NAOMI News

C. Benn (ING), R. Ostensen (ING), R. Myers (Univ. of Durham), T. Gregory (ING) and A. Longmore (ATC)

NAOMI, the WHT's adaptive-optics unit, is currently offered to observers with the IR imager INGRID. Performance predictions were given in the March 2001 *ING Newsletter*, and updates can be found on the ING web page, at `http://www.ing.iac.es/Astronomy/instruments/naomi/`

Much progress was made during NAOMI's recent commissioning run in May/June. The AO loop was closed on guide stars as faint as V=13, dithered observations were achieved without opening the loop (by moving the telescope and guide-star pickoff mirror in tandem), and a new control *gui* was implemented, allowing observing to be carried out routinely by ING staff.

NAOMI is optically and electronically much more stable than in the past, and it is now normal to observe for a whole night without having to repeat the afternoon calibration of the mirror shape. As usual, unexpected events (a devastating hacker attack, failure of the x-stage motor on the deformable mirror, and accidental rotation of one of the off-axis paraboloids) ate into the nights available, but for the first time NAOMI/INGRID service observing was attempted (25 proposals were submitted).

Performance with faint guide stars was found to be degraded by the lack of baffling around the guide-star pickoff mirror, allowing each cell on the wavefront sensor to see ~20 square arcsec of sky. A baffle is being installed.

The high (~100%) emissivity in K band has now been traced mainly to surfaces in the Nasmyth derotator and in the (NAOMI-specific) foreoptics in INGRID. Replacements for both are being investigated. Observing in H and J bands is not affected.

In September, NAOMI's performance in the optical (R, I bands) was characterised on sky. In reasonable seeing, NAOMI typically reduced the FWHM by a factor of nearly 2, and an example of this spectacular performance is shown on the front cover. This bodes well for deployment of the integral-field spectrograph, OASIS, with NAOMI in late 2002. Significant correction was obtained for guide stars down to R=14. Galaxies will be the principal science targets of OASIS, and the AO loop was successfully closed on the nuclei of several, including M31 and NGC 1068.

Performance in the IR (J, H, K bands) is not yet well characterised, and one of the goals for 2002A is to map performance as a function of guide-star magnitude, band, radius from guide star, and natural seeing (a large parameter space). Another important goal is commissioning of a mode in which information is binned up on the wavefront sensor, allowing ~1 mag fainter guide stars to be reached, and thus increasing sky coverage (but with poorer correction).

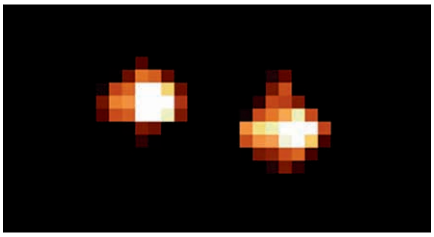

Figure 1. This 0.5-arcsec double star, R=11, was selected from the Palomar Sky Survey (on which it is unresolved) as the guide star for NAOMI observations of a nearby QSO. The wavefront sensor took this double image in its stride, and the delivered FWHM on the above 30-sec H-band exposure is 0.16 arcsec.

Commissioning of the coronographic feed to the science detectors (INGRID, OASIS) will take place early in 2002. ¤

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First Light on the New Small Fibre Module of Autofib2/WYFFOS

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Autofib2/WYFFOS is the multi-object, wide field fibre spectrograph working at the prime focus of the William Herschel Telescope. At the prime focus, the fibres are placed onto a field plate by the robot positioner Autofib2 (AF2) at user-defined sky coordinates. Object light collected at prime is transmitted along fibres 26 metres in length to the Wide Field Fibre Optical Spectrograph (WYFFOS). The path from prime focus to the spectrograph consists of a prism, fibre button, 26 metres of fibre, finger, microlens and the facet block.

At the end of July 2001, a major upgrade of the instrument was performed by successfully installing the new Small Fibre Module of AF2. With the new fibres, AF2 can presently observe up to 150 science targets over a field of 1 degree diameter (with an unvignetted field of 40 arcminutes). Each of the 150 science fibres has a diameter of 1.6 arcsec (90 micron), and runs without connectors from AF2 to WYFFOS. The fibres are high-content OH fused silica made by Polymicro.

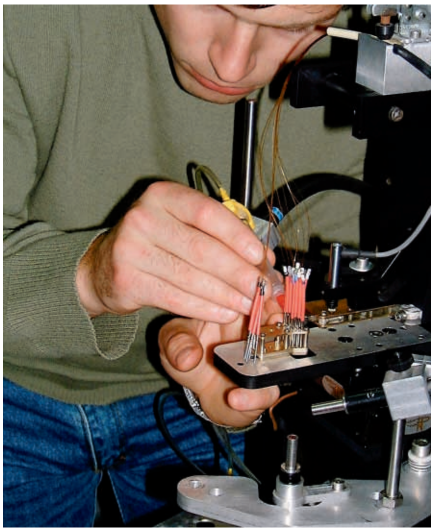
The small fibres replace the Large Fibre (2.7 arcsec diameter) Module, and have the following two main advantages:

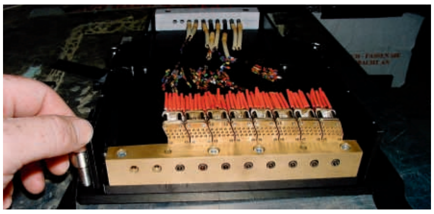
i) No light is lost because of fibre connectors, providing a much more homogeneous distribution of fibre relative throughput as compared to the large fibres, and a higher mean throughput.

ii) The sky/background contribution in observations with the small fibres is 3 times lower than with the large fibres. This means that, with the small fibres, the noise level in sky-limited observations is down by a factor of 0.6. The 1.6 arcsec diameter was chosen as a the optimal compromise between minimum sky contribution and maximal source contribution under good seeing conditions.

At the spectrograph focus, the small fibres are imaged onto less than 2 pixels (FWHM) on the TEK6 detector in the spatial and spectral directions. The full spatial image of the fibres is therefore sampled by less than 3 pixels. The fibre distance in the WYFFOS entrance slit is 1 mm, which transforms onto a peak-to-peak aperture distance of 6–7 pixels on the detector. Although the nominal spectral resolving power has increased as the ratio of large to small fibre diameters, the actual resolution is limited by the CCD pixels, because of the undersampling along the spectral direction. WYFFOS can achieve dispersions as high as 0.8 Å/pixel with the 2400 line grating with the present TEK CCD with 24 micron pixels. With the WYFFOS echelle grating the dispersion ranges from 0.24 Å/pixel to 0.57 Å/pixel.

With the Small Fibre Module, 10 new fiducial imaging bundles are available for field acquisition and guiding. Each imaging bundle (450 micron diameter) contains 10,000 individual fibres providing a rough imaging capability over a 8 arcsec round field. The new coherent bundles also allow for autoguiding.





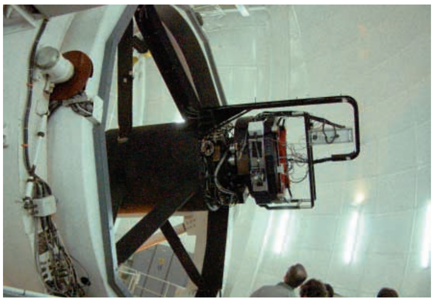


Figure 3 (left). Alignment of fibres into micro-lens finger holder. Figure 4 (top right). Fingers mounted onto the facet block. Figure 5 (bottom right). The Small Fibre Module at WHT prime focus.

In July 2001, we obtained the first measurements of the relative and absolute throughput of the science fibres. As mentioned above, the distribution of relative throughput is much more homogeneous than for the large fibres, and most fibres lie in the region within 15% from the median throughput. The absolute throughput of the small fibres was measured using grating R600B, under variable seeing conditions of 1–1.3 arcsec. Table 1 reports the magnitude of a star giving 1 electron/sec/Angstrom when observed at zenith. Numbers are scaled to the "median" fibre (i.e. to the median relative throughput).

These figures are similar to those measured in the past for the best large fibres, implying a substantial gain with respect to all those large fibres that had a much lower throughput because of light loss in the connectors.

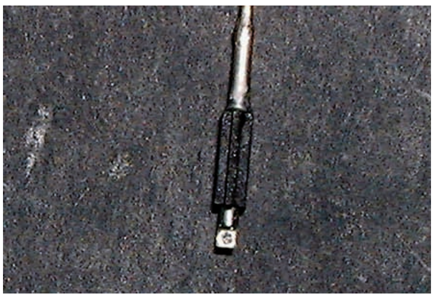
λ	4500	5000	5500	6000	6500
Mag	16.5	16.7	16.8	16.7	16.6

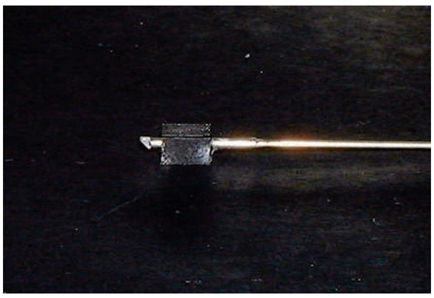
Table 1. Magnitude of a star giving 1 electron/sec/Angstrom when observed at zenith.

The Small Fibre Module is currently being offered to observers. More information about AF2 can be found in our web pages at: `http://www.ing.iac.es/Astronomy/instruments/af2/`

In spite of the successful commissioning, quite a lot of work is needed in order to improve and fully characterise the performance of AF2 and its new fibres. Further enhancements to the system are planned. A major improvement will be the introduction of the WYFFOS long camera. This will give twice the spectral resolution of the current camera, allowing us to increase the number of fibres on the chip. The long camera is under construction and is expected to become available at the WHT at the end of 2002.

Finally, we would like to acknowledge all people who took part in the various stages of the development of AF2, and in particular Mariet Broxterman, Nick Ferneyhough, Robert Greimel,





Figures 1 and 2: Top and side views of a fibre prism and gripper button.

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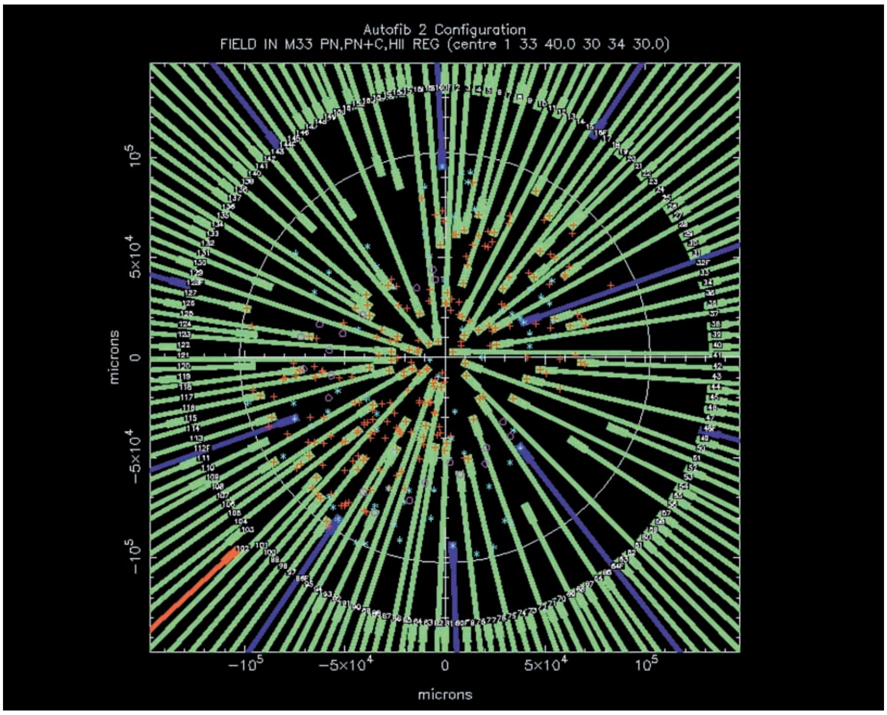

Figure 6. Example of a science fibre configuration on the nearby galaxy M33. The science fibres are shown in green (in red a fibre that was temporarily disabled), and the fiducial bundles in blue. Targets are the red crosses, while light-blue stars are fiducial stars for acquisition and guiding. The white circle shows the usable field of view (1 degree diameter).

The ING Red Sensitive CCD Project

Simon Tulloch (ING)

This project aims to improve the red sensitivity of our instruments through the use of low-fringing high-Quantum Efficiency (QE) CCDs. These are being produced by MIT Lincoln Labs for a consortium of observatories. Gerry Luppino manages the consortium at the University of Hawaii. His Company, GL Scientific, is providing CCD packages and cables. The ING commitment to the consortium is $141,000. This will give us at least three science grade devices.

The wafers will be divided and put through two different processes. The first process, called BIV, will give excellent red response but very poor blue performance. The second process, called UV or MBE, will improve the blue response whilst leaving the red response intact. The MBE process is still being developed (as of spring 2001). We have requested that our first chip be from the BIV process. This chip will be used at ISIS RED as its blue response is not important. Our subsequent chips will hopefully come from the MBE process, depending on its success. Two of these devices will be incorporated into a mosaic camera for use with WYFFOS long, UES and possibly for prime focus imaging on the WHT. If the wafer run has good yields we can expect a fourth device for use with OASIS. Additional sources are being investigated for a fourth chip should the yields from this contract be lower than expected.

CCD Characteristics

Size: 2048 × 4096 pixels
Type: CC1D20
Pixel size: 15 × 15 microns

Two outputs with a high sensitivity of 15 μV/e⁻

Fringing at 1000 nm ≤ 10%

Manufactured from 40-micron thick high-resistivity silicon

The Physics of Deep Depletion CCDs

Standard thinned CCDs are typically 15 microns thick. As the wavelength approaches 1 micron, the absorption depth of silicon increases rapidly and the CCD becomes transparent. The red sensitivity suffers accordingly. There is an additional problem, called 'fringing' which in some applications is an even more serious drawback than poor QE. As the transparency of the chip increases at longer wavelengths the CCD acts as a Fabry-Perot cavity with light reflecting back and forward between the front and rear surfaces. Interference is produced that heavily modulates the spatial uniformity and reduces the SNR of the observations. The solution is to make the CCDs thicker than the absorption depth of the silicon, incident photons will then be absorbed on their

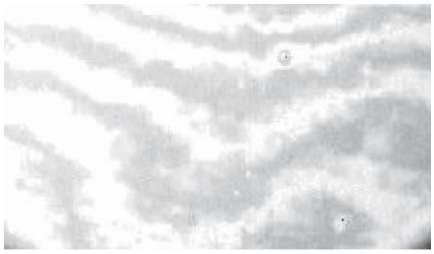

Figure 1. Image showing the effects of fringing in a thinned astronomical CCD.