Enhancements to AF2/WYFFOS on the WHT

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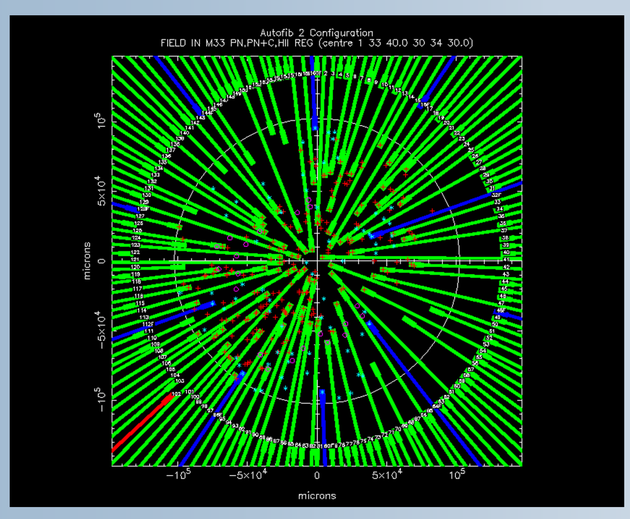
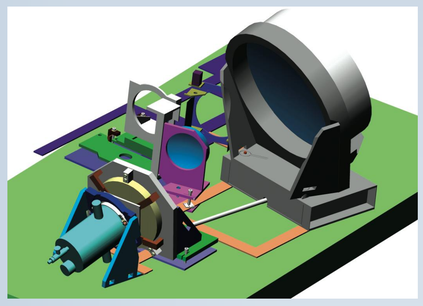
Introduction

AUTOFIB2 (AF2) is the robotic fibre-positioner at the prime focus of the WHT, and can place up to 150 fibres over the WHT's one degree field-of-view . The science fibres are high-content OH fused silica, with diameters of 1.6-arcsec, and feed the WYFFOS spectrograph, located in the GHRIL Nasmyth platform. WYFFOS uses the ISIS reflection gratings, and also has a low-order echelle mode, and offers resolutions from ~100 to ~9500 over a wavelength range 350nm to 1000nm.



An AF2 fibre configuration

The WYFFOS camera



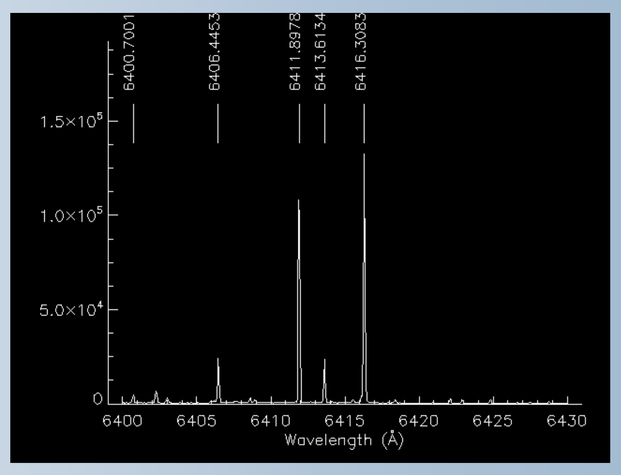
Multiplexed spectrographs on 4m-class telescopes, with their relatively large fields-of-view, excel in playing a supporting role to, and complementing, the 10m-class telescopes such as GTC. The proposed WEAVE multi-object spectrograph for the WHT, with 1000 fibres over a 2-degree field, is planned to begin survey operations in 2017. We describe a programme of enhancements which will allow AF2/WYFFOS to remain competitive until the advent of WEAVE.

Calibration lamps

The WYFFOS calibration unit, mounted at broken Cassegrain focus, contains helium, mercury and neon arc-calibration lamps, and a tungsten continuum lamp. The tungsten lamp of course acts as a flat-field light source, but does not produce enough flux in the extreme blue to trace the fibres. A quartz-tungsten-halogen (QTH) lamp is on order to address this.

Similarly, provision of a ThAr hollow-cathode arc lamp, with its rich line spectrum, is expected to improve radial velocity precision in the red by as much as a factor of two. This new lamp is currently under test.

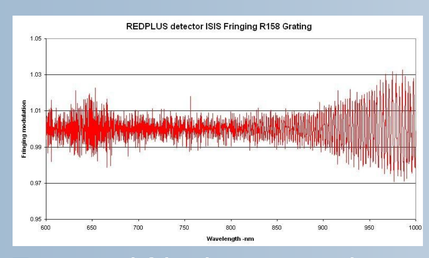
Generating adequate calibration lines in the two bluest echelle orders is difficult; the current mercury lamp has only four lines in echelle orders 6 and 7 combined. We are acquiring cadmium and zinc lamps to improve calibration capability in these orders.

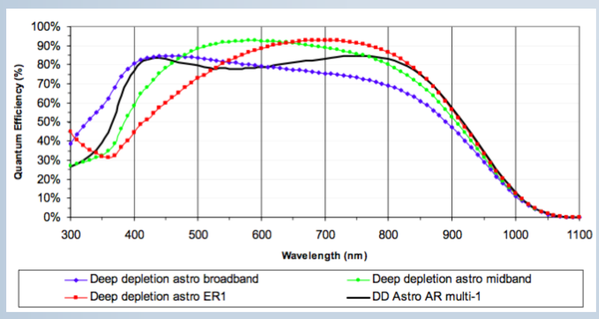


30Å spectrum from a ThAr hollow-cathode lamp

A new detector

The current AF2/WYFFOS blue-sensitive detector has degraded cosmetically, and exhibits fringing of ~20% at 700nm, and 50% at 850nm. Two thirds of AF2/WYFFOS allocations set a central wavelength >650nm, and these data are subject to significant levels of fringing. ING recently purchased an e2v 231-84 4kx4k, red-sensitive, fringe-suppression CCD, similar to the Red+ detector on ISIS, which will be commissioned in semester 2012A. This will benefit the majority of AF2/WYFFOS users by its ultra-low fringing (<1% at 850nm), and 25-60% better sensitivity in the red.





Expected fringing properties and sensitivity of ER1-coated CCD

Throughput

The total peak throughput of AF2/WYFFOS (sky-to-detector) for the low resolution gratings is ~6.5% in the R-band, falling to ~1.6% in the B-band, and less than 1% in U.

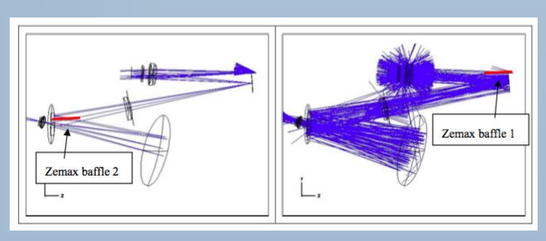
The visual-to-red performance of AF2/WYFFOS compares favourably with e.g. the contemporaneous original 2dF instrument on the AAT, but is worse in the blue by a factor of at least ~2. The spectrographs of the original 2dF were mounted on the telescope top-ring to allow short fibre runs, and enhance blue throughput. However, the peak throughput of AF2/WYFFOS is a factor of ~3.5 less than the bench-mounted AAOmega on the AAT, which uses broad-spectrum fibres and VPH gratings.

We have begun an audit of the optical components of AF2/WYFFOS to better understand its theoretical performance, and to identify if significant improvement is readily possible. This includes assessing throughput and ageing effects in the fibres such as focal-ratio degradation, and using reflectometer measurements to quantify the overall spectral response of the spectrograph.

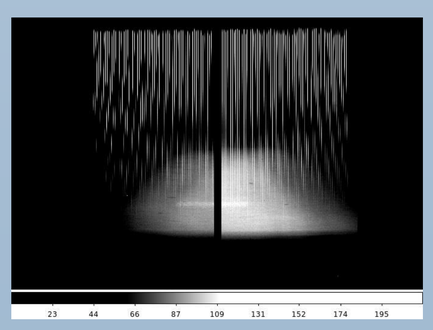
Scattered light and ghosting

As is the case for most spectrographs, WYFFOS suffers from scattered light and ghost images. Zemax modelling of WYFFOS (by Tibor Agocs) has identified strategic locations for baffling, which reduces scattered light to negligible proportions.

The WYFFOS design invokes a Baranne layout, in which the dispersed light traverses back through the collimator at a shallow angle of 7º in its path to the camera. This allows undispersed light reflected off the front of the broad-band-coated collimator optics to enter the camera. The ghost light is about 5% of total flux, and for higher-resolution gratings it becomes a significant fraction of the light in the spectral range. We are investigating an optimum choice of blocking filters to attenuate ghost light relative to dispersed light for the affected gratings.



Scattered light modelling in WYFFOS

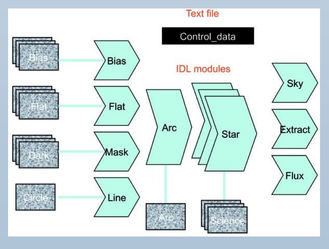


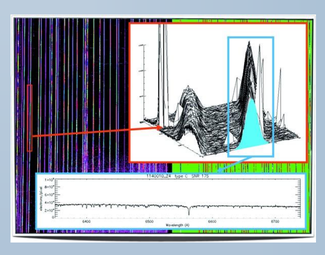
Ghost light, including slit image (R1200B grating)

Reduction pipeline

The scientific productivity of complex instrumentation is strongly linked to the availability of data reduction pipelines. An IDL-based pipeline has been developed to perform full reduction of AF2/WYFFOS data, including fibre-to-fibre sensitivity corrections and optimal extraction, with provision for quick-look, real-time analysis.

Pipeline overview





Optimal extraction

Operational improvement

Light–loss due to astrometric error or drift degrades throughput for point targets, and adapting observing strategy to sky position and conditions limits this loss. The operational efficiency of AF2/WYFFOS will be improved by providing quantitative estimates, as a function of hour angle, declination and seeing, of maximum observing periods before field reconfiguration is needed to limit fibre-aperture losses caused by differential atmospheric refraction across the field.

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