There may be a slight gain in S/N of the extracted spectrum with respect to the large fibre case, as less pixels will have to be extracted when sampling the wings of the spatial profile. For small fibres, the fibre distance in the WYFFOS entrance slit will be 1 mm, which transforms onto a peak-to-peak aperture distance of 6.7 pixels on the detector.

The nominal spectral resolution will increase as the ratio of large to small fibre diameters, although this number is limited as the detector will also undersample in the spectral direction. We expect the highest resolution to be around R ~ 7500 in echelle mode.

The 1.6 arcsec fibers were chosen as a compromise between minimum sky contribution and maximal source contribution. As the positioning, pointing and (automated) guiding errors may add to 0.5 arcsec, there will be no room anymore for astrometrical errors. Field setups that suffer from inaccurate astrometry or an insufficient number of fiducial stars may suffer light losses of more than 50% at the fibre entrance. We caution future observers about this effect, as bad astrometry may cancel all the gains that the new SFM will offer.

Information about AF2/WYFFOS can be found at: `http://www.ing.iac.es/~jht/af2wyffos.html`. ¤

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RoboDIMM

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All observations with ground-based astronomical telescopes are affected by image distortion which results when starlight passes through turbulence in the atmosphere above the observatory. The wavefront of the incoming light suffers random aberrations as it passes through regions where there is turbulent mixing of air of different temperatures and hence refractive indices. At the focus of a telescope the effect of these aberrations is to form a rapidly changing 'speckle' image. For long exposures the point-spread-function (PSF) is the co-addition of a large number of random speckle images. This results in an approximately Gaussian PSF with FWHM typically in the range 0.5 to 2 arcseconds at good observing sites (Wilson et al., 1999).

This so called 'seeing' is a fundamental limitation of the signal-to-noise and resolution of astronomical observations.

The standard model for astronomical seeing has been reviewed in detail by Roddier (1981). From this analysis it can be shown that the seeing limited FWHM of the PSF for a long exposure with a telescope with diameter much larger than r_0 is given by:

$$FWHM = 0.98\, \lambda / r_0 ,$$

where λ is the wavelength of observation, and r_0 is the scaling length (also known as Fried's parameter) which is a measure of the strength of the seeing distortions (Fried, 1965). This r_0 can be thought of as the telescope diameter that would produce a diffraction spot of the same size as that produced by the atmospheric turbulence on a point source observed with an infinite mirror. The typical size of r_0 at a good observing site is 10 cm at 500 nm, which yields an image width in a long exposure of approximately 1 arcsecond.

In reality, there are many other factors which contribute to the final PSF. These include variations in the tracking and errors in the focus of the telescope, and the quality of the optics and their alignment. Also aberrations caused by turbulence inside the dome ('dome seeing') can be important.

Figure 1. Mockup of RoboDIMM.

Monitoring the Seeing

Why is it of interest to have a seeing monitor? In the first place it will provide a baseline seeing measurement for quality control of all instruments and telescopes. This will give a real-time assessment of image quality (such as focus optimization, etc.), as well as data for long-term remedial work (such as improving the seeing at the INT). A good example of the latter has been the study of the seeing quality at the WHT (Wilson et al., 1999).

A seeing monitor will also provide an on-line measure of extinction and allow optimization of queue/service observing (e.g., for observing with NAOMI; see O'Mahony, 2001) — we would always have an accurate measure of the current/recent seeing and its stability. For these very same reasons many of the major observatories around the world are operating, or planning to operate, seeing monitors continuously.

Differential Image Motion Monitor

To measure the seeing one can look at the variance of the position of a star which is given by:

$$\sigma^2 = 0.373 \times FWHM^2 \left(\frac{r_0}{D}\right)^{1/3} ,$$

where D is the diameter of the telescope. Thus, measuring the motion of a star at a given wavelength λ define r_0, and hence the seeing can be deduced. This method has been used in the past, but it requires a very stiff (and therefore massive) telescope because the image motion will include variations due to tracking errors or wind shake.

To avoid these problems the differential image motion monitor (DIMM) was developed (Sarazin & Roddier, 1990, and references therein). The principle of the DIMM is to measure the variance of the differential motion of images of a star produced with the same telescope via two entrance pupils separated by a distance S. Using the differential image motion eliminates the effects of tracking errors and wind shake, and is little affected by small focus errors, giving an unbiased estimate of the image degradation due to the atmosphere alone. Two independent measurements are provided by the motion in the longitudinal and transverse direction (parallel and perpendicular to the aperture alignment), as given by the variance:

$$\sigma^2_{l/t} = \sigma^2 \left[1 - k_{l/t} \left(\frac{d}{S}\right)^{1/3}\right]$$

with

$$k_l = 0.541 \text{ and } k_t = 0.810 ,$$

where d is the size of the entrance pupils (Vernin & Muñoz-Tuñón, 1995). An added advantage of this method is that the two measurements also allows a direct check of the data.

RoboDIMM

In the past a DIMM has been operated at the ING as part of the afore mentioned study to investigate the image quality of the WHT. This DIMM was located on an open tower 100 m from the WHT building, so that dome seeing and low level ground-to-air seeing effects are avoided. However, the use of the DIMM required the permanent attendance of an operator, which is very expensive if you want to operate it continuously.

Recently a project was proposed to develop and install a 'RoboDIMM'. This project was approved in November 2000. The aim of the project is to provide automatic seeing measurements throughout each observing night. This includes automatic selection of targets, pointing of the telescope and tracking of the targets, and acquisition and processing of the data. Opening and closing of the dome will be done remotely from the WHT control room. Also, the general operation of the system will be monitored from the WHT control room.

The RoboDIMM will consist of a clamshell dome with a 12” Meade telescope installed on the existing tower (a mockup is shown in Figure 1). The detector will be a CCD which can provide 10 ms exposures, which is required to effectively freeze the wavefront variations. It will be controlled from a PC in the WHT control room, which will communicate via a fibre network connection to the DIMM tower.

The project is now well underway, and we have ordered the dome and the parts for the power supply and the fibre optics cable, and contracted a local company to modify the tower. In the near future we will order the telescope and the CCD, and we hope to finalise our negotiations with a software company to develop the control software. The current planning is to have the RoboDIMM assembled during the summer, and complete the integration and commissioning in the autumn of this year.

In the future the RoboDIMM could be upgraded easily to provide a more comprehensive seeing monitor for optimisation of Adaptive Optics (AO) at the WHT, based on the SCIDAR (scintillation detection and ranging) technique. The system would give real-time measures of the vertical profile of turbulence and turbulence velocity from the analysis of scintillation patterns of binary stars (Caccia & Vernin, 1990). For AO this data is required to optimise the PSF at off-axis field points, and to determine the (very large) anisoplanatic variations of the corrected PSF with field angle (for deconvolution and post processing).

The RoboDIMM project manager is Michael Simpson and the author is the project scientist. Also involved in this project are Karl Kolle and Neil O'Mahony, all of whom are working at the ING.

References:

Caccia, J. -L., Vernin, J., 1990, *J Geophys Res*, **95**, 13683.

Fried, D. L., 1965, *J Opt Soc Am*, **55**, 1427.

O'Mahony, N., 2001, "Astronomical Site Evaluation in the Visible and Radio Range", eds. J. Vernin, C. Muñoz-Tuñón, and Z. Benkhaldoun, *ASP Conference Series*, in press.

Roddier, F., 1981, "Progress in Optics 19", ed. E. Wolf, North-Holland, Amsterdam.

Sarazin, M., Roddier, F., 1990, *A&A*, **227**, 294.

Vernin, J., Muñoz-Tuñón, C., 1995, *PASP*, **107**, 265.

Wilson, R. W., O'Mahony, N., Packham, C., Azzaro, M., 1999, *MNRAS*, **309**, 379.

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