MODS

Instrument Observing Scenarios

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Contents

1 Introduction

1.1 Scope

This document describes a number of representative MODS observing scenarios (aka "use cases") to illustrate how MODS and the LBT system will interact. We only consider single and tandem MODS operation, and also consider hybrid configurations in which MODS and LUCIFER are used on the different primaries.

1.2 List of Abbreviations and Acronyms

AGW	Acquisition/Guide/Wavefront sensor unit
ARGUS	Integral Field Unit for the CFHT MOS-SIS spectrograph
CCD	Charge Coupled Device
CFHT	Canada-France-Hawaii Telescope
GCS	Guider Control System (LBTO interface application)
GMOS	Gemini Multi-Object Spectrograph
IFU	Integral Field Unit
IMCS	Image Motion Compensation System (MODS "flexure" control)
LBC	Large Binocular Camera
LBT	Large Binocular Telescope
LBTO	Large Binocular Telescope Observatory
LUCIFER	LBT NIR Spectrometer
M1	LBT 8.4m Primary Mirror #1
M2	LBT 8.4m Primary Mirror #2
MODS	Multi-Object Double Spectrograph
MODS1	MODS instrument #1
MODS2	MODS instrument #2
MOS	Multi-Object Spectroscopy
NOAO	National Optical Astronomy Observatories
OSU	The Ohio State University
PA	Position Angle
PASP	Publications of the Astronomical Society of the Pacific
S1	LBT f/15 Gregorian Secondary Mirror #1
S2	LBT f/15 Gregorian Secondary Mirror #2
TCS	Telescope Control System
WF	Wavefront

2 Direct Imaging Mode

These scenarios describe using MODS for direct imaging of fields in various configurations. In all cases we are assuming we are taking deep exposures requiring autoguiding.

2.1 Single MODS

Here we are taking a deep, guided image using only one MODS. This is the configuration we will use during side-1 commissioning (when only M1 is installed).

1. Configure instrument
   - Select Imaging Mode (Blue-only, Red-only, Dual)
   - Select the Imaging flats in the grating turrets as required
   - Select/deploy the imaging mask from the mask cassette
   - Select the filters.
2. Slew LBT to the target position
3. Snapshot image to verify pointing
   - Issue offset to LBT TCS to refine pointing as required
4. GCS acquire guide/WF star with AGW cameras
   - GCS makes wavefront corrections to LBT optics as required.
   - Initiate autoguiding ("mount guiding").
5. Initiate imaging of the field:
   - Select filter(s) as required
   - Integrate
   - Repeat until sequence completed
6. Done
   - Dismiss autoguider
   - End-of-observation housekeeping

2.2 MODS 1 & 2 in Tandem

In this mode we are imaging the same field with both MODS to get as much multiplex as possible (4 filters at once). There is no requirement that the two fields be spatially conjugate, other than to have rough alignment (e.g., centers should be close to co-aligned, but no need to super-refine that). MODS1 is designated as the "master" for mount guiding during the exposures, while side 2 is left passive.

1. Configure instruments (see 1.1, step 1)
2. Slew LBT to the target position

3. Snapshot image to verify pointing in MODS1
   - Issue offset to LBT TCS to refine pointing as required
4. GCS acquire guide/WF star with AGW cameras on each MODS
   - GCS makes LBT side 1 WF correction for MODS1 as required
   - GCS makes LBT side 2 WF correction for MODS2 as required
   - Initiate autoguiding – using the MODS1 AGW as the master ("mount guiding")
5. Initiate imaging of the field:
   - Select filter(s) as required
   - Integrate
   - Repeat until sequence completed
6. Done
   - Dismiss autoguider
   - End-of-observation housekeeping

3 Long-Slit Spectroscopy

These observing modes describe long-slit spectroscopy using either one MODS or two MODS working together. When observing with both MODS we designate MODS1 as the "master" for guiding, and MODS2 as the "slave".

3.1 <u>Long-Slit, MODS1 only</u>

This describes observing with only 1 MODS engaged, the other left idle (or during side-1 commissioning where only M1 is available).

1. Configure Instrument
   - Select Mode (Blue-only, Red-only, Dual)
   - Select grating(s) from grating turret and tilt to required central wavelength
   - Select/deploy long-slit mask
   - Select order-blocking filters (as required)
   - Set internal focus as required.
   - Setup the Image Motion Compensation System (IMCS)
2. Select Slit Position Angle
   - Instruct LBT to rotate instrument to selected position angle
3. Slew LBT to Target position
4. Optional: Acquire pre-observation wavelength calibration (zero-point calibration)
   - Deploy MODS calibration tower, close MODS darkslide

- Turn on calibration lamp(s)
- Acquire lamp spectra
- Turn off calibration lamp(s)
- Retract MODS calibration tower, open MODS darkslide

5. Deploy MODS AGW to acquire position, center target on slit
   - MODS UI commands AGW stage to locate the guide camera probe in the science field center, acquires object in guide camera via GCS
   - Issue offsets to LBT TCS to refine pointing as required
   - Verify target placement using a direct image through MODS long slit.
6. GCS acquires guide/WF star with front-side AGW
   - Select guide/WF star (either from menu, or pre-selected by observing template file)
   - GCS makes wavefront corrections to LBT optics as required.
   - Initiate autoguiding ("mount guiding").
7. Initiate IMCS lock and Science Integration
8. Optional: for very faint targets, nod the object along the slit between multiple integrations (not "nod-and-shuffle" using the CCD).
   - For small offsets, instruct offset from the LBT S1 hexapod
   - Instruct AGW to track the moving guide star and re-lock as required.
9. Done
   - Disengage IMCS
   - Dismiss autoguider
   - Optional: obtain post-observation wavelength calibration (cf. Step 4)
   - End-of-observation housekeeping

3.2 Long-Slit, MODS1 & 2 in tandem, same configuration

In this mode both MODS are used to observe the same target in the same configuration to get an effective 11.8m collecting area. From the user's perspective, MODS2 is slaved to MODS1.

1. Configure Instruments (see 2.1, step 1)
2. Select Slit Position Angle
   - Instruct LBT to rotate instruments to selected position angle on both foci
3. Slew LBT to Target position
4. Optional: Acquire pre-observation wavelength calibration (zero-point calibration)
   - Deploy MODS1/2 calibration towers & close MODS1/2 darkslides.

- Turn on calibration lamps
- Acquire lamp spectra
- Turn off calibration lamps
- Retract MODS1/2 calibration towers & open dark slides

5. Deploy MODS1 AGW stage to middle of science field, acquire target, & center target on slit
   - Issue offsets to LBT TCS to refine pointing as required (mount offset)
   - Verify target placement using MODS1 in direct imaging mode
   - GCS acquire a guide/WF star with MODS1 front-side AGW
   - GCS makes wavefront corrections to LBT optics as required.
   - Verify target placement using MODS1 image through long slit.
   - Begin mount autoguiding using the MODS1 front-side AGW
6. Deploy MODS2 AGW to acquire position
   - Issue secondary hexapod offsets to LBT S2 to co-align with reference location established on MODS1.
   - Refine co-alignment using the MODS2 rear-slit camera
   - GCS acquire the same guide/WF star used by MODS2.
   - GCS makes WF correction to LBT side 2 as required.
   - Verify target placement using MODS2 direct image through long slit.
   - Begin secondary (hexapod) autoguiding, slave to MODS1 mount autoguiding
7. Initiate IMCS lock & Science Integrations
8. Optional: for very faint targets, nod the object along the slit between multiple integrations.
   - Each MODS would separately command its secondary to offset ("nod") along the slit.
   - Also separately instructs its AGW unit to track the moving guide star and re-lock as required.
9. Done
   - Disengage IMCS
   - Dismiss autoguiders
   - Optional: acquire post-observation wavelength calibrations (cf. Step 4)
   - End-of-observation housekeeping

3.3 Long-Slit, MODS1 & 2, cross-slit configuration

Here the observations are taken of the same target, but with the slits oriented orthogonally (ΔPA=90°) for each spectrograph. This might be done when doing resolved galaxy kinematics in which you are simultaneously acquiring data long the major and minor axes.

1. Configure Instruments (see 2.1 step 1)
2. Select Slit Position Angles
   - Instruct LBT to rotate MODS1 to primary position angle.
   - Instruct LBT to rotate MODS2 to PA(MODS1)+90°
3. Slew LBT to Target position
4. Optional: Acquire pre-observation wavelength calibration (see 2.2, step 4)
5. Deploy MODS1 AGW to acquire position, center target on slit
   - Issue offsets to LBT TCS to refine pointing as required (mount offset)
   - GCS acquire a guide/WF star with MODS1 front-side AGW
   - GCS makes WF correction to LBT side 1 as required
   - Verify target placement using MODS1 direct image through slit.
   - Begin mount autoguiding using the MODS1 front-side AGW
6. Deploy MODS2 AGW to acquire position
   - Issue secondary hexapod offsets to LBT S2 to co-align with the reference location established on MODS1.
   - Refine co-alignment using the MODS2 rear-slit camera
   - GCS acquires the same guide/WF star used by MODS2. If unavailable, select an alternative guide/WF star.
   - GCS makes WF correction to LBT side 2 as required.
   - Verify target placement using MODS2 direct image through long slit.
   - Begin secondary (hexapod) autoguiding, slave to MODS1 mount autoguiding
7. Initiate IMCS lock and Science Integrations
8. Done
   - Disengage IMCS
   - Dismiss autoguiders
   - Optional: acquire post-observation wavelength calibrations (cf. 2.2 step 4)
   - End-of-observation housekeeping

4 Multi-Object Spectroscopy (MOS)

These observing modes describe multi-object spectroscopy (MOS) using either one MODS or two MODS working together. As with long-slit mode, when observing with both MODS we designate MODS1 as the "master" for guiding, and MODS2 as the "slave".

Note that in general we will advise observers to design masks to work with the slit axis of the max aligned North-South (PA=0°), and to observe their fields near transit when the parallactic angle is nearly 0° for most of the integration. This greatly simplifies mask design. Exceptions are possible, but should be discouraged unless absolutely required (it makes configuration very difficult).

4.1 MOS, MODS1 only

This describes observing with only 1 MODS engaged, the other left idle (or during side-1 commissioning where only M1 is available).

1. Configure Instrument
    - Select Mode (Blue-only, Red-only, Dual)
    - Select grating(s) from grating turret, and tilt to desired wavelength
    - Select/deploy MOS mask
    - Select order-blocking filters (as required)
    - Set internal focus as required.
    - Setup IMCS.
2. Instruct LBT to rotate instrument to PA=0 (N-S slit orientation).
3. Slew LBT to Target position
4. Acquire pre-observation flat-field & wavelength calibrations
    - Deploy MODS calibration tower and close dark slide
    - Turn on calibration lamp(s)
    - Acquire lamp spectra and flats
    - Turn off calibration lamp(s)
    - Retract MODS calibration tower and open dark slide
5. Deploy MODS AGW to acquire position for one of the mask alignment stars
    - Issue offsets to LBT TCS to refine pointing as required
    - Verify target placement using direct image through the mask.
    - Verify all alignment stars centered in their apertures, refine LBT offset and rotator PA as required.
6. GCS acquires guide/WF star with front-side AGW
    - GCS makes WF correction to LBT side 1 as required.

- Initiate autoguiding ("mount guiding").

7. Initiate IMCS lock and Science Integration
8. Done
   - Disengage IMCS
   - Dismiss autoguider
   - Optional: obtain post-observation wavelength calibration (cf. Step 4)
   - End-of-observation housekeeping

4.2 MOS MODS1 & 2 in tandem, same or complementary masks

In this mode both MODS are used to observe the same target in the same configuration to get an effective 11.8m collecting area. The procedure is a hybrid of 3.1 and 2.1 (long-slit, tandem), again working with MODS1 the "master" and MODS2 the "slave" for co-aligning the systems.

5 Hybrid Observing Modes

Hybrid observing modes are those that either mix major modes on MODS, or use MODS on one side and another instrument (LUCIFER or LBC) on the other for concurrent multi-instrument operation.

5.1 MODS Imaging+Spectroscopy

Here we use both MODS, one in spectroscopic mode and one in imaging mode. The instrument in spectroscopic mode is the "master"; the imager is the "slave" since imaging does not have the strict target positioning requirements of spectroscopy. The procedures would thus be similar to 2.2 (tandem long-slit, same config) and 3.2 (tandem MOS, same config), with the imaging configuration in the "slave" role. This mode might be used when observing a multi-target field in MOS mode, but using direct imaging to simultaneously acquire deep multi-color imaging for high-precision flux calibration and photometric redshifts of targets too faint for spectroscopy.

5.2 MODS+LUCIFER Imaging

Here we use MODS on one primary and LUCIFER on the other. The basic procedure is analogous to scenario 1.2 (tandem imaging). The choice of master/slave for guiding is up for grabs, though one might choose LUCIFER because of its tighter integration into its AGW. Procedures for conjugating focus are similar, but in general mount guiding is all that should be required because imaging does not have high-precision pointing requirements (FOVs of 6×6 and 4×4-arcmin for MODS and LUCIFER respectively give us a lot of latitude), and we not require high-precision co-alignment of the two sides beyond basic co-alignment (not like the case of dual spectroscopy where both channels have high co-alignment precision requirements).

5.3 MODS+LUCIFER Spectroscopy

Here we use both in their spectroscopic modes to realize full-wavelength coverage spectroscopy from near-UV to near-IR (320-2400nm). Here the requirement that both sides be co-aligned to a relatively high degree of precision to get the same target down the entrance slits of both spectrometers probably dictates that LUCIFER be the master and MODS the slave. The basic configuration procedure would be similar to that presented in 2.2 (tandem long-slit spectroscopy), with LUCIFER as the "master" (this all starts to sound vaguely apocalyptic after a while).

5.4 MODS+LBC

For example, a program where one is taking a long (>2h) integration with MODS in the Blue/UV on some quasar where single-point S/N is no problem but having a totally stable spectrometer configuration is essential, and using LBC-Red on the other side to take deep multicolor (VRIz) imaging of the same field. Here we mount-guide treating MODS as the master, which has the primary requirement of keeping the object(s) in the slit(s), and LBC as the slave, guiding however LBC will guide. This mode is likely to be unusual, but it was mentioned by a couple of people.

6 Post-Baseline Observing Modes

Previous scenarios have only considered observing using the baseline MODS instruments. Some possible post-baseline configurations include the following:

6.1 Integral Field Spectroscopy with MODS

Here an integral field unit replaces the slit mask. We envision a GMOS-style IFU, probably built by the Durham group for MODS.

Observing in this mode is essentially the same as long-slit spectroscopy, with the exception of how we acquire and center the target on the fiber feed. Experience with the ARGUS integral field system at the CFHT suggests that imaging the slit through the science camera when on-target is about the best means to ensure the target is centered. Calibrations proceed exactly as in long-slit and MOS modes.

6.2 Nod-and-Shuffle

This is a way to get very high-precision sky subtraction by combining small nods of the telescope along the slit with charge shuffling on the CCD to sample the object and the sky in the same pixels (see Glazebrook & Bland-Hawthorn, 2001, PASP, 113, 197 for details). This mode also permits the use of a larger number of tightly packed slitlets. Such modes entail a roughly 50% overhead (e.g., 1800s on-source integration require nearly 2400s to execute in nod-and-shuffle based on actual experience at the NOAO 4m).

For MODS this would require us to be able to command small offsets along the slit (few arcseconds, so likely hexapod moves rather than mount moves) to nod, and then modifications to the MODS CCD controller software to enable shuffling the charge between the "object" and "sky" nod positions. In principle, the telescope nods would be the same as those described under scenarios 2.1 and 2.2 above (long-slit single and tandem).