Instrument Overview

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(Subaru Telescope, NAOJ)

6/16/2016 ULTIMATE-Subaru Science Workshop 2016

ULTIMATE–Subaru instrument plans

1) Wide-field imager
2) Multi-object integral field spectrograph
3) Multi-slit spectrograph

	Imager	MOS	Multi-Object IFU[a]
Wavelength Coverage	0.8–2.5μm		0.9–1.8 μm
Plate Scale	0.10 arcsec/pix		0.15 arcsec/spaxel
FOV	ϕ=16′	ϕ=6′ – 16′[b] (TBD)	IFU: 1″.18×1″.18, Patrol area: ϕ ∼15′
Filters	YJHK + NBF/MBF/TBF[c]	—	—
Spectral Resolution	–	∼3000 (0″.4 slit)	500–3000
Multiplicity	–	∼100 slits (TBD)	8–13 IFUs (TBD)
Detector	4×H4RG(Teledyne)		2×H2RG(Teledyne)
Efficiency[d]	∼ 48%(J,H), ∼40%(K)	∼33%(J),∼35%(H,K)	∼7%(J),∼10%(H)

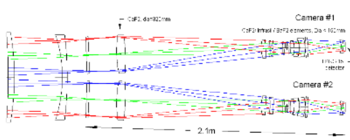
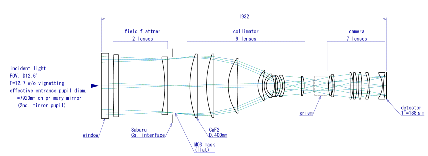
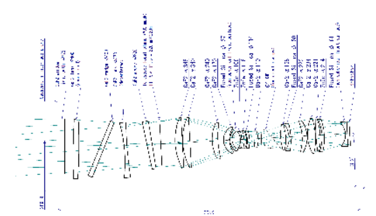
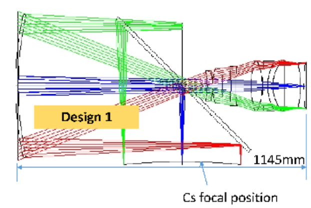
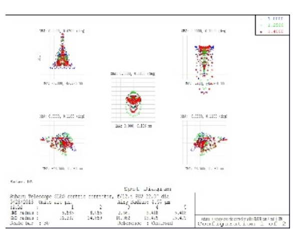
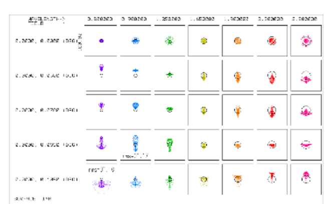
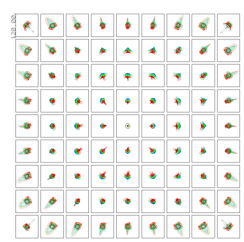
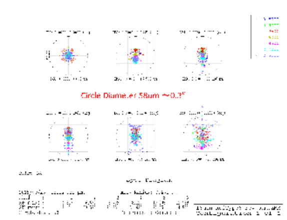
[a] In case of using MOIRCS as a spectrograph.
[b] FoV will be limited to 6′ if the instrument is installed at NsIR.
[c] NBF, MBF, and TBF indicate narrow-band, medium-band, and tunable filters, respectively.
[d] Total Efficiency includes atmosphere, telescope, and instrument (optics + detector).

Wide-Field imager: Baseline Specification

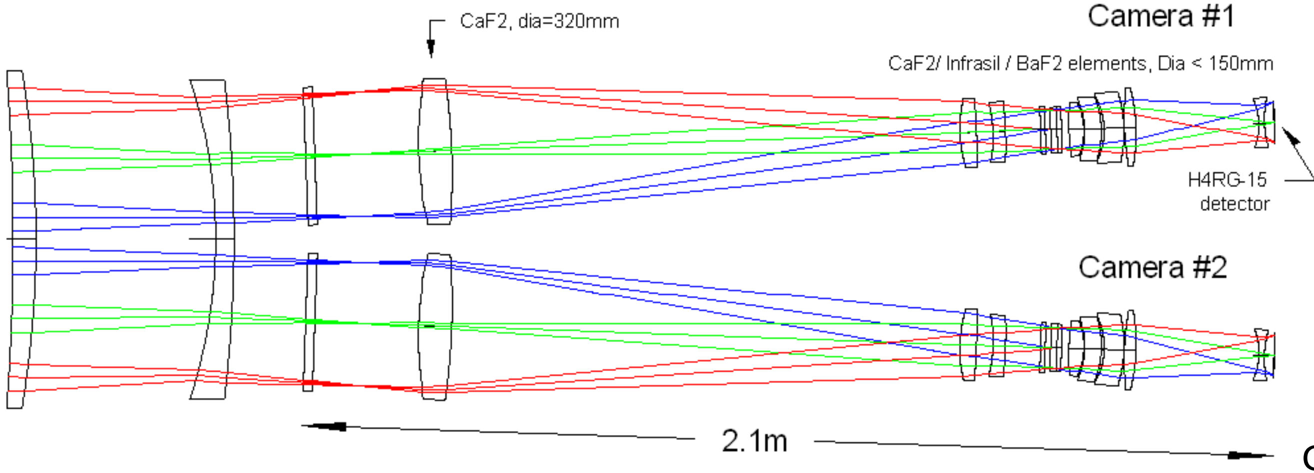
Wavelength coverage	0.8-2.5um	
Plate scale	0.10”/pix (TBD)	1pix=15um
FoV	ϕ < 16 arcmin	Separation of 4 areas TBD
Filters	BB / MB / NB (+ tunable filter ?)	See example in the fact sheet
Detectors	4 H4RGs (4k x 4k)	

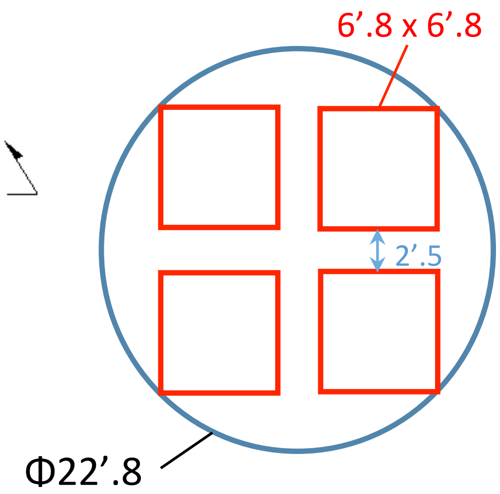
The WFI is currently 1st priority instrument among the three instrument plans for ULTIMATE.

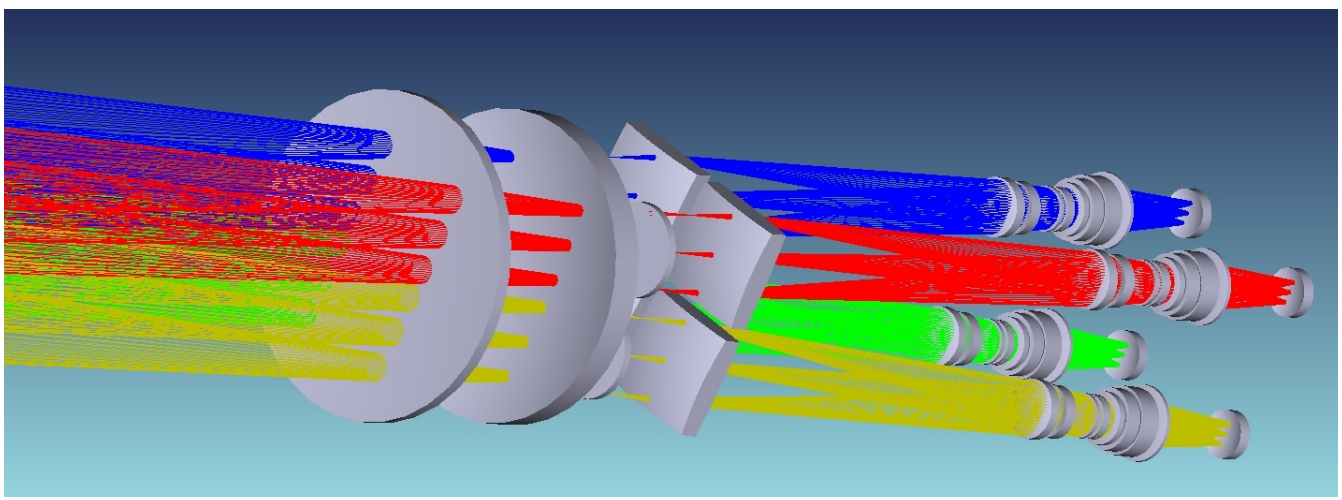
Wide-Field Imager: Conceptual optical design

Design	J. Pazder (HIA)	T. Yamamuro (OptCraft)	T. Yamamuro (OptCraft)	Y. Tanaka (Subaru)
Date	5/29/2013	3/30/2012	3/15/2013	9/29/2015
FoV	Φ20' (6'.8 x 6'.8 x 4)	Φ12'.6	11'.5 x 11'.5 x 4	Φ16'
Scale	0".1/pixel	0".08/pixel	0".08/pixel	0".077/pixel
Lens	14	19	21	8 + 2 mirrors
Purpose	design concept	MOS design	MOS design with FoV split	compact imager with a large spherical mirror
Note		FoV limited by Φ400mm CaF2	FoV limited by Φ400mm CaF2, feasibility problem	
Layout				
Spot Diagram	< ~0".1 	<~0".15 	<~0".16 but up to 0".27 at edge 	<~0".13 

Four Barrel Imager Design (J. Pazder, HIA)

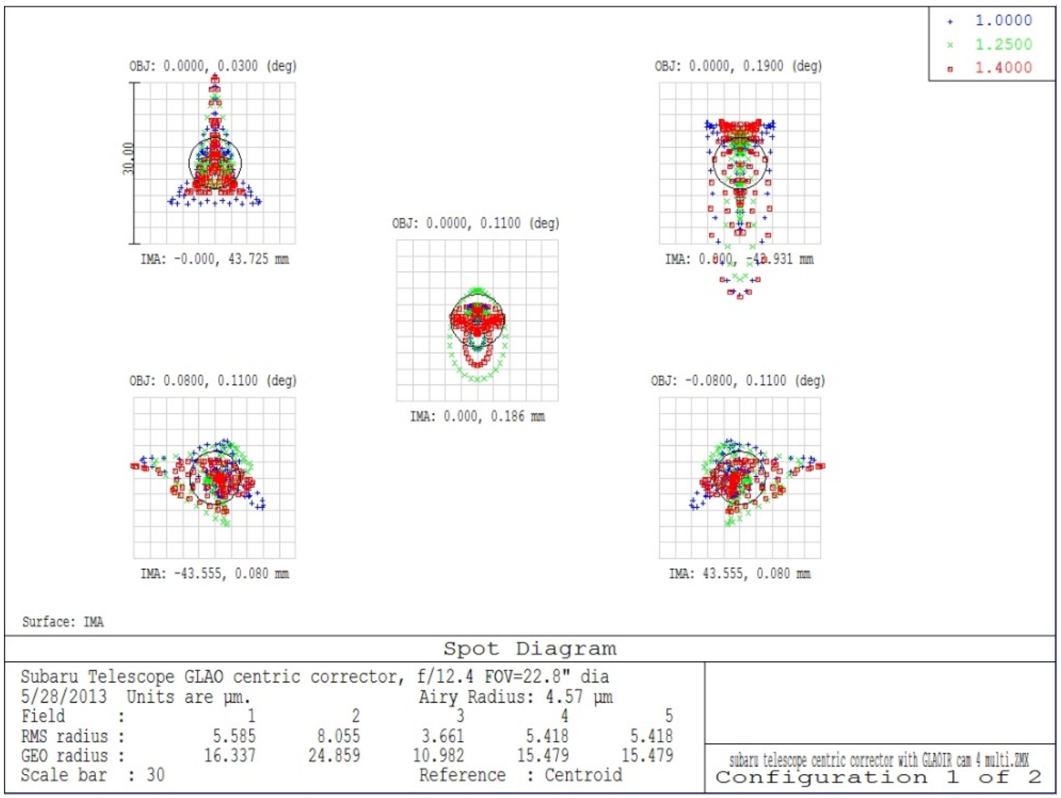






Four Barrel Imager Design (J. Pazder, HIA)

- each unit has 6'.8 x 6'.8 FoV (0".1/pixel with H4RG)
- good imaging performance (RMS diameter < ~1pixel=0".1)



Tunable filter for imager

- Alternative to NB filter set
- Fabry-Perot etalon
  - there were activities in developing cryogenic etalons
    - F2T2 (Flamingos-2 Tandem Tunable filter)
    - TFI (Tunable Filter Imager) for JWST
  - cryogenic and large aperture etalon may be challenging
    - feasibility and expected performance are under study
    - discussing with COM DEV Canada

Instrument	F2T2	JWST-TFI	ULTIMATE
spectral resolution	>800 (wing suppressed)	100	~100?
wavelength	0.95-1.35μm	1.5-5μm	0.8-2.5μm
field of view	50"-1'.5	2'.2	~16'
operating temperature	~110K	~35K	~120K
aperture size	60mm	56mm	~100mm
location	telescope focus	pupil	pupil

Multi-Object IFU spectrograph: Baseline Specification

Conceptual design by Australian Astronomical Observatory (AAO)

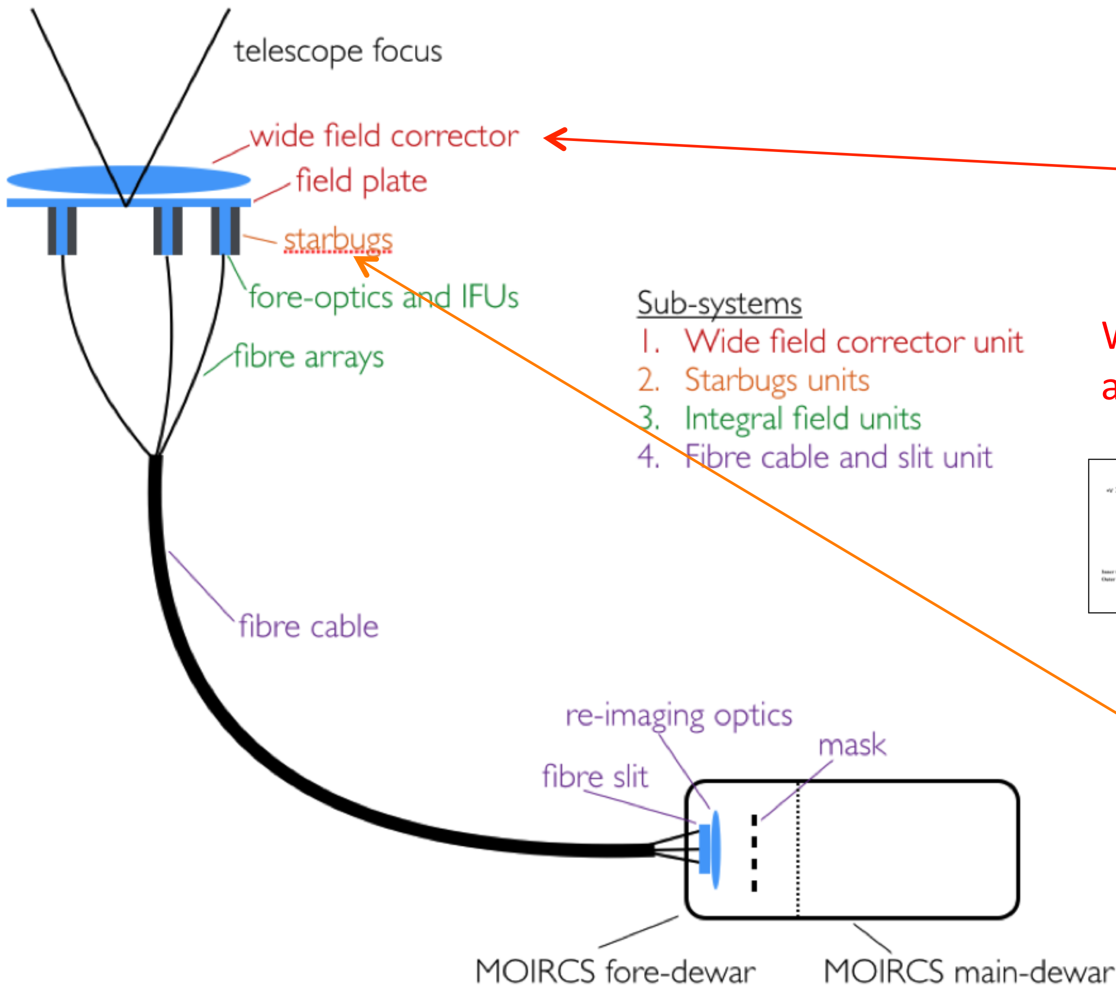
- Fiber-bundle IFU with Starbug positioners
- Re-use MOIRCS for initial phase observation.
- Develop a dedicated spectrograph to increase the number of IFUs and optimize the optical parameters

IFUs	
Number of IFUs	8-13[a]
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	$\phi \sim 15$ arcmin[b]
Minimum separation between IFUs	25 arcsec
Spectrograph (MOIRCS)	
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 in FWHM
Combined properties	
Total efficiency	9% (J), 12% (H)

Simon Ellis et al.

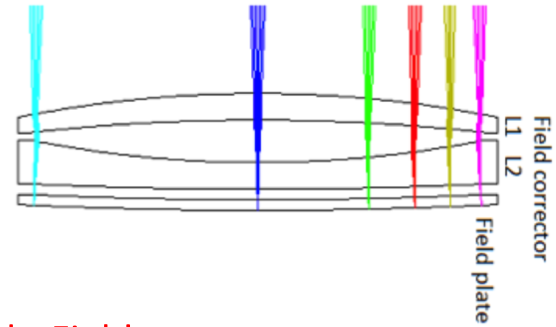
Multi-Object IFU spectrograph

Fiber bundle IFU with Starbug positioners

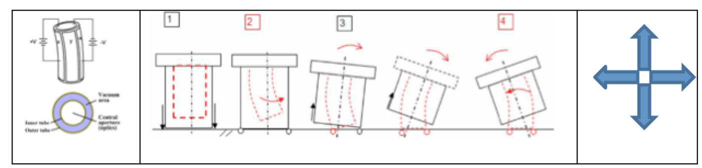


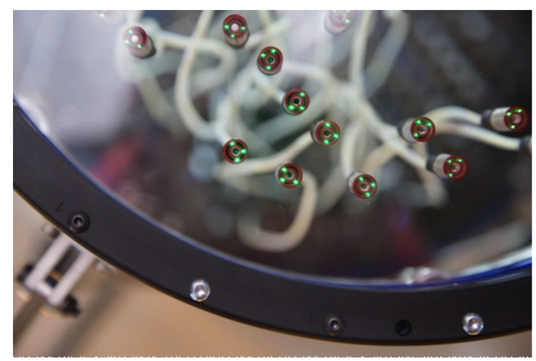
Sub-systems
1. Wide field corrector unit
2. Starbugs units
3. Integral field units
4. Fibre cable and slit unit

Conceptual design by AAO



Wide-Field corrector to compensate the astigmatism over 15’ FoV

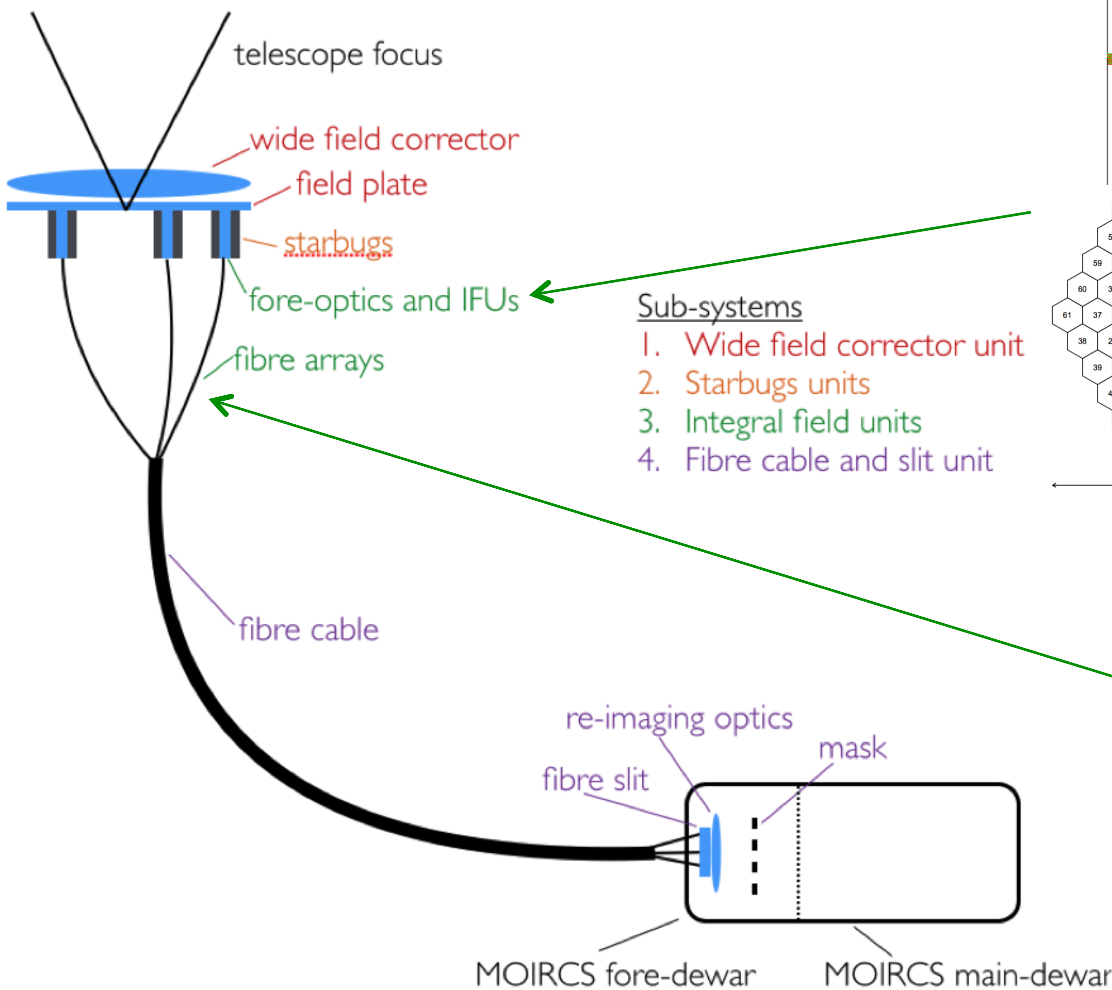




Starbug fiber positioner developed by AAO

Multi-Object IFU spectrograph

Fiber bundle IFU with Starbug positioners



Conceptual design by AAO

Sub-systems

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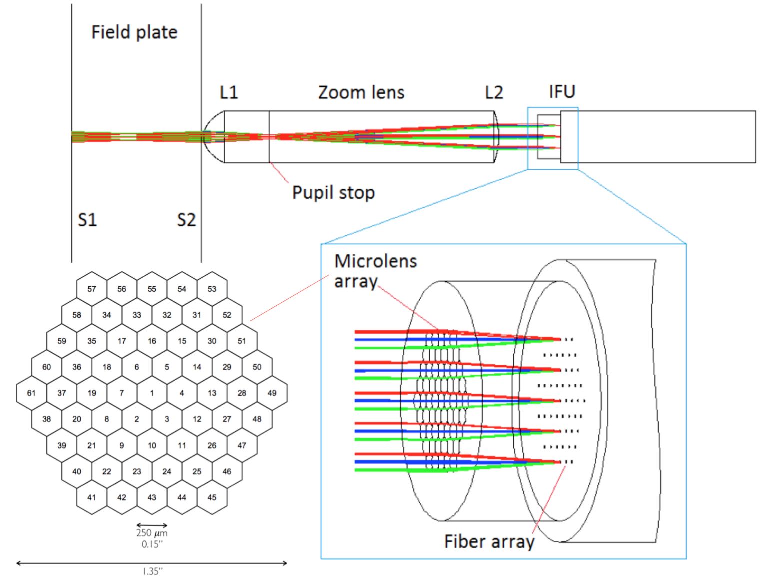
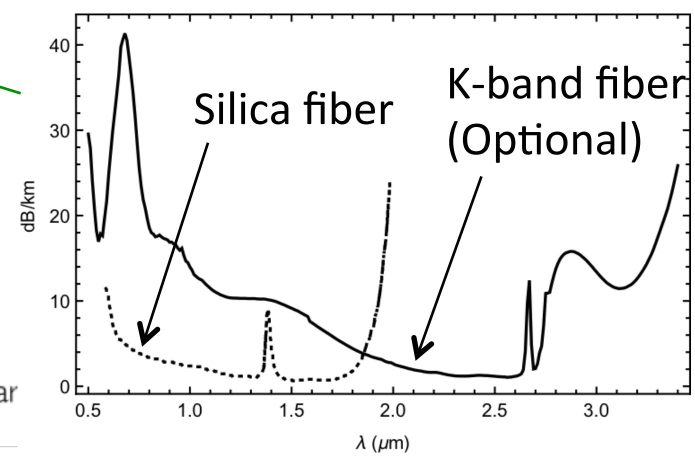


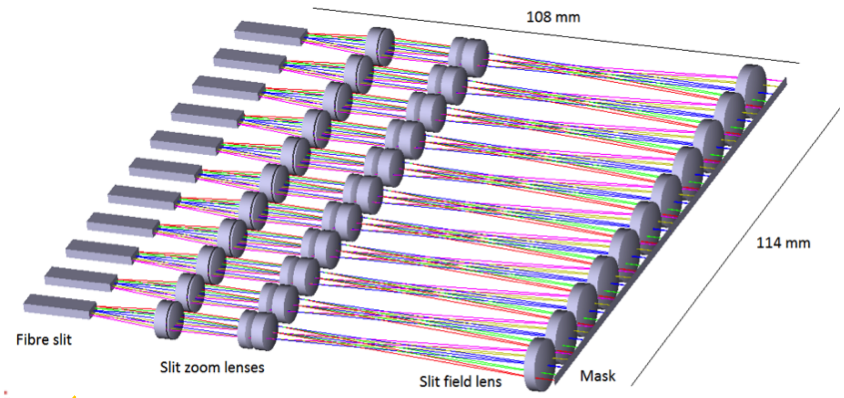
Fore-Optics and lenslet array



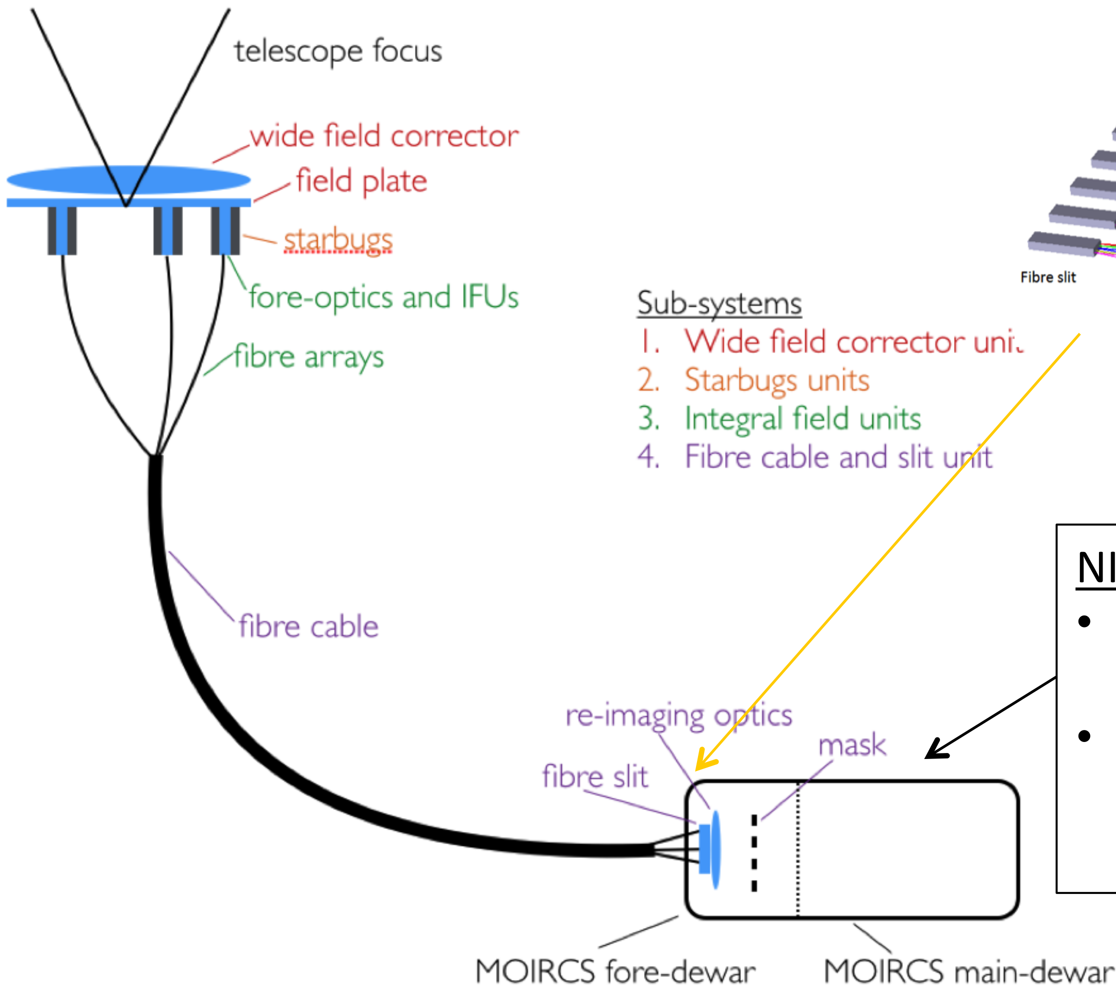
Fiber cable (~30m)

Multi-Object IFU spectrograph

Fiber bundle IFU with Starbug positioners



Fiber slit unit



NIR spectrograph

- re-use MOIRCS for initial observations.
- Develop a new spectrograph or use PFS spectrograph (<1.2 μm) with higher multiplexity

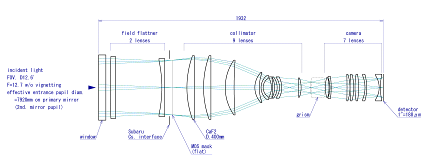
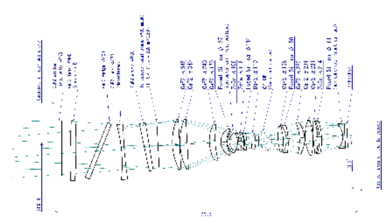
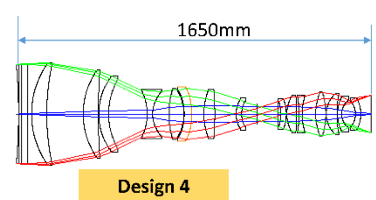
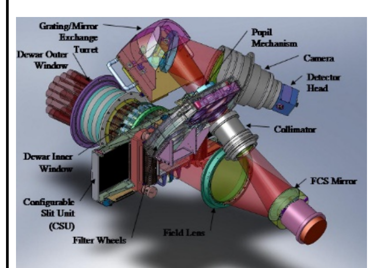
Conceptual design by AAO

Multi-Object Slit spectrograph: Baseline Specification

Wavelength coverage	0.8-2.5um
Plate scale	0.10”/pix (TBD)
FoV	6’ – 16’ (TBD)
Spectral resolution	~3000 (0.4” slit)
Multiplicity	~100 slits
Efficiency	~33% (J), ~35% (H,K)

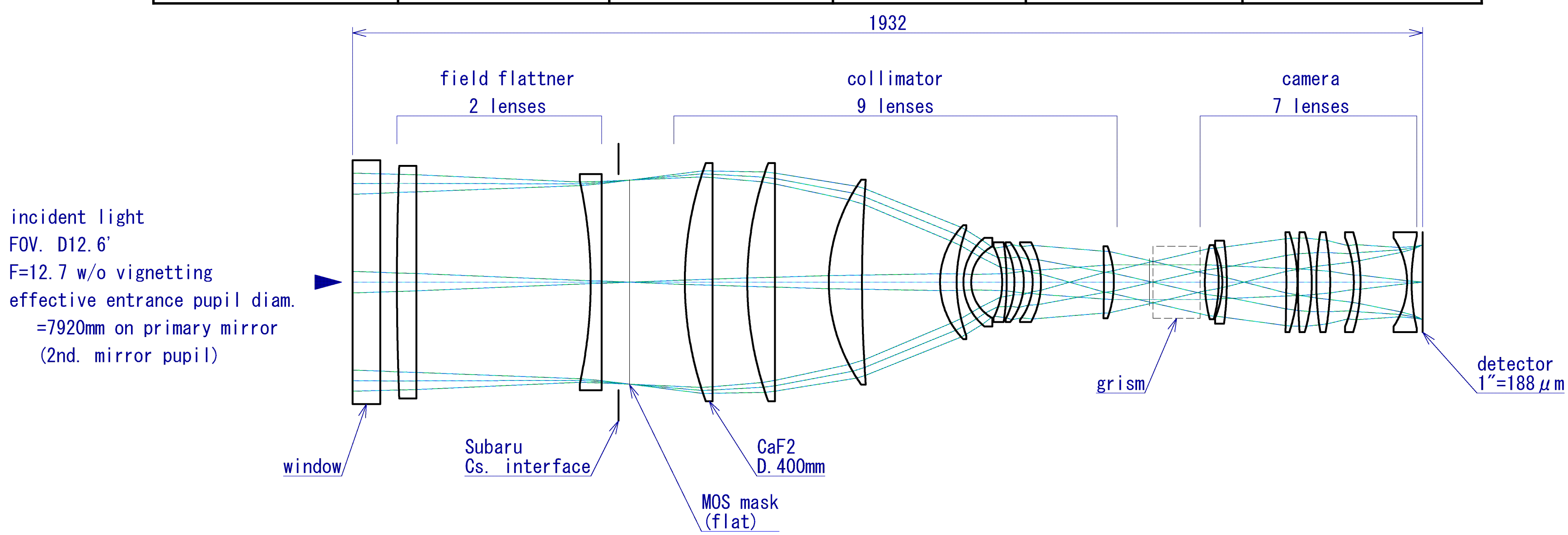
- The Specification of the Multi-Slit Spectrograph has not been studied yet.
- Currently, “Keck/MOSFIRE” like spectrograph is assumed.
- There is an idea to use “MOIRCS” as a first light instrument for GLAO.

Multi-Object Slit Spectrograph

Design	T. Yamamuro (OptCraft)	T. Yamamuro (OptCraft)	Y. Tanaka (Subaru)	IRMS
Date	3/30/2012	3/15/2013	9/29/2015	?
FoV	Φ12'.6	11'.5 x 11'.5 x 4	Φ16'	Φ6'
Scale	0".08/pixel	0".08/pixel	0".088/pixel	0".25/pixel
Lens	19	21	16	15
Multiplicity	50-100?	50-100?	50-100?	36
Resolution	R~3000	R~3000	?	R~6300
Note	FoV limited by Φ400mm CaF2	FoV limited by Φ400mm CaF2, feasibility problem		Nasmyth focus
Layout				

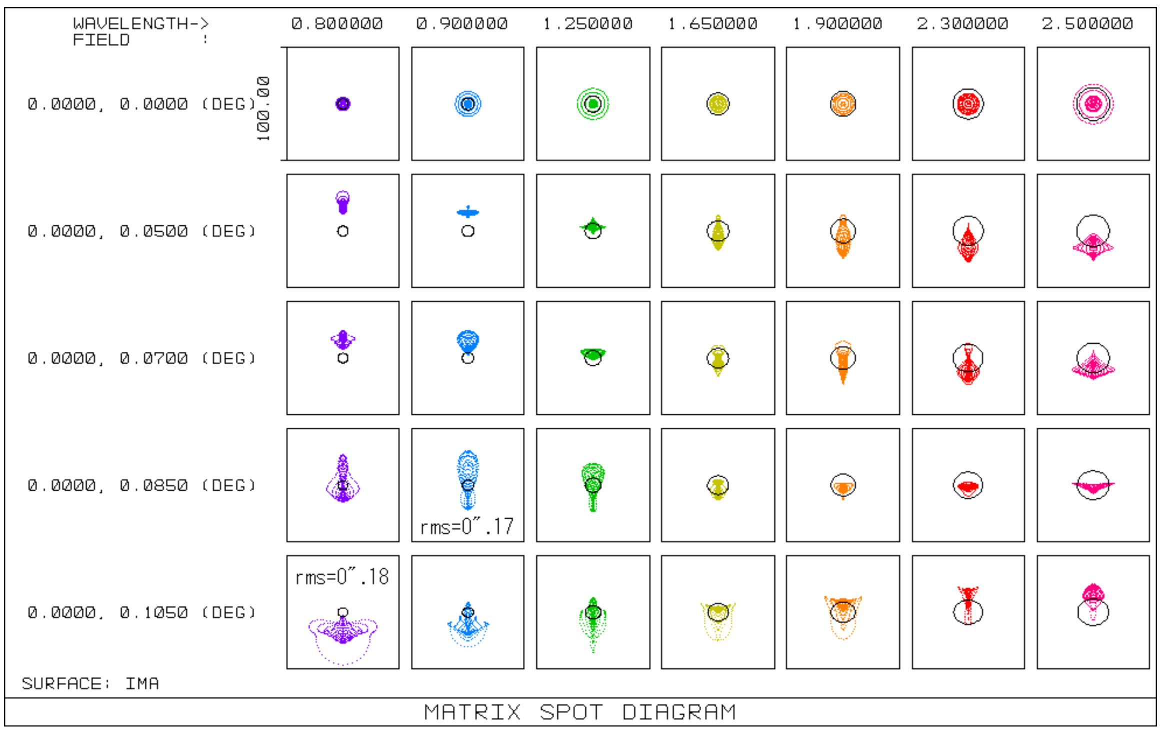
Wide-Field Near-IR Multi Object Spectrograph Conceptual Optical design (T. Yamamuro, OptCraft)

Design	I-A-1	**I-A-2**	I-B-1	II-A	II-B
M2	current	**current**	new	current	new
M1 shapre	current	**current**	new	new	new
FoV	Φ13'.2	**Φ12'.6**	Φ16'.2	8'.5x8'.5x4	11'.5x11'.5x4
Field flattener	no	**yes**	yes	yes	yes
Lens	17	**19**	19	21	21



Wide-Field Near-IR Multi Object Spectrograph Conceptual Optical design (T. Yamamuro, OptCraft)

- FoV (ϕ12'.6) is limited by D=400mm CaF2
- RMS diameter < 0".15 at most positions and wavelengths
- mechanical and cryogenic feasibility studies are needed



MOIRCS as a first light instrument

MOIRCS specification:

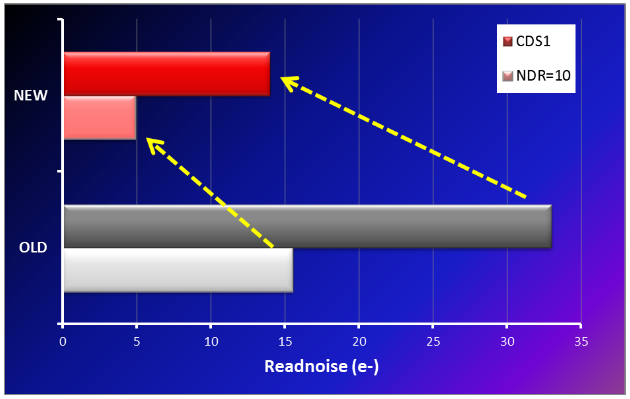
- Imaging … YJHKs & 11 NB filters, 4'x7' fov.
- MOS Spectroscopy … Low-resolution (ZYJH & HK: R~500) and the VPH medium-resolution (R2000-3400) are available.

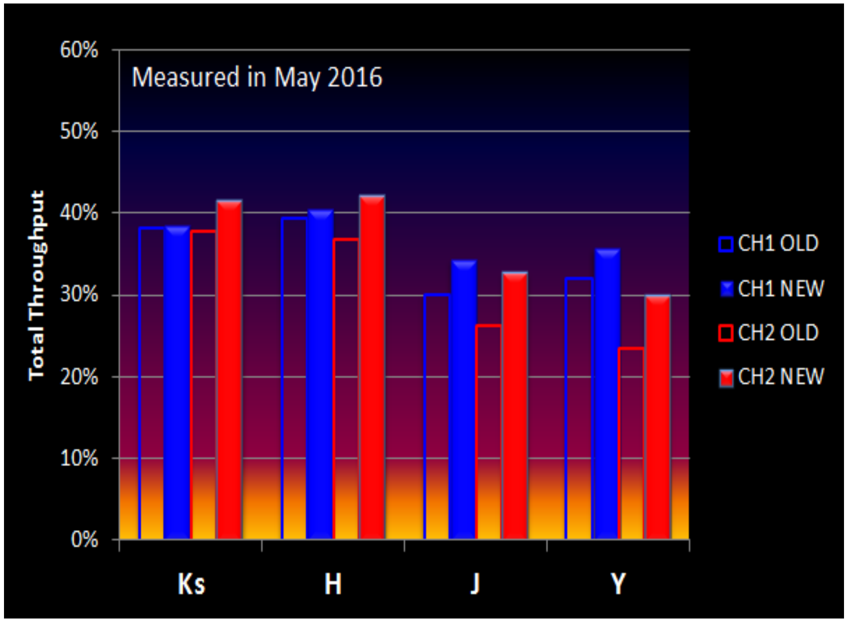
- It is almost impossible to develop 3 instruments at the same time.
- Use MOIRCS as a first light instrument (imager and spectrograph) for GLAO, as suggested by the reviewers during the external review on Feb.
- By using GLAO, MOIRCS sensitivity can be similar to or even higher than MOSFIRE with much better spatial resolution (0".5 → 0".2).

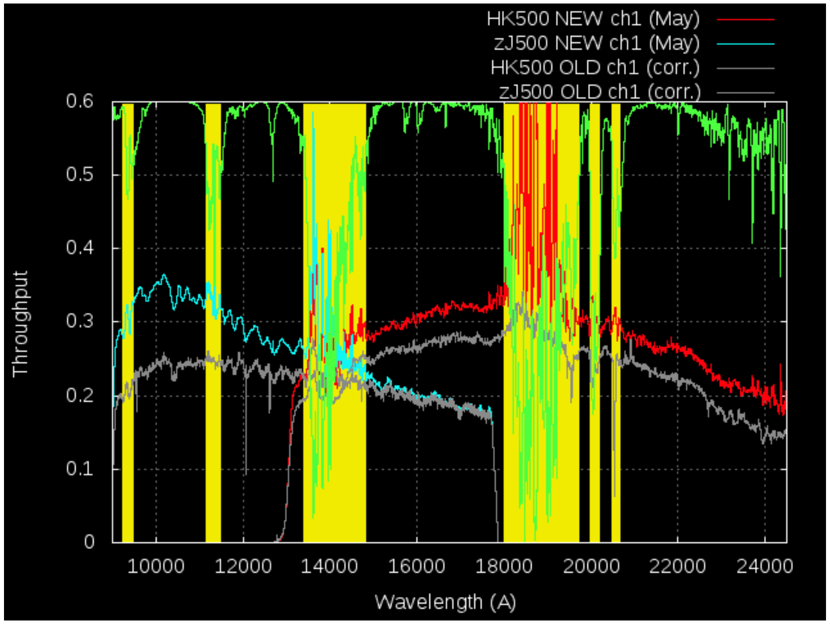
MOIRCS Upgrade (nuMOIRCS)

2015: Detectors Upgrade Completed!

- 2 Hawaii-2 RG + Sidecar ASIC, SAM controller.
- Good readnoise (5e- by 10 multi-sampling)
- Better total efficiency

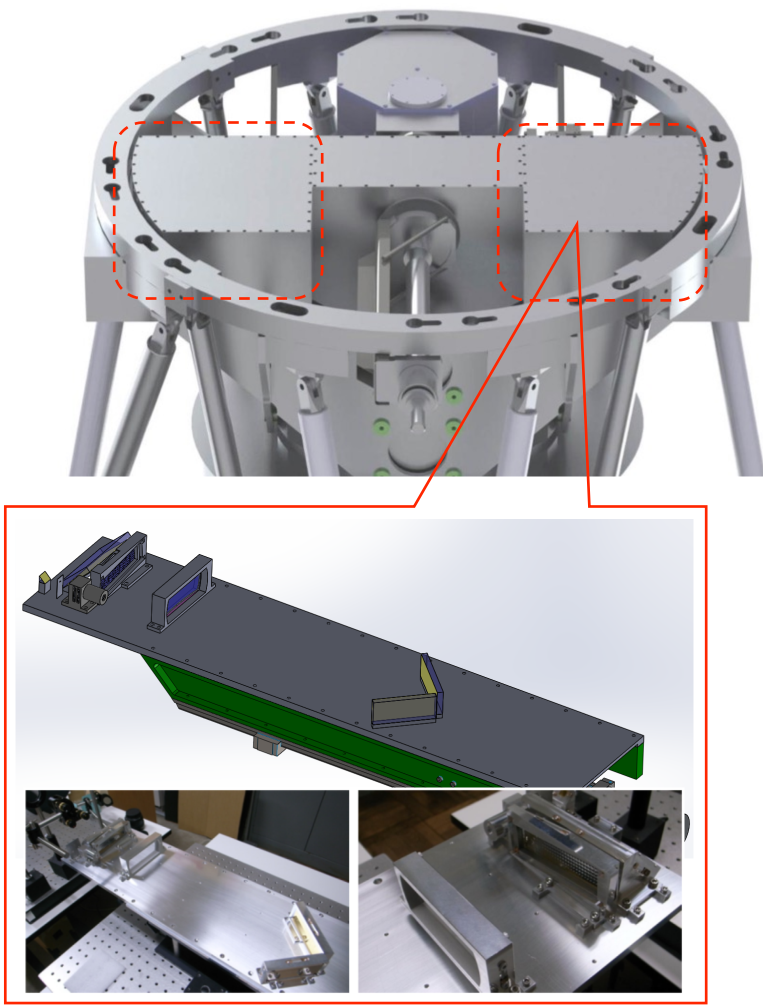






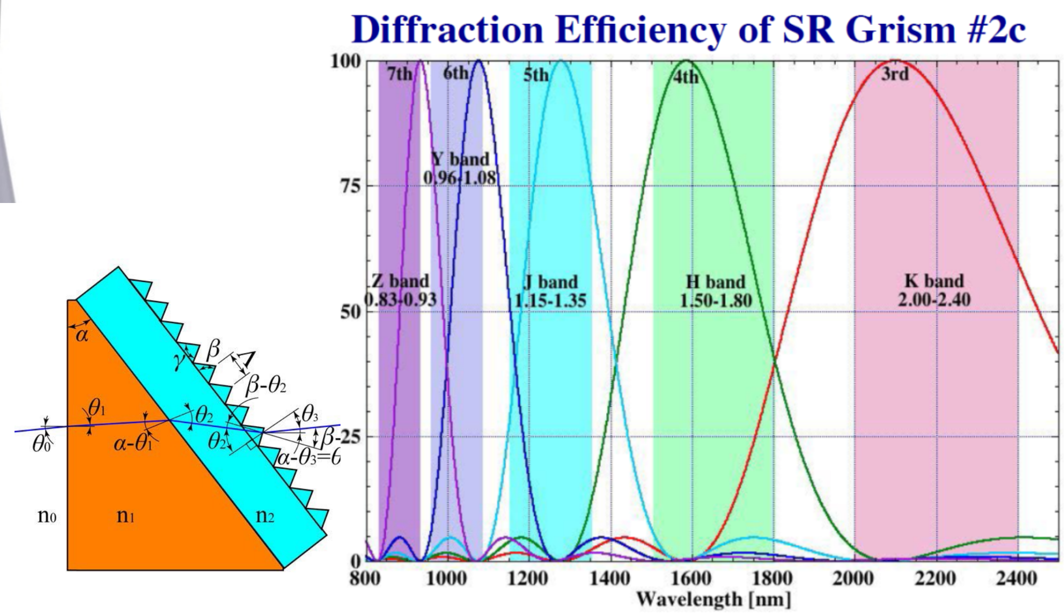
MOIRCS Upgrade (nuMOIRCS)

- 2017 (?) MLA IFU Installation (Ishigaki-san in Iwate Univ.) is being planned.
- New Grism development project is (→ Ebizuka san's Talk).



MLA IFU Specification

Spatial Sampling	0.2 arcsec
MLA format	9 x 31 lenses
Field-of-view	1.8arcsecx 6.2 arcsec



R~1400 Hybrid Grism Design (an example)

Summary

- Wide-Field Imager
  - good image quality (~0".1) over wide FoV (16'-20')
  - opt-mechanical feasibility studies are planned
- Multi-Object Integral Field Spectrograph
  - can utilize existing instrument MOIRCS and the large FoV of new GLAO system
  - difficulty in K-band
- Multi-Object Spectrograph
  - Further investigation to use MOIRCS as a first light instrument.
  - Need some more investigation for new instrument with single FoV cases (ϕ~13’)