LA SILLA PARANAL OBSERVATORY

LA SILLA ENGINEERING

NTT - Project
New EMMI Calibration Unit
Conceptual Opto-Mechanical Design

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## Change Record

<table>
<thead>
<tr>
<th>Issue/Rev.</th>
<th>Date</th>
<th>Section/Page affected</th>
<th>Reason/Initiation/Document/Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue 1.0</td>
<td>Oct. 2004</td>
<td>Several pages</td>
<td>Upgrade with several new inputs</td>
</tr>
<tr>
<td>Issue 2.0</td>
<td>Feb 2005</td>
<td>Several Pages</td>
<td>Including the Mechanical design and different concepts.</td>
</tr>
<tr>
<td>Issue 3.0</td>
<td>May 2005</td>
<td>Several Pages</td>
<td></td>
</tr>
</tbody>
</table>
1 Introduction.

The calibration unit of the EMMI instrument is located within the Adapter/Rotator B of the NTT. The early requirements concerned mainly an uniform illumination over the complete EMMI field of view of 9.1 x 9.1 arcmin for different lamp sources (FF blue and red, Argon, Helium, Thorium .......), but leaving the long slit mode to 5.5 arcmin length.

The solution adopted an integral sphere concept to ensure a flat illumination over the telescope pupil for the field required. If integral sphere delivers uniform illumination, the efficiency is very low for spectral lamp as Thorium type in Echelle REMD mode for lines bluewards of 600nm (short slit length) . We propose to modify the calibration lamp unit to ensure a better efficiency on REMD Echelle EMMI mode keeping the other configuration as efficient as it is actually.

1.1 Purpose and scope

This document is intended to act as a concise and centralized reference of the work done in developing the concept of the new calibration unit. Starting from the user requirements it shows the foreseen mechanical, optical and electronic solutions and finally to which extent the requirements could be meet by the present solutions.

1.2 Overview

Since the commissioning period the calibration unit use on REMD Echelle spectroscopy has shown a very low efficiency with Thorium integration time above 5000 sec to obtain a good calibration with high dispersion Echelle (#10 & #14).

The REMD EMMI mode is steadily more requested since the EMMI CCD upgrade and a more efficient calibration system is required to deliver exposure in a reasonable time (2 to 3 min max).

An overall inspection of the calibration unit didn’t show critical issues concerning a bad integration sphere coating or incorrect lamp dis-alignment.

1.3 Related Documents

[2] - EMMI user’s Manual - LSO-MAN-ESO-40100-001/5.0 -

1.4 Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMMI</td>
<td>ESO Multi Mode Instrument</td>
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<tr>
<td>RILD</td>
<td>Red Imaging Low Dispersion</td>
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<tr>
<td>REMD</td>
<td>Red Medium Dispersion</td>
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<tr>
<td>BLMD</td>
<td>Blue Medium Dispersion</td>
</tr>
</tbody>
</table>
2 User Requirements

The user requirements are listed below corresponding to the document [1]. Following each point a short text explains up to which extent each requirement could be fulfilled.

1. It should provide a good REMD-Echelle Th-Ar two dimensional frame in a time similar to that Feros or Harps calibration unit (~120sec) over the full wavelength range covered by the echelle gratings with or without dross-disperser (450-959nm), including the order overlapping regions.

_The concept of the integrating sphere should be kept for the non Echelle spectroscopy modes. Solutions using higher efficiency output suffer from non-uniform light distribution over a square field of 9.2 arcmin or 100 mm side. Experience on other Echelle spectrographs illustrates the higher efficiency reached on direct Thorium cathode imaging covering the spectrograph slit aperture._

2. The other arc lamps work fine with the current system, hence the modification must not affect the wavelength calibration for RILD, REMD modes and BLMD mode (which uses a ThAr lamp as well)

_It is a fact that the existing illumination system is acceptable for all the other EMMI modes than Echelle spectroscopy. The foreseen solution by merging the integrating sphere with a more efficient direct mode for the Echelle spectroscopy._

3. The sphere is used for technical templates, like grism and slit alignments, and spectroscopic internal flats (RILD), which make use of continuum lamps, hence these cannot be discontinued. For the same reasons, use of the actual integrating sphere or a similar device cannot be discontinued as well.

_We foresee to keep the integrating sphere without affecting the existing calibration modes (scientific and technical)_

4. It must not compromise the balance of the instrument.

_The modification of the integrating sphere will be counter-balanced on the rotator B, trying to avoid excess weight._

5. It should be made available to the users community possibly within the year, technical issue allowing it, due to the increasing user’s demand on echelle mode.

_The final solution retained is simple and could be implemented easily during the year. The only critical delay could depends on the optical piece delivery. Agreed earlier optical final design review could certainly help on reducing the delay risk._

3 New Calibration Concept

3.1 Overview

Several preliminary tests have been conducted to check the validity of illumination concepts. A specific EMMI instrument set-up with grating medium dispersion REMD and Echelle mode was selected to perform these preliminary tests.

- The first approach concerned the replacement of the integrating sphere by holographic diffuser. The diffuser was mounted replacing the sphere and a collimated calibration beam was projected using an additional Thorium Argon hollow cathode lamp.
The better illumination flux flatness reached only 10% between the center and the edge of the field on the best case. The integrating sphere allows better than 2% flatness over the slit full length. The solution to replace the integrating sphere by holographic diffuser is not satisfactory.

- A direct projection mode was also tested. The same Thorium lamp was used and mounted with an achromat lens to collimate the light beam at the equivalent location of the sphere. The lens was with a smaller diameter than required to match the intermediate pupil size. The magnification of the lens system allowed a cathode image of the lamp of around 4 mm on the entrance long slit. The following picture (pic.1) shows the thorium spot image over the slit, the slit viewer of EMMI was used. With an exposure of 1 sec and a lamp current of 5mA the Echelle Thorium spectra is very good with easily detected blue lines as shown on picture (pic.2).
On the Picture 2 the blue is located at the left. The Argon red line are saturated. A proper filter using BG type Schott will balance the red/blue flux as it has been done on Harps and Feros.

**Not affecting the Sphere use on the existing calibration for the REMD/BLMD, the conceptual design document proposal concerns an additional Thorium-Argon lamp mounted on a direct mode.**

### 3.2 Optical Layout and Design

The proposed solution add a direct Thorium spot projection over the entrance slit. The following parameters are important to follow:

- Two separated concepts - Integrating sphere with present lamps and the new direct projection system
- The projection system will have to simulate the intermediate telescope pupil size.
- The additional lens will not introduce image aberration affecting the spectrum position with respect to science exposures
- A small field is required only to cover the slit aperture for Echelle mode
- A spot size of at least 10 time the slit longer size in echelle mode will minimize eventual flexure residual effect
- The central obstruction of the pupil will be simulated *(it was not the case with the integrating sphere)*
- The aperture ratio of the projected beam should be at least corresponding to the F/11 telescope aperture ratio.
The goal is to obtain below 1mn correct Thorium spectra without too large losses in flux.

- Diffuse interorder Thorium light must be below 10% of the nearby continuum order

The area of the integrating sphere is presented on the following picture {3}.

![Picture 3. Integrating Sphere of EMMI](image)

On the picture the four mounting screws of the complete unit are visible on the main black support plate. On the top picture part the calibration fiber is visible meanwhile on the bottom the pencil Neon and Thorium lamp are mounted, both lamps have a specific shutter. The red unit corresponds to the rotator brake device, at its location the rotator is fix (telescope) meanwhile from the most left sphere side all parts rotate with the instrument. The new lamp unit should fit within the same space without affecting the rotation of the adapter/rotator.

### 3.2.1 Optical Concept

A custom designed achromat will collimate the light coming from a new thorium lamp. The present optics within the adapter will focus the cathode spot over the slit simulating a large object projection. With a lens designed to fit the sphere present aperture, the F/ratio will be preserved. A focal length (higher than 300mm) of the achromat will allow space and scale to produce a right size spot over slit unit. With this value the cathode of the new thorium lamp (Cathodeon) of about 4 mm size will be imaged on 8 mm over the slit unit. The Thorium lamp actually in use is mounted on the sphere side to allow the diffusion and integration of the light. This lamp must remain as it is for the Thorium calibration performed with a long slit. The Thorium cathod of the lamp have some intensity variation over the emitting surface. Defocus or diffuser will help on reducing these unwanted effects. The focus position of the integrating sphere is not very sensitive (diffuse source area). No central obscuration
mask simulate the telescope pupil. The achromat will have to be located at the adapter entrance flange pre- 
ently corresponding the the integrating sphere output aperture. The achromat will have to be set in position or removed to allow the integrating sphere modes. 

**Outcomes:**

- The achromat lens should have a diameter of 72 mm to match the pupil diameter (output sphere aperture) 
- A central obstruction disk (installed on the adapter side of the new lens) will simulate the pupil M2 shadow. 
- The focal length of the lens will amount around 300 mm to allow a factor two in transverse magnification projection of the Thorium cathod over the slit aperture 
- An UV holographic diffuser will be mounted at the lamp aperture to introduce a blur effect. A 0.5 deg circular one will not modified the beam aperture and add the required effect 
- Coloured Schott filters could be also mounted to balance the blue and red spectrum side difference. (High intensity Argon red lines compared to the Thorium ones, Effect is also large with different lamp refilling gaz as Ne .. )

### 3.2.2 Mechanical design approach.

Free space around the integrating sphere is not large. The adapter edge has regularly espaced ribs along its pe- 
rimeter to reinforce its structure. The integrating sphere is located in between two ribs not allowing the lateral 
displacement of the sphere. On the Fig.3 the sphere is shown as fixed on a main plate by means of two lateral 
support holding the different lamp unit. The main plate is bolt by four screws on special flattened ribs. The only possibility is a radial move (with reference the adapter axis) of the sphere. 

The above mentioned optical concept can fit the available space using a simple solution not involving com- 
plex mechanisms. The new unit must behave also properly in term of flexure when rotator moves. By moving away the sphere from the adapter by about 35 mm, a space is allowed to mount the lens. A carriage can be used to move the lens in and out the sphere aperture without moving the sphere.

The easier solution keeping the sphere as it is and translating it is not feasible for the space limitation. 

The remaining problem is to mount the Thorium lamp. With fixed integrating sphere a small hole has to be made on top to allow the light going through. Meanwhile on non Echelle spectroscopy the sphere must be kept 
close to not disturb the light homogeneity. The only solution is to use a closing shutter properly painted to 
minimize the sphere aperture effect. Opposite to the sphere exit aperture an aperture of 30 mm diameter will be done. An additional in/out disk function will close or open the sphere. The sphere side of the disk will use latest high efficiency diffusing paint (like Spectralon).

### 3.2.3 Pre-Design

Using an optical design program a first layout is performed. The design included the present projector and 
mirror unit of the calibration unit mounted within the adapter. The calibration unit lens has a focal length of around 720 mm. The new lens has a focal length of 310 mm. The magnification of the complete system will amount 2. The image quality of the new lens is not very critical being an illumination device (The ThAr spectral line po- 
sitions and width must be not affected by the insertion of the lens: the spectrum will be comparable with ‘that 
of a ThAr acquired with the old mode). However the transmission must be very good on the range 350-950 
nm. The Silica and LLF2 glasses are correct (used for the present calibration unit lens). A wide anti-reflection 
coating will be used.
Residual axial chromaticism is still not completely corrected as it was also present on the actual system. The poly-chromatic image (350-950) size 0.7 mm diameter on 80% Encircled Energy on direct imaging without the diffuser. On the following picture {4} the layout is presented.

By removing the new lens and closing the top part of the sphere the calibration mode will be identical than before for the RILD/REMD/BLMD modes with or without the slit mask.

3.2.4 Design Implications

To facilitate the integration of the new system without requiring long installation period, a new sphere should be purchased if available. Only one sphere will be used at EMMI, the old one kept intact as a spare. Both opening aperture of the sphere could be required at the purchase. Two functions will be required to move the disk and the achromat in/out. The complete unit will be exchanged when ready, only the lamps will be exchanged as well. In case of unsuccessful purchase a Sofi period will be used to modified the unit accordingly.
3.3 Mechanics Implications

The mechanical design must include the following specifications:

- A new or modified support for the sphere will be designed. It will use the same interface mounting screws (x4). Attention should be plan to check carefully the space availability restricted by the adapter ribs.
- The four lamps actually mounted on the sphere side will have to be installed as there are actually.
- Two in/out functions will drive the lens and the sphere closing disk, two motors could be used without encoder.
- A bi-stable mechanical design type could be used at least for the sphere closing disk.
- Both lens and closing disk area will have to be light proof.
- Lens in/out moves will require short time (up to the warming up time for the lamp)
- Closing disk moves will require below 1 sec also considered as lamp shutter (delay, speed, ...)
- Position locking of the added lens will have to be considered to ensure stability and decrease flexure effects. When reaching the inserted in position the lens position error and flexure should be smaller than 0.2 mm with respect to the mounting interface.
- The mounting of the Thorium lamp will have also to be stable with respect to the lens by 0.2 mm when rotating the adapter/rotator
- The two functions will require position sensors.
- The mounting of the new thorium lamp will include holders for the diffuser and the coloured filter (mounted close to the lamp front)
- The mounting space limitation is not too restrictive but keeping in mind the rotation of the adapter
- The unit must be as compact as possible
- Rough positioning adjustment will be required with the new unit to center the spot image of the Thorium cathode centred on the long slit. Adjustment for the lens and the thorium lamp must be considered and will be done for the first installation. Eventual lamp adjustment could be required after changing the bulb
- Old lamps will also require simple alignment.

3.4 Electronics Implications

Two functions will have to be controlled as well as a new lamp.

The LEMCAL LCU already in use will be used to control the new unit.

A new ACRO module of 64 bits will be enough the control the complete unit.

Interface to control the motors and the lamp will have to be defined after looking the simplest solution.

The control will concern then:

- Turn on/off the lamp (1b)
- lamp hour counter
- lamp sensor on/off info (1b)
- Achromat lens in/out (1b)
- Position sensor of the lens in/out (2b)
- Closing sphere disk in/out (1b)
- Position sensor of the disk in/out (2b)
- Eventual re-cabling of the others lamps
Cabling has to be done from the unit to the LCU.
A total of 8 bits could be enough to control the unit.
A small handset for manual function moving will be compulsory in low level engineering mode.

3.5 Software Implications

A control software will be required.
The VLT standard can be used to control these functions through the LEMCAL LCU unit and the ACRO module.
For the observer point of view this additional function will be seen as a new lamp on/off control.
Once detected the function status (lens in position, lamp on) the closing sphere disk will be used as the lamp shutter.
Meanwhile an engineering panel will be compulsory to move manually the functions and check status.

The functions will be:
- Lens in/out
- New lamp on/off
- Closing disk in/out and used as lamp shutter

The cycle of function use will have to be:
- Old calibration exposures will require to check the lens out position.
- New thorium lamp calibration will require first to turn on the lamp, move the lens in, open shutter (closing disk), run the exposure, close the shutter, turn off the lamp and then move the lens out.

Fits header regarding the lamp use for the calibration exposure will require an upgrade.

3.6 Science Operation implications

The calibration templates will have to be modified to allow the lens out position check for the “old” type calibration exposures.
A new template will have to be edited concerning the new REMD Echelle Thorium calibration using the above described function and new lamp.
As mentioned above the Fits header regarding the lamp use for the calibration exposure will require an upgrade.

3.7 Maintenance implication.

New functions will have to be regularly checked within the NTT adapter maintenance.
The lamp status will have to be also included checking the illumination level with SCIOP maintenance order as well as checking the hour meter.
4 Mechanical Conceptual Design.

A first approach of the mechanical solution is presented taking in account all the requirements mentioned above.
Other concepts as translation of the actual integrating sphere have been discarded because requiring more modifications and more space.

![Picture 5.: Mechanical Concept](image)

The figure 5 above illustrate the sphere moved up by around 35 mm with the lens and part of the new Thorium lamp. It is important to notice the ribs on the lower part of the drawing corresponding to the rotator edge.
The sphere is mounted with all the present calibration lamps. An input aperture is shown on the top sphere part. The lamp support is cemented on the sphere meanwhile the lamp holder is fixed by screws to allow adjustment.
On the Figure 6 a side view is presented.
More details are presented for the lens carriage. The adapter ribs are also illustrated. The original position of the integrated sphere is also shown.
On the next figures the Thorium lamp unit and the top view of the lens carriage are presented
Figure 7: Thorium lamp unit.

Figure 8: Lens Carriage
The carriage uses two end switches as well as a spring sheet for position stabilization.

The shutter function defined as bi-stable has been designed to minimize the shutter mechanism thickness mounted on the limited space available on the thorium lamp output.

5 Required resources on the Project and cost estimation

Optical elements (Sphere, Lamp and Lens) will amount 5000 Euros. Meanwhile the final design, integration and test will concern about 40 m/hrs of Optics resource.

Mechanical design and detailed drawing will require about 50 m/hrs (partially done on 2D). About 150m/hrs will be required to complete the mechanical design in 3D. Additional 250 m/hrs are defined to produce detail drawings, manufacturing and assembly.

Material cost could be evaluated at 500 Euros.

Electronics ACRO Module cost around 2500 Euros. Design, integration and test will need about 120 m/hrs of Electronics resource.

Software using standard ESO issue will require also about 100 hrs.

The final version of the New EMMI software control will have to be installed and tested. The new lamp software will have to be performed according the new version.

The project cost estimation concerns on 8000 Euros of material and 600 hrs in total of Engineering resource shared between the different specialities.

6 Tentative Project Schedule

The project is now on its conceptual design phase. The CDR meeting is scheduled for the 27 of May.

The following tentative schedule could be foreseen with the different Milestones:

- Conceptual design and user requirement Review - May 2005
- Final design Review - July 2005 (require Mechanics, Electronics and Software)
- Ordering phase completed (Optics) - June 2005 (could be agreed early)
- Integration and lab Tests - September 2005
• Installation and Commissioning - Fourth trimester 2005 (require day time commissioning only)
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