Progress Report on the Multi Object Spectroscopy (MOS) mode for ALFOSC at the Nordic Optical Telescope

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Contents

1 Introduction

Multi object spectroscopy for the *FOSC type instrument has been discussed for some time. It will increase the efficiency of the instrument by giving 10+ spectra on one CCD image. Such a system was recently installed at the Nordic optical Telescope, La Palma.

2 The system

Multi object spectroscopy (MOS) consists of a number of subsystems

- A CNC milling machine
  The aperture plates are produced on a CNC milling machine delivered by Servo Products Systems Inc. USA. A plastic material called ABS (Acrylonitril-Butadien-Styren) is used for the aperture plates. It has a thermal expantion coefficient of 0.08-0.11 mm/m. pr. degree celcius. The manufacturing is done with a conical tool and the width of the slits is thus determined by the cutting debth of the tool.
  A water cooling system has been installed in order to lubricate the tool and control the temperature of the tool and aperture plate.

- Field aquisition software
  The first approach consists of determining the rotation and the translation from two separate images. In this way the center of rotation does not need to be known.
  The rotation is determined from the center of two slits and the center of the two corresponding stars. After the correction to the rotation has been determined, a new image needs to be obtained. This image is then used to determine the telescope offset needed to bring the object to the position of the slits.
  This method works in most cases. In others, a solution with a higher accuracy is needed.

- MOS plate manufacturing software
  Two programmes are essentially used in the manufactoring process. One is used for determining the Z axis zero point based on a slit plate with 10 slits cut in different debth and the second is used for designing the actual MOS masks.
  The program used for designing the MOS masks is based on a direct image of the field for which the MOS mask is to be made. When the image is loaded, slits of a variable length and width can be placed on object, using either a Gauss fit or the cursor X,Y position. The layout of the slits can be controlled by switching to spectra mode, where the resulting spectra is shown. The choice of grism can be changed to visualize the corresponding change in spectral range.

3 Installation

Before the techincal time in March 2000, the CNC milling machine was installed in the mechanical workshop. A water cooling system attached to the pressure unit is fitted and the vaccuum cleaner is not used anymore. It has been shown that the water cooling system is capable of purging the cutting debree in an efficient way.
The MOS mask layout software is installed on one of the instrument control computers under a dedicated account.
The aquisition software was designed in cooperation with Per Kærgaard and implemented as two functions in the BIAS CCD control program. This software was meant to be used for evaluation of the aquisition method.

4 Results from March 2000 technical time

4.1 The CNC machine

The CNC milling machine is working well. The problems with loss of initalization in the Z axis seen during tests on the Danish 1.5m are not occuring any more. The operation is well described in the manual (Making Multi Object Spectroscopy aperture plates for ALFOSC; observers and operators manual, March 2000) exept for the change of tools, which can be problematic if you want to ensure that the tooldoes not move down into the brass plate. The following method was used successfully to ensure that the tool (Z axis) has the right height given that the tools are of equal lenght (the current tools are 54.25mm +0mm -0.15mm).

1. Insert the tool all the way to the bottom of the collet and tighten the screw well.
2. Before running any NC programs ensure that the tool will not reach the brass plate when the `mos_zero.nc` program is run. The lowest position is Z = -56.5 (March 2000) and with the Z axis at this position there should be about 0.5 mm space between the tool and the brass plate.
3. Move the Z axis down in steps small enough to keep control of the distance between the tool and the brass plate until the position Z = -56.50 is reached.
4. Hold a feeler gauge of 0.5 mm flush on the brass plate and next to the tool and look if the tool is clear of it. Do NOT slide the feeler gauge in between the tool and the brass plate as this can destroy the tool.
5. If the tool is more than 0.5 mm from the brass plate, adjust the Z zeropoint manually by moving to a Z position that will bring the tool closer to the plate , i.e '`Z -0.3 G92 Z`' if the tool needs to be 0.3 mm closer to the brass plate.
6. The Z position of the new tool is now ready to be finetuned using the procedure described in the manual.

After this has been done, the adjustment of the Z axis zeropoint and manufactoring of MOS plates is trivial.
The axis origo for the Z axis must lie at the interface between the two plastic plates. After analyzing a mos_zero plate cut after setting the Z axis zeropoint to the correct value, the new value was found to be -56.15 (see figure 1).

One problem remains to be solved. The tools are worn out after about 3-4 MOS plates (depends of the amount of slits, of cause). At present, here at the NOT, there does not exist knowledge of how to make new tools or renovate existing, worn tools. It is also a very time consuming job to renovate old tools or produce new tools. It is recommended that a couple of third-party very hard tools that will last for many more MOS plates are aquired.
Several "mos_zero" plates was made during the period. All with nicely defined slits. One normal MOS plate was made in order to check the scale (see below). This plate was suffering from what looked like a worn out tool, but was useful for the test purpose it was made for.

4.2 Aquisition

The aquisition method described earlier takes some time to perform. A total of three images needs to be taken, one of the target field, one of the calibration lamp illuminated mos mask and one more of the target field (this last for determining the x,y offset). Assuming 70 seconds of readout time

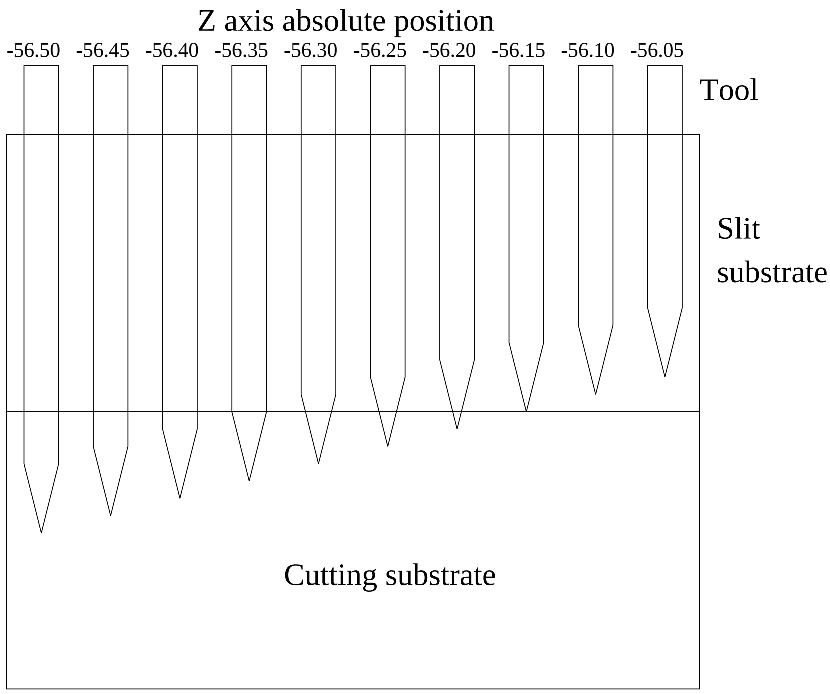

Figure 1: The layout of a plate cut with the "mos_zero.nc" program. The 8'th slit from the left is at the interface between the two plastic plates.

and 60 seconds of exposure time for the target fields and 1 second exposure time for the mos mask this gives a fixed time of 331 seconds or 5.5 minutes. To this should be added time to analyze the images, change the field angle of the telescope and start/stop of autoguider. The four taget aquisitionsmade on the first night of the tests required 0.84 hour, 0.44 hour, 0.94 hour and 0.47 hour to be completed.

These aquisitions was made with mos masks made at Copenhagen University Observatory and these mos masks had some distorsion in the positions of the individual slits that required more time in aligning. An aquisition made on the third night with a mos mask manufactured at the NOT consumed 10 minutes of aquisition time. In all of the aquisitions, the rotation needed was less than one degree.

There are various sources of error that can cause the individual slits to be displaced like it was seen with the MOS masks manufactured in Copenhagen.

- Thermal expansion
  The difference in temperature between the production environment and the operation environment of the MOS masks is around $10-15\ ^oC$. With an expansion coefficient of the plastic material of 0.10 $mm \cdot m^{-1} \cdot\ ^oC^{-2}$, one degree would give a shift of 0.2 pixels over the field of a 2048×2048 CCD. This effect is compensated by the slit layout software for a temperature difference of 10 ^oC.

- Flexure/stress
  When mounting the MOS masks in the aperture wheel, pressure is applied to the MOS masks. This is however applied perpendicular to the surface of the mask and can thus not account

for the effects seen.

- Determination of the center of the objects
  In the aquisition procedure, the position of the stars used for rotating/offsetting is determinated by a centroid. The position of the slits are determined by the cursor x,y position and can therefore be wrong. This seems unlikely as the midpoint of the slits are determined under a great zoom factor and with easy positioning of the cursor.

- Stability of the CNC machines used in manufacturing
  This is unlikely, as these machines rutinely operates at tolerances of $1\mu m$.

- Differential refraction
  Amounts to 0.5 pixels from top to bottom of the field at altitude 65 degrees.

- Inaccurate coordinate transformation
  Although there has not been observed any systematical errors in the shift of the slits, this seems like the most likely cause. As the MOS masks manufactured at the NOT does not suffer from these errors, it seems that it is the coordinate transformation on the CNC machine in Copenhagen that causes the problem.

It can be concluded that the time spend on aquisition greately depends on the manufacturing accuracy of the mos masks. Furthermore, seen in the light that one MOS exposure can give 8 - 20 spectra, an aquisition time of 10 - 30 minutes does not seem unresonable.

Various methods involving the use of more that two stars/slits for the aquisition has been considered, one of these based on the use of SExtractor for generating the lists of slits/stars and the IRAF tasks 'geomap'/'geotrans'. Another improvement could be to use the ALFOSC aperture wheel for rotating the field. This would mean that autoguiding can be conserved throughout the aquisition procedure thus saving time.

4.3 Manufactoring software

The program for laying out the MOS masks works well. The only features one would wish are the ability to change the colour table and the high/low cuts when displaying the image and the ability to use the cursor keys to position the slits instead of only the mouse.

4.4 Future plans / discussion

- Sceduling of MOS observations.

The production of MOS masks puts some constraints on the way MOS observations are to be sceduled. A lead time of at least 1.5 to 2 weeks should be reserved for manufacturing the MOS masks prior to the observation run where they are to be used. This implies that the observer should be granted 1-2 nights for obtaining field images for aquisition and 1.5 to 2 weeks later granted the MOS observation run.

- New, better tools.

5 Results from September 2000 technical time

5.1 The CNC machine

The procedure described earlier was used again, and is working satisfactory. This procedure takes 2 - 4 hours to perform. The short lifetime of the tools is still a problem. It has been found that approximately 3 `mos_zero` plates and 6-10 normal MOS plates containing around 15 slits each can be manufactured with each tool. After this point, only very wide slits can be made with such a tool. In a meeting between Per Kærgaard (CUO), Tim Abbott (NOT) and Jacob Clasen (NOT) in August 2000, it was decided to investigate the possiblilties of having more rugged tool manufactured by a commercial company. Parallel with this decition it was recognized that only 2-3 MOS runs will be sceduled per semester once the MOS mode is commissioned. Based on this assumption, it is feasible to be entirely supplied with MOS tools from CUO. Apart from this, there is presently no suitable machines at NOT for making MOS tools.

5.2 Aquisition

A new aquisition method was tested during this technical time. It is an IRAF task that takes two images and a slitposition file as input and returns an pixel x and y offset and a rotation expressed as a change to the current field angle. This task can use more than 2 stars for determining the requiered offset/rotation and is thus more accurate than the BIAS-based tweak procedure tested in the March technical time. The task needs to know the ccd x,y position of the center of rotation of the field rotator. During these tests this position has not been accurately measured and the position (1024,1024) was used.
The approximate accuracy obtained using this task for aligning the MOS plates is less than 1 arcsec based on the required posterior corrections. It should be noted that the errors in the slitpositions observed during the March techinical time using the MOS plates manufactured at CUO has not been seen in the MOS plates manufactured at the NOT.

5.3 Manufactoring software

No further comments.

5.4 Future plans / discussion

The IRAF aquisition task needs to be improved in the following points: The high/low cut needs to be better determined for easier visibility of slits and stars. Userfriendly tools for applying the offset should be produced. At present, the telescope needs to be offset and rotated by hand.

6 Results from September 2000 scheduled MOS observing run

6.1 The CNC machine

For this observing run a total of 12 MOS plates was produced. One tool was unfortunately destroyed in the initialization process. All 12 MOS plates was cut with the same, newly mounted, tool and was of a resonable quality. One end of a single slitlet looks slightly larger corresponding to the position where the tool has entered the MOS plate. The actual slit is then cut by moving the tool through the plate and this probably has the effect of pushing/compressing the plastic material rather than removing it (see figure 2). A slower motion through the plastic material could improve this potential problem.

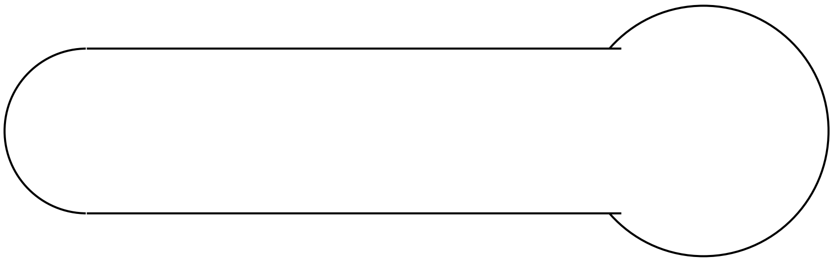

Figure 2: The form of a slitlet manufactured by the tool.

6.2 Aquisition

Taken into account that the IRAF task was offered in the same state as tested during the September technical time and the observer used it with very little documentation, the task performed satisfactory.
MOS specific technical support was only given on the first half of the first night (which was cloudy) and two hours on the first half of the second night.
The only recorded problems was

- Lost connection between IRAF and display program (SAOimage DS9)
  This problem is inherent to IRAF and can be solved by exiting both IRAF the the image display program.

- Absence of half of the slitposition definition files needed by the IRAF task
  This was due to a human error and the fact that the second half of the MOS masks was produced on day 2 of the observing run. The problem was corrected by simple file copying.

- One of the slits was outside the imagedisplay upon aquisition
  The IRAF aquisition task displays the smallest area that contains all the slits as read from the slitposition definition file. The task is now changed to display the whole image.

6.3 Manufactoring software

Two fields each containing 2 times 3 strips of stars resulting in 6 MOS plates was manufactured. As the objects was very faint (fainter than mag. 20), direct identification using a field image could not easily be made. As the `mosplate` program has provitions for reading lists of object pixel coordinates, this was used. After loading this list, the objects for one MOS plate could easily be identified even though a small offset exsisted.
The `mosplate` program has a problem with the slit sequence numbers. When loading an input coordinate file the slits are numbered correctly. Subsequent manual placement of slits results in numbering from 1 again, which in turn results in a corrupted sequence of slits. The interrim solution was to manually lay out the 4x4 asec slits for the aquisition stars and then load the input coordinate file.
After examination of the layed out slits and correction of their position a correct `NC` file was produced.
Another error occurs when changing to spectrum mode and back to image mode; the slits defined in the input coordinate file are no longer displayed.

6.4 Future plans / discussion

The errors discovered in the `mosplate` program should be corrected.

The procedural question of the layout and production of the MOS masks needs to be addressed. It was initially intended that the visiting observer should do the layout of his/her MOS plate based on an earlier obtained field image. This is only possible if the visiting observer is present at the telescope and thus only when the field image is obtained in connection with the actual MOS observing run. If the field image to be used is of an earlier date, the observer should either do the layout at his/her home institute using the `mosplate` program or prepare an input coordinate file. This input coordinate file can then be layed out by a staff member using the `mosplate` program. The first option is not desireable as it requires the observers home institute to have IDL and the visiting observer to posess knowledge of the `mosplate` program. If, on the other hand, the visiting observer is using the `mosplate` program on the telescope there will be access to support and guidance.

The time used for the layout of 6 MOS plates and production/control thereof was 8 hours not including breaks.

The items regarding the IRAF aquisition task discussed earlier still needs to be done.

7 Acknowledgments

We would like to thank all of you.

8 References

- Andersen, M.I., Clasen, J.W., Rasmussen, P.K, Commissioning the Multi Object Spectroscopy (MOS) mode for ALFOSC at the Nordic Optical Telescope, March 26, 2000.

A Target aquisition, user manual (No longer used)

Necesary preparations:

- Make MOS plates.
- Have at least 2 apertures for field stars.
- Identify the apertures to be used for aquisition.
- Mount MOS plates in ALFOSC aperture wheel.
- The position of one of the slits used for alignment stars must be in the obs1/alfosc/slitpos.def

1. Select the following ALFOSC configuration:
   - Aperturewheel: Empty
   - Filter wheel: The filter that matches the grism to be used most.
   - Grism wheel: Empty.
   - FASU A wheel: Empty.
   - FASU B wheel: Empty.
2. Make an exposure of the target field. Remember the filename.
3. Select the following ALFOSC configuration:
   - Aperture wheel: The MOS plate to be used.
   - Filter wheel: The same filter as before.
   - Grism wheel: Empty.
   - FASU A wheel: Calib. Lens.
   - FASU B wheel: Empty

   Turn on the halogen calibration lamp.
4. Make a 1 second exposure of the halogen lamp. Remember the filename.
5. In BIAS, type 'tweak filename1 filename2', where 'filename1' is the name of the image made in step 2) and 'filename2' is the name of the image made in step 3)

   The cursor will now move to the SAOimage window.
6. Position the cursor over the first of the stars to be used for the aquisition. Press 'z'.
7. Position the cursor over the second of the stars to be used for the aquisition. Press 'z'.

   The image of the halogen lamp thrugh the MOS plate will now be displayed and the cursor will move to the SAOimage window.
8. Locate the slit where the first star will shine through. Amplify the image using the SAOimage controls and position the cursor in the middle of this aperture (may it be a slit or a hole). Press 'z'.

9. Repeat step 7) for the aperture corresponding to the second star.

   The program will tell you the new telescope field angle.

10. On the TCS console, change the field to the new value using command: `'field nn.nn'`.

11. Start autoguiding again.

12. Make an image with the same ALFOSC configuration as in step 1).

13. Type 'imexa' and position the cursor on the star to be used for offsetting the telescope. Press 'z'.

14. Type the number of the slit that corresponds to the position of the MOS plate slit for this star.

    The telescope will do an offset.

15. Put in the MOS plate and make an exposure of the field to check if all the objects are on the desired positions.

B Target aquisition (IRAF task)

This section lists the procedure for and the IRAF help page describing the task ALFOSCMOS. An actual technical documentation or user manual is beyond the scope of this report.

Preliminary guide for using the 'alfoscmos' IRAF task for aligning MOS mask

1. Log in on *florence* as guest.
2. `cd` to `jacob/iraf`.
3. Type `cl` to start IRAF.
4. Type `cd ../images`.
5. Make sure that the aperture definition file for the MOS mask in use is in the directory (name: `MOS00??.nc.ap`)
6. Type `alfosc` to load the IRAF alfosc package.
7. Type

   ```
   alfoscmos <mask-image> <objectfield-image> <aperturefile> 4.0
   ```

   ,where `<aperturefile>` is the file MOS0020.nc.ap if MOS mask 20 is in use.
8. The maskimage will be displayed. Position the cursor over the slit that is marked with a BLUE circle. Press 'a'. When the statistics appear in the text window press 'q' to move on to the next slit that will be marked with a blue circle.
9. When all usefull slits are marked, the image of the object field will be displayed and the forst alignment start will be marked with a BLUE circle. Position the cursor on that star and press 'a'. Press 'q' after the text appears to move on to the next usefull star.

   OBS.: The circles will often not be exactly at the position of the stars, so take care when identifying them.
10. After the last star has been marked, the program displays the amount to offset the telescope in the pixel X and Y direction and how much to rotate the field.
11. Change the field angle in the following way:

    The 'alfoscmos' IRAF task shows "Rotation angle -0.5 (degrees)" The new field angle is -89.50 (if you started at field -90.0).

    - Stop autoguiding.
    - Change field (new guidestar (the same) will be found).
    - Open or set tv-filter.
    - Start relaxed autoguiding (important).
12. Offset the telescope in the following way:

    The 'alfoscmos' IRAF task shows

```
"X shift     9.886 (arcsecs)"
"Y shift     1.852 (arcsecs)"
```

Open an 'Xterm' on sandra and type:

```
teloffset 161.72.5.7 <accesscode> -9.886 1.852
```

,and wait until the offset has been done and the telescope is guiding.

13. Make an image of the field through the MOS mask and check the alignment of the start and objects.

14. Done.

C Manual page for the 'ALFOSCMOS' IRAF task

This manual page is subject to changes.

```
ALFOSCMOS (May2000)               NOT              ALFOSCMOS (May2000)


NAME
    alfoscmos -- find telescope tweak parameters from two  images  taken
    with a mask and of the object field.


USAGE
    alfoscmos maskimage objectimage maskdefinitionfile holesize


PARAMETERS

    maskimage
        Name of the image taken WITH a mask of a calibration lamp.

    objectimage
        Name of the image taken WITHOUT a mask of the target field.

    maskdefinitionfile
        Name of the MOS mask definition file (.ap file).

    holesize
        The  diameter  of  the  fiducial holes in arcsec.  In this task,
        this parameter affects the centroid algorithm.


DESCRIPTION
    This task determines the centroid positions of  the  fiducial  stars
    and  the  fiducial holes on an image of the mask and an image of the
    target object field. To measure the pixel coordinates on  the  image
    the interactive task imexamine is used.

    The differences in the measured positions of the stars and the holes
    are then transformed into telescope tweak  parameters:  offsets  and
    rotation.  Ask somebody who knows about it (maybe yourself) to apply
    this tweak, which should bring the  fiducial  stars  closer  to  the
    centre of the fiducial holes of the mask.


EXAMPLES
    Take  an  image  of a calibration lamp (i.e. halogen) with the mask,
    at the required telescope position and rotator angle, and  an  image
    of the target astronomical field, and do
```

```
alfoscmos jc240011 jc240012 MOS0006.ap
```

Ask yourself to apply the recommended tweak (first the offset, then the rotation). This tweak should bring your fiducial stars closer to the centre of the mask holes.

Iterate the tweak by using the task finetweak until the stars are properly positioned in the holes.

THE INTERACTIVE PART OF THE TASK

This task will display the section of the mask image which contains the fiducial star slits; the slits are marked by a circle. The user is advised to adjust the colour scale of the image display tool such that the fiducial stars AND the fiducial holes are clearly visible. The object field image will be displayed in full size and the fiducial stars will be marked as described above.

The user has to point the cursor at the fiducial stars (slits) marked by a YELLOW circle, and has to press key -a- to activate the centroid algorithm. If key -a- is pressed more than once, the final press will be evaluated. Each press will be acknowledged by statistics appearing on the terminal that runs IRAF. To advance to the next star (slit), press -q-. To avoid a particular star (slit) to take part in the tweak fit, press -q- WITHOUT pressing -a- first.

On the image display the centroid positions of the slits and stars will be marked by a RED circle.

When all fiducial slits and fiducial stars have been marked by the user, the tweak will be computed.

If one of the centroid positions of the stars or holes seems wrong (judging from the RED circles), the task can be run again with the user discarding the star in the way described above.

A good tweak fit needs no less than 3 stars. Nevertheless, a tweak can be computed on only 2 stars.

TIME REQUIREMENTS

A lot less than doing it by hand.

BUGS

email Jacob W. Clasen (jclasen@not.iac.es),
for bug reports and constructive remarks

SEE ALSO

alfosc_mos, finetweak