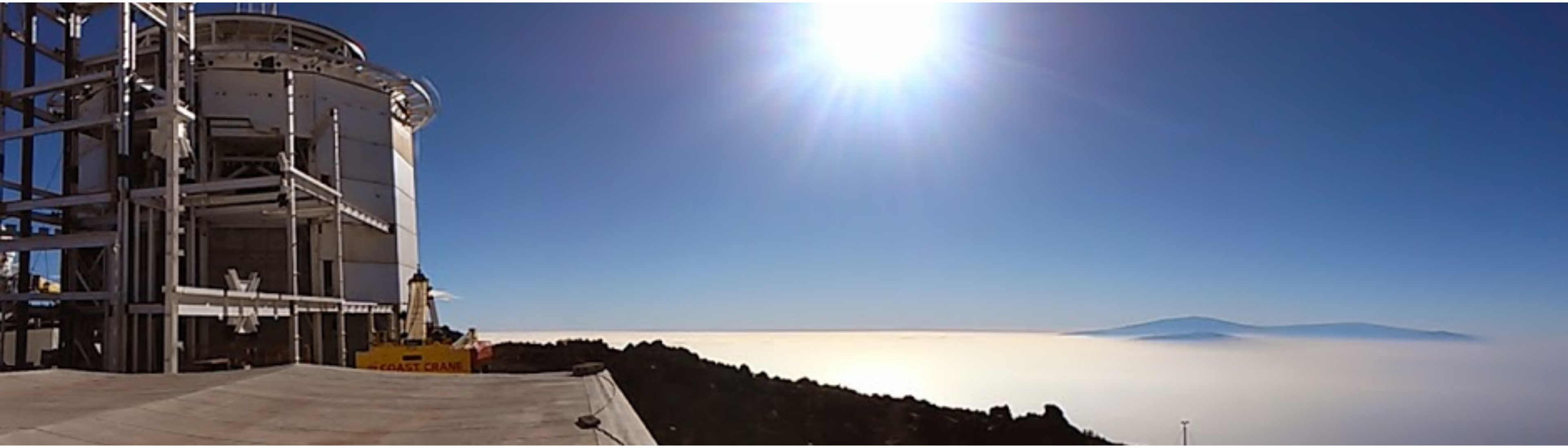
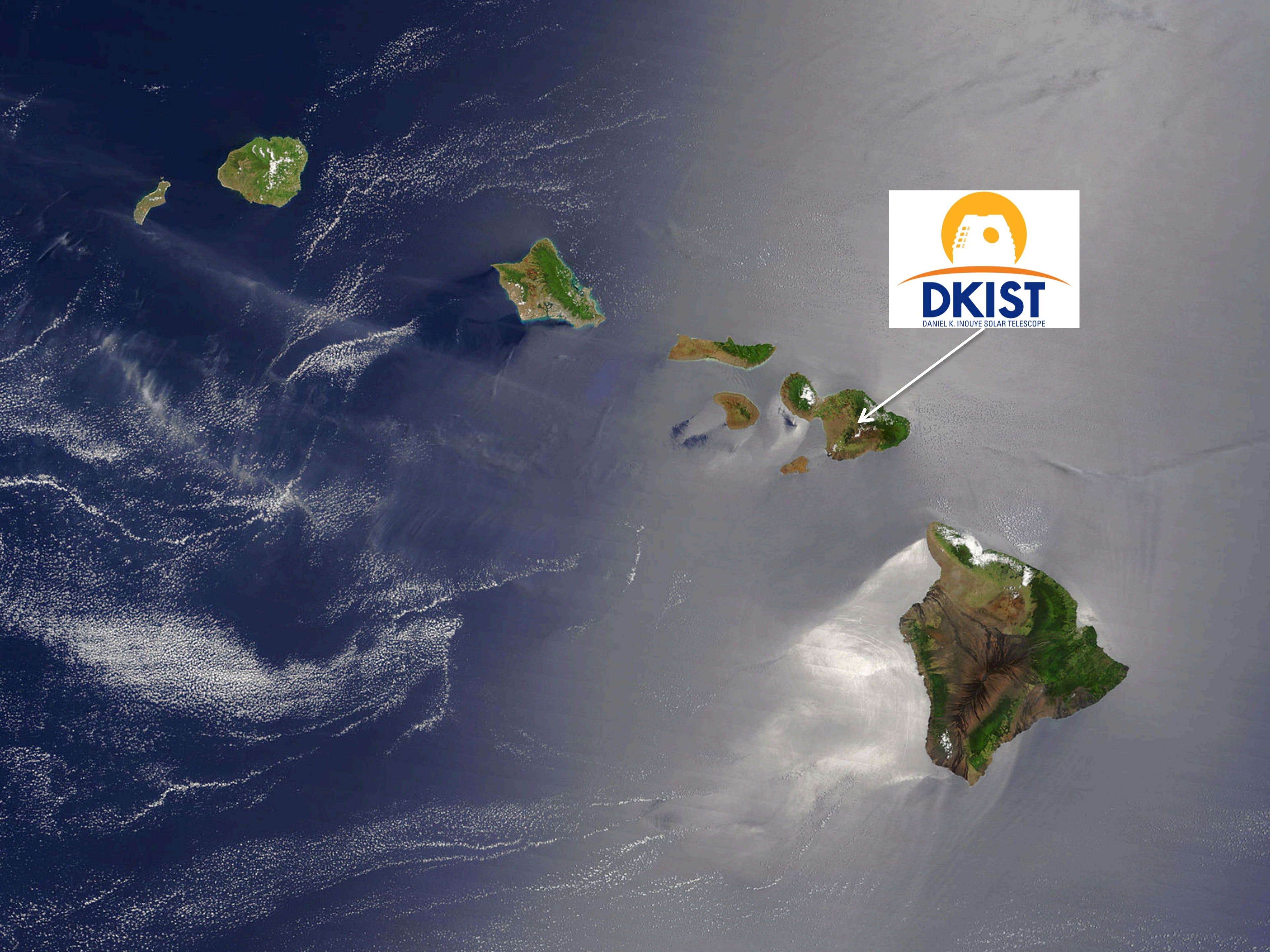
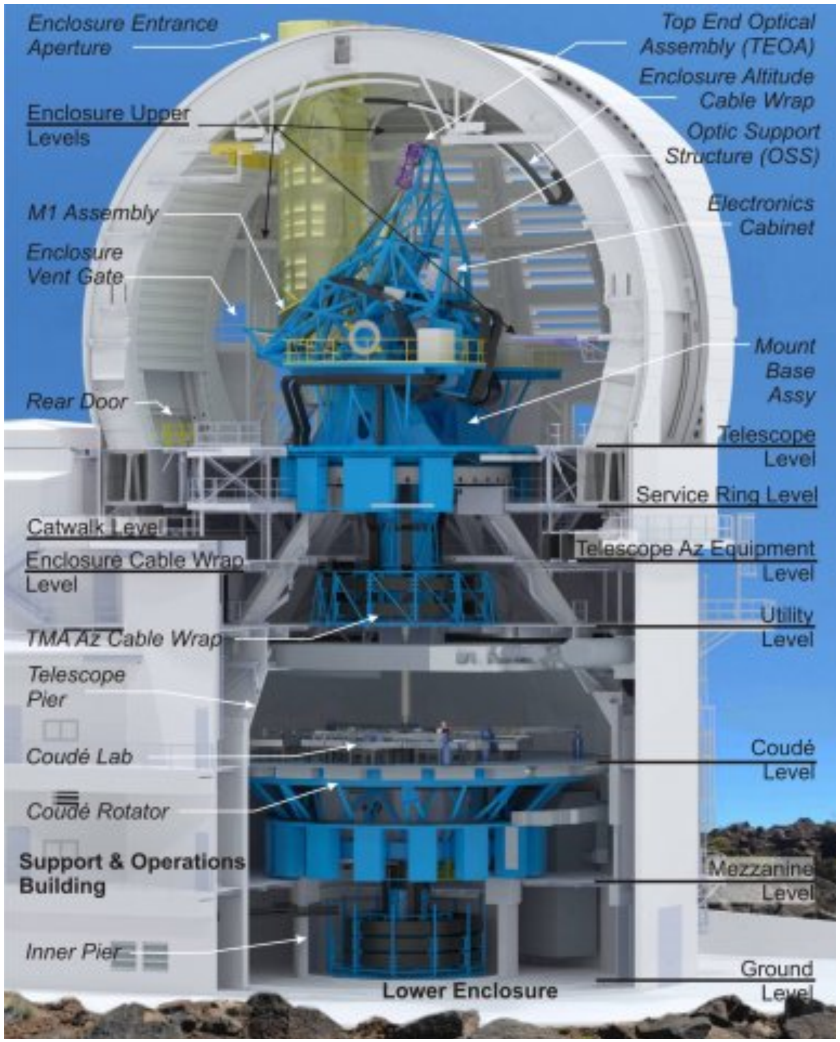


Future Prospects with DKIST

Tom Schad – DLNIRSP Instrument Scientist – Univ. of Hawaii/IfA
ISSI Workshop on Coronal Rain: 23 – 27 February 2015, Bern, Switzerland


DKIST
DANIEL K. INOUYE SOLAR TELESCOPE

Senator Daniel K. Inouye Solar Telescope (DKIST) [previously ATST]



- 4 m aperture
- Haleakala, HI (10010 ft; 3050 m)
- Gregorian, off-axis, Alt-Az
- Coude instruments:
  - VBI
  - VISP
  - VTF
  - DL-NIRSP
  - CRYO-NIRSP
- FOV: 2.8 (max 5) arcmin

Charge to our ISSI team!

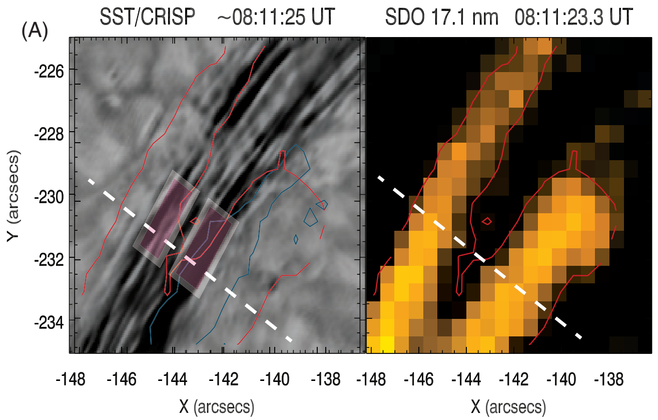
- DKIST will be operational and ready to carry out its Critical Science Plan (CSP) in Fall 2019.
- What critical coronal rain observations can our team propose for DKIST?
  - Target for next meeting: draft experiment details using designed instrument capabilities?

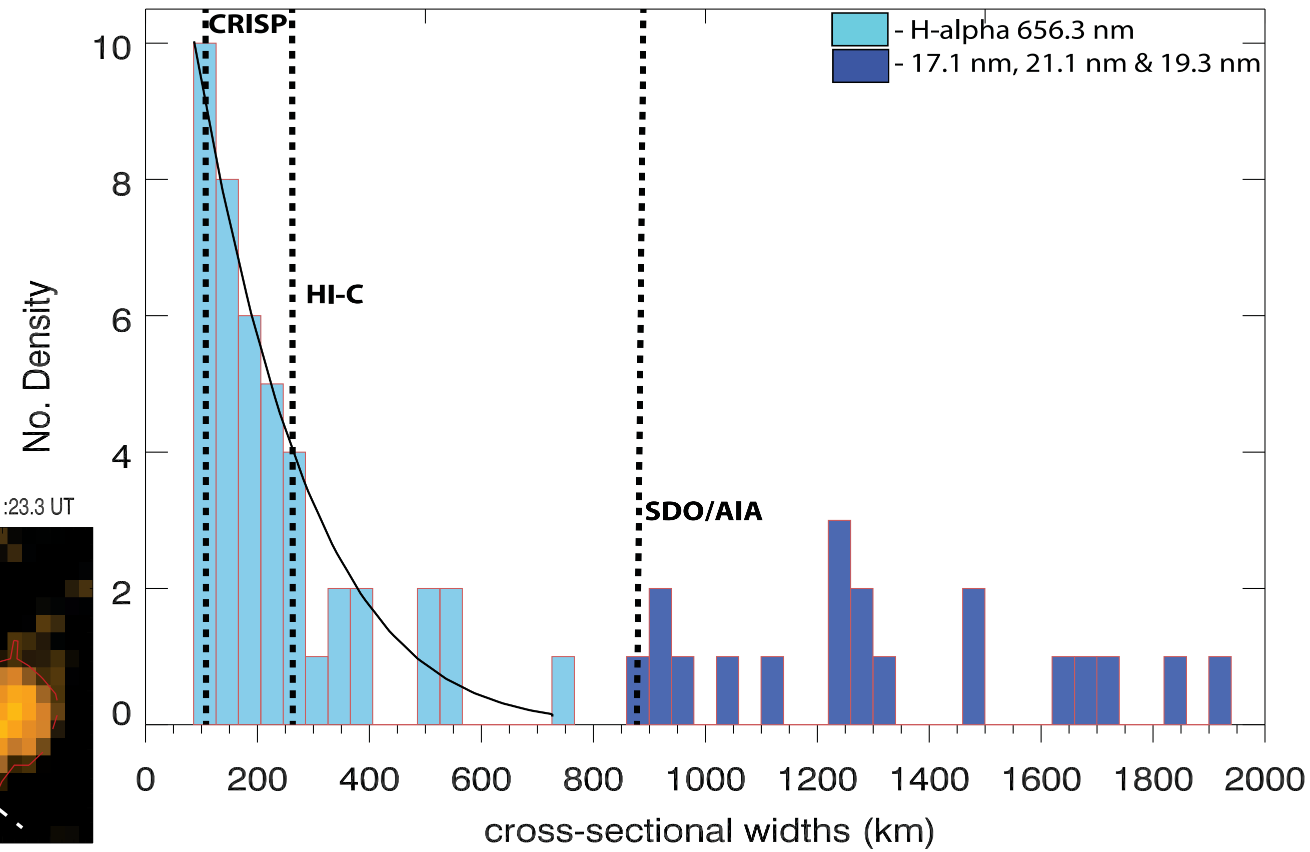
DKIST
DANIEL K. INOUYE SOLAR TELESCOPE

dkist.nso.edu/science

Three reasons we need DKIST for coronal rain

- #1 Coronal structure is not resolved!





DKIST resolution at H-beta: 21 km

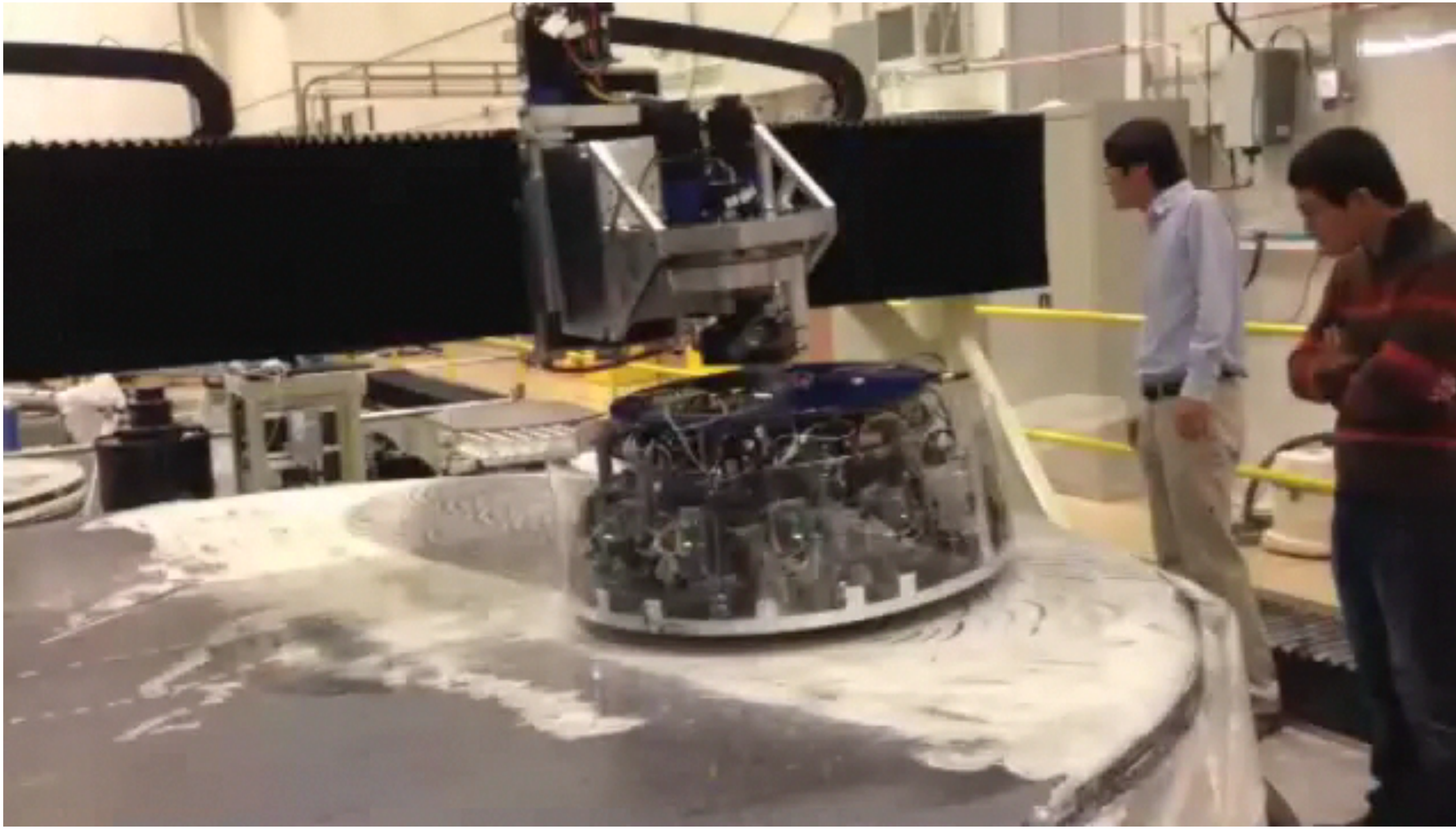
Three reasons we need DKIST for coronal rain

- #1 Coronal structure is not resolved!
- #2 Photons!
  - Rain signals very weak in optical/IR diagnostics
  - Where is the rest of the coronal rain mass?
  - Time-resolved chromospheric polarimetry
- #3 Coronal Field Diagnostics (esp. in near/mid IR)
  - Control of scattered light → Off-axis design
  - Active occulter at Gregorian focus; Lyot stop
  - No windows! -> Extends max wavelength range out to ~ 28 um

DKIST Construction Update

- Construction started on Haleakala late 2012
- Mirror fab started well in advance of 2012.
- Large systems (*i.e.* telescope mount, enclosure, etc.) near/ past acceptance in many cases.
- Now the presence on the mountain is very real!

Stress-lap polishing of M1 commissioning blank (U. of Arizona)



Movie courtesy of NSO/DKIST

Telescope enclosure assembled in Spain by IDOM.

Will be installed on site this spring!

Image courtesy NSO/DKIST

Telescope Mount Assembly

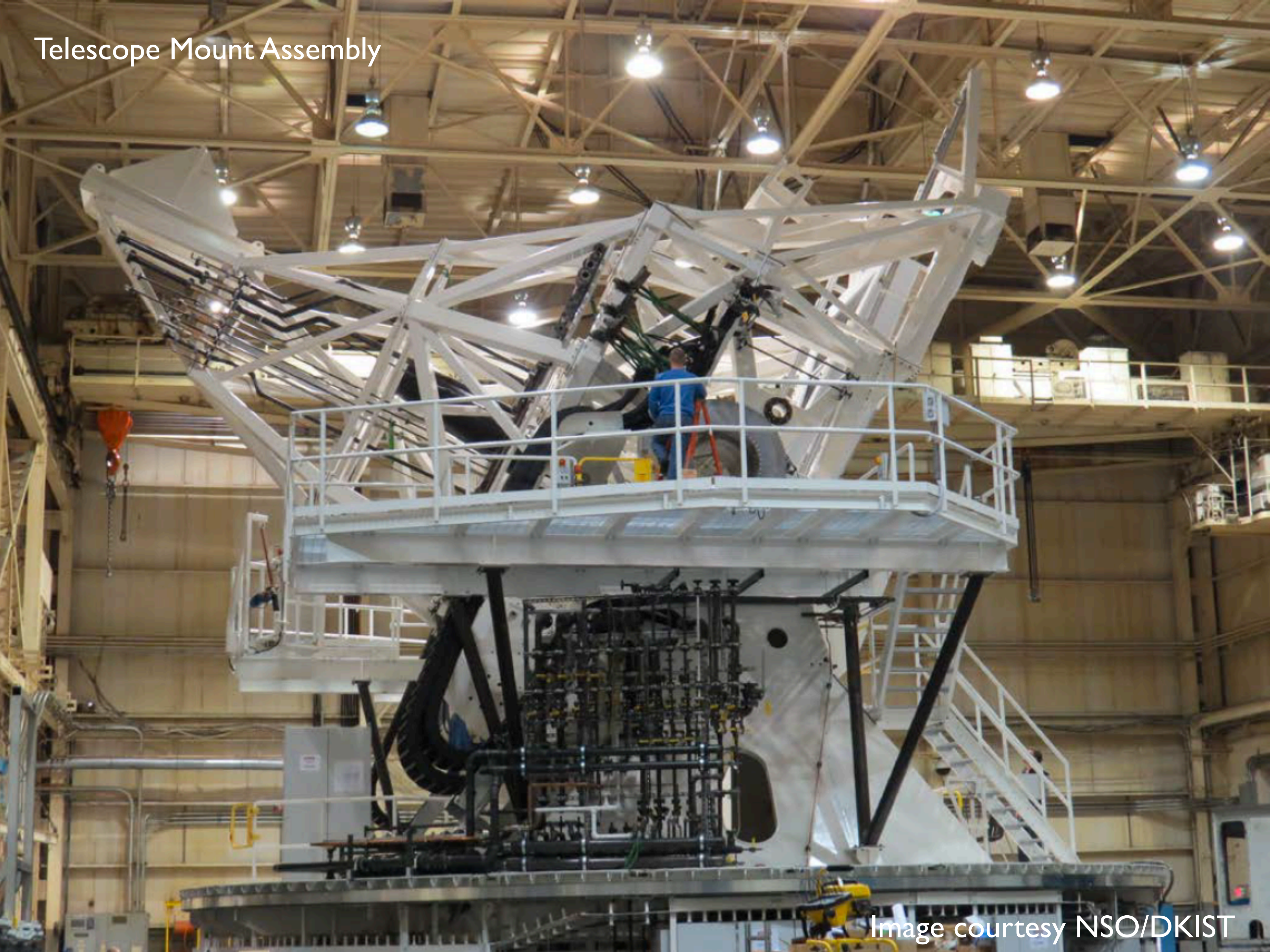
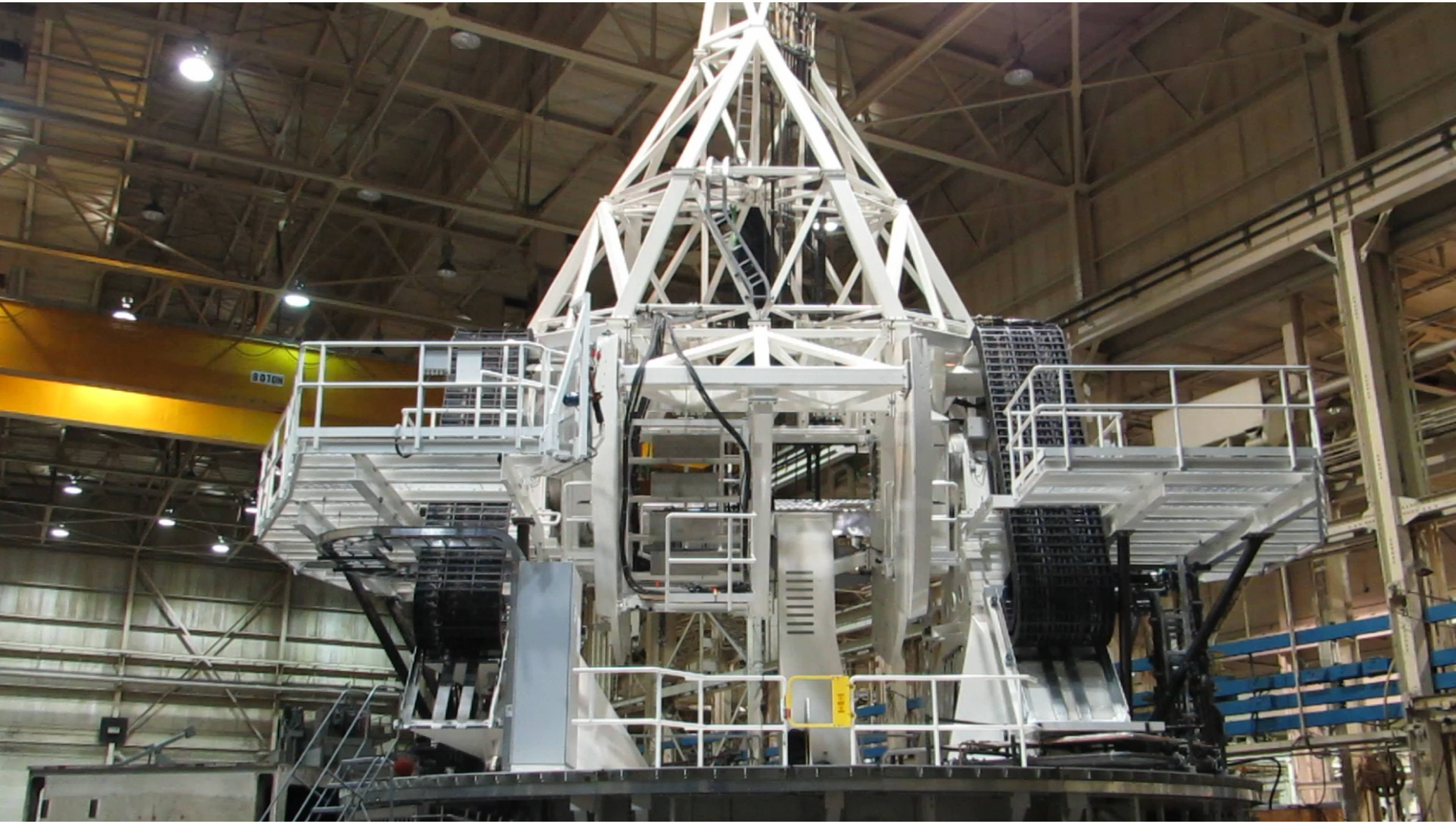
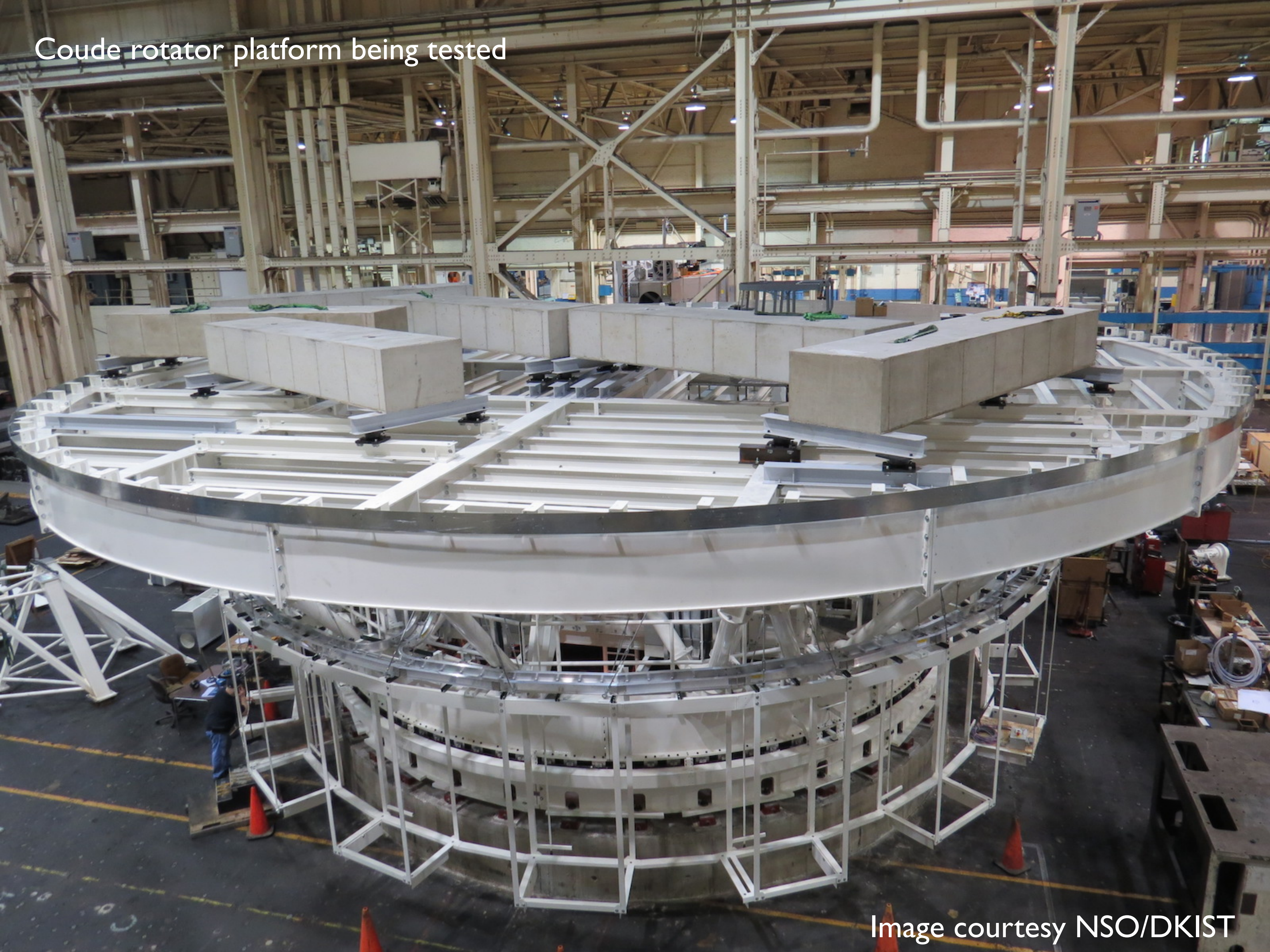


Image courtesy NSO/DKIST

Telescope Mount Assembly – Slewing



Movie courtesy of NSO/DKIST

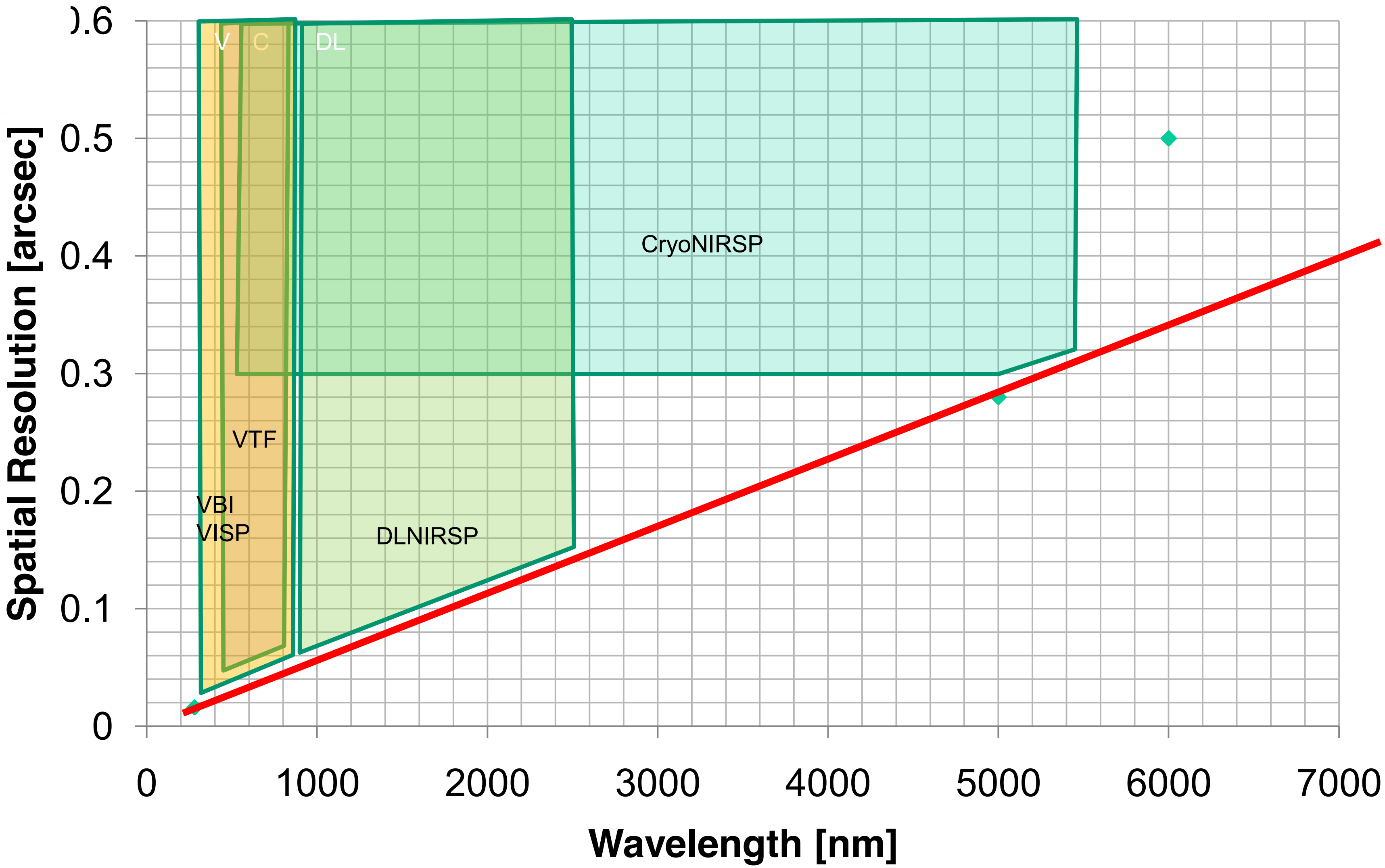

Coude rotator platform being tested
Image courtesy NSO/DKIST

Coude Lab Platform and Mount in Factory

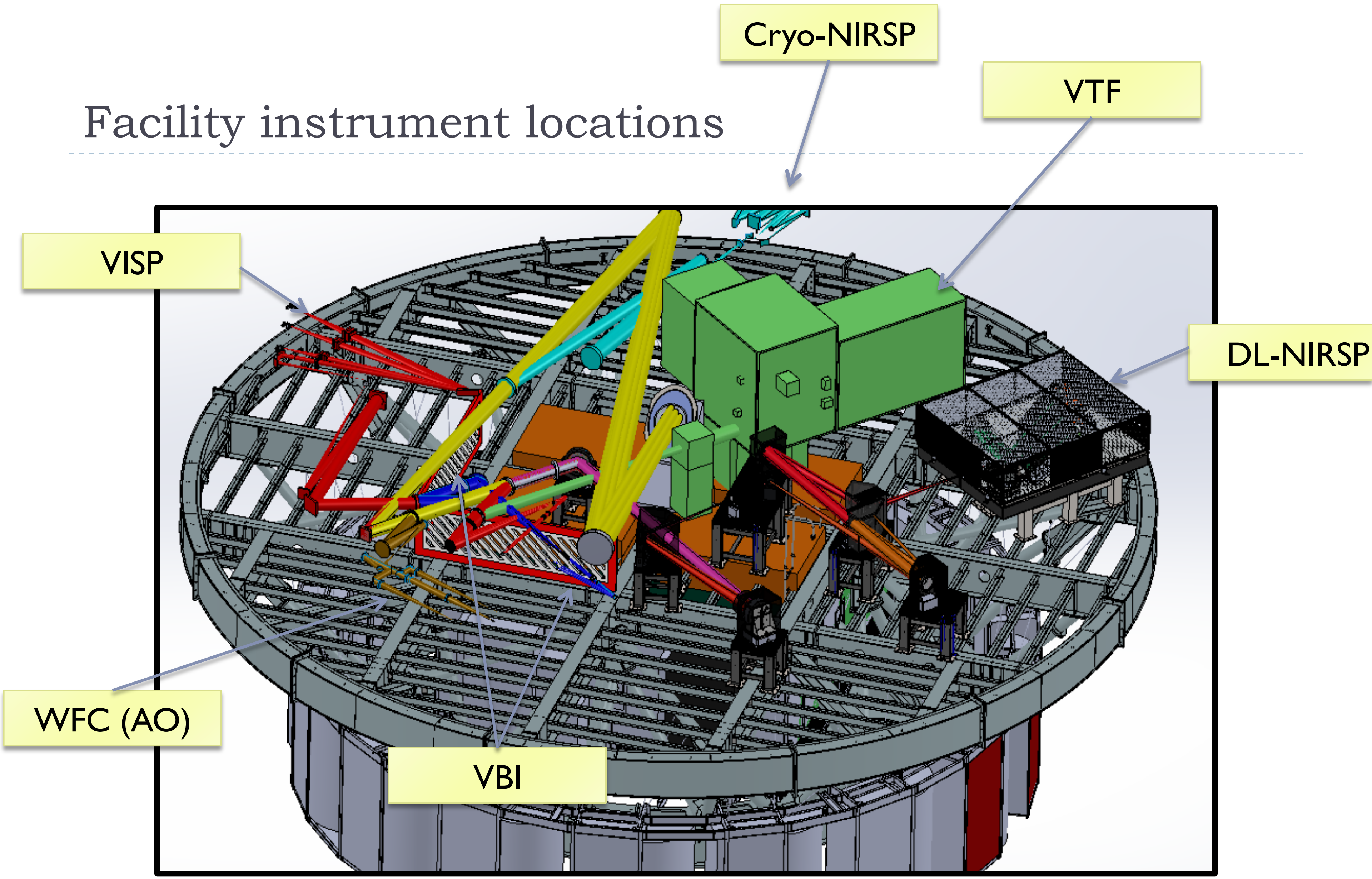
Movie courtesy of NSO/DKIST and Ingersoll

16 February 2015
Photo by Tom Schad

DKIST Facility Instruments

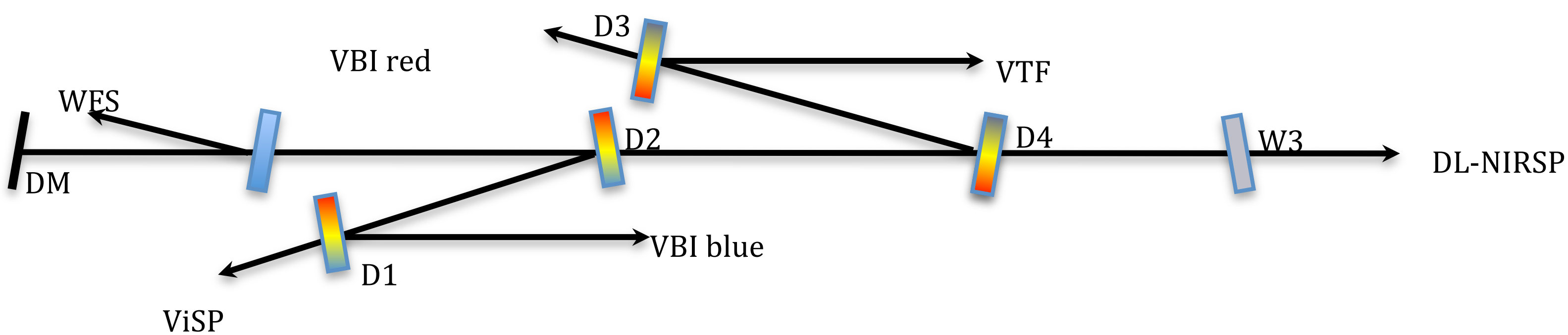


Facility instrument locations



DKIST Spectral Distribution (*i.e. the Autobahn)*

- Spectral distribution controlled by series of dichroic beam-splitters downstream of AO DM.
- Manual setup; must be selected for given experiment
- Cryo-NIRSP operates alone; No AO.



dkist.nso.edu/inst/beamsplitter

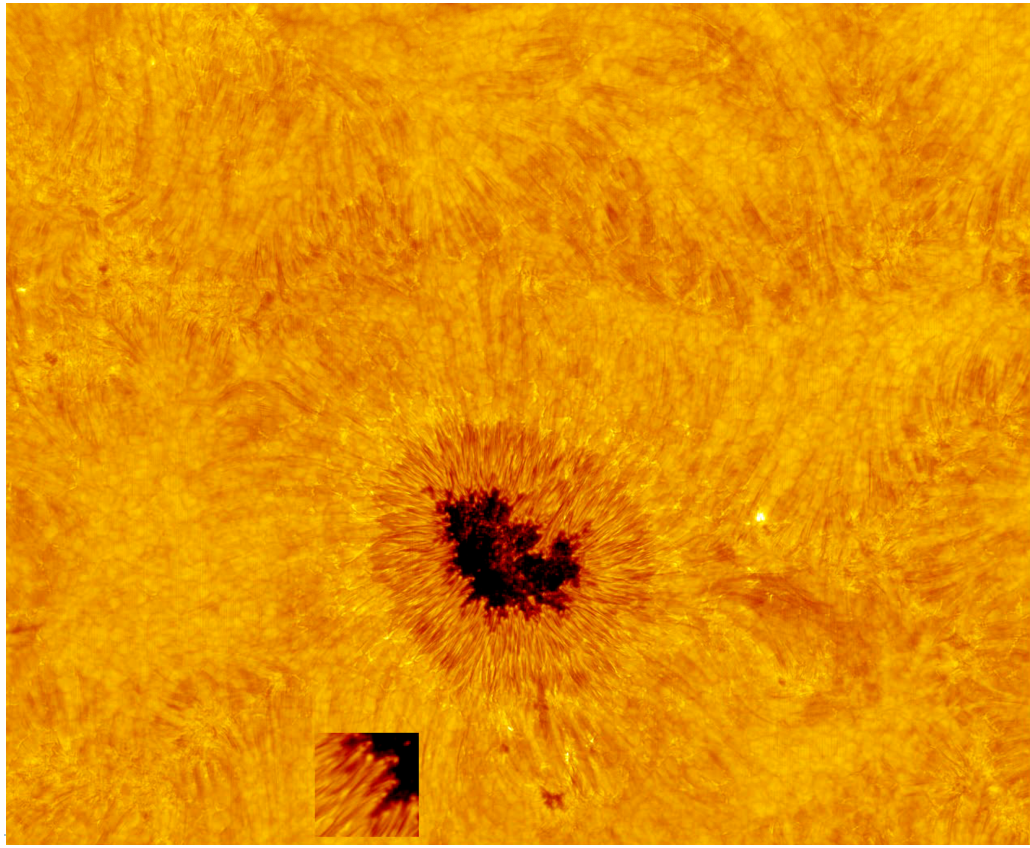
And now, a **very** brief introduction to the instruments…

VBI	VISP	VTF	CRYO-NISRP	DL-NIRSP

VBI: The Visible Broadband Imager

- Developed by the National Solar Observatory (NSO), Boulder CO
- Fast 4K x 4K SPECKLE-imaging! Up to 3.2 sec cadence for reconstructed images
- Blue-red channels simultaneously; synchronized to 10 ms
- FOV: Up to 2' square; 45" / 69" physical (blue/red)
- 11 and 17 mas sampling!
- VBI-blue:
  - **393 nm (rain!)**
  - **H-beta 430 nm (rain!)**
  - 450 nm
  - 486 nm
- VBI-red:
  - **656.3 nm (rain!)**
  - 668.4 nm
  - 705 nm
  - **? (hot coronal filter?)**

VBI H-Beta Filter Obs at DST



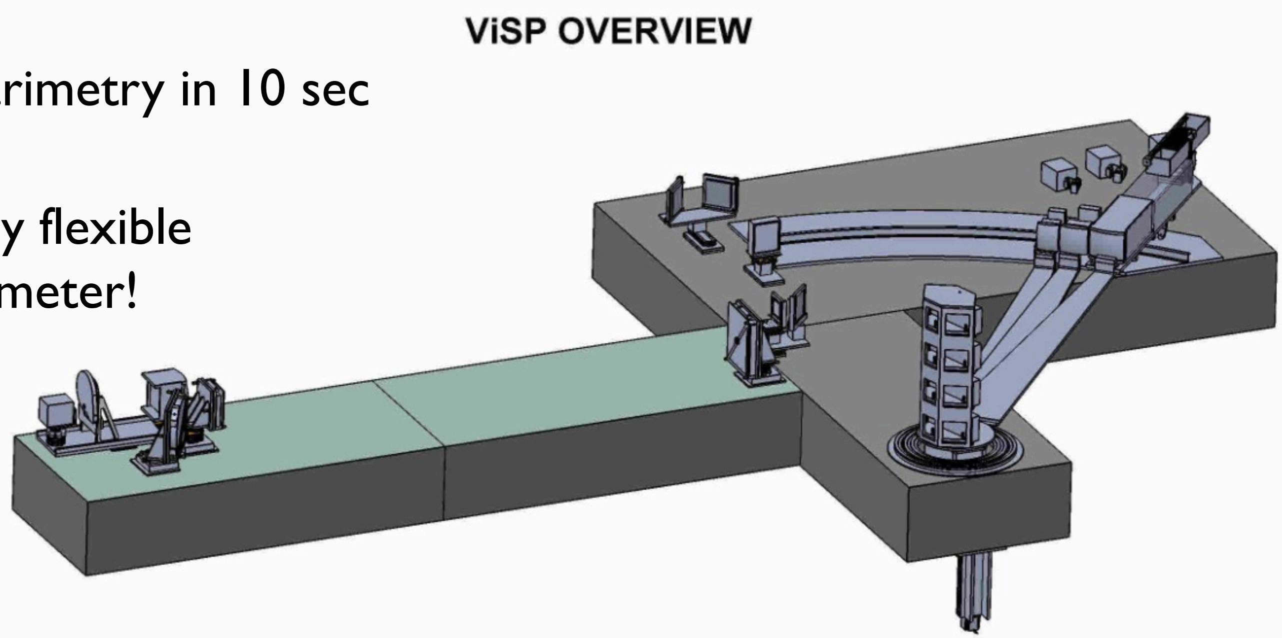
Movie courtesy of NSO/DKIST

VISP: The Visible Spectropolarimeter

- Developed by High Altitude Observatory (HAO), Boulder, CO
- 380 to 900 nm [380 – 1600 nm goal]
- Up to three line simultaneously
- 0.07" spatial resolution
- R >= 180000
- 10^-3 I_{cont} polarimetry in 10 sec

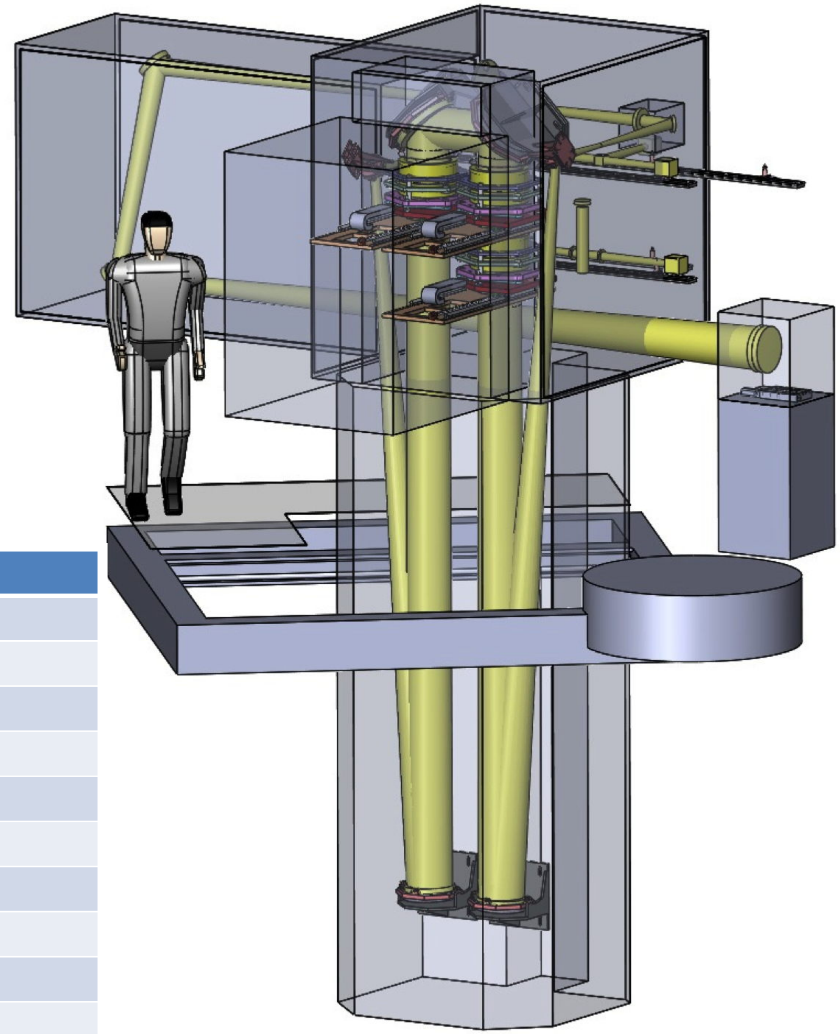
An extraordinarily flexible slit-spectropolarimeter!

For coronal rain:
Sit-and-stare polarimetry?



VTF: Visible Tunable Filter

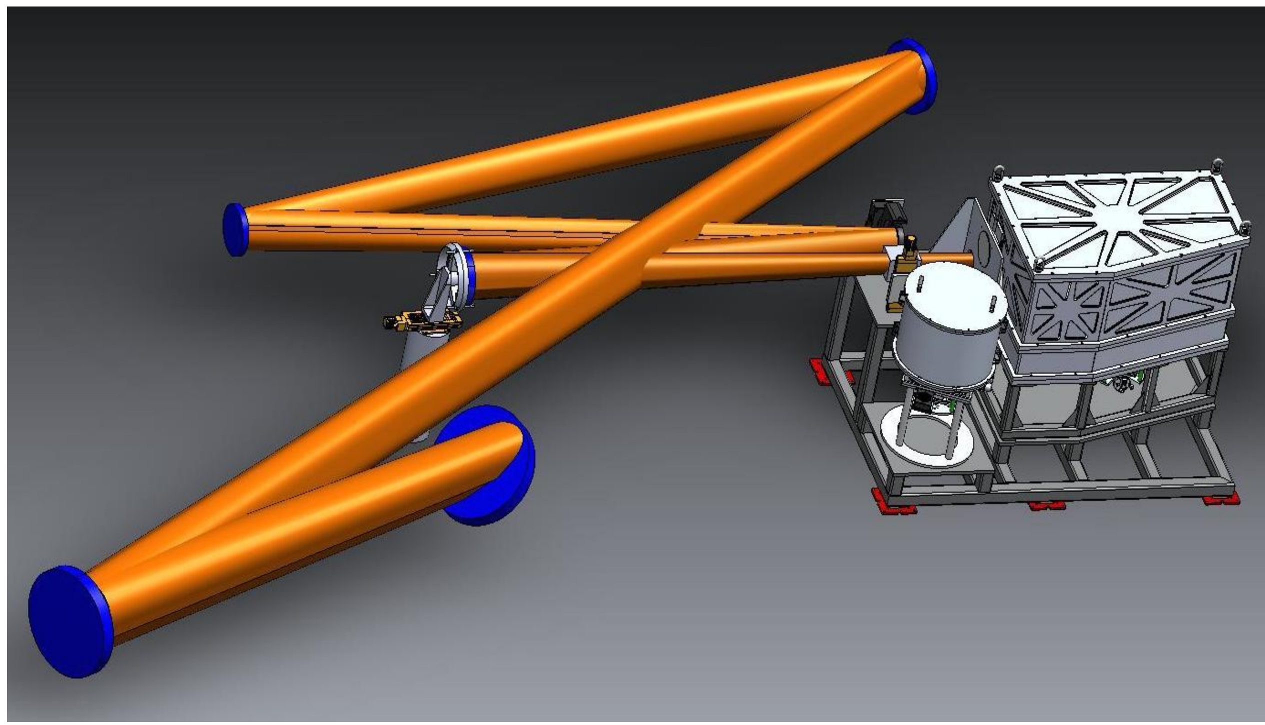
- Developed by KIS, Freiburg, Germany
- Fabry-perot imaging spectropolarimeter; similar in functionality to CRISP!
- **Rain: He D3; H alpha; Ca II 854 nm**



Description	Value	Comment
Wavelength range	520 – 870 nm	
Spatial resolution	0.028”	Diffraction limited
Spectral Resolution	6 pm	at 600 nm
Spectral sampling	3pm	at 600 nm
Cadence, Full Stokes	13 s	SNR=650, 30 Hz frame rate
Field of view	60” x 60 ”	4 k x 4k detector
Doppler sensitivity	85 m/s	
Polarimetric sensitivity	3×10^{-3}	SNR=650
Magnetic field sensitivity	20 G	longitudinal

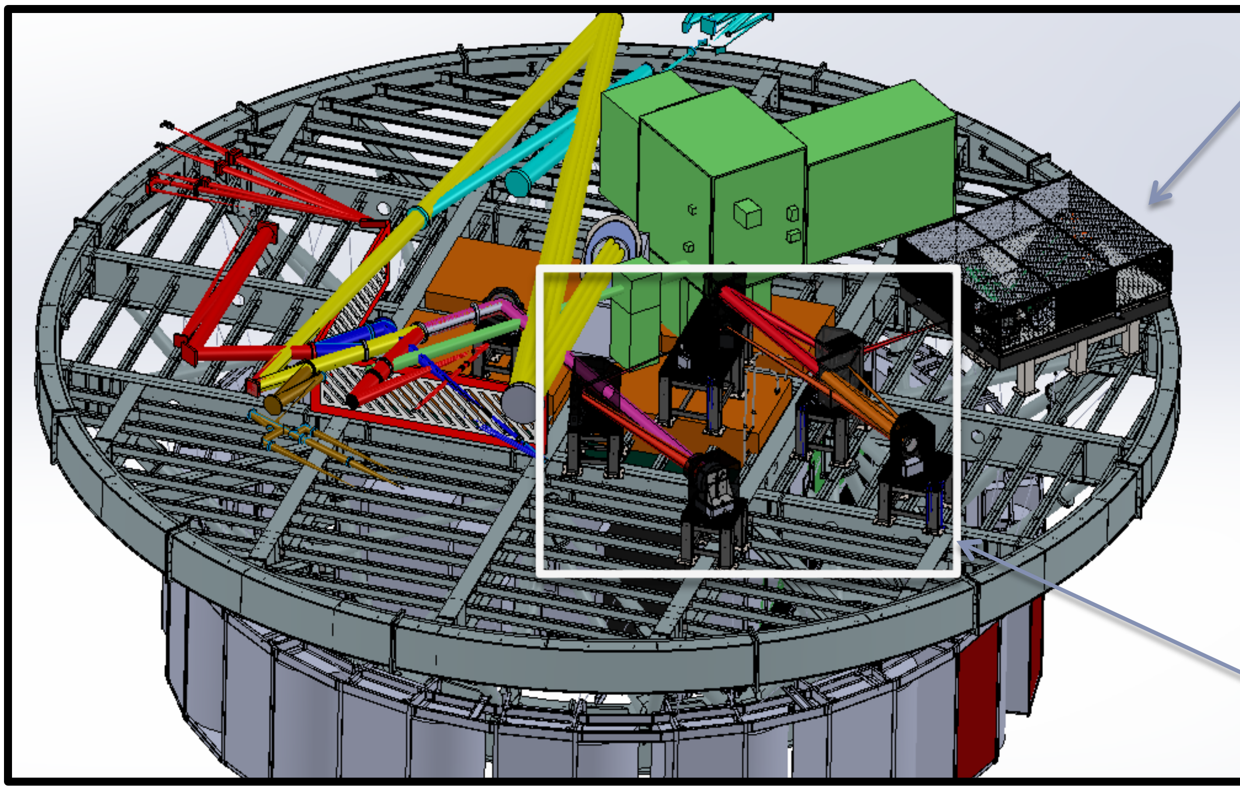
Cryo-NIRSP: The Cryogenic Near-IR Spectropolarimeter

- Developed by University of Hawaii - Institute for Astronomy (IfA)
- Operates alone; No AO
- Huge FOV (5’); deep cyro-genic instrument. Specializing in coronal magnetic fields!
- 500 to 5000 nm
- First set of lines:
  - Fe XIV 530 nm
  - Fe XIII 1074.7
  - He I 1083 nm
  - Si X 1430 nm
  - Si IX 3930 nm
  - CO 4651 nm

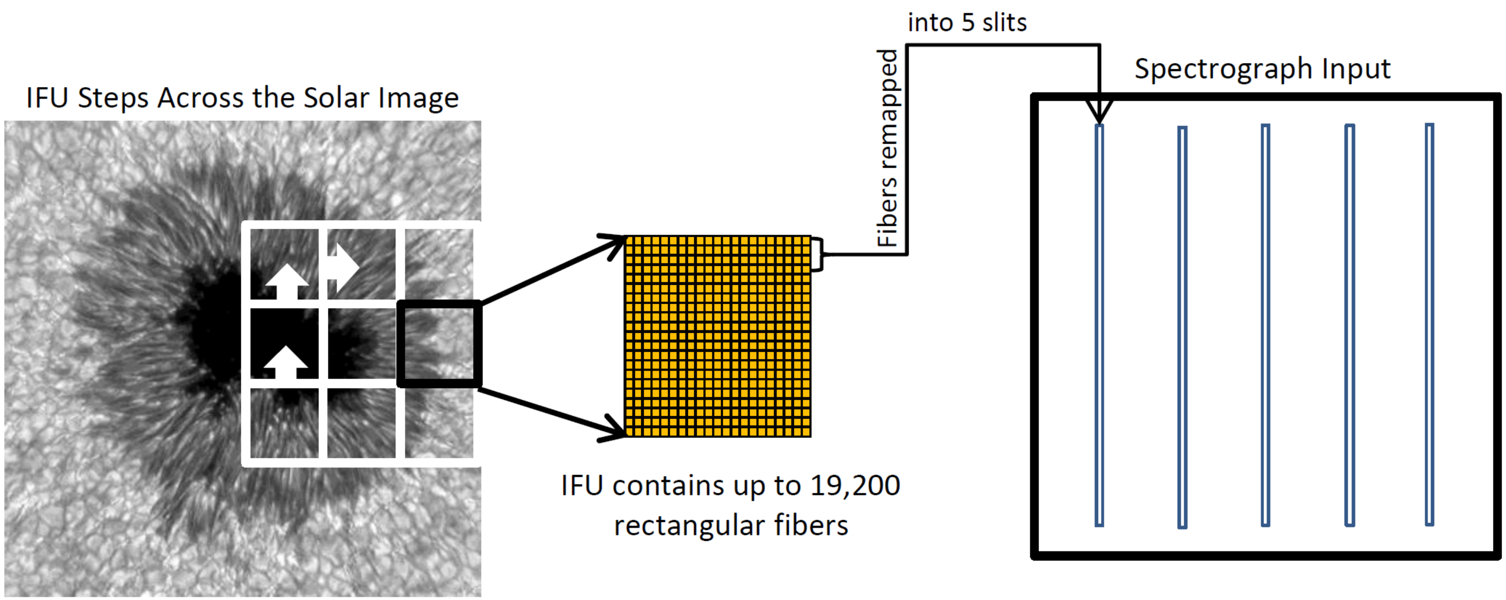


The Diffraction-Limited Near IR Spectropolarimeter (DL-NIRSP)

- Developed by University of Hawaii - Institute for Astronomy (IfA)
- The first IFU based spectropolarimeter for solar physics!



The Diffraction-Limited Near IR Spectropolarimeter (DL-NIRSP)



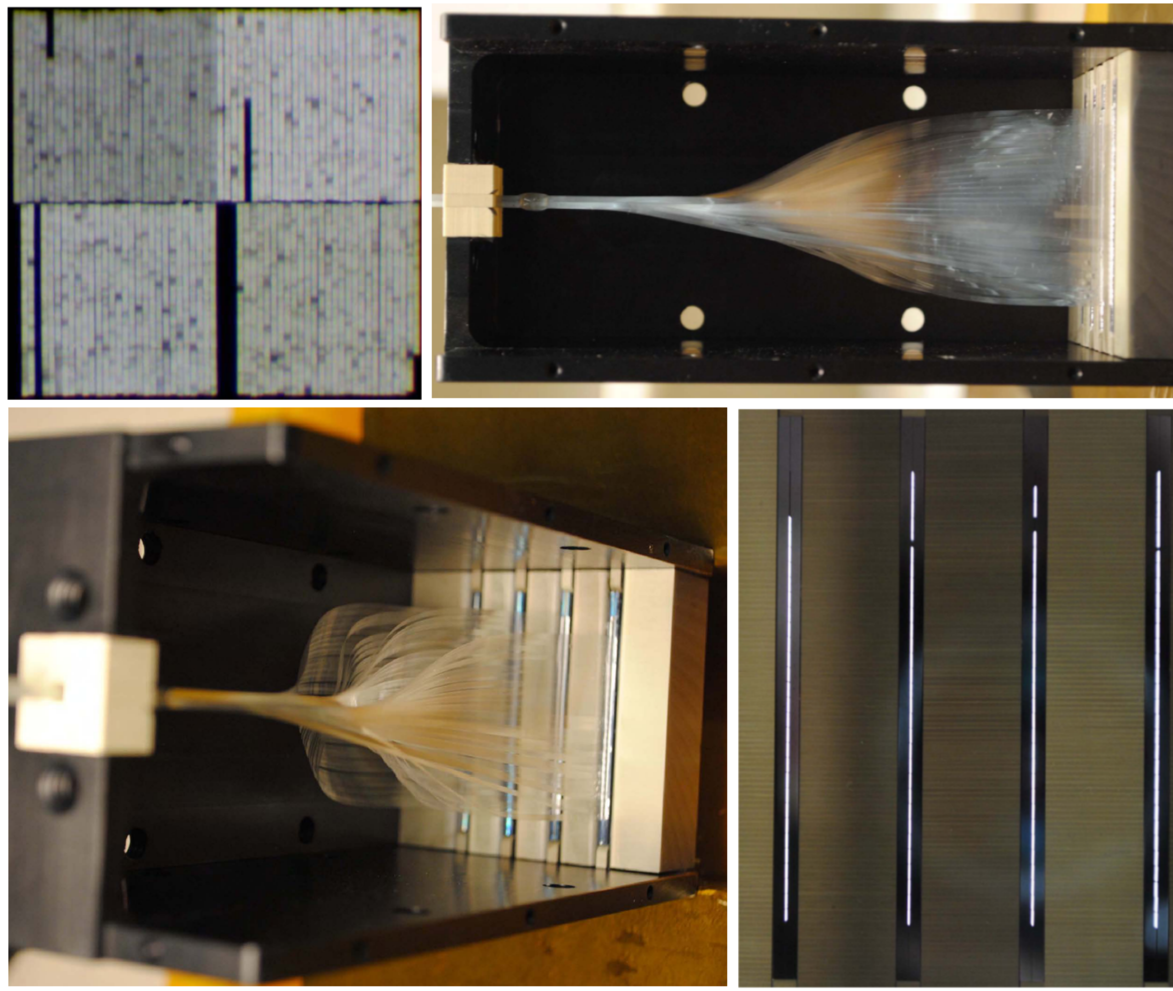
One tile at a time, DL-NIRSP builds spectropolarimetric full data cubes: [X ; Y ; λ ; S [=I,Q,U,V] ; t]

Quick Facts

Instrument type:	Reflection-grating based, ***multi-arm integral field spectrograph***
Spectral Range:	500 nm to 1800 nm
Number of cameras/channels:	3
Spectral channel ranges:	500 nm to 900 nm (most subject to beam sharing!)
	900 nm to 1350 nm
	1350 nm to 1800 nm
Field of View:	Up to 165" circular (120" x 120" square)
Polarimetry:	Full Stokes (or Spectroscopy-only)
Target Polarimetric accuracy:	> 5×10^{-4} I_c (dependent on polarization amplitudes)
Parallel Operations:	Can observed in parallel with WFC, VBI, VISP, VTP
Target domain:	On-disk and off-limb

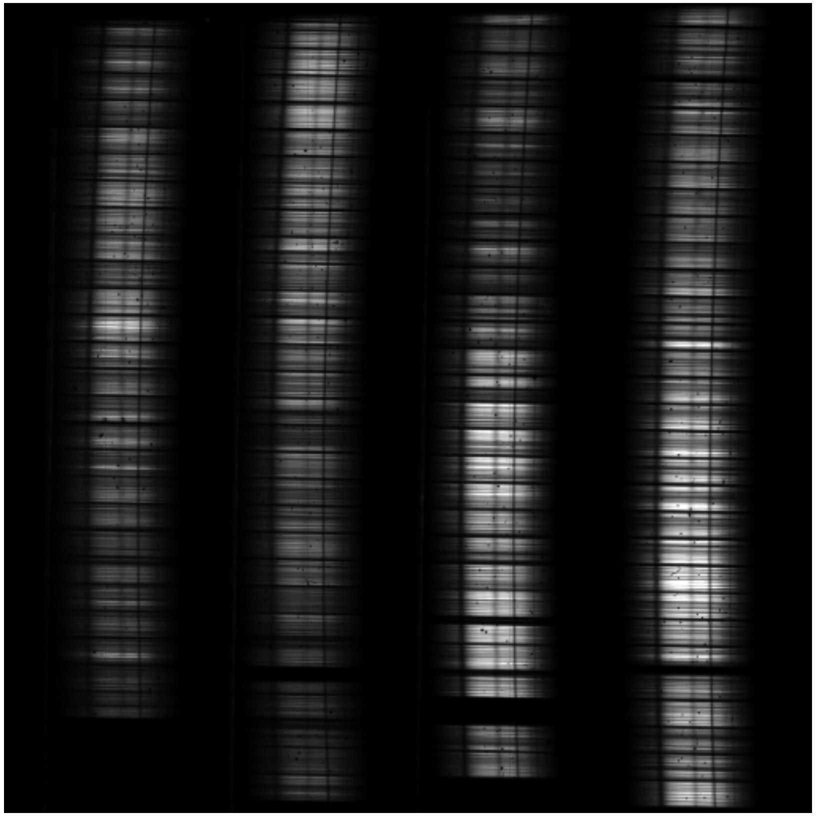
DL-NIRSP's enabling technology

BiFOIS: The Birefringent Fiber-Optic Image Slicer

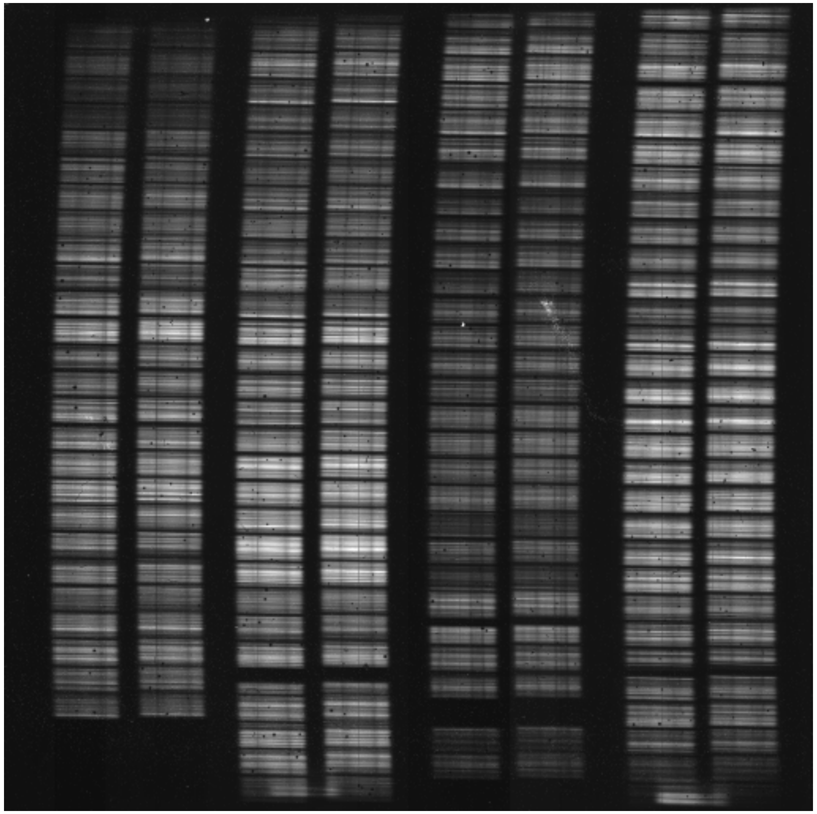


Lin & Versteegh SPIE (2006); Schad et al. SPIE (2014)

Real examples of prototype spectra

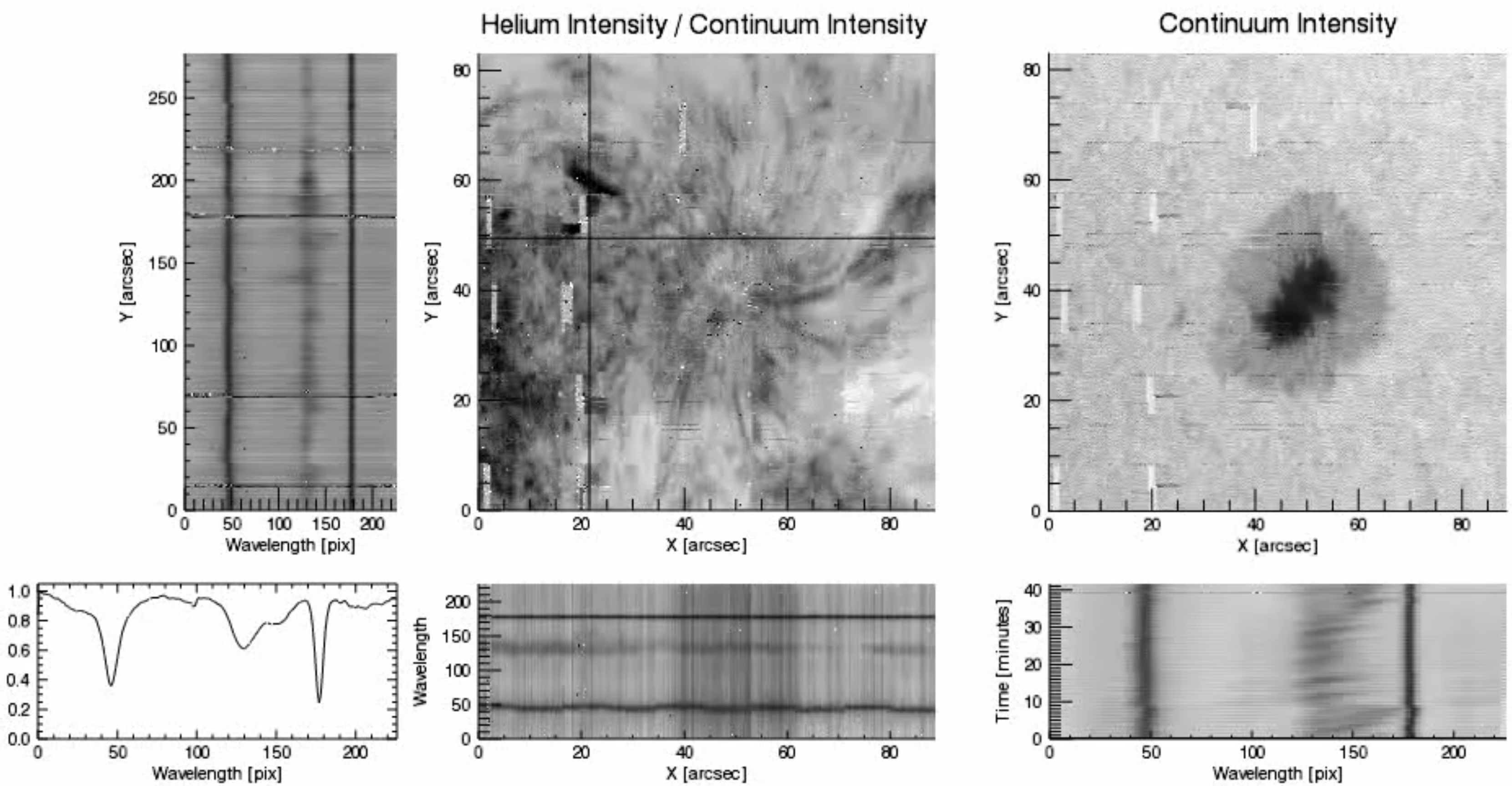


He I 1083 nm



Fe I 1565 nm

SPIES He I 1083 nm



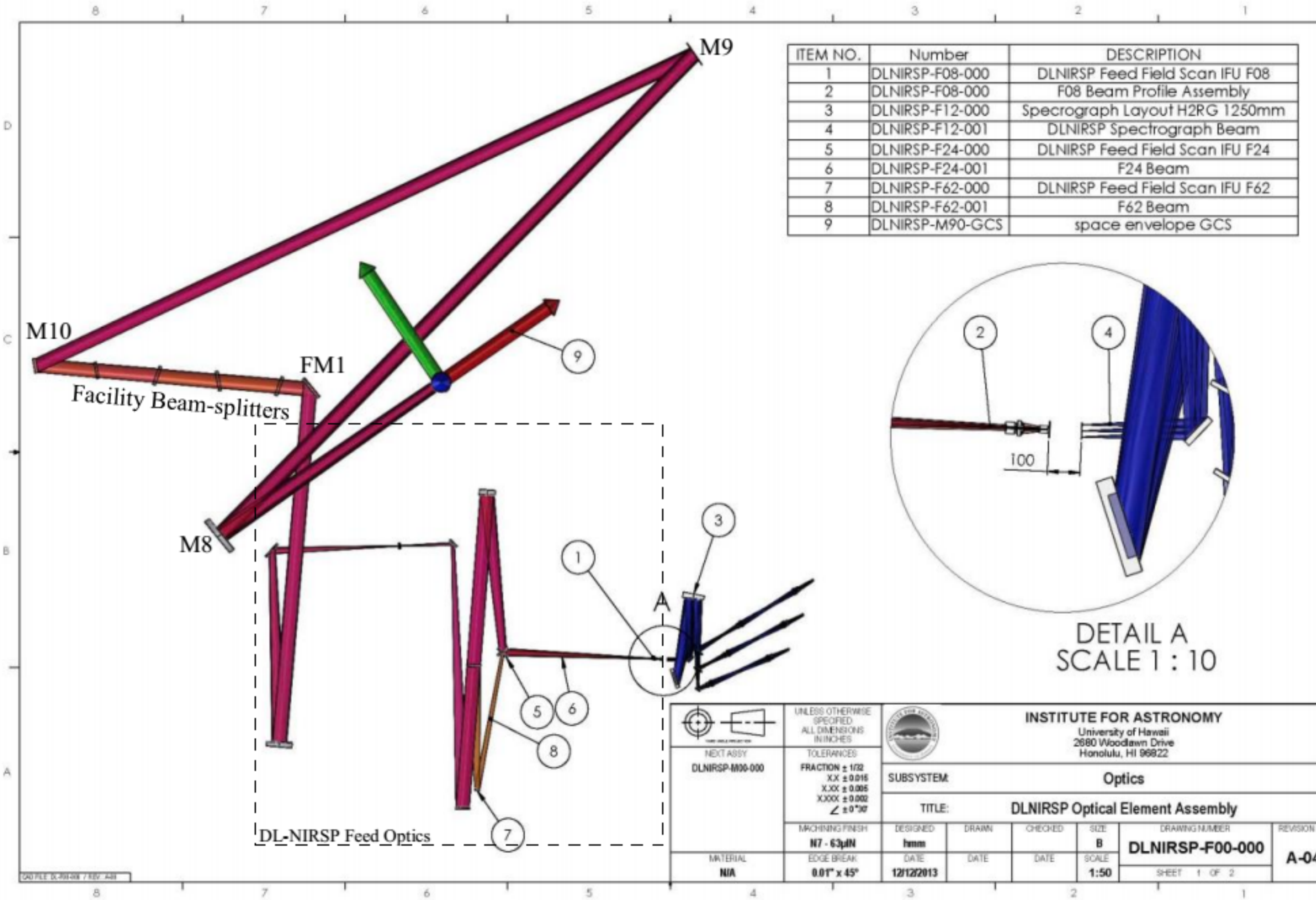
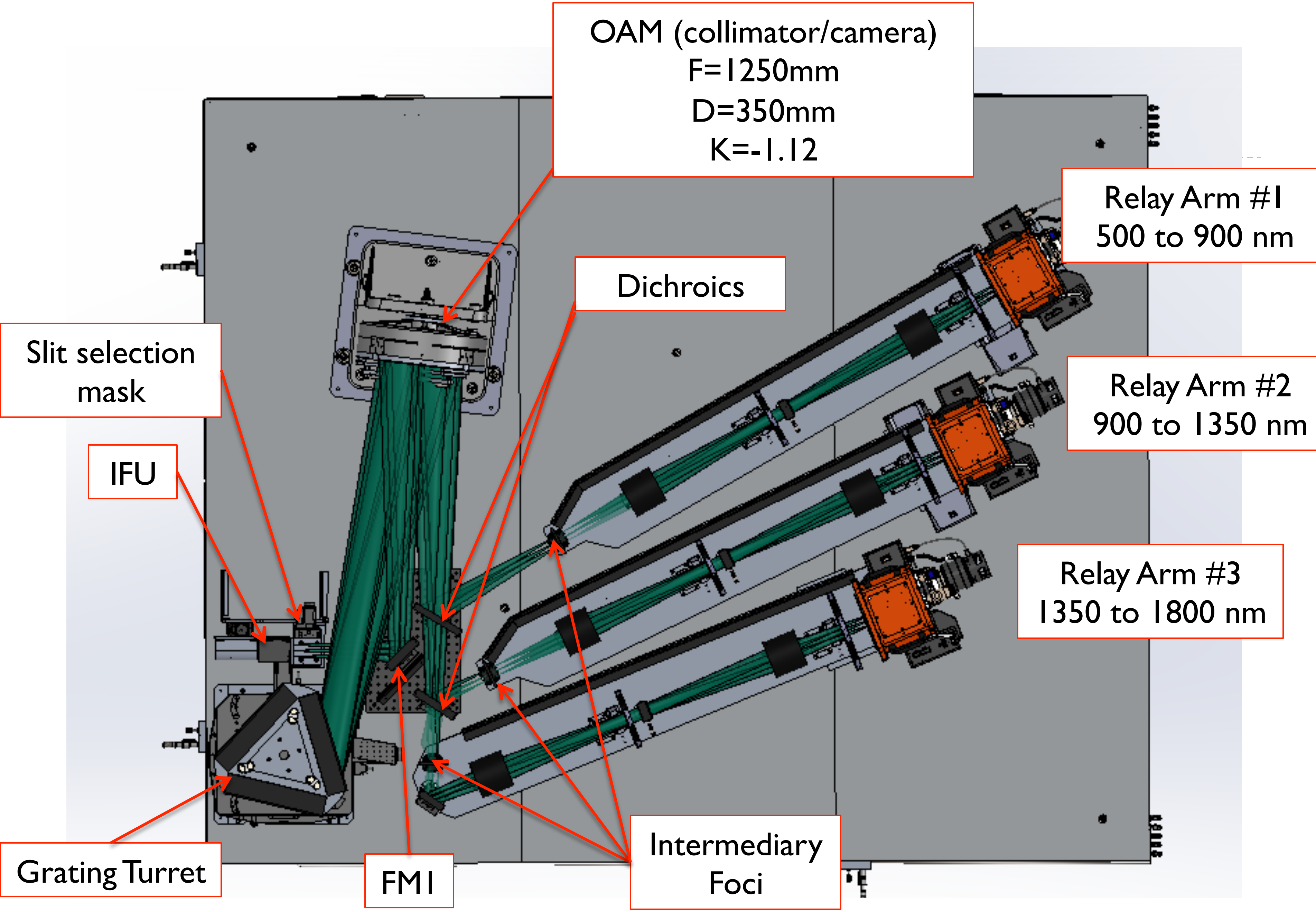
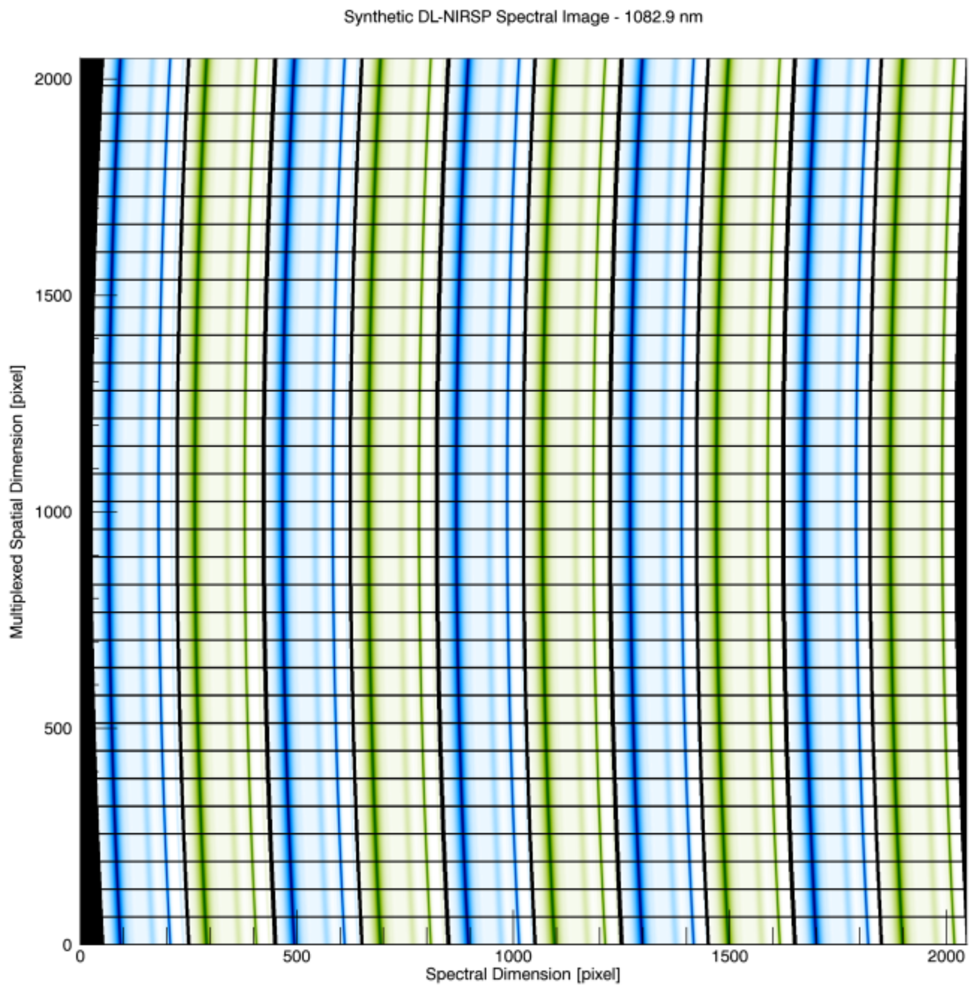


Figure 1: The optical system of the DL-NIRSP, including DKIST M8, M9, and M10


OAM (collimator/camera)
F=1250mm
D=350mm
K=-1.12
Relay Arm #1
500 to 900 nm
Dichroics
Slit selection
mask
Relay Arm #2
900 to 1350 nm
IFU
Relay Arm #3
1350 to 1800 nm
Intermediary
Foci
Grating Turret
FM1

What will DL-NIRSP spectra look like?



DL-NIRSP Spatial Resolution Modes

Table 1: DL-NIRSP Spatial and Spectral Sampling Resolution Modes (reproduction of DL-NIRSP DRD Table 1).

Mode	Feed Optics	IFU	Spatial Sampling[1]	IFU Format	Unit IFU FOV	Spectral Sampling
High-Res	F/62	BiFOIS-5K-36	0.03″	80 x 60	2. 4″ x 1.8″	~ 250,000
Mid-Res	F/24	BiFOIS-5K-36	0.077″	80 x 60	6.16″ x 4.62″	~ 250,000
Wide-Field	F/24	BiFOIS-2.5K-72	0.464″	60 x 40	27.84″ x 18.56″	~ 250,000

Summary

- DKIST will be an ordinarily flexible instrument!
- Fast high resolution instrumentation!
- Deep spectropolarimetry of fine scaled structure!

A shopping list of DKIST rain observations…

- VBI-blue: Ca H/K + H-Beta + Green line?
- VISP: (not initially used for rain; or sit-n-state mode)
- VTF: H-alpha + Ca 854.2 nm
- DL-NIRSP:
  - He I 1083 nm
  - Si X 1430 nm
  - Fe XIII 1074.7 nm
  - Fe XIII 1080 nm

- Cryo-NIRSP
  - TBD..