A MULTI OBJECT IFU FOR ULTIMATE on Subaru

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Today’s talk

• A bit about the AAO

• Fiber positioners
  • MANIFEST: Parallel Fiber Head positioning with Starbugs
  • Echidna: Spine-based positioner

Astro-Photonics

• GNOSIS: OH-SUPPRESSION fibers for IR spectroscopy

• HEXABUNDLES AND SAMI: Fiber IFU’s
  Integrated Photonics Spectrographs

• Phase I – Modify MOIRCS with Fibre feed
• Phase II – MOSFIRE/KMOS on Subaru
AAO

- *Opened* 1974 as Anglo-Australian Observatory
- 2010 AAO became part of the Australian Department of Innovation Industry Research and Tertiary Education, Now just Department of Industry
- Operates AAT and UK Schmidt at Siding Springs
- National facility for 400 Australian Astronomers (+200 students)
- Represents Australia at Gemini Observatory (6% partner)
- Represents Australia at GMT (5% + 5% ANU)
The 2dF Galaxy Redshift Survey redshifts for approximately 250,000 galaxies to measure BAO, correlation functions, peculiar velocities and the matter density of the Universe, and the cosmological mass density from clustering (14,000 Citations)
The 6dF Galaxy Survey redshifts of around 150,000 galaxies, and the peculiar velocities of a 15,000-member subsample, over almost the entire southern sky (1000 Citations)

Radial Velocity Experiment (RAVE) radial velocities and stellar atmosphere parameters (temperature, metallicity, and surface gravity) of up to 500,000 stars using 6Df(1200 Citations)
WiggleZ spectroscopic survey of 400,000 star-forming galaxies selected from a combination of GALEX ultra-violet and SDSS + RCS2 optical imaging (600 Citations)

- 1000 sq deg, 0.2 < z < 1.0
- 200,000 redshifts
- Blue star-forming galaxies

WiggleZ Dark Energy Survey

- 1000 sq deg, 0.2 < z < 1.0
- 200,000 redshifts
- Blue star-forming galaxies

WiggleZ spectroscopic survey of 400,000 star-forming galaxies selected from a combination of GALEX ultra-violet and SDSS + RCS2 optical imaging (600 Citations)
AAO Previous instruments

- AAT: 2df, AAOMEGA, IRIS, GNOSIS, CYCLOPS
- UKST: 6df
- Subaru: FMOS Echidna
- ESO: OZPOS
• AAT: Praxis, HERMES
• UKST: TAIPAN
• GHOST (selected for build)
• Manifest (selected for CoDr)
FMOS ECHIDNA

- 400 science fibers
- 14 guide fibers
- 7.2 mm pitch, 180 mm long
- Carbon fiber spines
- 0.5 degree (dia) FOV
- Invented for this application
- Since then we have seen improvements in:
  - Materials
  - Mounting
  - Piezos
The MOIRCS cryostat consists of a slit-mask exchanger, a main dewar, and a detector dewar (Figure 4). The dewars are made of aluminum alloy. This cryostat provides a vacuum and cryogenic environment for the detectors and all the optical components inside the cryostat. Two cryogenic coolers are mounted on the system. One cooler cools the detectors and optical components down to 77 K, while the other cools the stored slit-masks down to 150 K. A few layers of super-insulation will be used to reduce the external thermal radiation.

Both sets of optical trains and detectors are mounted on back-to-back the optical bench plate which is 20 mm thick aluminum alloy (6061-T651). In order to stabilize the structure of the optical bench and lens mounts at 77K, we made a heat treatment for them. The procedure of the treatment consists of rough machining, quenching in liquid nitrogen, aging, and final machining. The bench is suspended from the inner surface of the main dewar with epoxy glass-fiber (G-10) straps which have low thermal conduction, low-thermal contraction, and stiffness in the cryogenic temperature. Three wheels for filters, grisms, and cold stops are placed in the collimated section of each optical train and cryogenic motors drive these wheels.

The cryostat and electronics boxes are mounted on the 2m-cube frame with supporting braces (Figure 1) and are installed to the Cassegrain flange automatically. The total weight of MOIRCS including the support frame will be 2 metric tons.

Finite element analysis (FEA) has been done during structural and thermal designing processes in order to examine the effects of thermal contraction and to verify that structural deflections due to an instrument orientation and atmospheric pressure are within an allowable range.
Fibre-based MOS for Ultimate

Phase II

Fibre Cable

WFC  IFU/Starbug  MOSFIRE/VMOS
Instrument setup

- Starbugs unit will be attached to the Cassegrain focus
- Spectrograph will be placed at the observation floor or at Nasmyth platform and connected to the starbugs with fibers.
  - F-conversion might be necessary to reduce the F# (12.4 → (e.g. 3.0) and avoid the effect of FRD (?)
  - Throughput of the fiber will be (e.g. 90%@NIR).
- Fiber will be connected to the fiber slit in the focal plane module, which is placed in the cryogenic condition.
  - Minimum spacing in between fiber centers should be 4 pixels or larger and the minimum spacing between the 90% EE diameter of each adjacent fiber should be 1 pixel or larger to avoid significant cross-talk and ensure the accuracy of the sky subtraction (<0.5%? based on PFS study).
  - F-conv. optics in side of the FP module might be necessary to change the F# back to the original (12.4) or to the optimum number for the spectrograph.
Ultimate IFU Stages

- **Stage I** A fibre fed IFU for nuMOIRCS using the STARBUGS fibre positioning technology. Assuming that the spacing between adjacent fibres is 4 pixels (KOALA spacing), the number of 61 element IFUs is 16.

- **Stage IIA** Increase in the number of IFUs with the installation of the new spectrograph. Assuming that the spacing between adjacent fibres is 4 pixels (KOALA spacing), the number of 61 element IFUs is 32. Or maybe 2 spectrographs giving 64 IFU’s.

- **Stage IIB** Replace the fibres with OH suppression fibres
**Fibre Bundle Configuration (1)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of fibres</td>
<td>37 (7 fibres on an axis)</td>
</tr>
<tr>
<td>Spatial sampling</td>
<td>0.2 arcsec / fibre</td>
</tr>
<tr>
<td>Bundle sky diameter</td>
<td>1.4 arcsec (point to pint)</td>
</tr>
<tr>
<td>Number of detector pixels per fiber</td>
<td>4</td>
</tr>
<tr>
<td>Number of pixels per bundle</td>
<td>148</td>
</tr>
<tr>
<td>Number of bundles per 2k detector</td>
<td>13 (1924 pixels; plus sky fibers?)</td>
</tr>
<tr>
<td>Object Multiplicity (MOIRCS)</td>
<td>26</td>
</tr>
<tr>
<td>Sky Fibres/detector</td>
<td>30 sky fibres with 1 fibre gap</td>
</tr>
</tbody>
</table>
### Fibre Bundle Configuration (2)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of fibres</td>
<td>19 (5 fibres on an axis)</td>
</tr>
<tr>
<td>Spatial sampling</td>
<td>0.2 arcsec / fibre</td>
</tr>
<tr>
<td>Bundle sky diameter</td>
<td>1.0 arcsec (point to pint)</td>
</tr>
<tr>
<td>Number of detector pixels per fiber</td>
<td>4</td>
</tr>
<tr>
<td>Number of pixels per bundle</td>
<td>76</td>
</tr>
<tr>
<td>Number of bundles per 2k detector</td>
<td>26 (1976 pixels; plus sky fibers?)</td>
</tr>
<tr>
<td>Object Multiplicity (MOIRCS)</td>
<td>52 (feasible??)</td>
</tr>
<tr>
<td>Sky fibres /detector</td>
<td>17 sky fibres with a 1 fibre gap</td>
</tr>
</tbody>
</table>

*N=19 bundle*
<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of fibres</td>
<td>61 (9 fibres on an axis)</td>
</tr>
<tr>
<td>Spatial sampling</td>
<td>0.2 arcsec / fibre</td>
</tr>
<tr>
<td>Bundle sky diameter</td>
<td>1.8 arcsec (point to point)</td>
</tr>
<tr>
<td>Number of detector pixels per fiber</td>
<td>4</td>
</tr>
<tr>
<td>Number of pixels per bundle</td>
<td>244</td>
</tr>
<tr>
<td>Number of bundles per 2k detector</td>
<td>8 (1952 pixels; plus sky fibers?)</td>
</tr>
<tr>
<td>Object Multiplicity (MOIRCS)</td>
<td>16</td>
</tr>
<tr>
<td>Sky fibres/detector</td>
<td>23 sky fibres plus 1 fibre gap</td>
</tr>
</tbody>
</table>
For comparison, each SAMI IFU consists of 61 fused fibres. A one-to-one comparison between SAMI at z=0.05 and ULTIMATE at z=1.0 is shown in the following table.

The IFUs can be built in stages. They allow one to start doing science with the upgraded version of MOIRCS (nuMOIRCS) and to upgrade when new technologies (for example, OH suppression) become mature enough to implement and when the spectrograph with the 2 4k by 4k detectors becomes available.

**Stage I**
A fibre fed IFU for nuMOIRCS using the STARBUGS fibre positioning technology. Assuming that the spacing between adjacent fibres is 4 pixels (KOALA spacing), the number of 61 element IFUs is 16.

**Stage II**
Replace the fibres with OH suppression fibres.

**Stage III**
Increase in the number of IFUs with the installation of the new spectrograph. Assuming that the spacing between adjacent fibres is 4 pixels (KOALA spacing), the number of 61 element IFUs is 32.

**Target densities and typical exposure times**
We have used v4.1 of the UltraVISTA catalogue to estimate the likely number of targets one could observe. We consider two classes of objects (star forming galaxies and non-star forming galaxies) and two redshift ranges: 0.8 < z < 1.0, which roughly corresponds to the redshift interval within which the H-alpha line lands in the J band, and 1.3 < z < 1.6, which corresponds to the H-alpha line landing in the H-band.

**Emission Line Objects**

<table>
<thead>
<tr>
<th>IFU</th>
<th>narrowest axis</th>
<th>longest axis</th>
<th>FoV</th>
<th># IFUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>61 element 0.2''</td>
<td>1.8''</td>
<td>2.08''</td>
<td>2.81</td>
<td>16 (32)</td>
</tr>
<tr>
<td>91 element 0.2''</td>
<td>2.2''</td>
<td>2.54''</td>
<td>4.19</td>
<td>10 (20)</td>
</tr>
<tr>
<td>KMOS</td>
<td>2.8''</td>
<td>2.8''</td>
<td>7.84</td>
<td>24</td>
</tr>
</tbody>
</table>

**KMOS:** spatial = 0.2”
24 IFU’s
14 x 14 spaxals

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>SAMI @ z-0.05</th>
<th>ULTIMATE @ z=1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of fibre bundles</td>
<td>13</td>
<td>16 (32 with new spectrograph)</td>
</tr>
<tr>
<td>FoV of positioned</td>
<td>1 degree (3.6Mpc)</td>
<td>14’ x 8’ (6.9 Mpc x 3.9 Mpc)</td>
</tr>
<tr>
<td>Number of fibres per IFU</td>
<td>61</td>
<td>61</td>
</tr>
<tr>
<td>Fibre pitch</td>
<td>1.6” (1.6 kpc)</td>
<td>0.2” (1.6 kpc)</td>
</tr>
<tr>
<td>Minimum separation</td>
<td>30” (30kpc)</td>
<td>20” (160 kpc)</td>
</tr>
</tbody>
</table>
Optical design
Corrector and fibre coupling
• Zero power corrector
• Dia 450 mm, FOV 14.5 deg
• 2 lenses: center thickness of lenses 25 mm
• Axial thickness 100 mm
• Starbugs plate curved
• Starbugs can mount on the second lens

• Material: IR grade fused silica
Wide field corrector performance

IR Grade Fused Silica Transmittance

Image quality
Fibre injection optics

IFU: hexagonal lens array, circular lens array, fibre grid
61 elements total, 9 elements across
Flat to flat dimension 117 µm (Similar to GHOST slit, prototyping required)
Fibre Ø 30/65 µm core/clad
Wavelength range: up to 1.8 µm

Telescope focal plane
61 element IFU, FOV
1.35", 0.15"/element

Pupil stop
Ø 0.25 mm

Magnifier lens
1.64x, Ø2 mm

F12.4 F4
12 mm 2 mm
Fibre extraction optics

- Magnification 3.1
- Glasses IRG7, CaF2, Fused Silica
- Image quality: diffraction limited
- Used for HERMES

Slit – detector imaging:
- Core Ø 30µm \(\rightarrow\) 2.0 pixels res element
- Center to center 72 µm \(\rightarrow\) 4 pix spatial separation

Number of fibres per slitlet: 45
Number of slitlets: 88
The Starbug

A discrete stepping robot
Theory of operation

Piezo tubes:

\[ \Delta x < \sim 10 \ \mu m \]

\[ \Delta x < \sim 25 \ \mu m \]
Discrete stepping in $x$ and $y$
Starbugs

- Starbugs consist of co-axial piezoelectric tubes: stepping motion achieved by appropriate high-voltage waveforms sent the electrodes
- Optical payload (single fibre for TAIPAN) installed at centre of inner tube
- Back-illumination metrology fibres are mounted between the two tubes
- Vacuum is applied between tubes to hold Starbug onto glass field plate
Starbugs

• Starbug movies
• Field plate assembly is mounted inside telescope tube at focal plane
• Metrology camera is mounted through hole in centre of primary mirror
TAIPAN-MANIFEST

- TAIPAN is a Starbug-based fiber positioner and spectrograph being developed for the 1.2 m UK Schmidt Telescope (150 Starbugs with single fibre payload in each bug)
- TAIPAN is prototype for the MANIFEST fibre positioner for GMT
- MANIFEST will have several hundred Starbugs across 1.3 m field plate using multiple microlens arrays as pupil slicers
Integral Field Units

- Integral field unit (IFU) spectrographs collect both spatial and spectral information simultaneously.
- Current approaches use lens arrays or slicing mirrors.
- We have developed new “hexabundle” fibre IFU technology (61 core for SAMI) and lens array technology (1000 element for KOALA).
Fibre throughput model

fibre only, no coupling losses or FRD

Transmission for 20m FIP
Mathematica-based model to calculate SNR for J and H band observations with new MOIRCS fed by fibre IFU's.

• OH-emission-line model for sky

• Continuum model for sky brightness, Zodiacal-light + thermal emission from sky

• Throughput estimates for fibre based on KOALA measurements, scaled to NIR

• Coupling efficiency estimates for fibre based on KOALA measurements, scaled to NIR.

• Background model based on injection optics feed design, with Narcissus mirrors (at the intermediate pupil in the starbug) and expected thermal emission from telescope optics and background.

• Slit background assumed to be negligible (as it will be cooled to 120K?)

• Can be used to model SNR for real spectra through the system.
System modeling

shows the background components - black = total, red = oh lines, brown = interline continuum (measured at 590 ph/s/m^2/um/arcsec^2 by Maihara 1993), grey = fibres, green = zodiacal scattered light, purple = telescope (0 deg), blue = fore optics, yellow = gold pupil stop, cyan = microlens array
the background at the detector in 1 hr per pixel per spaxel – each component has been multiplied by the exposure time, the throughput of the downstream components, convolved with PSF, binned into pixels, and multiplied by the A Omega of the system, assumed to be preserved throughout
show the signal to noise per spectral resolution element per spaxel in 1 hr as a function of redshift for observations of galaxies with a total SFR of 3, 10 and 30 Msun/yr. In all cases I assume the galaxy is 2” diameter, and the SFn is uniformly spread over the area and the Ha line has a FWHM of 10A and the signal is extracted from 1 FWHM
In the following figure we plot a histogram showing the number of galaxies with star formation rates exceeding the values given in the horizontal access. The number has been scaled so that it matches the number within the 14' × 8' field of view of ULTIMATE. The red lines are the number of IFUs in stage I and stage II.

Fig. 1: Cumulative histograms of star forming galaxies in the ULTIMATE FoV for two redshift ranges.

It can be seen that there are around 30-50 galaxies in the ULTIMATE field with star formation rates (SFR) exceeding 10 solar masses per year. SFRegions are clumpy at this redshift, so may get an improved SNR with GLAO due to spatial increases.
It can be seen that one needs to reach limiting magnitudes of 20.5 in J and 21.5 in H in order to occupy all 16 IFUs. We now compute the expected signal-to-noise ratio for a 28,800 second exposure, with half the time spent on observing the sky. This corresponds to one night of integration. In computing the signal-to-noise ratio we use the assumptions that we used for emission line objects. Not unsurprisingly, exposure times for continuum source are long and signal-to-noise ratios are modest.

There is one important caveat. We have assumed that the background between the OH lines is similar to that used in the KMOS ETC. There has been considerable uncertainty in the true value of this background, as part of it may come the scattered wings of the bright OH lines. Removing the OH lines may result in significantly less background.

For objects as faint as J=20.5 and H=21.5, the signal to noise ratios are more than sufficient to measure redshifts; however, they are about half of what is typically required to measure kinematics or abundances. Spatially resolved studies will be confined to brighter objects.

Science Cases

We consider three scientific cases that could be tackled by ULTIMATE, a SAMI-like survey targeting field galaxies between z=0.8 and 1.7, a study of lensed field galaxies, and a survey targeting galaxies in distant rich galaxy clusters.
We now compute the expected signal-to-noise (S/N) ratio for a 7200 second exposure, with half the time spent on observing the sky. In computing the signal-to-noise ratio we use version 5.01 of the KMOS exposure time calculator.

- Assume 70% throughput for the fibres (measured results with Koala including coupling losses and FRD).
- Assume that nuMOIRCS has 15% (20%) efficiency in the J and H bands.
- Make use of the R=3000 VPH gratings.
- Assume that RON performance of the detectors in both instruments are the same.
- Assume 0.8" seeing in V (0.63" in H and 0.67" in J).
- Use the Kennicutt relation to convert from SFR to H-alpha flux.
- Use a SFR of 10 solar masses per year (the number density of sources is such that this could be raised to 30 solar masses per year).
- Integrate the signal over 1.65(2) Angstrom bins in the J(H).
- Assume that the H-alpha line is 10 Angstroms wide.
It might be possible to use dedicated sky fibres to subtract the sky, in which case exposure times will be halved.

The signal-to-noise ratio can be increased by

- computing this ratio over a larger wavelength region (a gain of ~2 can be expected) and/or several spaxels
  - exposing longer
  - choosing brighter targets
signal-to-noise ratio for a full night exposure, nodding

- 28,800 sec exposure, half the time spent on observing the sky.
- This corresponds to one night of integration
- Not unsurprisingly, exposure times for continuum source are long and signal-to-noise ratios are modest.
- There is one important caveat. We have assumed that the background between the OH lines is similar to that used in the KMOS ETC. There has been considerable uncertainty in the true value of this background, as part of it may come the scattered wings of the bright OH lines. Removing the OH lines may result is significantly less background.
- For objects as faint as J=20.5 and H=21.5, the signal to noise ratios are more than sufficient to measure redshifts; however, they are about half of what is typically required to measure kinematics or abundances. Spatially resolved studies will be confined to brighter object and/or fewer binned spaxals.
- Phase II (a and b) will improve this!

<table>
<thead>
<tr>
<th>Redshift</th>
<th>Mag (AB)</th>
<th>Wavelength</th>
<th>S/N KMOS</th>
<th>S/N nuMOIRCS</th>
<th># IFU elements</th>
<th>S/N per IFU element</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9</td>
<td>20.5</td>
<td>1182</td>
<td>1.65</td>
<td>12</td>
<td>9</td>
<td>61</td>
</tr>
<tr>
<td>1.45</td>
<td>21.5</td>
<td>1653</td>
<td>2.03</td>
<td>9</td>
<td>6</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>MOIRCS</td>
<td>MOSFIRE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------------</td>
<td>----------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Current</td>
<td>New</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FOV</td>
<td>4’x7’</td>
<td>6’.1x6’.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imaging throughput</td>
<td>0.23(J), 0.34(H), 0.30(K)</td>
<td>0.54(J), 0.56(H), 0.50(K)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(atm+Telescope+Instrument)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectral resolution</td>
<td>500, 1300, ~3000(VPH)</td>
<td>3500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grating diffraction</td>
<td>HK500: 0.8(J), 0.78(H), 0.65(K)</td>
<td>0.60(J), 0.65(H), 0.70(K)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>efficiency</td>
<td>R1300: 0.2(J), 0.3(H), 0.5(K)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VPH: ~0.75(J), ~0.7(H), 0.80(K)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spec. throughput</td>
<td>HK500, zJ500: 0.18(J), 0.26(H), 0.20(K)</td>
<td>0.325(J), 0.361(H), 0.350(K)</td>
<td></td>
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<tr>
<td>(atm+Telescope+Instrument)</td>
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<td></td>
<td></td>
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<tr>
<td>Detector</td>
<td>HAWAII-2</td>
<td>HAWAII-2RG</td>
<td>HAWAII-2RG</td>
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<td></td>
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</tr>
<tr>
<td>QE</td>
<td>~80%(JHK)</td>
<td>~80%(JHK)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Read-out noise</td>
<td>15e rms (16NDR)</td>
<td>5e rms (16NDR)</td>
<td>5e rms (16NDR)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sensitivity comparison with MOSFIRE

- Current MOIRCS sensitivity is 4~7 times lower than MOSFIRE (difference in the telescope diameter is not taken into account).

- If the new MOIRCS can successfully reduce the RO-noise down to 5e-, the sensitivity difference is about 1.4(VPH)~2.3(R1300).

- This difference can not be reduced without changing the optical coating.
  - MOSFIRE has 31 surfaces
  - Average throughput in each surface is about 0.992.
  - Total throughput of the optical coating is about 0.78
  - MOIRCS has 24 surfaces.
  - Average throughput of the coating is 0.983.
  - Total throughput of the coating is 0.64.
PHASE IIb

• OH Suppression fibres
OH-SUPPRESSION
WITH PRAXIS
Atmospheric OH emission

OH airglow emission lines are orders of magnitude brighter than objects of interest – sky must be subtracted lead to high noise
Also spatially and temporally variable

Ellis & JBH 2008
Spectrograph scattering

Scattering in optics of spectrographs show broad Lorentzian wings. OH dispersion masking cannot thus remove. Other techniques for pre-filtering technologically very difficult.

(a) AAOmega, $\alpha = 0.97$ and $f = 5.5$.

(b) IRIS/2, $\alpha = 0.89$ and $f = 4.0$. 

Intensity/photons s$^{-1}$ m$^{-2}$ arcsec$^{-1}$ $\mu$m$^{-1}$
A fibre Bragg grating (FBG) consists of a fibre with a periodic variation of core refractive index that acts as a wavelength specific dielectric mirror.

Requires single mode fibres: thus need photonic lantern

Very complex pattern of refractive index variation in optical fibre core can be used to cancel out all of the (hundreds of) atmospheric OH emission lines. The most complex filter ever conceived, manufactured and demonstrated...

GNOSIS preliminary results

Commissioning at the Anglo-Australian Telescope during 2011

- Demonstrated operational requirements met
- Demonstrated level of suppression
- Interline continuum not yet reached – detector noise specification
- **Next steps:** Instrument scalability an issue – significant R&D program to address and develop J-band gratings for 8-metre class telescopes
• GNOSIS used fibre Bragg gratings to suppress OH emission with IRIS2: issues with sensitivity
• PRAXIS is new dedicated spectrograph with H2RG detector
• Parallel development of FBG in multi-core fibres
• PRAXIS due on-telescope at AAT early 2015
• Likely require high altitude site for verification of technique – late 2015
• Standard fused-silica fibres limit operation to H band and shortwards.
• Flouride fibres are available that transmit to K band and beyond however these are impractical
  – Absorption limits length to a few metres (ie spectrograph not gravity invariant)
  – Significant development required for interfacing
  – High cost
  – High risk
K-band fibre technology

- Production lines are built to satisfy the needs of industry
- Telecommunications required low OH (water free fibres) in early 2000.
- Fibres were developed and they are used for 20-30 meter fibre feeds in J and H bands
- Industrial applications of IR fibres are limited to laser power delivery over short distances
K-band fibre technology

- Typical transmission of IR fibres is 0.1-0.2 dB/m ~ 30% over 30 meter link

- Fibres were considered for KMOS instrument
- KMOS was built with optical IFU slicer
K-band requirements:
Fibres must be short (1-2 meters)
Fibres must be cooled for K-band (-100°C)
Domo arigato