

Title: “GNIRS image slicers at GEMINI: Design & manufacturing”

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Gemini North telescope

ABSTRACT

This contribution presents two image slicers (low resolution (LR) and high resolution (HR)) being built at Durham University for the Gemini Near-Infrared Spectrograph (GNIRS) at the 8m Gemini North telescope. The original LR IFU was destroyed during a thermal runaway in 2007. The same design is currently being re-manufactured with enhanced diamond turning techniques and materials, improving the surface roughness on the optical surfaces to sub 4 nm RMS. For the HR IFU a new image slicer has been designed within the same envelope defined by the LR IFU (0.1 x 0.2 x 0.1 m³) and it will also be manufactured at Durham University. The LR IFU was designed to sample the 20th percentile seeing obtained with just tip-tilt correction. The field of view is 15 arcsec² (3.15" x 4.80") covered by 21 slices with a spatial sampling of 0.15 x 0.15 arcsec². The HR IFU will be optimised for fully adaptively corrected images over a field of view of 2.25 arcsec² (1.80" x 1.25") covered by 25 slices giving a spatial sampling of 0.05 x 0.05 arcsec². Both designs are diffraction limited at infrared wavelengths (1 - 5.4μm).

GNIRS spectrograph at Gemini North



- The Gemini Near-Infrared Spectrograph (**GNIRS**) covers a spectral range from 1.0 to 5.4 microns. GNIRS is a medium resolution spectrograph that provides 2-pixel spectral resolutions from 1,200 up to 18,000 and has single disperser and cross-disperser modes yielding simultaneous spectral bandwidths from 40nm to 1,650nm. GNIRS has four observational modes: long-slit (50-100" slit), cross-dispersed (5-7" slit), low resolution (LR) IFU and high resolution (HR) IFU. The specifications of the IFUs are as follows:
 - **LR IFU**
FoV= 15 arcsec² (3.15" x 4.80"); 21 slices; spatial sampling= 0.15x 0.15 arcsec²
Original design by R. Content (Allington-Smith et al, Mon. Not. R. Astron. Soc. 71, 380-394 (2006))
It was destroyed during a thermal runaway in GNIRS in 2007. The same design is currently being manufactured at Durham University with enhanced techniques improving the surface roughness on metallic slicers to sub 4 nm RMS.
 - **HR IFU**
FoV= 2.25 arcsec² (1.80" x 1.25"), 25 slices, spatial sampling= 0.05x 0.05 arcsec², optimised for fully adaptively corrected images.
For the HR IFU a new image slicer is being designed within the same envelope defined by the LR image slicer (0.1 x 0.2 x 0.1 m³) and it will also be manufactured at Durham University using advanced diamond turning techniques.

Specifications for the HR image slicer design



The HR IFU is composed of two subsystems: a fore-optics subsystem (with anamorphic magnification) and an image slicer subsystem.

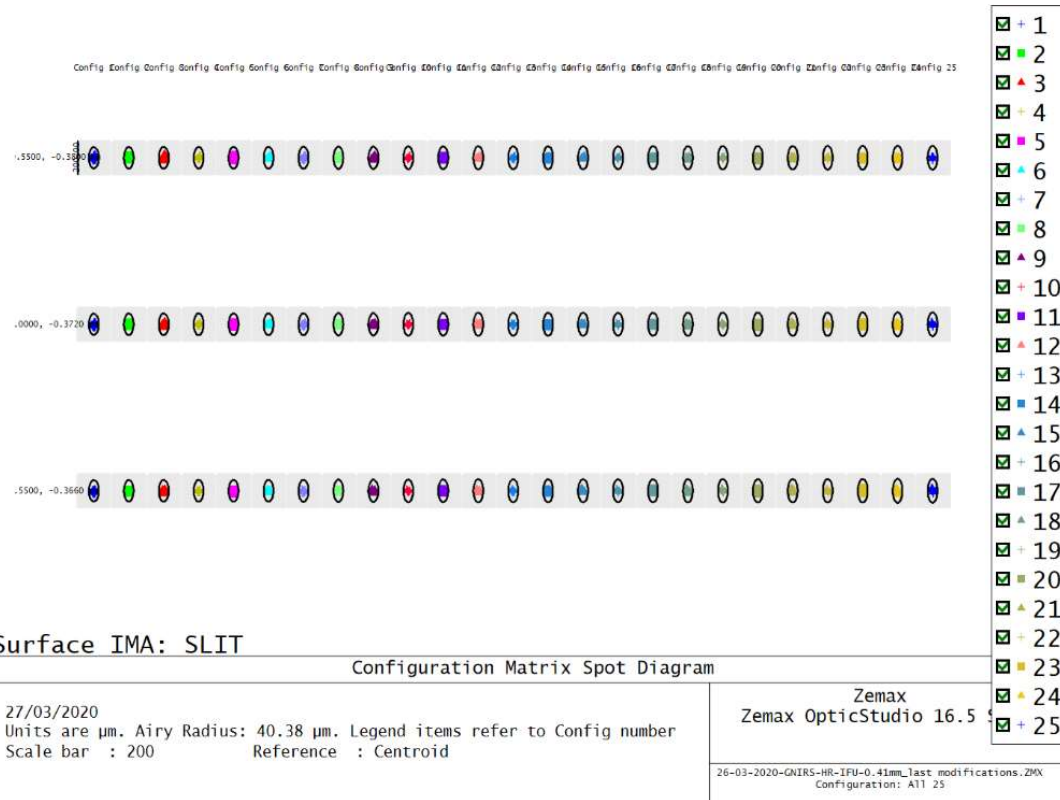
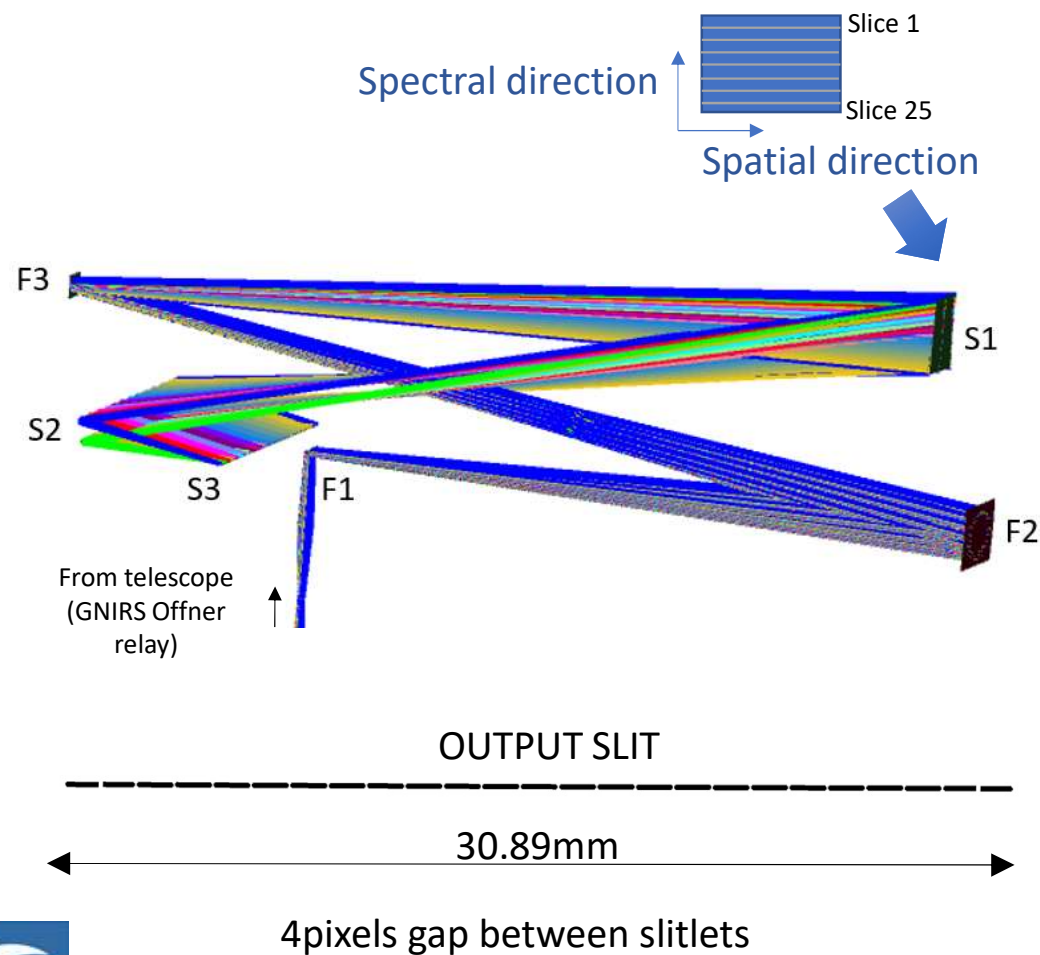
- Fore Optics (3 mirrors): F1 (flat), F2 (toroidal), F3 (toroidal)
- Image Slicer (3 mirrors): S1 (slicer mirrors, spherical), S2 (pupil mirrors, spherical), S3 (slit mirrors, toroidal)

The HR IFU has been designed to fit within the same envelope defined by the LR IFU ($0.1 \times 0.2 \times 0.1 \text{ m}^3$), keeping the same input and output (generated slit) locations.

Specifications	
Spectral range	1 - 5.4 microns
FOV	1.80 arcsec x 1.25 arcsec
Spatial sampling	0.05arcsec x 0.05 arcsec
Number of spatial elements	900
Output slit length	30.89mm

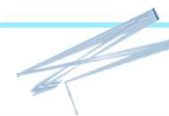
DESIGN PARAMETERS	
Field of View (FoV)	1.80 arcsec x 1.25 arcsec
Telescope effective focal length	128.12m
Telescope focal-ratio	F/16
Plate scale	1.610 arcsec/mm
Linear size of the FoV at the telescope focal plane	1.118mm x 0.776mm
Number of slices	25
Magnification along spatial direction	5.687
Magnification along spectral direction	13.275
Width of slicer mirrors	410 μ m
Dimensions of slicer mirrors (after anamorphic relay)	6.358mm x 0.410mm
Linear size of the FoV at slicer mirror array position	6.358mm x 10.300mm

Optical design results

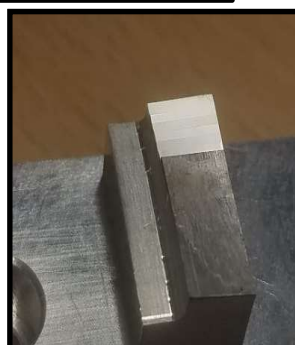
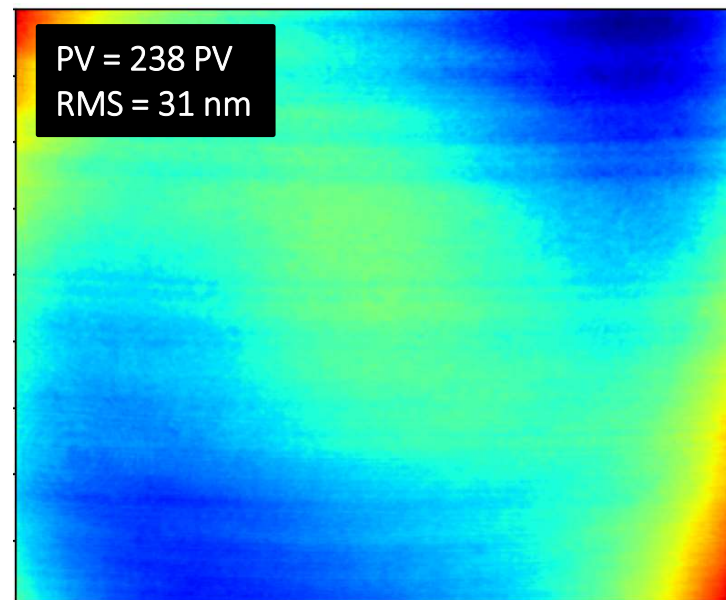
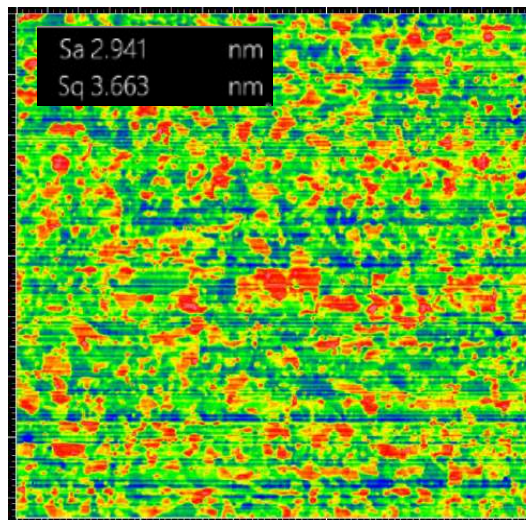


Diffraction limited optical quality is obtained at the image slicer image focal plane (slit position) and at the fore-optics focal plane (slicer position)

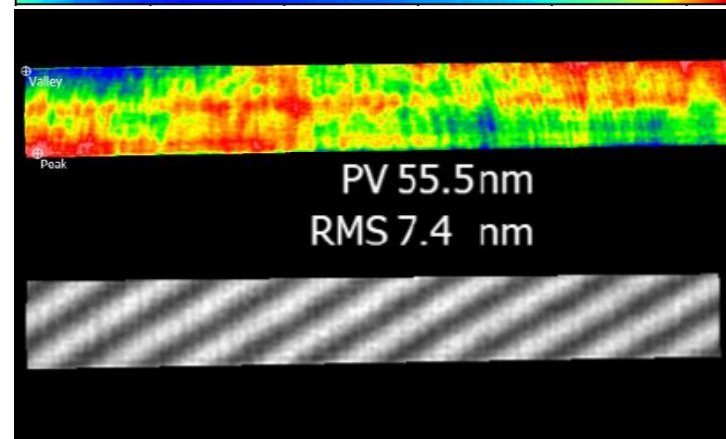
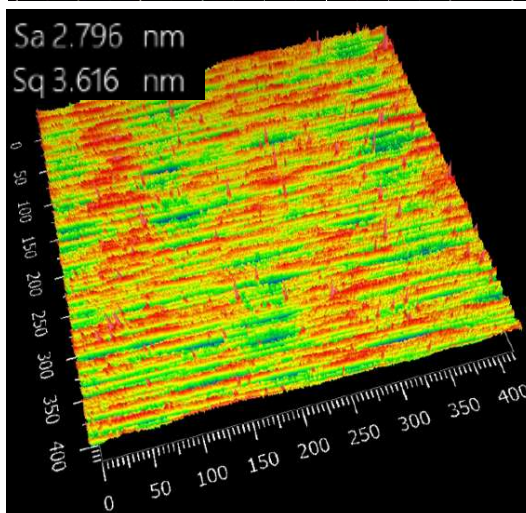
Manufacturing results



Material : RSA 6061
Roughness : average 3.5nm RMS
Form : 31 nm RMS
Fore optics shape: freeform



Material : RSA 6061
Roughness : 3-4 nm RMS
Form : 10 nm RMS
Fore optics shape : spherical



Impact and prospects for the future



- These two image slicers will provide GNIRS with two IFUs modes: LR and HR
- Both IFUs are design within the same envelope volume ($0.1 \times 0.2 \times 0.1 \text{ m}^3$) and keep the same entrance (fore-optics entrance) and output (generated slit) positions.
- The HR IFU has been optimised to work with AO but it can also operate without it
- Both IFUs are being manufactured with enhanced diamond machining techniques, improving the surface roughness on metallic slicers to sub 4nm RMS.
- The improvement in surface roughness reduces stray light and improves the instrument sensitivity.

Durham University experience on Image Slicers:

Durham University has 20 years of experience on the design and manufacturing of IFUs

Metrology facilities and on-going image slicer design projects

Currently, the typical surface roughness is < 4nm RMS

No limitation on slicer width or conic shape

Freeform manufacturing capability

Some of our other image slicers projects are KMOS (VLT) & NIRSpec (JWST)

