1. Decisions to be made on the design of NAOMI **wht-naomi-60**

There are a number of issues that have arisen when looking at the detailed implementation of components of NAOMI and their interaction. In this document I put forward a number of proposals which I hope can then be used as the basis for furthering the design.

1.1. Minimising the aberrations introduced by the dichroic substrate

It is possible to reduce the aberrations introduced by the dichroic beamsplitter by

a) Putting a small wedge angle on the back surface of the dichroic substrate (˜0.3°)

b) Adding in a plate similar to the dichroic at the opposite angle of incidence to that of the dichroic and with each of the two plates having the same small wedge angle.

Table 1 give the spot sizes (diameter in arcsec for 100% encircled energy, ? 0.5-1.0µm) for various options of the dichroic and field lens. Columns 1 and 2 give the x and y field positions, column 3 gives the spots sizes for a system without dichroic and field lens for comparison.

Columns 4 &5 are spot sizes for a system with parallel sided dichroic, no compensation plate and a field lens.

Columns 6 & 7 are spot sizes for a system with a wedged dichroic, no compensation plate and the field lens. Columns 8 & 9 are spot sizes for a system with a wedged dichroic, wedged compensation plate and the field lens.

The backfocal distances (field lens to focus) are 20 and 30 mm for the pairs of columns.
For comparison at ?=0.65 µm the diffraction limit for a 4.2 m telescope is 0.038 arcsec, and for a 57 cm sub-aperture is 0.47 arcsec.

1	2	3	4	5	6	7	8	9
			Back focal distance (mm)					
			20	30	20	30	20	30
Field position (arcmin)		No dichroic, field lens	Parallel sided dicroic		Wedged dichroic		Dichroic and compensator both wedged	
0	0	0.000	0.137	0.138	0.040	0.038	0.026	0.026
1.45	0	0.202	0.200	0.205	0.230	0.241	0.240	0.247
0	1.45	0.185	0.257	0.264	0.256	0.269	0.232	0.239
-1.45	0	0.202	0.200	0.205	0.230	0.241	0.240	0.247
0	-1.45	0.185	0.372	0.379	0.190	0.196	0.199	0.209

Table 1

The main effect of adding compensation, either by adding a wedge to the dichroic or including the compensating plate, is to improve the on-axis performance - Field position 0,0, Columns 6-9.

For the other field positions the spot size actually increases at 3 of them (rows 2-4) when the aberration compensation is added.

For the 4th position (bottom row) the image size is halved.

There is not much improvement in image size when going from the wedged dichroic alone to the system with dichroic added.

Assuming a perfect WFS transfer function these offaxis aberrations would not matter. More detailed analysis is required to see whether the WFS performance on-axis (where higher Strehl is required) is enhanced by having low offsets. Chromatic effects on pupil imaging also need to be investigated. If there is a wavelength dependent lateral shift of the image of the DM at the lenslets then this will degrade the performance. It is not clear which of the options gives the best performance in this regard.

On the other hand a case can be made for improving the image quality when using the optical science port with eg. an IFU. If just a plane parallel dichroic is used then the static 0.14 arcsec on-axis image would need to be corrected by the AO system in the presence of photon noise. It is better to correct the aberration with a static optics.

1.1.1. Proposal 1

Subject to further investigations the option of adding a wedge to the dichroic should be adopted.

1.2. Back focal distance

Request from RGO -The 20mm back focal distance from the field lens to the focal plane be increased to =30mm.

A comparison of image sizes for the 20 and 30mm back focal distances in table 1 shows there is not much differenece so that the 30 mm value can be used. It may also be possible to improve the images with small changes to the field lens design.

1.2.1. Proposal 2

A back focal distance at the field lens of 30 mm is used in the design of the NAOMI

1.3. WFS pickoff and orientation

The addition of an extra fold in the WFS pickoff train has enable vertical motion of the whole WFS to be eliminated. A further simplification can be made by making the main axis of the WFS perpendicular to the optical axis at the f/16.6 corrected focus. However this means that the WFS will encroach in to the space envelope allocated to the TTS. Below I list a number of options for the TTS and make a proposal as to how to proceed.

1.3.1. TTS options

1.3.1.1.NGS only.

1. Use optical science port. This could be done because the ~36 mm of focus adjustment to get to the LGS focus is not required. Use a flip in mirror for acquisition
2. Mount vertically. Not an option if IR or CCD because of the weight of the detectors
3. Use currently allocated space. Can probably squeeze it in, but field lens may have to be moved from 20 mm away from focus to 30 mm. This has been raytraced and the results are shown in

Table 1. The design of the WFS would also need to place as much as possible of the wheels, lens supports etc on the 'downstream' side, (away from the allocate TTS space)

4. IR - Only possible with cold and therefore expensive detectors. But it does give increased sky coverage Note that option 1 is not suitable for an IR TTS, i.e. it would need to further upstream to obtain access to IR radiation.

1.3.1.2.LGS

1. IR - as above but more money should be available
2. Take away field lens which should leave sufficient space between the WFS pickoff and the dichroic for the TTS. The resulting system would be non-telecentric but a LGS is always used on-axis (only close to on-axis: does this make any difference? - AJL) and realignment of the DM with the lenslets can be an automatic procedure, see next section.

1.3.2. Proposal 3

The design of WFS with all components moving along the same axis will be cheaper, more reliable, easier to align and install and should therefore be implemented if possible.

From these options a strawman design for a TTS is developed by RGO that allows the 90^o orientation of the WFS axis to be used.

1.4. Alignment of the DM to WFS

1.4.1. Requirement

There is a need to remove and insert the DM (c.f. NAOMI/Durham MOU). After each insertion one would need to realign all lenslet arrays, relay and CCD to the DM segments. The lenslets could be realigned by rotating the whole WFS assembly about the WFS field stop. This would be difficult to do while maintaining the relative offset, in image space, between the WFS and the science fov.

1.4.2. Proposal 4

?? DM to be put on a powered xy-stage (a non-powered stage was already proposed by ROE as part of the OMC design for ease of alignment). This stage would need to move to an accuracy of ?0.05 of a sub-aperture i.e. ±0.2 mm.

?? Align DM-lenslet array using DM x,y mount

1.4.3. Advantages

a) Moving lenslets by hand difficult
b) Would otherwise have to redo all of the lenslets each time DM is inserted
c) CCD and relay do not need to be motorised in x,y
d) the procedure can be automated, see next section
e) if system is not truly telecentric, one can realign for off-axis stars.

1.4.4. Disadvantages

a) small shifts of the pupil on DM but pupil is not circular anyway (hasn’t this now been modelled by Ron and confirmed to be OK? - AJL)
b) The reconstructor needs to take into account the alignment of the pupil with respect to the DM segements in order that, when modal control is used, the correct signals are applied to the DM.

i.e the centre of the pupil and the origin for the Zernikes used in the wavefront reconstruction must be aligned.

1.4.5. Automatic procedure

The WFS camera can be moved so that the lenslets, and hence DM, are imaged on to the WFSC. Alignment can then be carried out in principle by using the small amount of vignetting at the lenslet and mirror segment boundaries but this would probably need to be done by hand

The above method could be made easier, and probably automated, by using a mask at the DM to illuminate only one segment of the mirror.

An alternative which eliminates the need for a mask is to use the capability of the segmented mirror to displace the images from one sub-aperture 8x8 pixel sub-array into a nearby sub-array. This is illustrated in Fig.1 which shows the ELECTRA DM segments and the WHT pupil. This figure can also represent the lenslets or the 8x8 pixel sub-arrays on the detector.

The images arising from the sub-aperures adjacent to sub-aperture **a** are redirected into pixel sub-arrays as shown. For a perfectly aligned DM/lenslet array the shaded pixel sub-arrays will then have no signal in them. Misalignment of the DM and lenslets will cause light to appear in the shaded area on the detector. The amount and direction of the spillover will give an error signal with which to drive the DM x,y stage. The procedure can be repeated for other sub-apertures such as **b**.

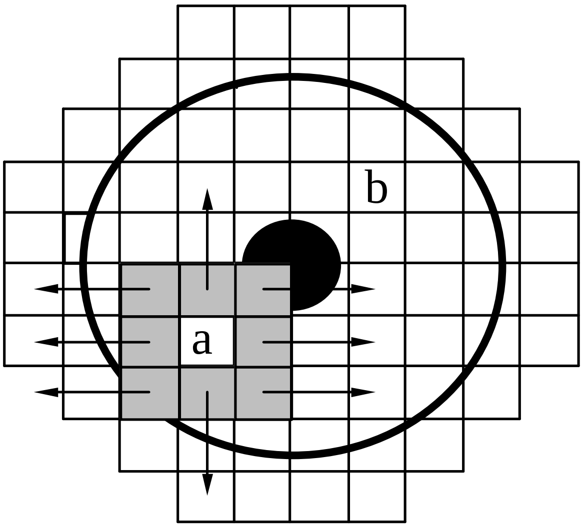

Figure 1

1.4.6. Proposal 5

Fine DM-WFS alignment be carried out using the above process and a motorised DM x,y stage.

1.5. Internal alignment of the WFS

If fine alignment of the DM to lenslets is carried out using the above procedure then the internal optics of the WFS (lenslets, relay lens and CCD) can be aligned with respect to each other and then fixed. This removes the need to move the lenslets by hand to ±50μm during normal operation and for the camera/relay lens to be on a separate x,y stage.

1.6. Acquisition

1.6.1. On to an imager

The smallest IR fov that will be used is ˜256*0.04=10 arcsec. The TCS can point to better than this and can therefore be used for blind (no visible image) acquisition.

1.6.2. On to an IFU

For an IFU working in the visible then acquisition can be achieved using the NAOMI acquisition camera. The offset between the acquisition detector and the IFU would need to be calibrated, using the WFS probe as a transfer device.

1.6.3. On to a narrow slit

For an IR spectrometer blind pointing to better than a half a slit width of 0.1 arcsec is not possible because of instabilities in the sky to Nasmyth focal plane mapping which are of order 0.1 arcsec.

1.6.3.1.Proposal 6

Any IR spectrometer designed for use with NAOMI should have an imaging mode.