The AAO:
current and future status, instrumentation, and ULTIMATE-Subaru

Simon Ellis

AAO organisational timeline

1974 - **Anglo-Australian Observatory** opens
- jointly operated by Australian and British governments

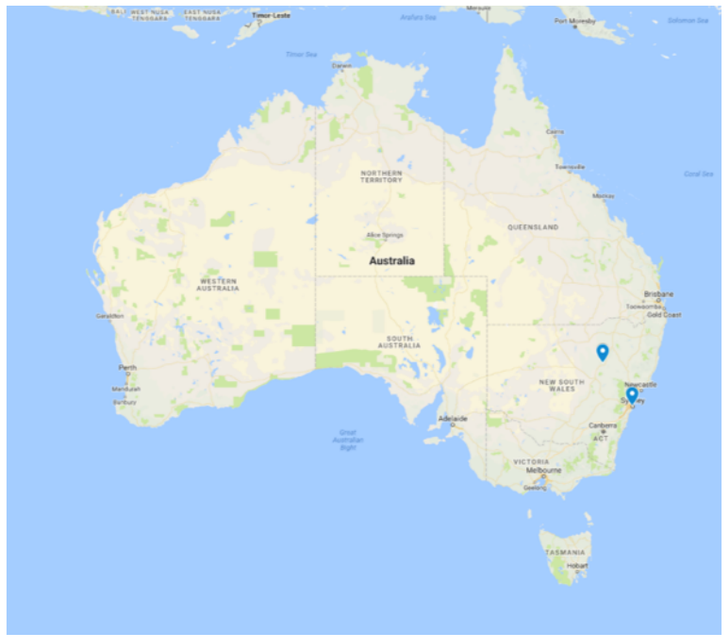
2002 - UK joins ESO
2006 - UK begins phased withdrawal from AAO
2010 - **Australian Astronomical Observatory**
- part of Australian Federal Government
Department of Innovation, Industry, Science and Research

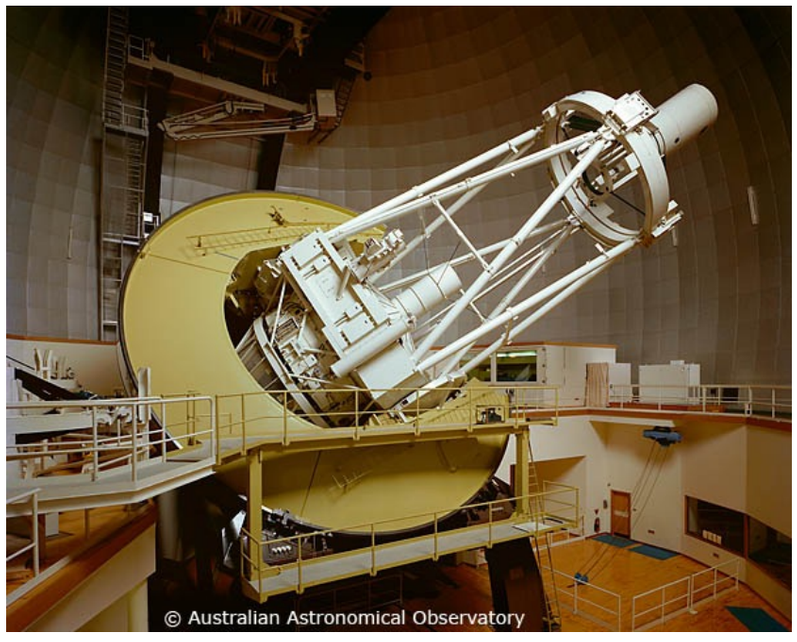
2017 - Australia become strategic partners in ESO
- funding from AAO budget
2018 - **Australian Astronomical Optics?**

AAO today

Approx. 90 staff split between Sydney and Siding Spring

- Operates AAT and UK Schmidt
- Instrumentation programme and research
- Observational support and astronomical research
- Outreach, ICT, data





AAO future plans

AAT
telescope operations

Operated by a consortium of universities led by Australian National University (ANU)

AAO
instrumentation programme

Consortium led by Macquarie University in partnership with University of Sydney and ANU

AAT

Operations led by ANU
Funded by consortium partners
based on past use of telescope

Review of operations by Markus Kissler-Patig
Possible new operations models:

1. Status quo
2. Specialisation as survey telescope
3. Specialisation as instrument testbed
4. Change the science support model
5. Reduce the number of offered instruments
6. Move to full remote observing
7. Use as training centre for young scientists
8. Accept higher technical downtime.
9. Site focus on operation - move development projects off site
10. Decoupling of the UK Schmidt Telescope

AAO - instrumentation

Part of Macquarie University Faculty of Science
Led by Macquarie University in partnership with University of Sydney and ANU

- instrumentation hub
- national optical instrumentation capability

Australia Astronomy Ltd. committed in principle to funding $5m/yr for next 10 years (to be reviewed after 4 years)
Further funding from instrument contracts

Transition mid-2018

AAO

- National Instrumentation Capability
  - broadens collaboration, especially with ANU and USyd
  - strengths instrument opportunities in astronomy
- Commercialisation and industry engagement
  - new revenue stream
  - new grant opportunities
  - new collaborations
- University environment
  - expansion is possible
  - access to grants
  - access to students
  - access to central services

AAO instrumentation - past

Over last 42 years we have delivered over 47 instrument projects and 30 design studies

KOALA – 2014
AAOmega upg – 2014
MS-DESI – 2014
SAMI – 2013
CYCLOPS2 – 2012
GNOSIS – 2012
CURE – 2012
DESpec – 2012
SAMI prototype – 2011
CYCLOPS – 2010
NG1dF – 2010
Fireball – 2010
APT camera – 2008
AAT-TCS – 2008
WFMOS-A – 2008
PILOT – 2008
FMOS/Echidna – 2007
WFMOS – 2007
AAOmicron – 2007
HESP – 2007
SPIRAL – 2006

AAOmega – 2006
WFMOS-K – 2006
SONG – 2006
FMOS-DR – 2005
WFMOS – 2005
Ukidna – 2004
FASTCAM – 2004
IRTF – 2004
OzPoz – 2003
DAZLE – 2003
HISPEC – 2003
GRB catcher – 2003
PNS – 2003
BTODSS – 2003
MOMFOS – 2003
WiFeS – 2003
IRIS2 – 2002
6dF – 2001
ANDES – 2001
KOSMOS – 2001
WFI – 2000

PFU – 2000
MAPPIT 2 – 2000
Taurus Pol. – 2000
SOAR-IFU – 2000
SPIRAL-B – 2000
UKS-TCS – 2000
OSIRIS – 2000
GIRMOS – 2000
IRIS2-g – 2000
ALTAS – 1999
LDSS++ – 1998
SOAR IFU – 1998
Australis – 1998
Taurus II – 1997
SPIRAL-A – 1997
2df spectro. – 1997
2df positioner – 1997
UNSWIRF – 1996
UHRF – 1993
FLAIR II – 1992
UCLES – 1988

LDSS – 1988
Autofib – 1987
FORS – 1984
Taurus – 1980
IRIS – 197?
Auxiliary CCD cam – 197?
FOCAP – 197?
RGO – 197?
Cassegrain spectro. – 197?
Coude Echelle spectro. – 197?
IPCS – 197?
IRPS – 1978
Wamplertron – 1975

AAO instrumentation - past

- Fibre positioning systems
  - 2dF - 400 fibre positioner for AAT - 1997
  - 6dF - 150 fibre positioner for UKST - 2001
  - OzPoz - fibre positioning robot for the VLT - 2003
  - FMOS/echidna - fibre positioning robot for Subaru - 2007

- Spectrographs
  - IRIS2 - NIR slit-mask spectrograph and imager for AAT -2002
  - AAOmega - optical multi-object spectrograph for AAT - 2006
  - HERMES - high resolution optical spectrograph for the AAT- 2014

- Fibre Systems
  - CYCLOPS2 - fibre image slicer for UCLES at AAT - 2012
  - SAMI - multi-IFU hexabundle fibre feed for AAT - 2013
  - KOALA - 1000 element fibre-IFU for AAT - 2014

AAO instrumentation - current

International Projects

- MANIFEST @ GMT
- 4MOST @ VISTA
- GHOST @ Gemini
- AST3-NIR @ Dome A
- PLATO @ Antarctica
- PRAXIS @ AAT
- Sphinx @ MSE
- NBS @ Subaru

National Projects

- TAIPAN @ UKST
- Hector 1 @ AAT
- Veloce-Rosso @ AAT
- Huntsman @ SSO

AAT Facility Upgrades

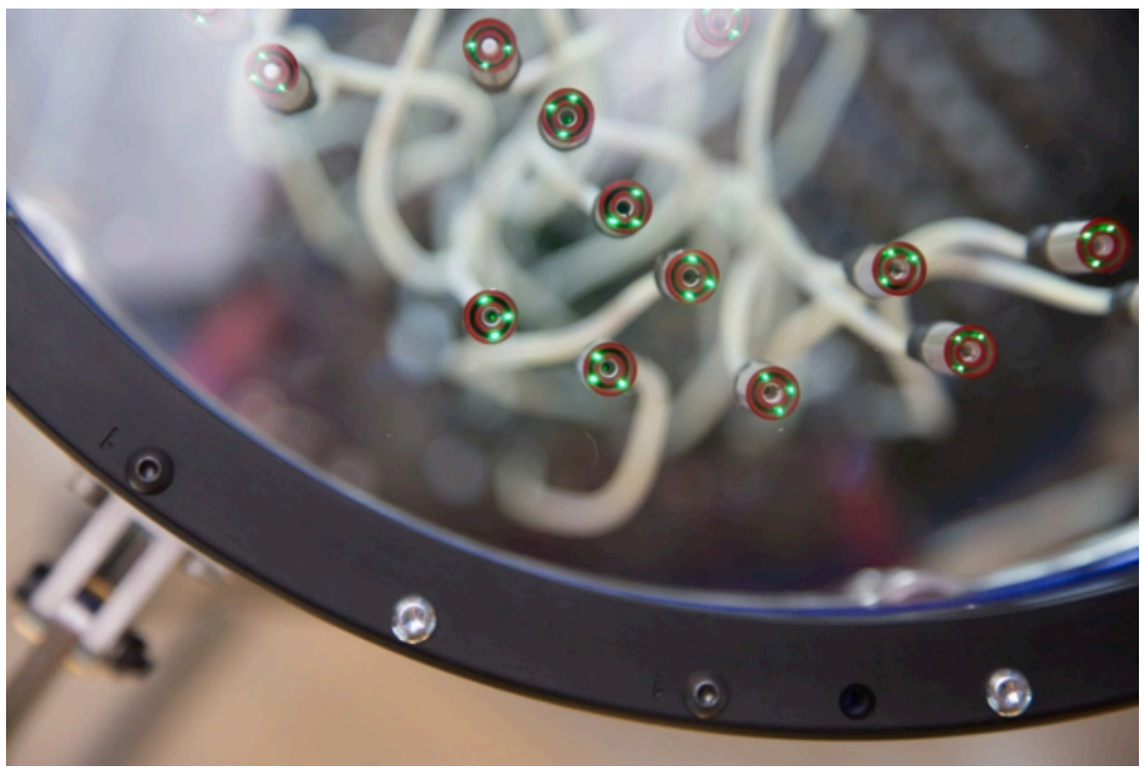
- 2DFDR @ AAT
- 2df upgrade @ AAT
- HERMES upgrade @ AAT
- Flat-field @ AAT

Research and Development

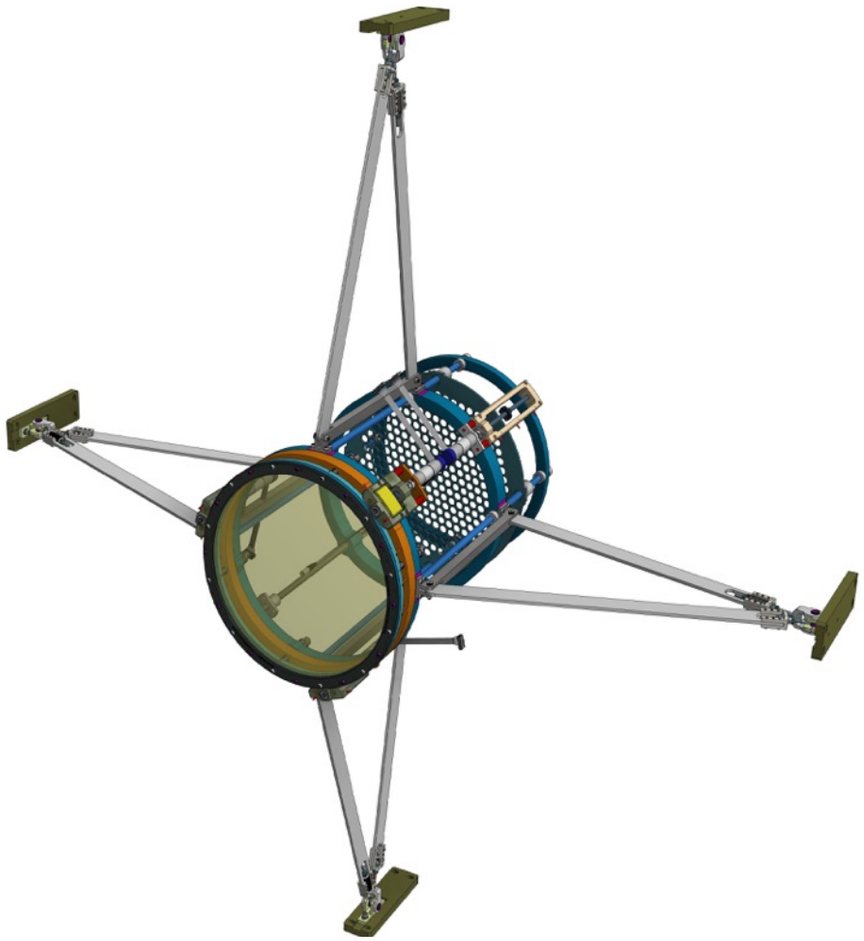
- Positioning technologies
- Ring resonators
- K band fibres
- Detector controllers/cryostats
- Single-mode spectrographs
- Photonic interferometry
- Orbital Angular momentum
- Multi-core FBG for OH suppression
- Adaptive optics WFS and modes

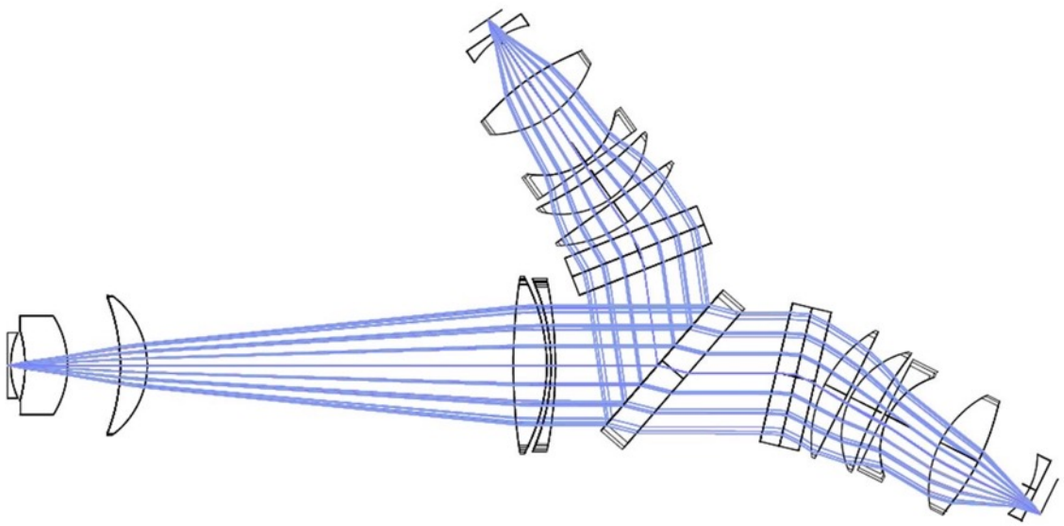
TAIPAN

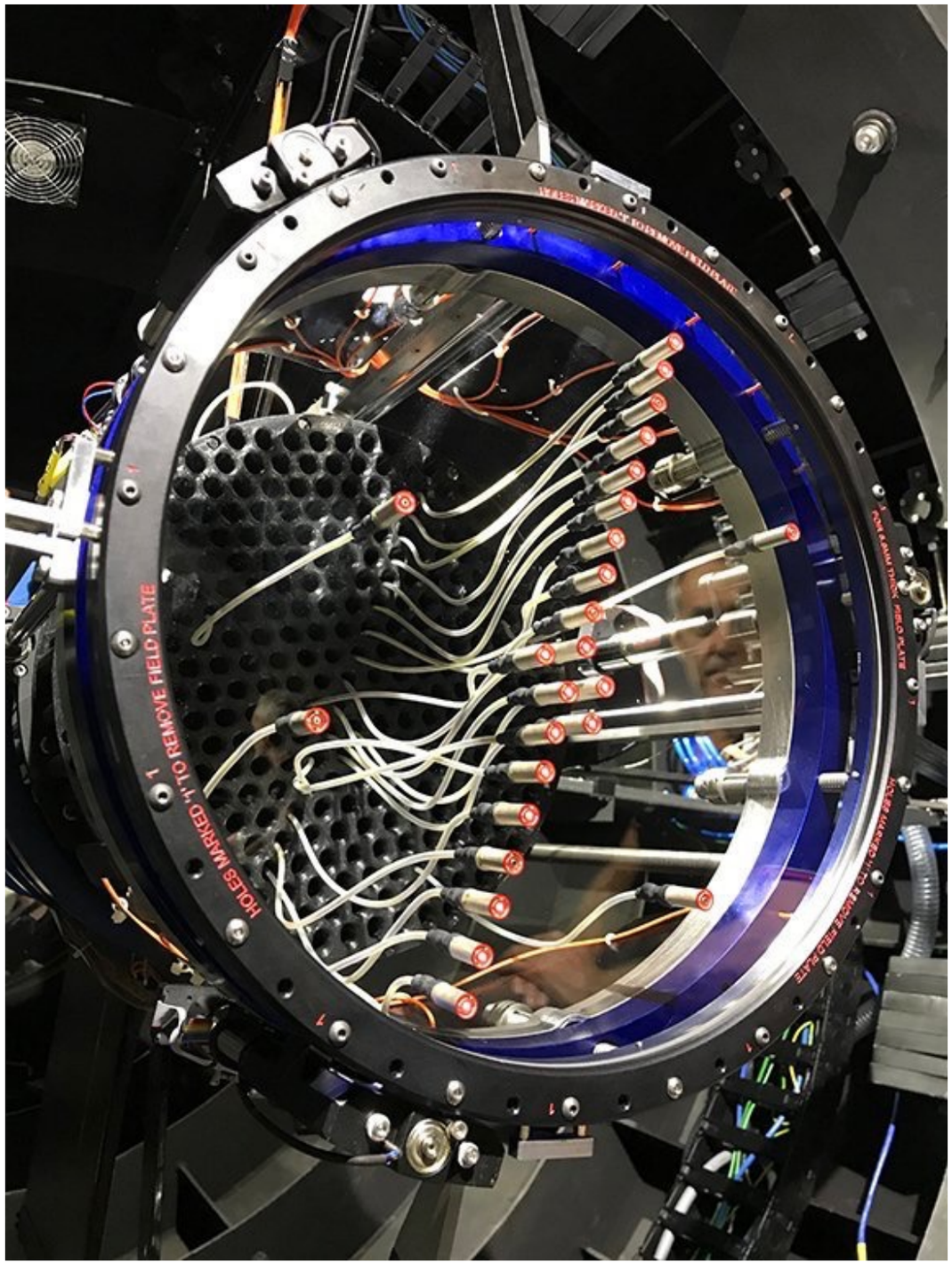
- TAIPAN is a fibre positioner and spectrograph being developed for the UK Schmidt Telescope
- Positioner uses Starbugs technology, developed as a prototype for MANIFEST on GMT
- 150 fibres (upgrade to 300) over 6 degree FoV feeding a low resolution, R=2300, optical spectrograph (370 - 870 nm)
- Commenced mid-2013, due for science early 2018
- Will survey 10^6 galaxies and 10^6 stars for a range of science cases



TAIPAN

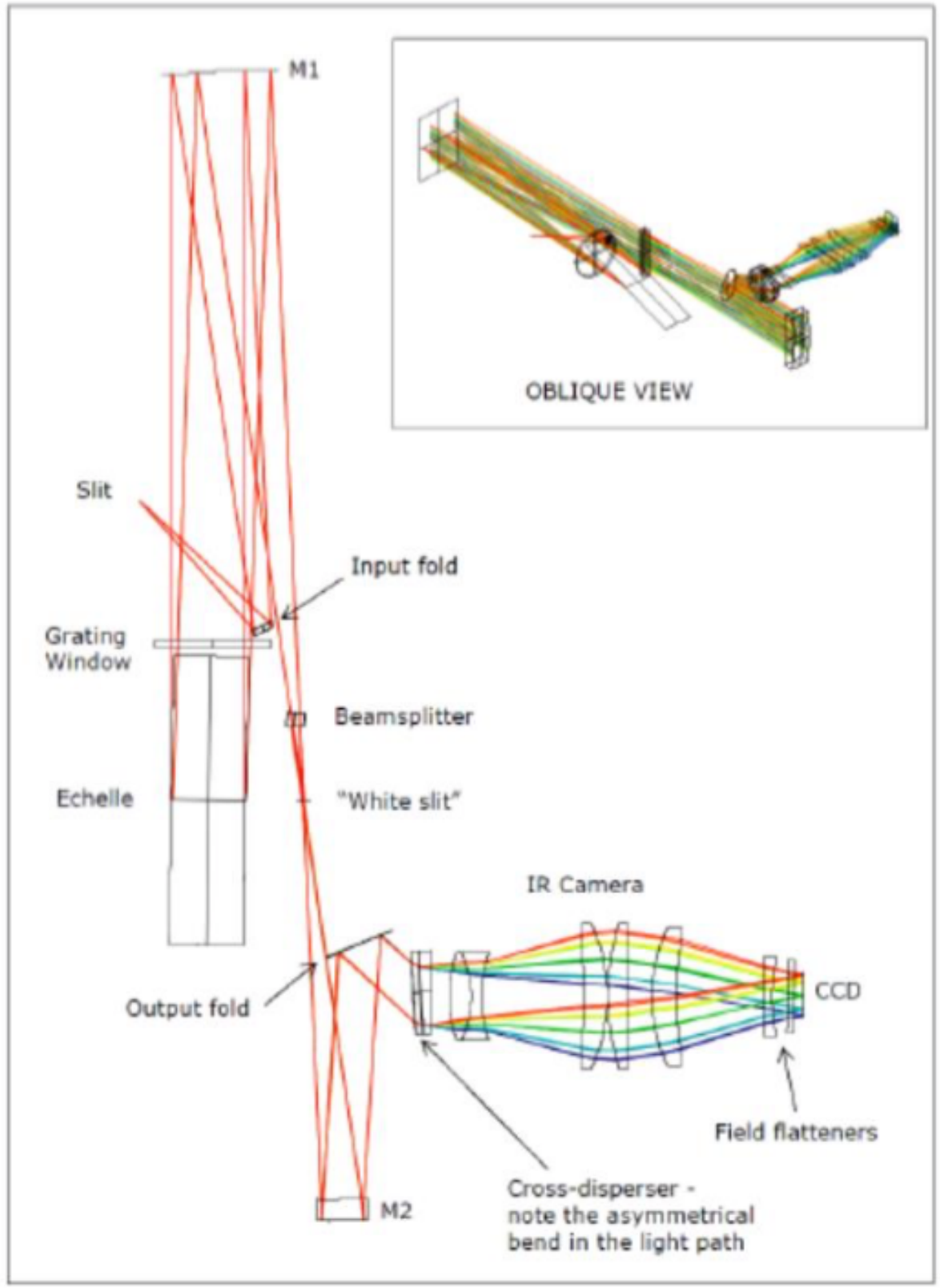






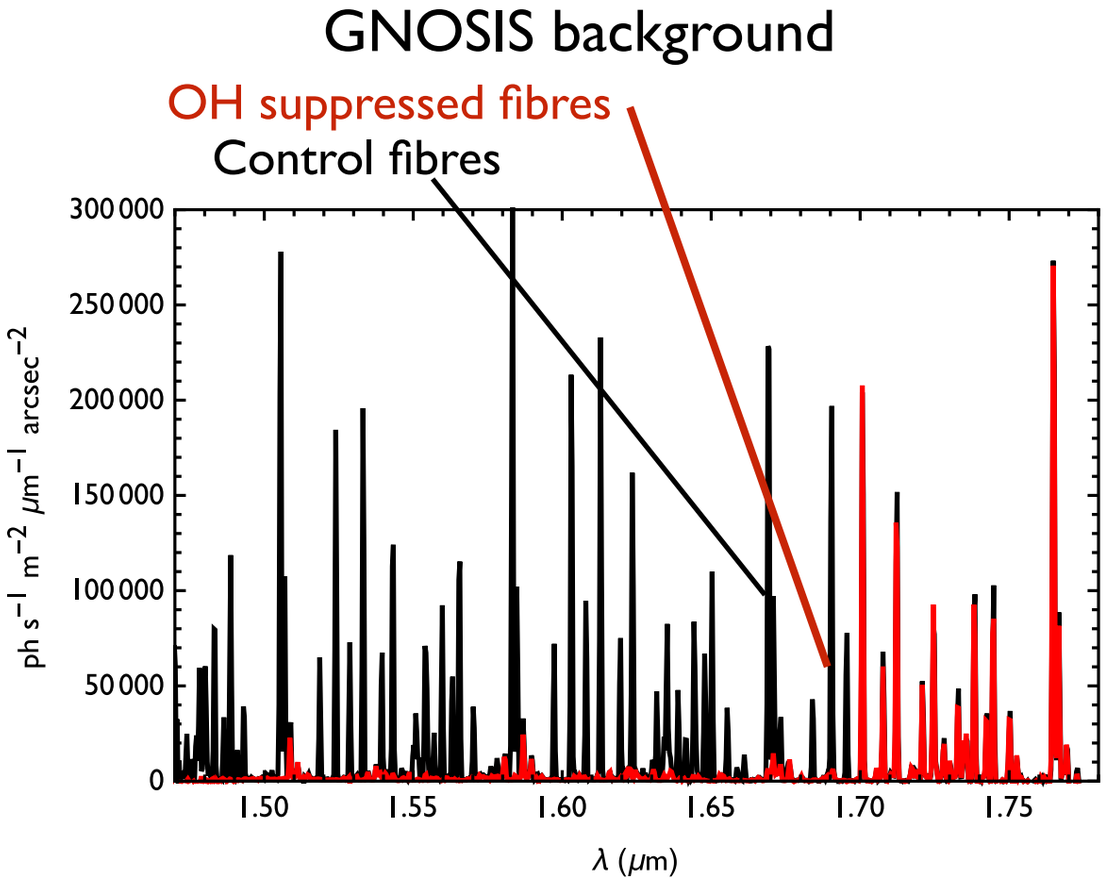
Veloce

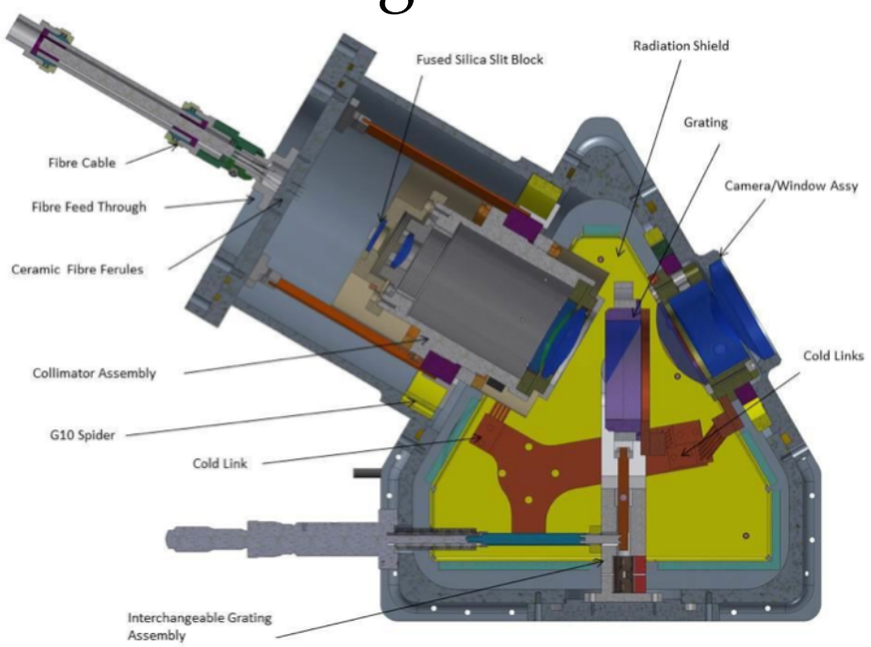
- Precision radial velocities
- UNSW led, ANU spectrograph, AAO fibre cable and interface
- R=80,000
- Single object (plus sky)
- Fibre image slicer
- 600-950 nm (upgrade to 370 nm, two extra arms)
- White pupil échelle
- Simultaneous calibration with Menlo laser comb
- Radial velocity precision of 0.5 m/s (temp. and pressure stabilised)

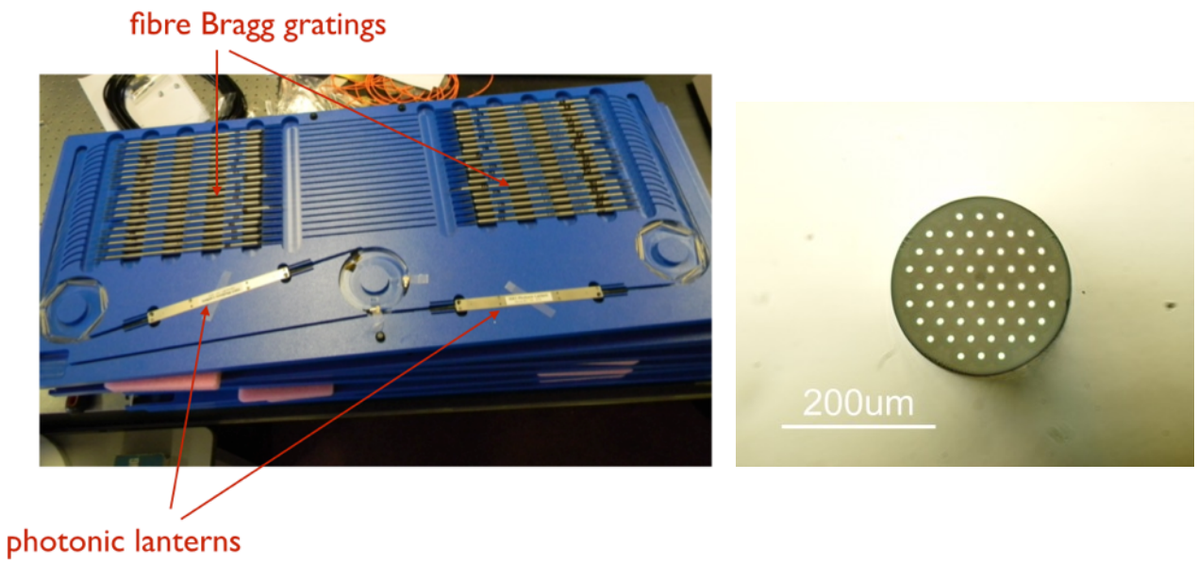


PRAXIS

- Dedicate NIR OH suppression spectrograph using FBGs
- AAO spectrograph, AIP detector (H2RG)
- Parallel development of multicore fibre Bragg gratings (USyd)
- GNOSIS suppressed sky lines but suffered from thermal background and detector noise
- Commissioning 2018

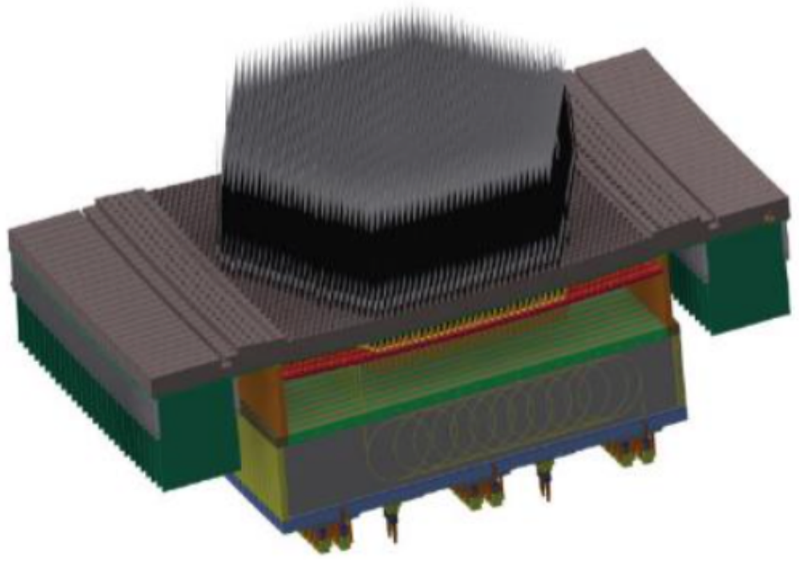


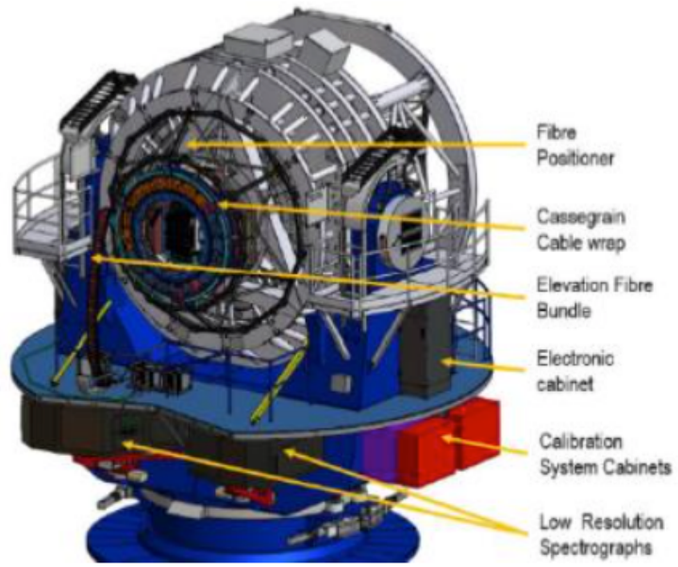




AESOP
4MOST on VISTA

- 4MOST is a MOS on ESO VISTA telescope
- AIP led, AAO fibre positioner
- AESOP 2400 spines based on FMOS echidna
- Fibres feed 3 banks of optical spectrographs
  - 2 x low res (R=4000 - 8000 with 370 - 950 nm)
  - 1 x high res (R=20,000 with 400 - 680 nm non-continuous)
- Science: cosmology, galaxy evolution, Galactic science

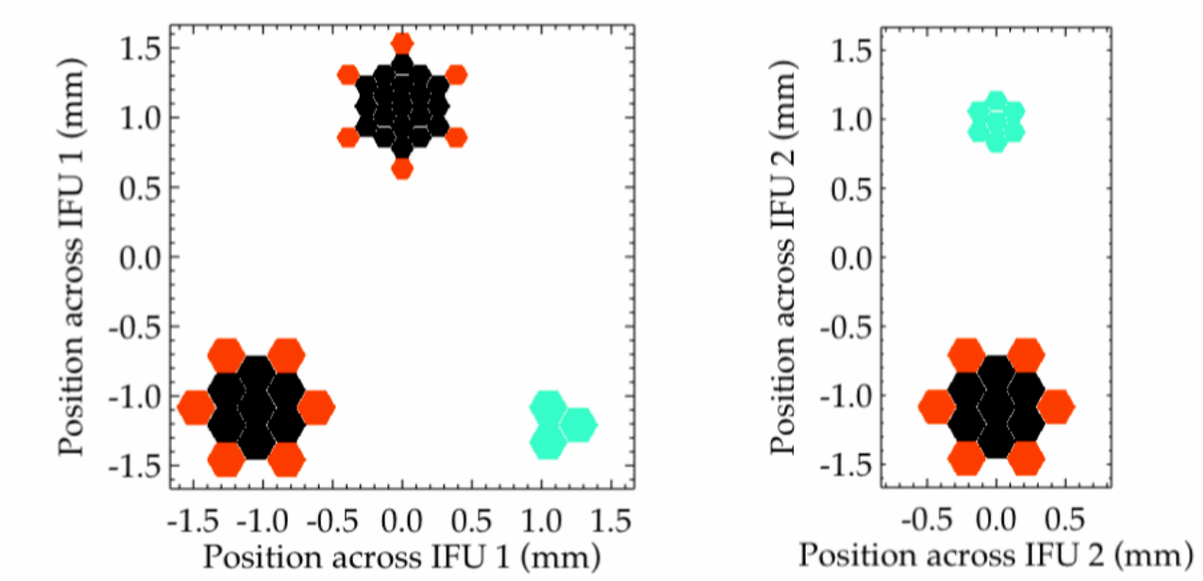


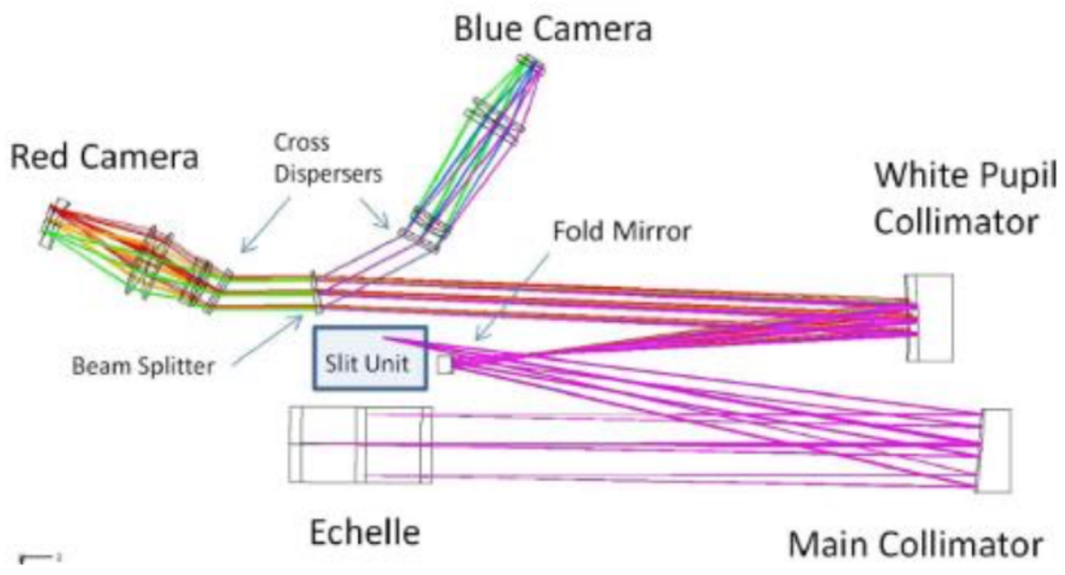


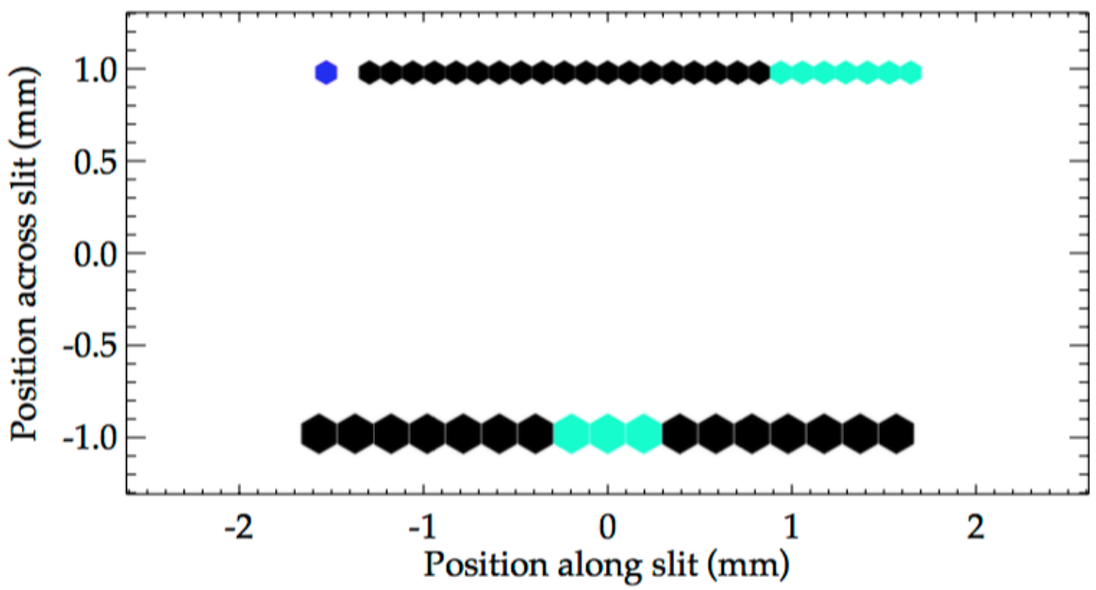
GHOST

Gemini

- GHOST is a high res. spectrograph for Gemini south
- AAO led and positioner, NRC spectrograph, ANU software
- Fibre image slicer
- R=50,000 (2 object), R=75,000 (1 object)
- Wavelength 360 - 1000 nm
- White pupil échelle
- In build phase, commissioning early 2019
- Science: stellar abundance, metal poor stars, glob. clusters, dwarf galaxies, exoplanets

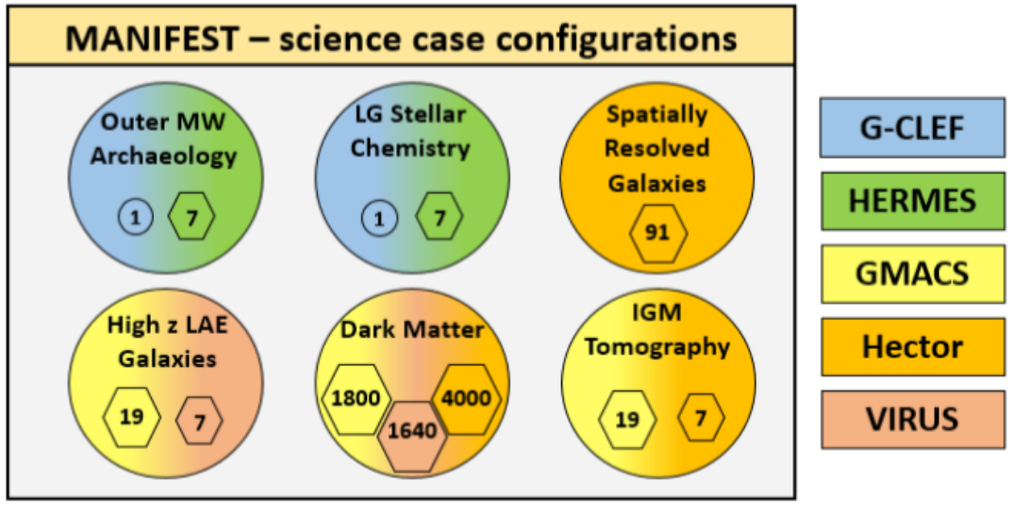






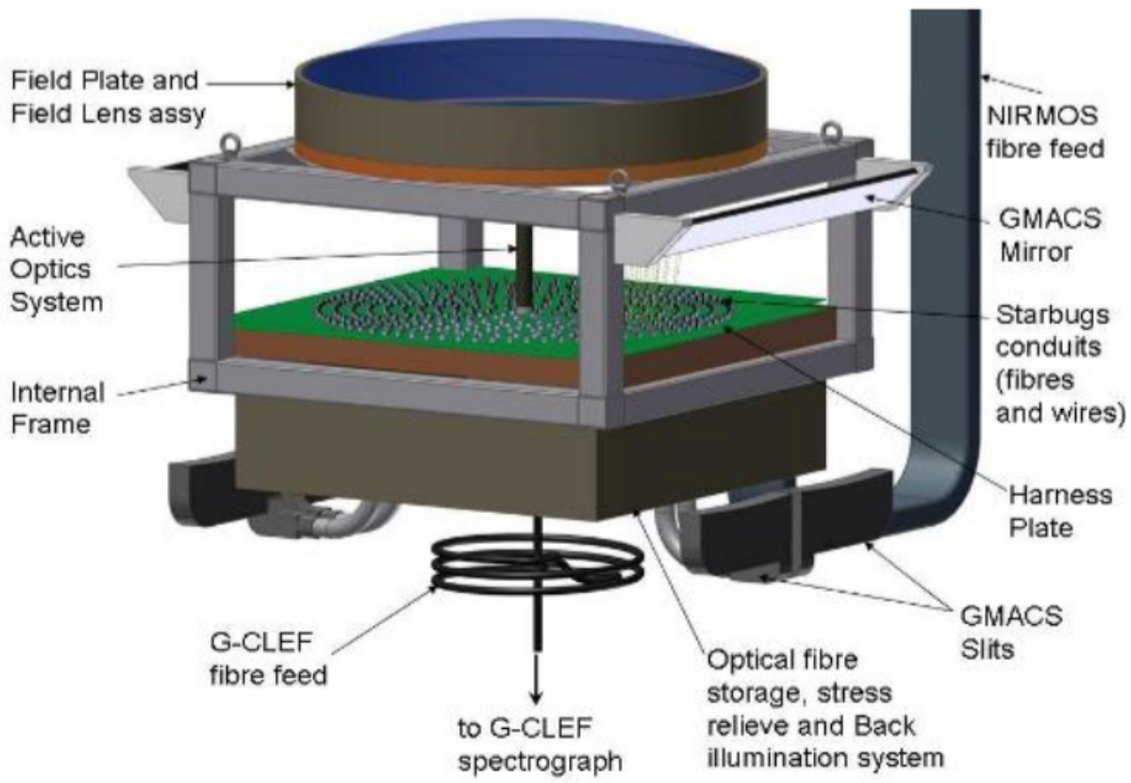
MANIFEST
GMT

- MANIFEST is an extension of TAIPAN for GMT
- Feed GMACS and G-CLEF (low res. and high res. spectrographs)
- IFUs on starbugs
- High spatial res., wide FoV, high multiplex

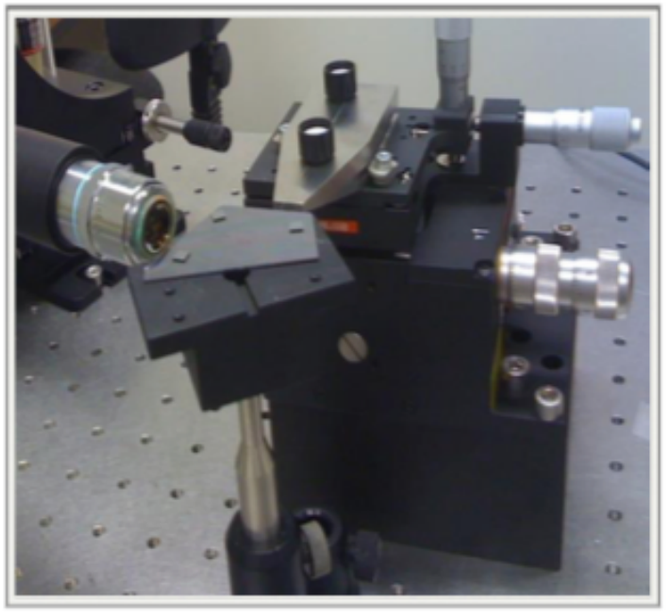


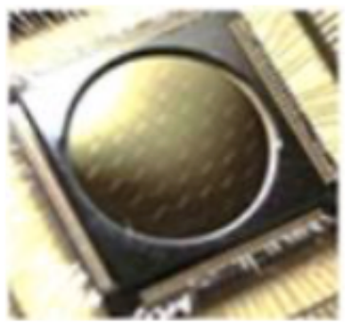
	TAIPAN	MANIFEST
Number of Starbugs	150-300	>2000
Field of View	6 degrees	20 arcmins
Field ROC	3 m	3.3 m
Field diameter	330 mm	1250 mm
Pitch	~12 mm	~50 mm
Payload	Single fibre	IFU

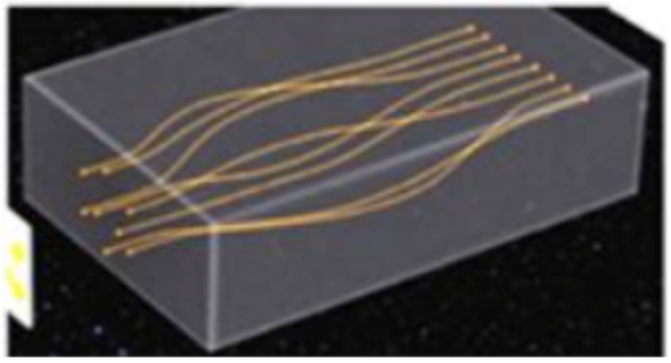
Spectrograph	# IFUs	Fibres per IFU	FOV per IFU	Resolution	Bandwidth
G-CLEF	4/40	1	0.7"	35K	550/15 nm
HERMES	56	7	1"	28K	100 nm
GMACS	60	61	1.1"	6K/20K	600/200 nm
GMACS	95	19	1.25"	3K/10K	600/200 nm
Hector	44	91	2.8"	5K	680 nm
Hector	560	7	0.75"	5K	680 nm
VIRUS	1	1640	14"	2K	630 nm
VIRUS	235	7	0.9"	2K	630 nm

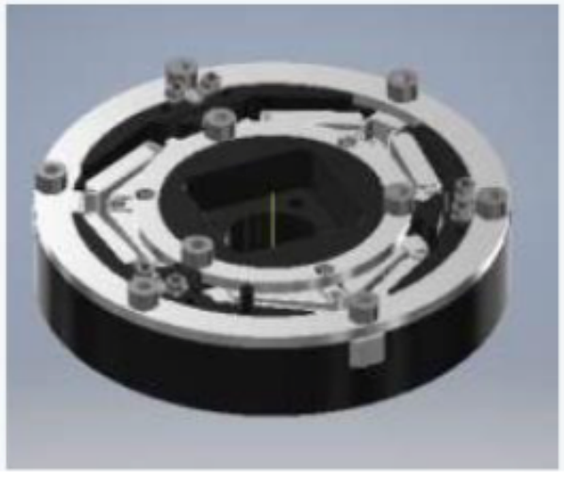


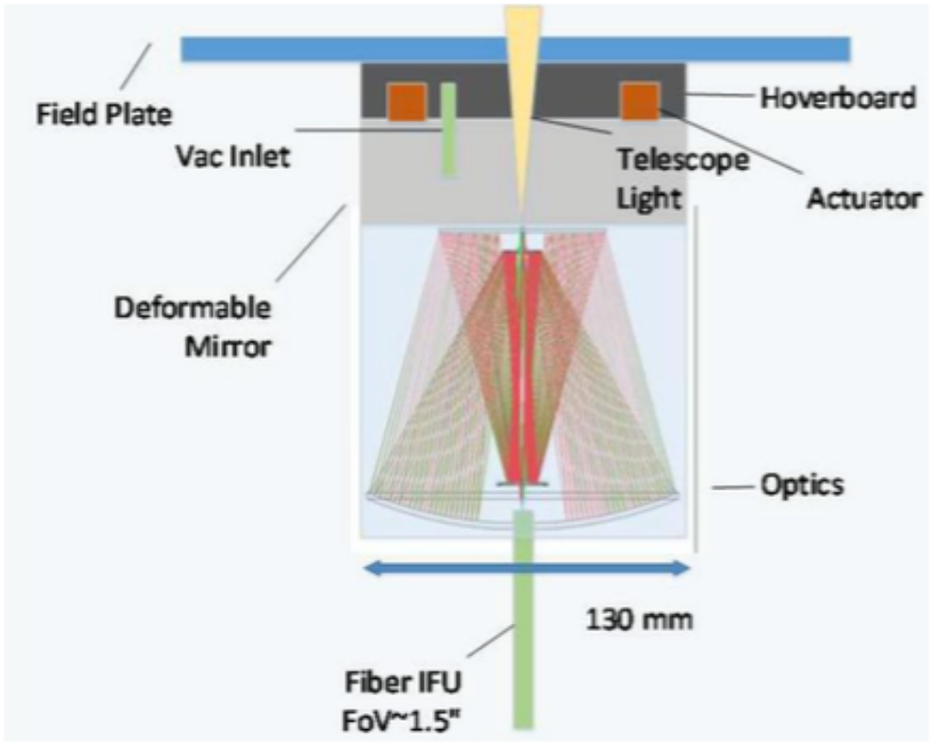
AAO instrumentation - research and design



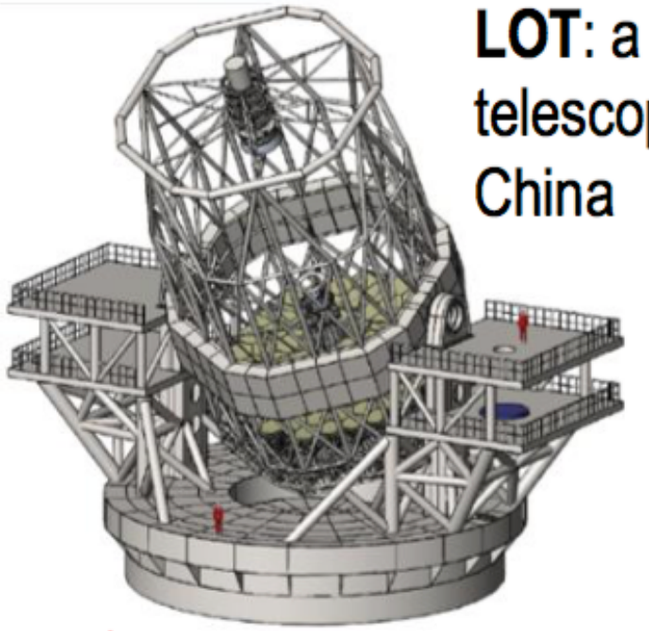






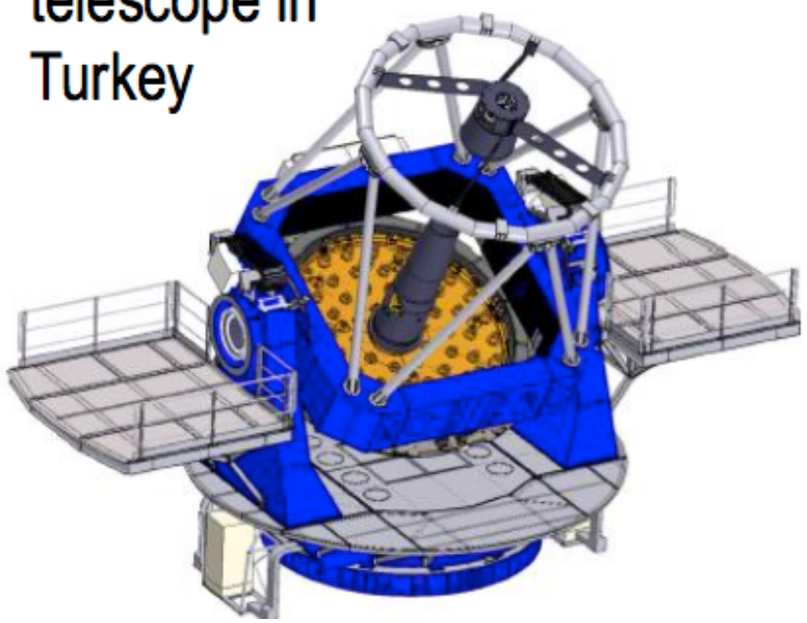


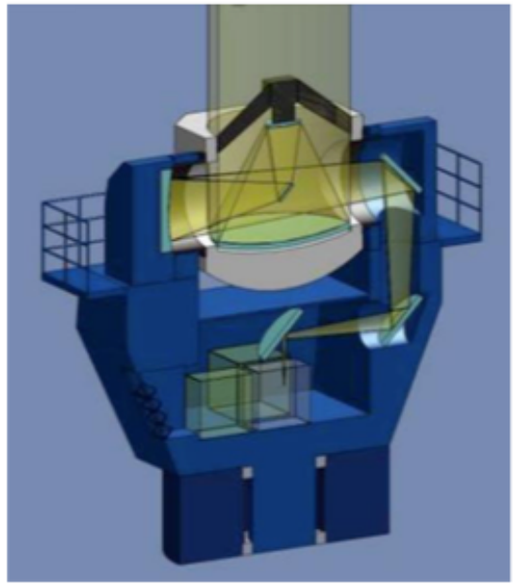
AAO instrumentation - future



LOT: a new telescope in China

DAG: a new telescope in Turkey



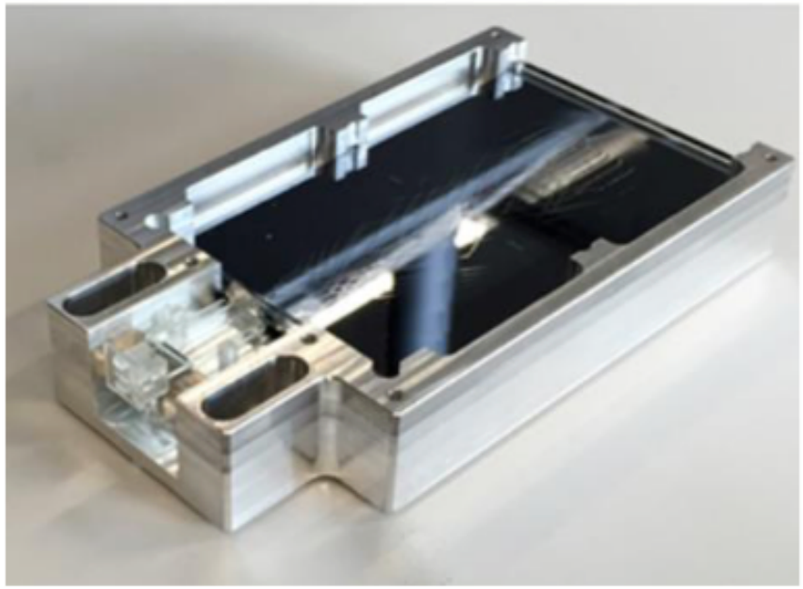


KDUST: a new telescope in Antarctica

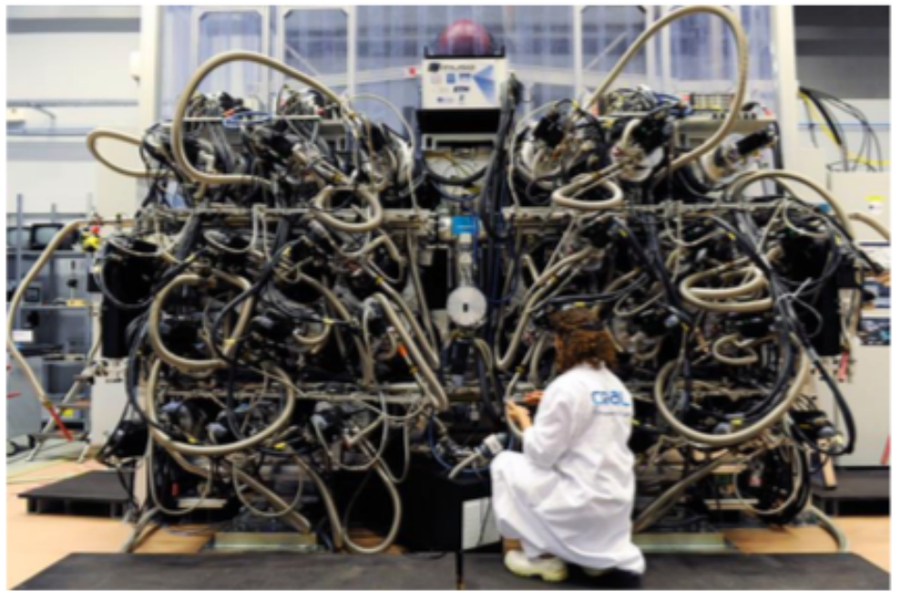
CA 3.5m: an existing telescope in Spain

MSE: a new telescope in Hawaii

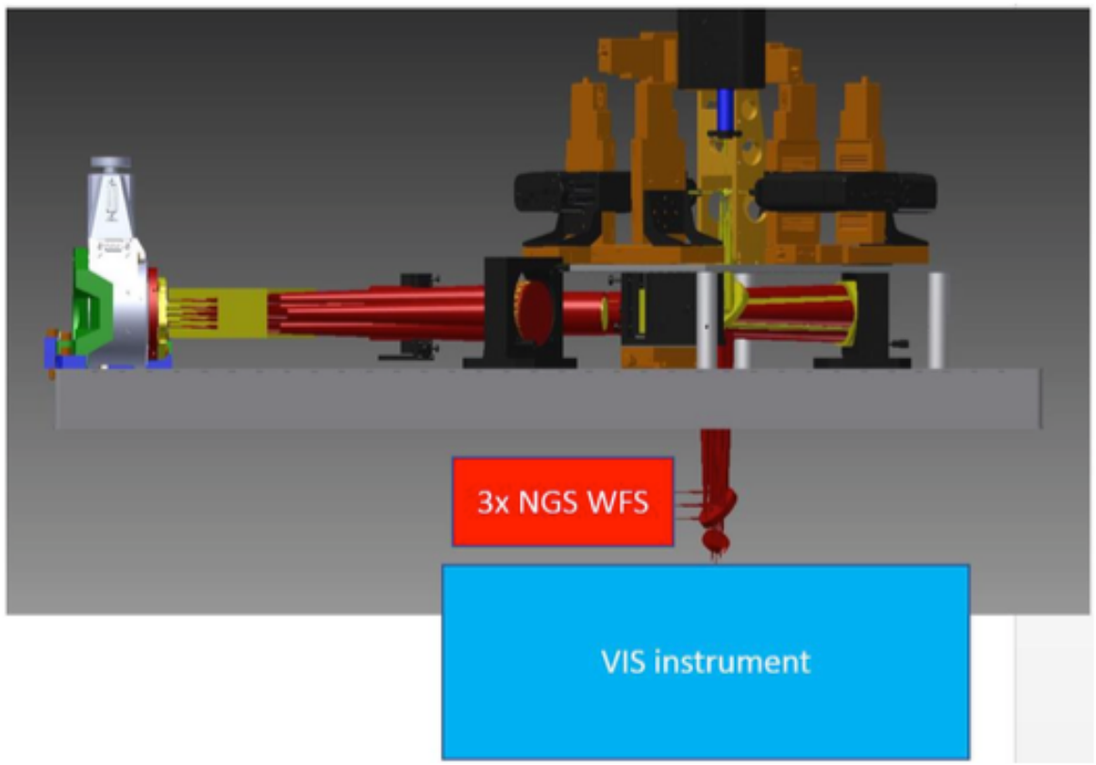
AAO instrumentation - future



Hi-5: a photonic interferometer



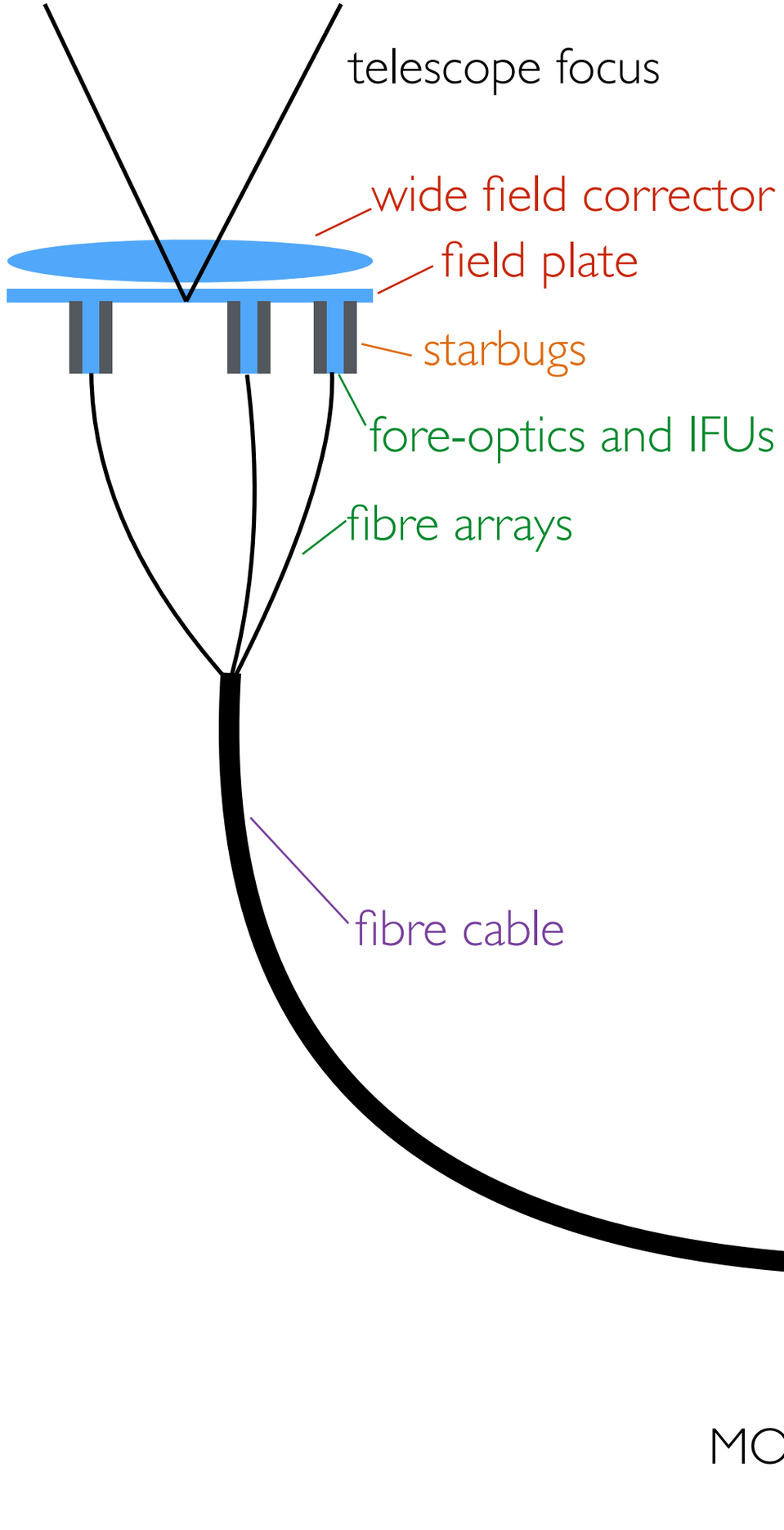
Blue-MUSE: upgrade blue arms to the VLT integral field unit spectrograph



VIMCAO: a VLT multi-conjugate adaptive optics imager and spectrograph

VLT plan: FORS2, CUBES, UVES, Sphere fibre link

ULTIMATE - IFU



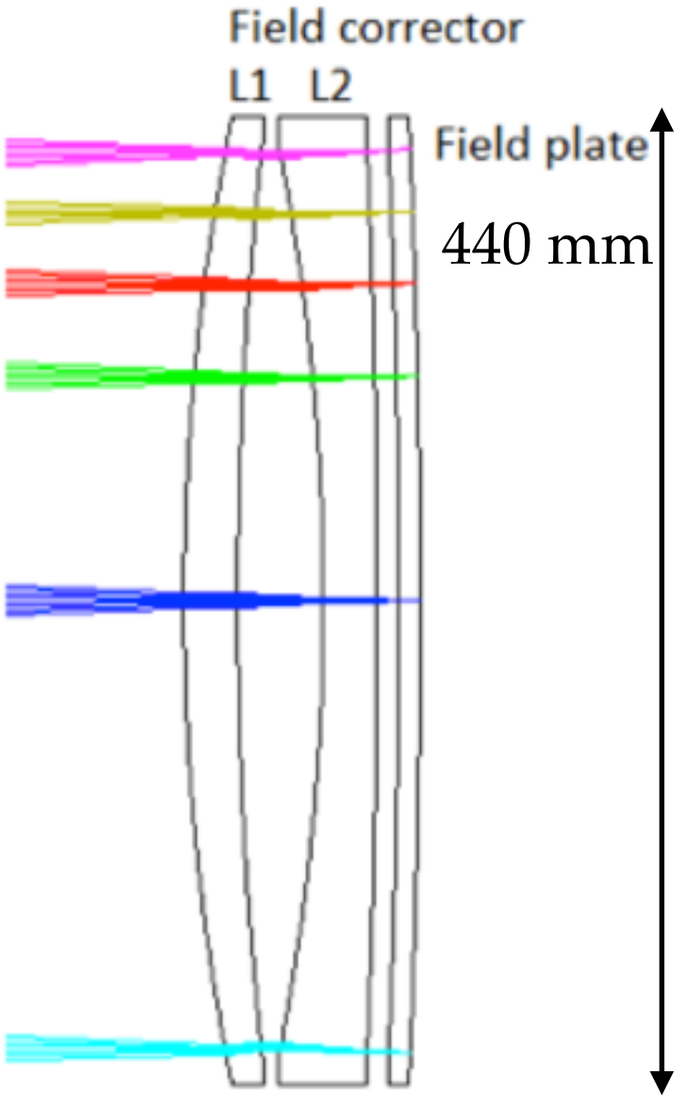
Sub-systems

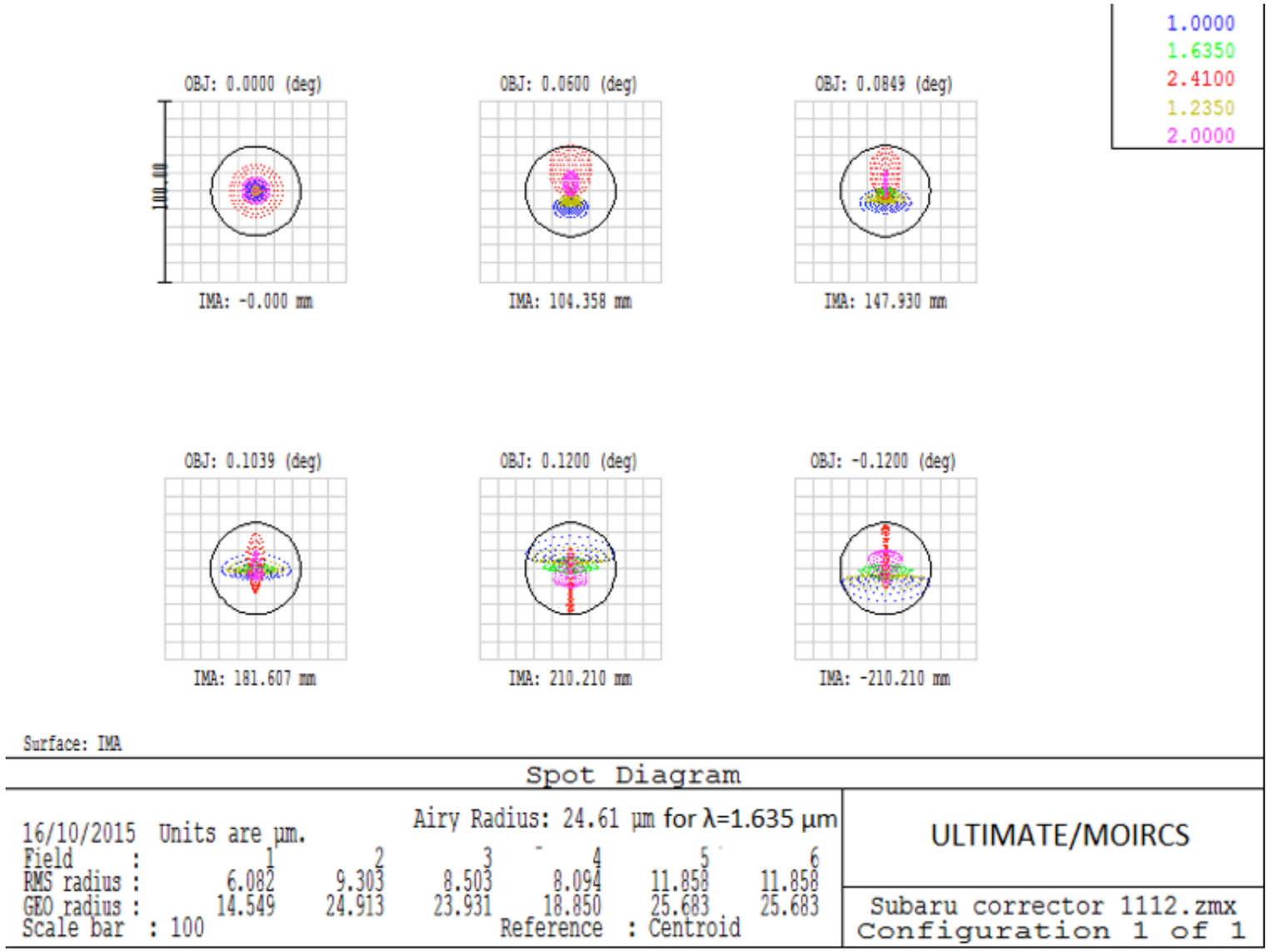
1. Wide field corrector unit
2. Starbugs units
3. Integral field units
4. Fibre cable and slit unit

Main instrument parameters

IFUs	
Number of IFUs	8 - 13
Number of elements per IFU	61 hexagonally packed
Spatial sampling per element	0.15 arcsec
Total field of view per IFU	1.18 square arcsec
Total patrol area	14 x 8 arcmin
Minimum separation between IFUs	20 arcsec
Spectrograph	
Wavelength coverage	0.9 – 1.8 μm
Spectral resolving power	500 – 3000
Dispersion	1.6 Å per pix (J), 2.1 Å per pix (H)
Sampling	2 - 5 pixels FWHM
Combined properties	
Total efficiency	9 % (J), 12 %(H)

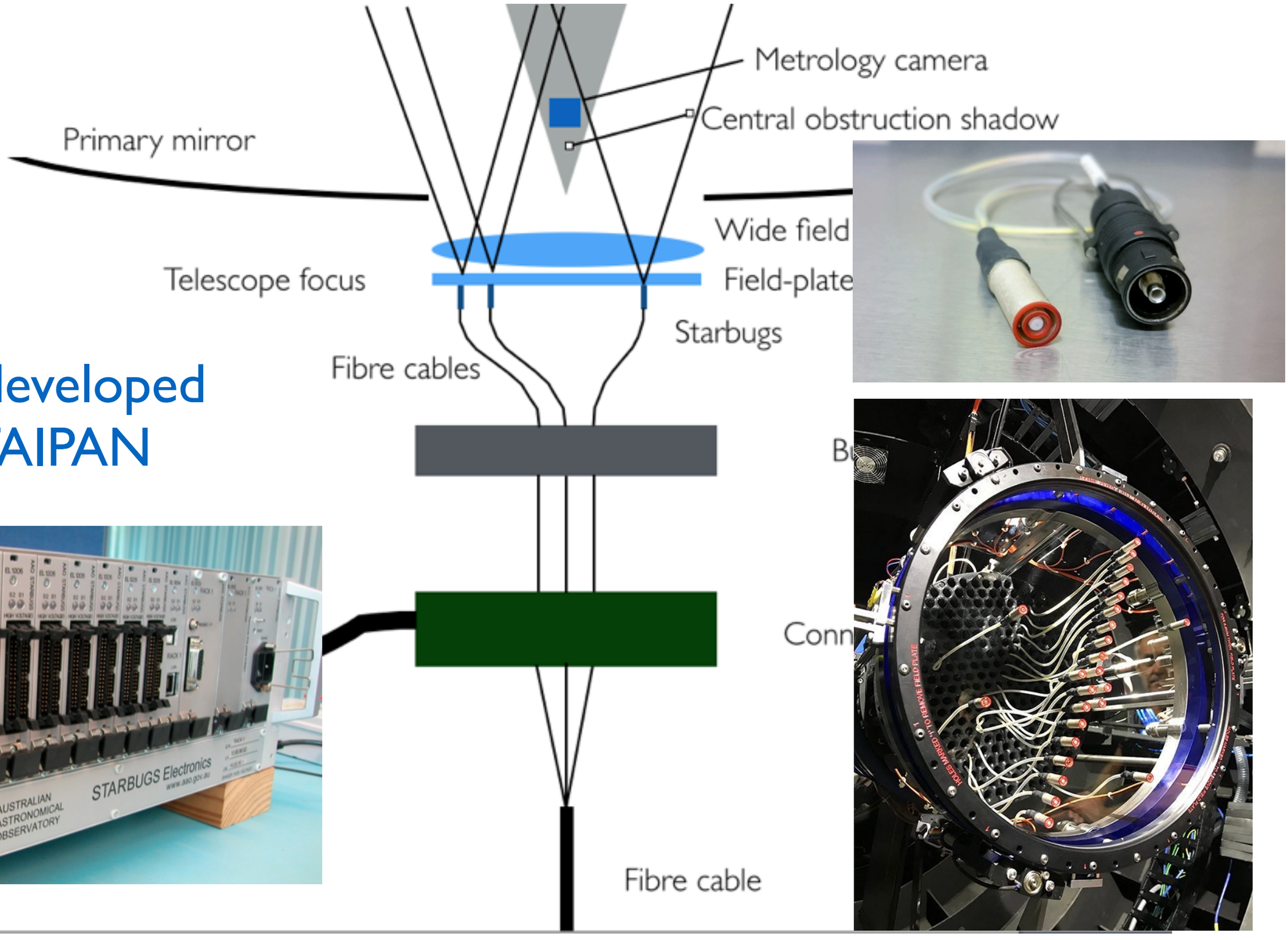
Wide field corrector





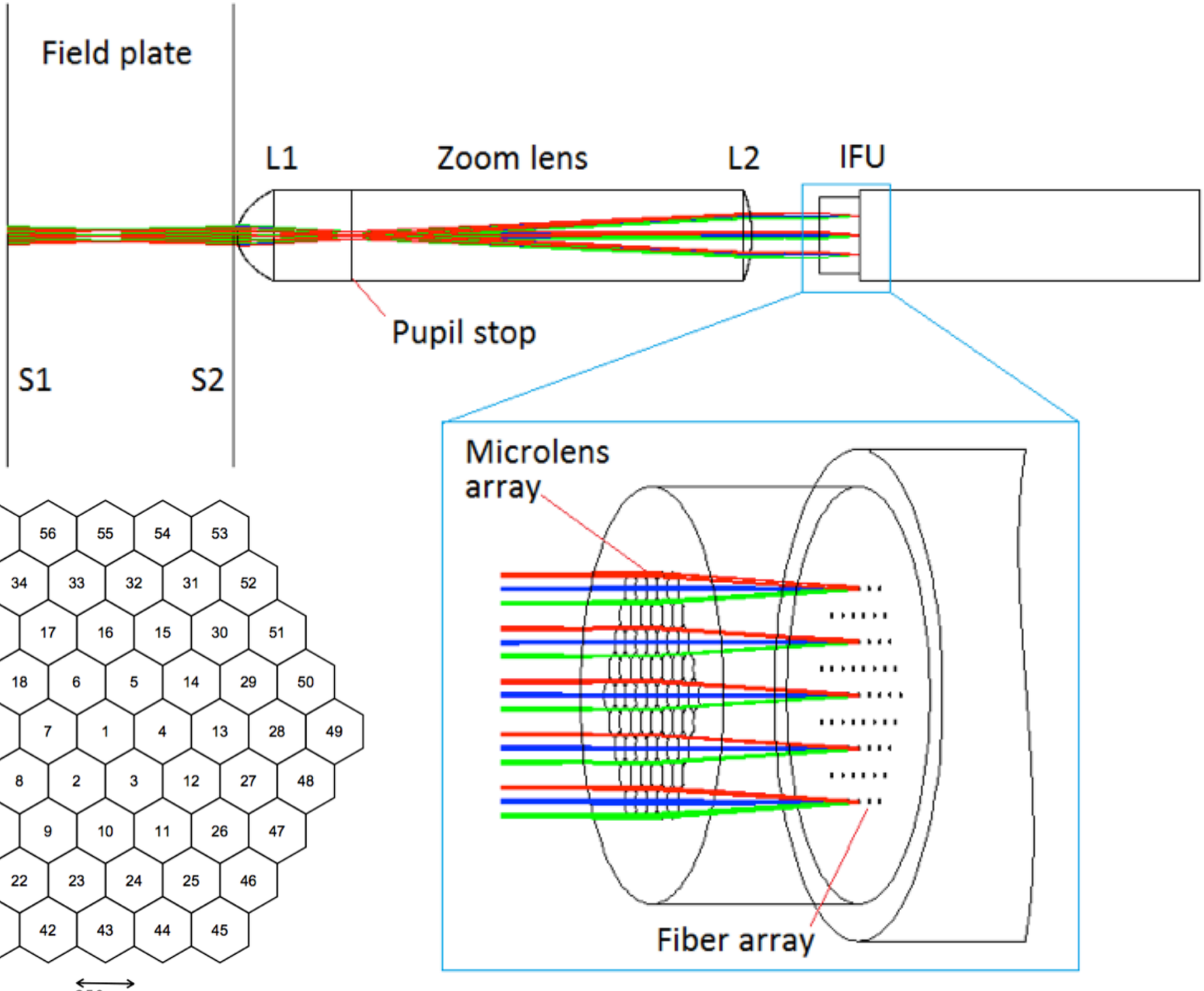
λ (µm)	Dispersion (arcsec)
0.9 – 1.15	0.17 arcsec
1.15 – 1.35	0.07 arcsec
1.35 – 1.8	0.12 arcsec

Starbugs Unit

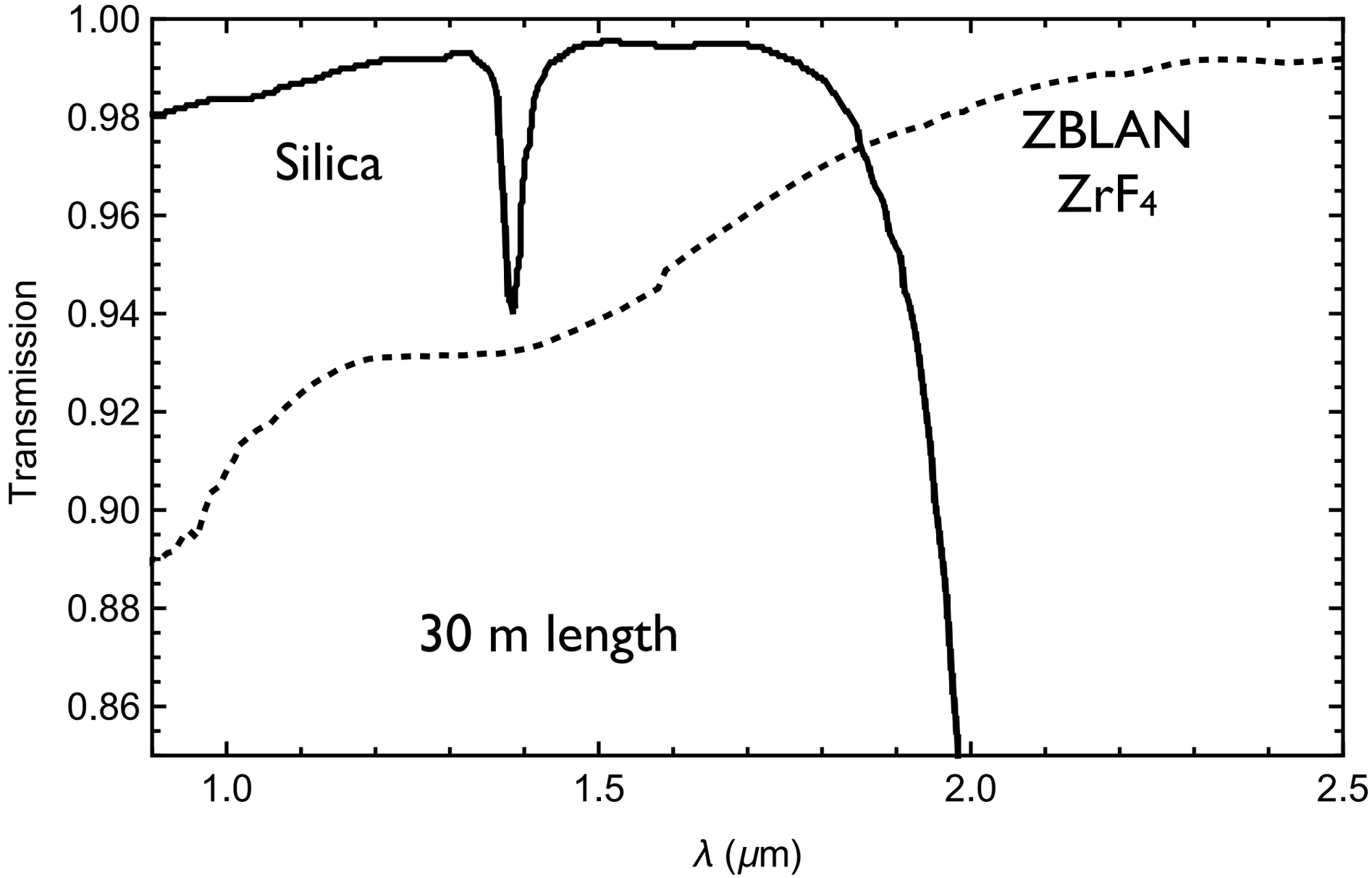


Being developed for TAIPAN

Fore optics


Field plate
L1
Zoom lens
L2
IFU
Pupil stop
S1
S2
Microlens array
Fiber array
57 56 55 54 53
58 34 33 32 31 52
59 35 17 16 15 30 51
60 36 18 6 5 14 29 50
61 37 19 7 1 4 13 28 49
38 20 8 2 3 12 27 48
39 21 9 10 11 26 47
40 22 23 24 25 46
41 42 43 44 45
250 μm
0.15"
1.35"

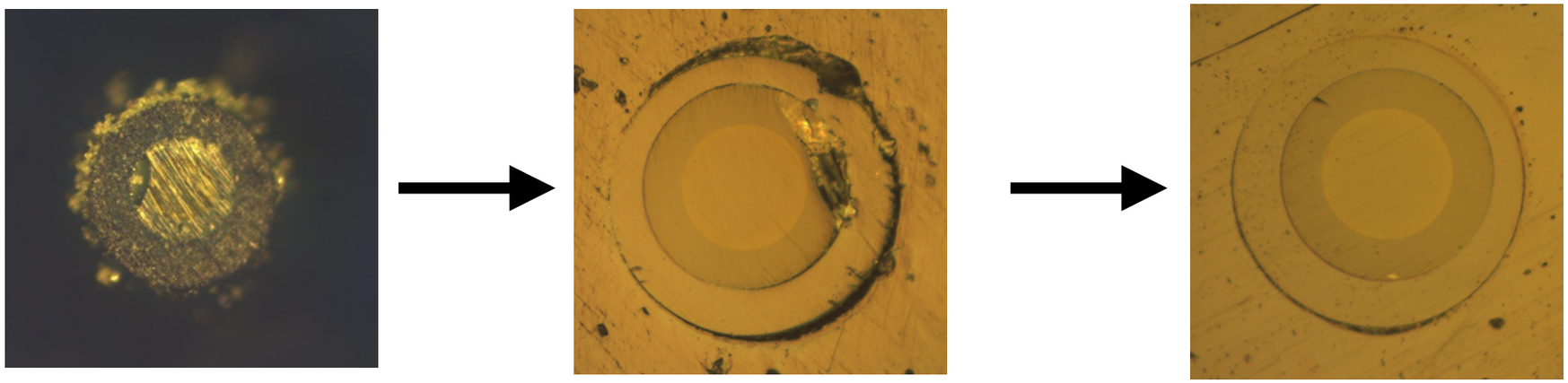
Fluoride fibres



Excellent transmission. Good FRD. In use by Spirou and OHANA.

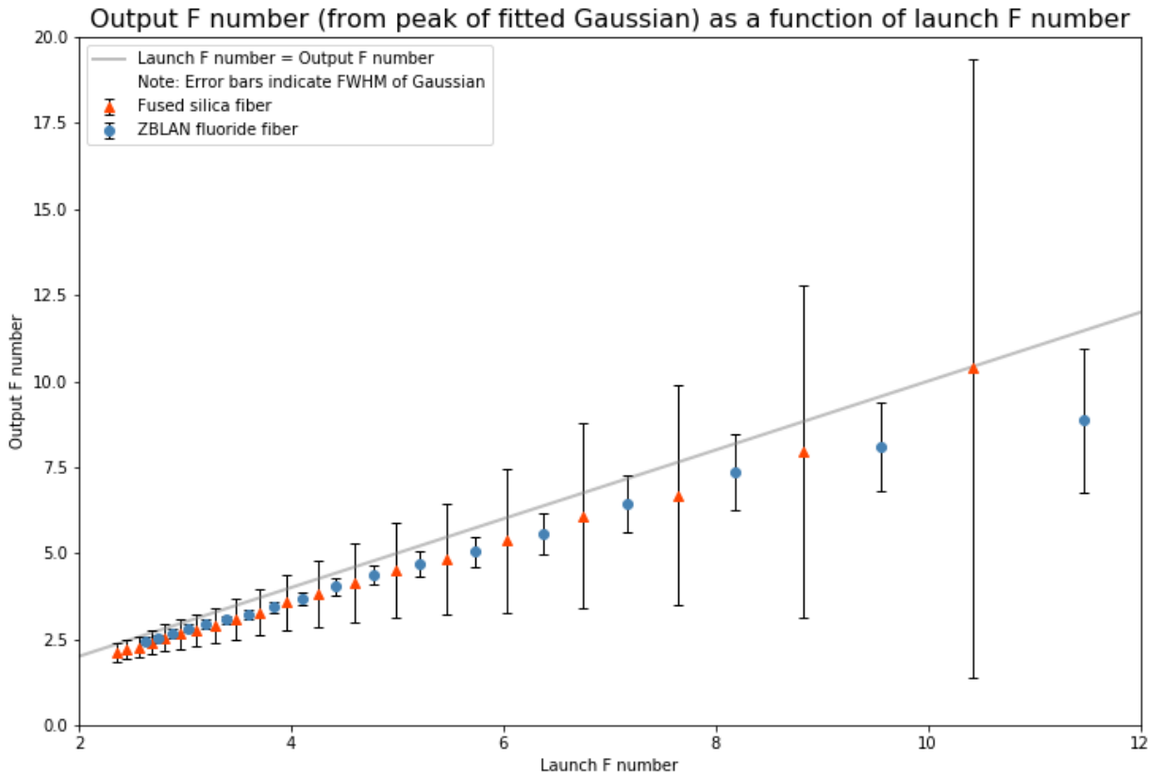
Handling? Polishing? Lab tests necessary.

Fluoride fibres - lab tests



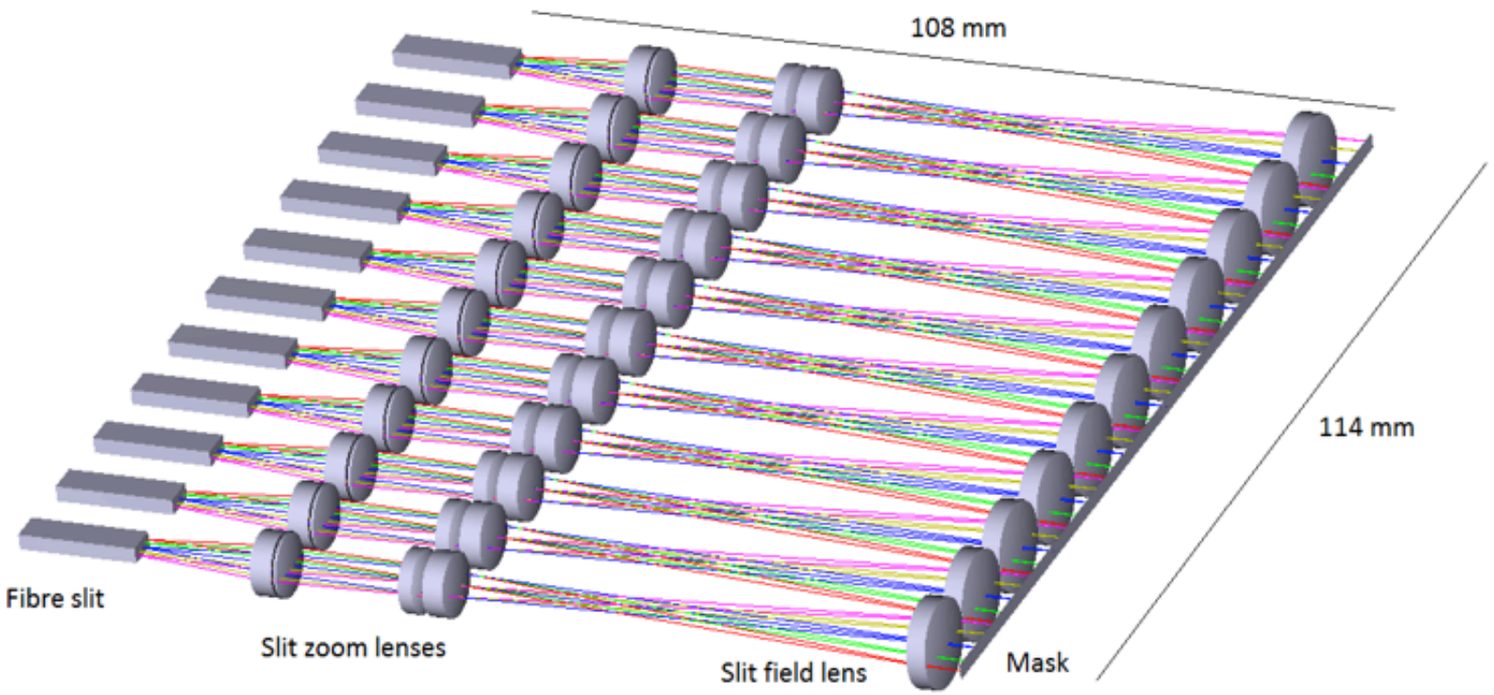
Cleaved → 1 x polish → 2 x polish

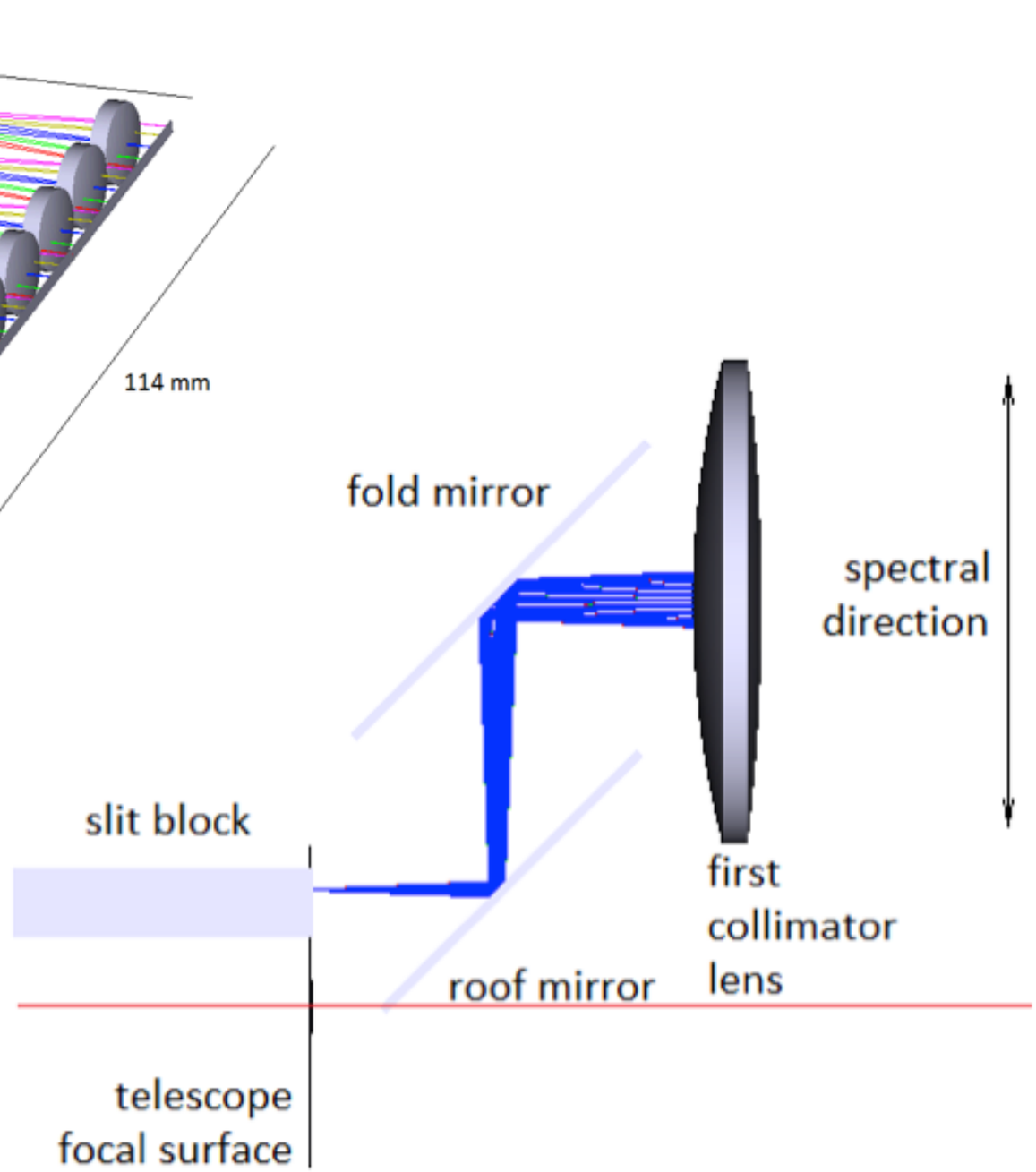
dry polish in ferrule with Al_2O_3



Preliminary FRD tests at 600 nm

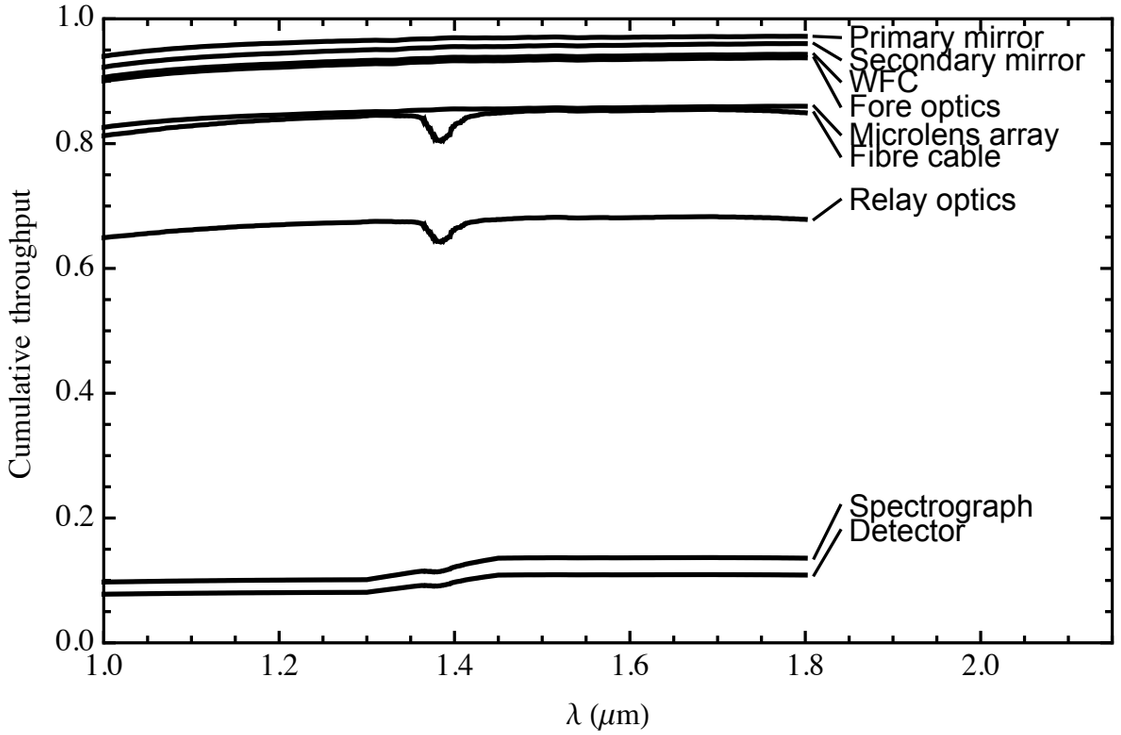
Slit unit


108 mm
114 mm
Fibre slit
Slit zoom lenses
Slit field lens
Mask

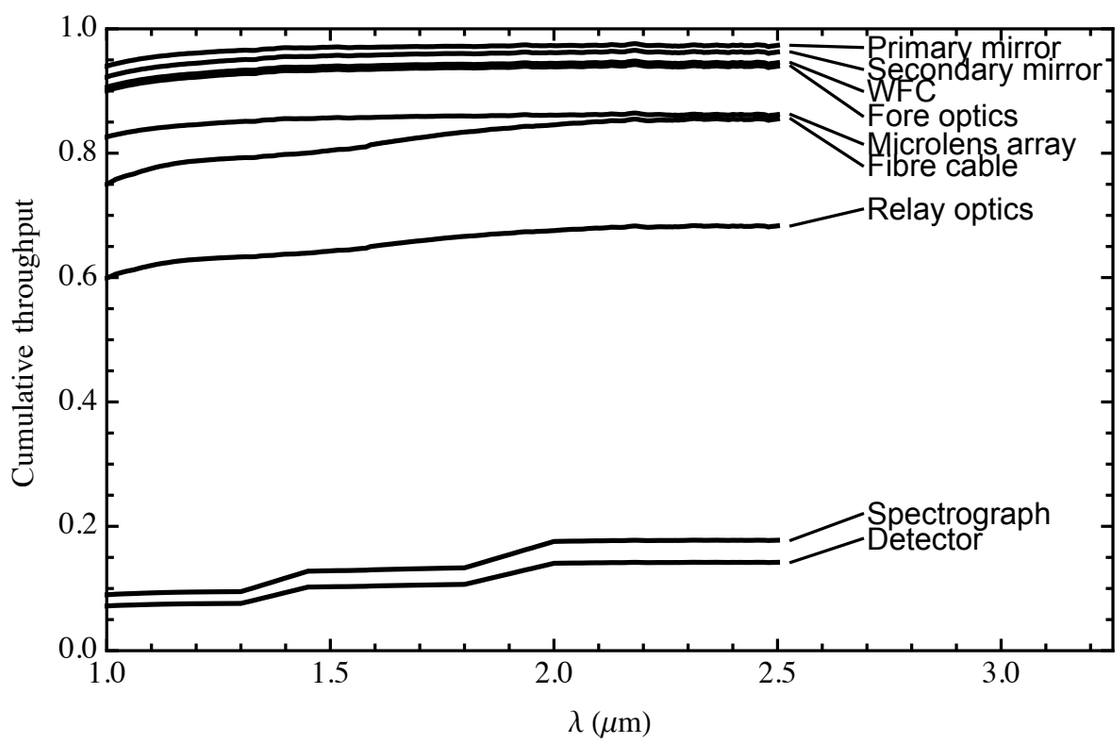

fold mirror
spectral direction
slit block
first collimator lens
roof mirror
telescope focal surface

Throughput

Silica

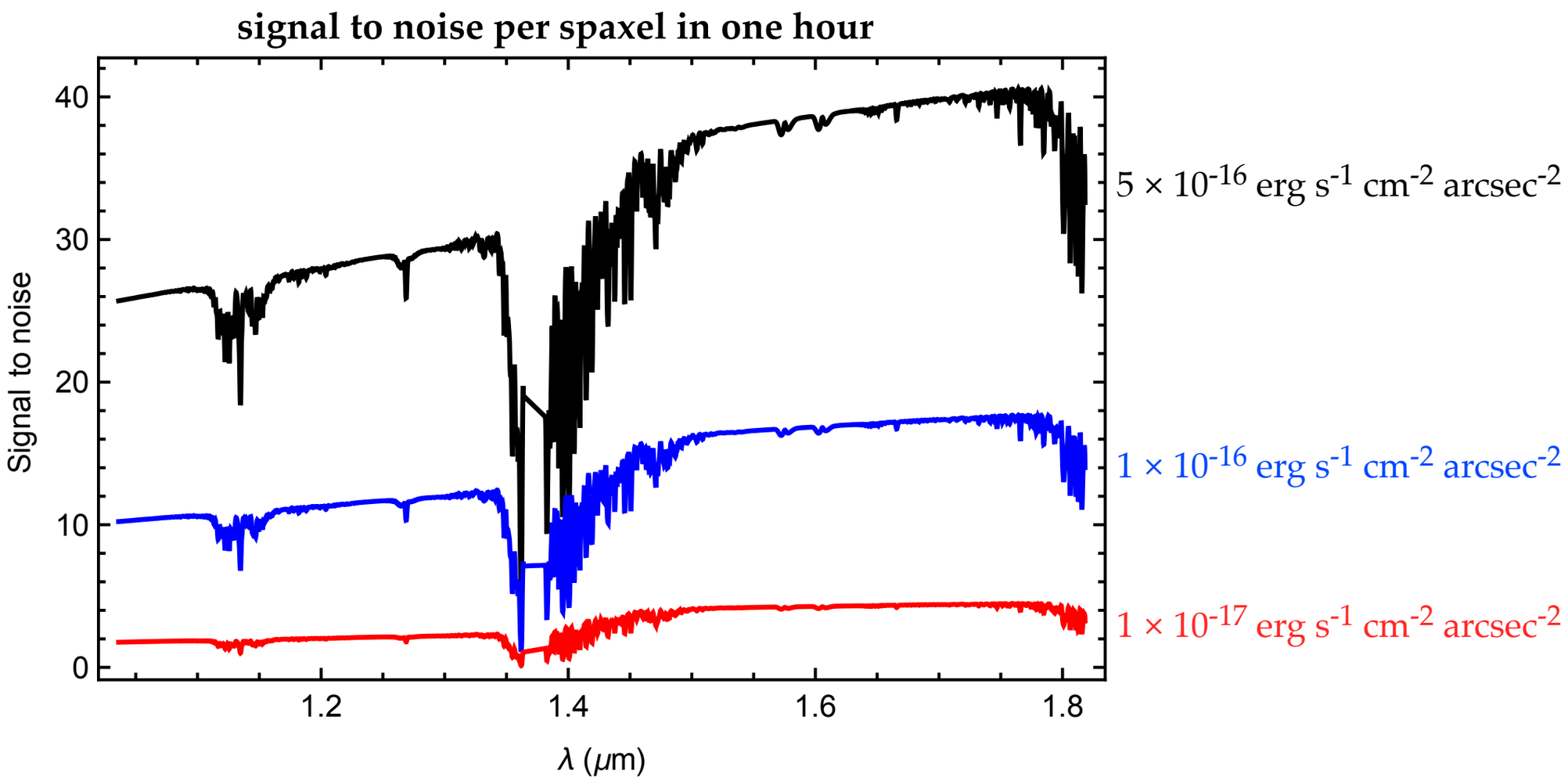


ZBLAN



Wavelength (μm)	**Silica fibre %**	**ZBLAN fibre %**
1.2	9	8
1.6	12	11
2.2	0	15

Signal to noise



Signal to noise estimates for 1 hour observations of the H alpha line in a galaxy with a star-formation rate of 10 solar masses per year, uniformly distributed over a galaxy disc of radius 8 kpc.

Survey	S/N over 1 square arc-second	S/N per spaxel (0.15”)	KMOS (0.2” by 0.2”)
ULTIMATE @ z=0.6	108	15.1	10.0 (0.165 nm bin)
ULTIMATE @ z=0.9	80	11.3	7.4 (0.165 nm bin)
ULTIMATE @ z=1.4	69	9.6	2.8 (0.2 nm bin)

Conclusions

- AAO in period of transition
  - move to university sector offers new opportunities
  - maintain a national optical instrumentation group

- AAO instrumentation programme in good shape
  - many ongoing and future national and international project
  - many collaborative projects around the world
  - strong R&D programme

- Primary AAO interest in ULTIMATE is for IFS
  - instrument projects and collaborations remain the focus of new AAO
  - experience in many aspects of optical instrumentation