Notes from Operational Concept Meeting, 28 Nov 1996.

wht-naomi-88
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Present: RMM, MW, AJL

Purpose

The purpose of the meeting was to continue the walk-through of how the current design would be used for alignment and observing. The main thrust was to determine global module alignment mechanisms and AO-specific alignment.

Acronyms

DL	Diffraction limited
DM	Deformable mirror
FSM	Fast steering mirror aka OAP1
ISU	Integrating Sphere unit
ISUM	Integrating Sphere Unit Mask
OAP2	Off axis parabola which focuses light at ?f/16 optical and IR foci
OMC	Opto-Mechanical chassis
NCU	Nasmythcalibration Unit
NFPM	Nasmyth Focal plane mask
WFSC	Wavefront Sensor Camera

Definition of axes

The axes of the system are as follows

X	Horizontal, perpendicular to the local optical axis
Y	Vertical, perpendicular to the local optical axis
Z	Horizontal, along the local optical axis

Thus Z_WFS refers to an axis internal to the WFS along its optical axis

Initial Assumptions for on-telescope setup procedures

1. GHRIL micro-alignment telescope must previously have been confirmed as giving correct optical axis, tested with real star and rotation of de-rotator.
2. Optical chassis internally aligned, included OAP to FSM, mutual alignment of dichroic and compensating plate and field lens.
3. Voltages to obtain DM (local) flat are known.
4. WFS internally aligned; camera focused on field stop (done in lab, and checkable on GHRIL, by flood-illuminating field stop and moving WFS collimating lens, lenslets and camera together to obtain sharp images of stop), with collimating lens/lenslet/camera combination at nominal settings for conjugation of lenslets to DM.
5. WFS lenslets are aligned to WFS camera pixels.

6. WFS optical axis (Z_WFS) is parallel to the mechanical motion along the 'rails'.
7. The Z_WFS input axis is perpendicular to Z_WFS.
8. Calibration unit internally aligned; spherical (or possibly OAP) mirrors mutually aligned to tip-tilt injector mirror at its nominal datum. Fold mirrors between ISU and first spherical mirror (reflection) aligned. Beam splitter mirror at nominal angle to feed NCU to Nasmyth focus.
9. Pre-alignments between modules (NCU, opto-mechanical chassis, WFS) are assumed to have been done in the laboratory; repeatability of mounting is assumed to be possible to 1mm (hopefully this is conservative) and 1/200 rad (bench-space angle)
10. A method is assumed to exist (MW to determine) to transfer the Zygo (or equivalent) f/11 beam used for off-telescope alignment of OMC to 'posts' (target plates?) defining the optical axis behind the FSM.
11. A graticule-type reference is required which can be mounted repeatably in the collimated beam between the DM and the OAP2. This is used during lab alignment to mark the position of the collimated (by the FSM) f/11 beam from the Zygo.
12. Each module should have some form of alignment self-test mechanism. This could be just an indication that something is wrong rather than a diagnostic of precisely what.

Opto-mechanical chassis alignment

1. A working assumption was made (MW to confirm) that the overall alignment of the OMC to the telescope needs only to be to a mechanical accuracy.
2. Put OMC on GHRIL bench and align to micro-alignment telescope using posts referred to above. Locate repeatably by use of spacers from fixed mounts/references on GHRIL bench. This aligns horizontal tilt angle and XY position to axis but not focus (Z motion).
3. The focal plane mask (NFPM) used to generate the on-axis DL source is inserted and moved by direct measurement (relative to the front edge of the GHRIL bench) to the nominal optimum Nasmyth focus. This aligns focus (Z) position. TBD: the vertical tilt angle tolerance is such that it will not need adjustment. The angle between the GHRIL table and the Nasmyth optical axis needs to be known.
4. The OMC must have a removable reference point mounted to it which is at the nominal location of the WFS XY pick-off. This could be a focal-plane mask. This is used later.

Alignment of Nasmyth Calibration Unit to OMC

The notes here are based on a design for the NCU which uses only spherical mirrors and does not contain any collimated beams.

1. Module needs design which allows rotation in horizontal plane with rotation centre at the Nasmyth focus.
2. NCU Tip-tilt mirror needs known repeatable datum position which is correct for static alignment.
3. Glass with an optical path length equivalent to the colour and ND filters must be in the ISU source beam during alignment. This also means that if the concept of a single mechanism is used to deploy the colour and ND filters (by having several versions of each colour filter with different accompanying ND filters) plane glass must be used to make up the optical path difference when no or thin ND filters are in use. (NOTE: this may not matter if the holes in the NFPM define the image size).
4. Install calibration unit and check that focus of ISU source is at Nasmyth focus mask X and Z positions (sketch needed). Adjust by X and Z motions of the NCU.

5. Adjust the calibration unit source mask so that the white light image is correct in Y at the Nasmyth focal plane mask (NFPM). (Alternatively this might be done using first white-light fold).
6. Once the pre-correction TV has been set up to be on the optical axis, it could also be used to help in the image alignment.
7. Check that the position is also correct at the fiducial marking the place of the WFS pick-off (DM nominal flat; how detected? [WFS camera?])
8. Adjust the laser injection mirror to get the laser spot to the same position and focus as the white light source.
9. Now adjust for correct pupil injection. Insert the graticule set up during lab alignment, mentioned in item 7 of section 1 and take out the NFPM..
10. Adjust horizontal position of pupil by rotating NCU module about the Nasmyth focus, until pupil is correct on graticule.
11. Then adjust the NCU feed mirror (beam splitter) about the horizontal axis perpendicular to the optical path, to steer the NCU pupil to the correct Y location. This will also move the ISU source image.
12. Iterate 3 and 8 (replacing NFPM when necessary) to get the image and pupil correct simultaneously.
13. Check X image position is still correct (could change if NCU rotation is not exactly about Nasmyth focus).
14. Iterate processes again as required if image and/or pupil positions are incorrect.
15. The turbulence generator is inserted when required by removing the ISU (ISU mask remains so must be mounted separately). The optical science port is cleared if necessary. The turbulence tube + a white light source + achromat are inserted in place of the ISU, focused at the ISU mask.
16. Switch on pre-correction camera to check alignment versus white light source.

Alignment of WFS Module to OMC.

1. WFS module needs design which allows horizontal rotation of entire module about field stop for alignment purposes.
2. Slide WFS mount into position by eye so that laser spot position and focus is coincident with field stop centre. Can move pick-off mirror/field stop by small amount if necessary (may be needed especially to get best Y adjustment).
3. Insert a pupil fiducial (e.g. 7.35mm diameter circle on glass screen) as close as possible to position of lenslets (can it be in lenslet wheel?).
4. Rotate WFS module about a point at the field stop to get pupil X position correct on pupil fiducial.
5. Rotate pick-off mirror mounting disk about the incoming Z axis to get pupil Y position correct.
6. Check XY position of image in field stop. Iterate to get pupil and image position correct simultaneously. Note that a motion of the WFS module perpendicular to the WFS_Z axis (in the plane of the bench) is required to move the module from the focus on the field stop position to the mean position of the curved focal plane. Do this by comparing the focal position of the WFSC on the field stop and on the DL point source, then backing off a calculated amount towards the field lens. (slightly unclear ~ position when DL/WFSC is in focus on WFSC - needs further thought)

GHRIL Procedure to check lenslet conjugacy to DM

1. Put in multi-source ISU mask and NFPM, with ISU source.
2. Record with WFS camera the spot illumination pattern.
3. Move WFSC to focus on lenslets. Take out lenslets.
4. Move a DM segment significantly but such that light still goes through field stop.
5. Illumination should not change if DM is conjugate to current camera focus.
6. NOTE that NCU exit pupil is not conjugate with the DM at all field positions; therefore there may be a telecentricity problem to be solved here still as telescope pupil is at 12m. Check of changes in off-axis compared to on-axis illumination through the multi-hole masks can be used also to check for correct pupil illumination, but this will be affected by incompatible exit-pupil positions. Telecentricity may be checkable via looking for insensitivity of WFS output focus terms to camera focus (MW to work through this with 'final' CU design).

Alignment of DM to lenslets

1. Check lenslet conjugacy to DM, as above.
2. Put in on-axis point source NFPM and ISUM.
3. Set WFS pick-off to on-axis.
4. WFSC is on and at image focus.
5. Close loops on segment tilts, with zero offsets and no off-load to the TCS.
6. Put WFS offsets onto the 'guard-ring' of a selected DM segment(s).
7. Measure signal in guard ring, generate an X,Y error signal.
8. Servo this directly to the DM X,Y offset and drive DM to null position.
9. Repeat with other segments if required (will check relative DM/lenslet rotation).

Optional test on sky

At this point it may be appropriate (but not absolutely necessary) to put a real star through the system. It is before any IR image optimisation/non-common path aberrations have been calibrated, but there is no point in doing these if the system is not working to first order. A star could be used to perform valuable checks.

1. That by rotating the de-rotator while looking at the pre-correction camera, the camera is still on axis, thus confirming that use of the micro-alignment camera and CU combination has aligned the system to the correct position.
2. By putting at least a video camera at the optical science port, confirm that light is getting right through the system; (could be 2 plate scales or two camera, a full Nasmyth field one checking light over the whole 2.9 arcmin field and a 5" field looking at image quality and position). A very large format (4000 x 2000 ?) CCD could instead (or as well!!) be deployed if available!
3. With lenslets out, focus WFSC to look at telescope pupil - should see clear pupil. Return to WFS image focus.
4. Put in nominal WFS offsets, close WFS-FSM and WFS-DM loop and check that long-term focus changes are off-loading correctly to secondary mirror (need software to introduce artificial focus term) and if possible that something sensible is happening at the optical science port (I band).
5. Check FSM off-load to TCS is operating by moving pick-off a known amount and checking telescope follows, image moves appropriately on pre-correction camera and FSM mean returns to zero.

6. Save and analyse WFS data, comparing power spectra etc. with lab norms, previous on-sky experience and predictions.

Do WFS internal calibrations

For this meeting it was assumed that the procedures RAH has devised to put into the Excel OCD are carried out successfully. These include WFSC flat-field and bias, WFS transfer function to DM and FSM.

IR Path Calibration - Internal

Basically by an as yet to be fully agreed Durham method!

1. The ISUM and NFPM mask needs a hole located 2 - 3 arcsec from the on-axis point-source, with the NFPM hole size giving an IR full-pupil diffraction-limited image.
2. Turn on white-light on axis full-aperture DL source.
3. Move IR camera to best focus and do standard camera alignment.
4. Start up rapid image facility.
5. Optimise on-axis IR offset using 'some' algorithm (quickest way will be via direct IR image quality - DM loop, not via WFS).
6. Measure offset pattern for other field positions if necessary (but see below).

NOTE: we haven't yet described how the iteration between this internal calibration and the colour effects allowance for a real star are first simulated using the colour filters. However if the inverse-calibration procedure described below using the ELECTRA DM negligible hysteresis property works, some of this iteration may not be needed (but we'd better keep them for a Xinetics DM until we have developed an inverse variant which would work for that - would seem to need at least a figure sensor which could do snapshots on-sky (pulsed laser?).

On-axis on-sky aberration corrections

Method 1.

1. Acquire star on axis.
2. Enter and adjust Zernike terms 'by hand' (software slider?) until happy.

Method 2.

1. Acquire star on axis
2. Turn on fast IR image acquisition.
3. Use IR image optimisation algorithm with some integration time (possibly with phase locking in the case of injecting a periodic phase distortion [pistons only] to implement phase diverse detection) to smooth out seeing.

Off-axis on-sky aberration corrections

Method 1 (first order)

1. Calculate theoretical off-axis aberrations of the telescope relative to current on-axis measurements and apply as WFS offsets.
2. Possibly augment this theoretical information with extra measurements during commissioning.

Method 2.

1. Go to required offset guide star.

2. (Optional) Put GS on-axis (actually it should be positioned on what is planned to be the premium science field position in the eventual sky position - could even be some sort of field average); Close loops; optimise IR image; save WFS offsets and average position of DM actuators (both need to be known from earlier on-axis alignment if not re-measured now).
3. Go to required off-set guide position
4. Close loop; measure average difference over ‘suitable’ integration time between on- and off-axis positions of DM actuators.
5. Invert this difference to calculate corresponding WFS offsets (or back-off by adjusting WFS offsets until mean on-axis DM actuator positions are recovered).
6. Put in new WFS offsets and work closed-loop with offset guide star.

Summary of Design Implications

The following design implications are extracted directly from the bullets in the above procedures and additional notes from the meeting.

1. A graticule-type reference is required which can be mounted repeatably in the collimated beam between the DM and the OAP. This is used during lab alignment to mark the position of the collimated (by the FSM) f/11 beam from the Zygo.
2. The OMC must have a reference point mounted to it which is at the nominal location of the XY pick-off. This could be a focal-plane mask.
3. Module needs design which allows rotation in horizontal plane with rotation centre at the Nasmyth focus.
4. Both NCU and OMC tip-tilt mirrors needs known repeatable datum position which is correct for static alignment.
5. Glass with an optical path length equivalent to the colour and ND filters must be in the ISU source beam during alignment (but see note in relevant item).
6. WFS module needs design which allows horizontal rotation of entire module about field stop for alignment purposes.
7. WFS needs a pupil fiducial (e.g. 7.35mm diameter circle on glass screen) which can be placed by hand as close as possible to position of lenslets (can it be in lenslet wheel?).
8. The ISUM and NFPM mask needs a hole located 2 - 3 arcsec from the on-axis point-source, with the NFPM hole size giving an IR full-pupil diffraction-limited image.
9. Appropriate alignment adjustments are required on the beam splitter, WFS pick-off fold mirror (see text above for the axes needed).
10. Accurate control is required of the vertical height of the aperture masks which are inserted in front of the ISU (best if one adjustment applies to both single and multiple hole masks).
11. The ‘single hole’ aperture masks (ISU and Nasmyth focal plane) require a second hole which gives an IR (2.2?m) DL image, 2 - 3 arcsec from the central hole (i.e. not overlapping!).
12. Note requirement to be able to remove and replace the ISU repeatably to use turbulence generator.

Actions

1. MW to devise technique to transfer optical chassis input optical beam to behind FSM, to be marked by fiducials to be used with micro-alignment camera.
2. RAH/MW to advise on amounts required on adjustments of beam splitter, WFS pick-off fold mirror, module mechanical alignments controls.

3. RAH to check WFS specification has field stop in front of pick-off which moves with pick-off.
4. MW/CJD to sketch in figure sensor space envelope, including a mounting concept.
5. RMM to compile report on ELECTRA interferometers from experience of their use.
6. MW to investigate if NCU can be made to have 12m exit pupil design.
7. AJL to circulate this document to RGO ASAP so that they can give feedback especially on WFS alignment proposals and corresponding design implications.
8. RMM to ensure URD has specification for averaging DM actuator positions.