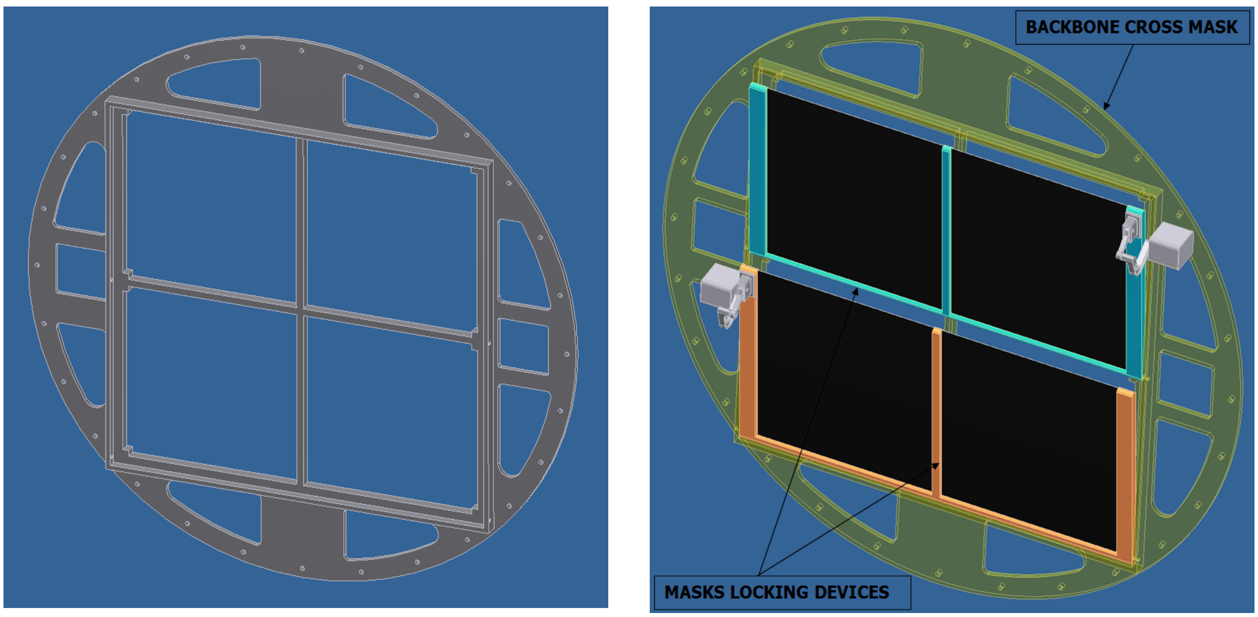

Figure 4. Backbone cross mask & mask locking devices.

The locking devices can be operated only when the plate (and hence the entire instrument) is rotated in a predefined reference position. If no masks are inserted (e.g. for imaging observations) the locking devices shall be in closed position.

4.2 Masks Exchange Robots

When the instrument is at a fixed reference rotation angle, masks can be exchanged using two independent robotic arms, mounted on a separate support structure, with a vertical excursion (Y) and able to insert the masks in the focal plane (see Fig. 5). The left and right arm serve the left and right reservoir and the associated couple of quadrants.

Each arm is equipped with a mask manipulating device with movements along 2 degrees of freedom (probably two rotational axes which, coupled with the main arm motion, will allow a step-wise fine Y-and-Z movement to search masks in the reservoirs, and a tilting movement for mask insertion in the locking devices). Each manipulating device is equipped with a reader capable to read the mask and reservoir identifiers.

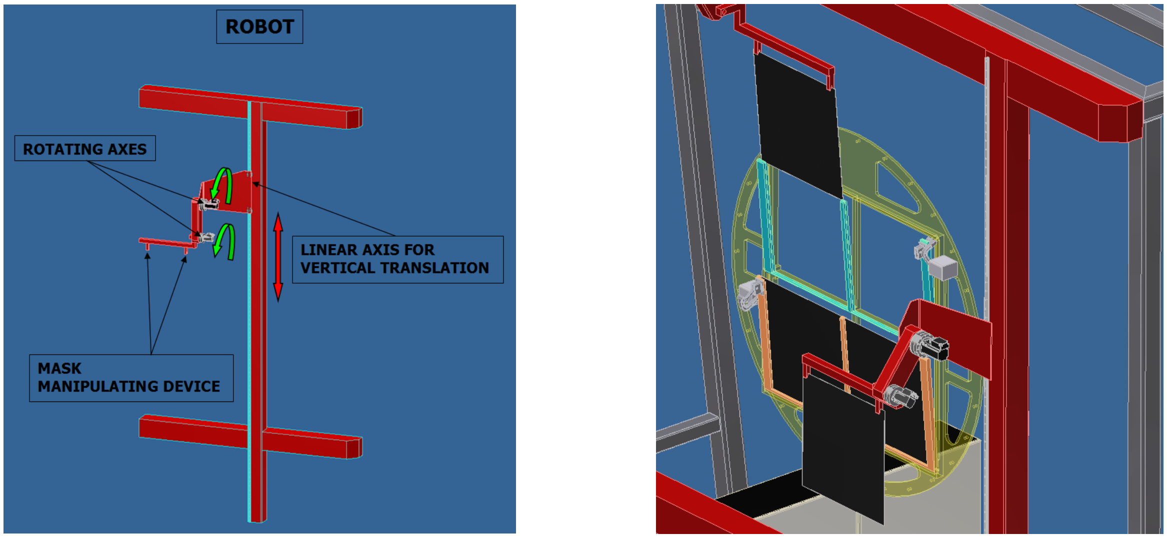

Figure 5. Schematic of exchange robot system.

5. MASKS RESERVOIRS

We estimate that a minimum of 10 mask sets, i.e. 40 masks, should be made available for each observing night. Masks will be arranged in 1 set of reservoirs (a reservoir set is composed of 2 reservoirs). Each reservoir will contain masks for 2 predetermined quadrants (VIS and NIR) and thus hold 20 masks (in the next phase will be studied the possibility to increase such number to 24).

The weight of each reservoir, once filled with masks, will be approximately 113kg, and its dimensions approximately 830x460x1200mm.

Identification of the reservoirs may be required to associate a reservoir in a set to a quadrant, and forbid that masks of the wrong quadrant be inserted in it, or that the reservoir of a given quadrant is mounted at an incorrect position at the spectrometer. In the case there will be two reservoirs set (e.g. while one is at the instrument the other one is at the Masks Manufacturing Unit) it is also important to know which one is in use, since it will have implications in the way robotized units will access it (they will presumably need to read the slot position from a calibration table).

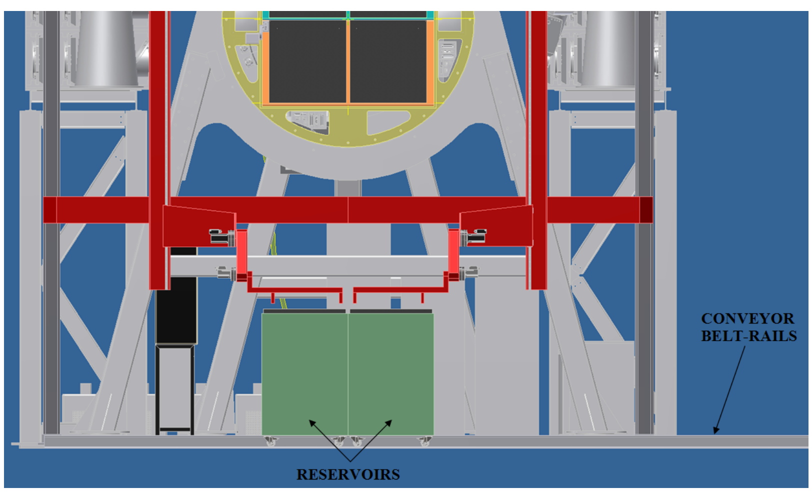

Figure 6. Schematic of reservoirs position on the Nasmith platform.

Each reservoir will be marked with a barcode of the same type used for the masks, and containing predefined standard string values (different from mask identifiers), can be permanently attached to the reservoirs, so that the MEUS robot can move to a predefined position to read and verify the reservoir identity. There will be a minimum of 2 reservoir sets (typically one at the MMUS and the other one at the Telescope – see Fig. 6), and a maximum of 4 (the other two could be kept as spare or could supplement the used sets).

REFERENCES

[1] De Caprio, V., Maccagni, D., Chiappetti, L., Incorvaia, S.: "Slit Mask Manufacturing and Exchange Units Design and Analysis". E-ELT PROGRAMME OPTIMOS Study – E.S.O review document n.: E-TRE-DIO-509-1056.

[2] Chiappetti, L, Bottini, D., De Caprio, V.: "Software and Operational Requirements for DIORAMAS masks". E-ELT PROGRAMME OPTIMOS Study – E.S.O review document n.: E-TRE-DIO-509-1052.

[3] Lucien H., Le Mignant, D., Le Fèvre, O.: "Dioramas Opto-Mechanical Design And Analysis". E-ELT PROGRAMME OPTIMOS Study – E.S.O review document n.: E-REP-DIO-509-1054.

[4] Le Fèvre et al., "VIRMOS: visible and infra red multi-object spectrographs for the VLT", SPIE 3355, pp 8-19.