Coronal Capabilities II

Tom Schad and the DKIST Team
27 June 2018

Highlights/review from the telecon

- ***DKIST provides an unprecedented ability to remote sense coronal magnetism.***
- Optical/IR coronal (log T >≈ 5.8) spectral lines observed off-limb have higher Zeeman sensitivity and have scattering-induced (mostly saturated Hanle) polarization.
- DKIST capabilities include:
    - Low scattered light coronagraphy
    - High accuracy (crosstalk <0.05%) polarimetry
    - Instruments span 0.38 to 5 µm for diverse (and exploratory) coronal science.
    - Diverse multi-wavelength capability for multi-phasic/thermal coronal studies in a single facility with clear benefits for coordinated science as well.

DKIST: Transformative Coronal Features

Excellent Haleakala Skies!

*~**1000** hours per year with sky brightness <25 x 10^{-6} at R = 1.1 and at 1000 nm.*

4 meter aperture → 25 km; SNR!

Access to the infrared:

All-reflective design (transmission out to 28 µm)

First light instruments to 5 µm

Minimizes scattered light by:

Off-axis design (no beam obsuration)

High-grade M1 polish (~1nm microroughness)

In-situ cleaning procedures (CO_2 + washing)

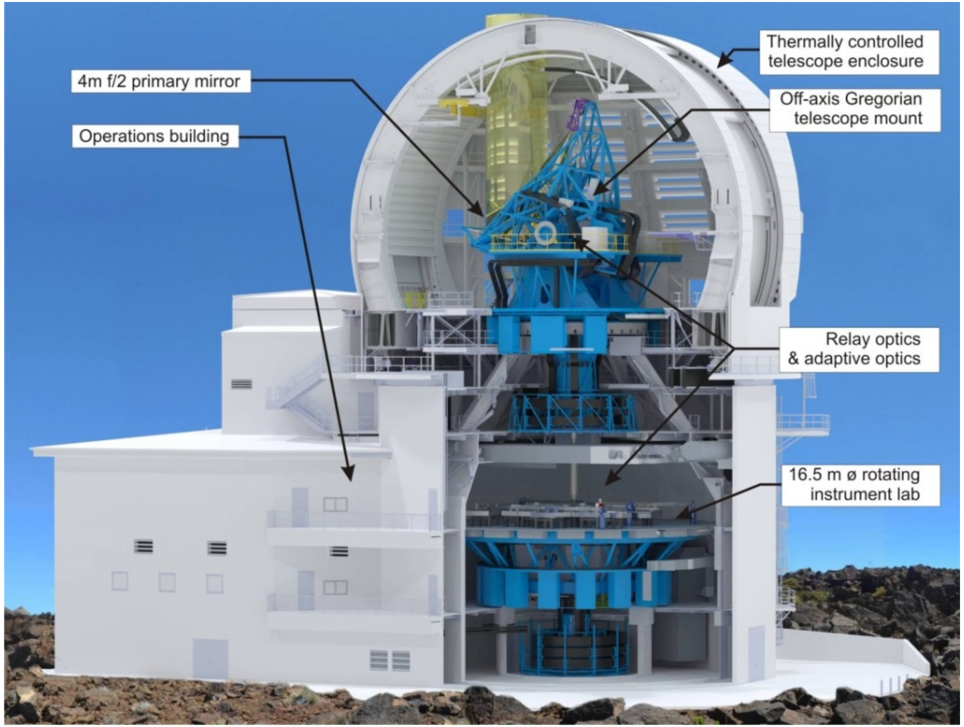
Takes advantage of reduced scatter in IR.

Occulters and stops:

Inverse occulter at prime focus (large 5' FOV)

Lyot stop at intermediary pupil

Limb occulting with tracking at Gregorian focus



DKIST: Broad Coronal Science Mission

Key coronal science areas from SPEC-0001 (Science Requirements Documents):

Derived from reports of the Coronal Working Group (2002)

1) Coronal Magnetic Fields
    - *Pre/post CME/flare configurations; field dynamics during eruptions; origin of coronal loops; prominence cavities; etc.*
2) Coronal Plasmoid Search
    - *Mass flux and acceleration mechanisms of plasmoids; field interactions*
3) Coronal Velocity and Density in Active Regions Loops
    - *Loop evolution and structure; nature and mechanisms and energy deposition, heating; loop classification*
4) Coronal Intensity Fluctuation Spectrum
    - *Size and spatial distribution of possible nano-flaring events, relation to CMEs*
5) Coronal Intensity Oscillations
    - *Coronal seismology to obtain coronal physical parameters and understand wave dynamics*

DKIST supports mission with diverse imaging, scanned-slit spectroscopy and spectro-polarimetry, and fiber-optic based integral field spectroscopy and spectropolarimetry.

DKIST: Estimating performance in the corona

From SRD: *"Science requirements for coronal observations are not easy to define as those for photospheric observations because they present very different challenges."*

- Loosely-known/region-dependent (polarized-) line intensities with strong radial gradients
- Daily variations in sky background (with rapid fluctuations).
- Radial/spectral dependent instrumental background changing with dust accumulation.
- Evolving and developing techniques for deriving physical parameters.

Site survey and derived specifications specify performance benchmark at wavelength of 1000 nm (near Fe XIII pair) at radius of R = 1.1 solar radii.

Sky background: ~1000 hours per year at Haleakala with sky brightness $<25 \times 10^{-6}\ I_{disk}$ at R = 1.1 and at 1000 nm.

Instrument background: Dominated by fully-illuminated primary mirror.
Requirement: $<25 \times 10^{-6}\ I_{disk}$ at R = 1.1 and at 1000 nm.

Total Requirement: $< 50 \times 10^{-6}\ I_{disk}$

DKIST: Estimating performance in the corona

Concluding statements from coronal working group (assuming relatively low 1% spectrograph efficiency) – see also Penn et al. 2004:

> For a 4m aperture ATST with a mirror roughness of *1.2* nanometers rms with a dust coverage of *0.036%* at a site with a sky brightness of *25* 10^{-6} $B_\odot$ at a wavelength of 1000nm the magnetic sensitivity in a coronal loop with a brightness of *40* millionths at a height of *1.1* $R_\odot$ will be 30^{+30}_{-15} Gauss for a 1 arcsec^2 pixel and an integration time of 1 second.
>
> With an rms roughness of 1.2 nm at a height of 1.1 $R_\odot$ the expected mirror background contribution is $2.53(1.2)^2 = 3.6\ 10^{-6}$ $B_\odot$ at a wavelength of 1000 nm from Hubbard (2002). With a dust coverage of 0.036% expected one-day after cleaning the ATST primary mirror the instrumental background increases to $3.6 + 525(0.036) = 23\ 10^{-6}$ $B_\odot$. With a sky brightness of 25 10^{-6} $B_\odot$, the total background is 48 10^{-6} $B_\odot$.

DKIST M1 Requirement: 20 Angstrom micro-roughness rms
Coronal Working Group Assumption: 12 Angstrom micro-roughness + 1 day dust

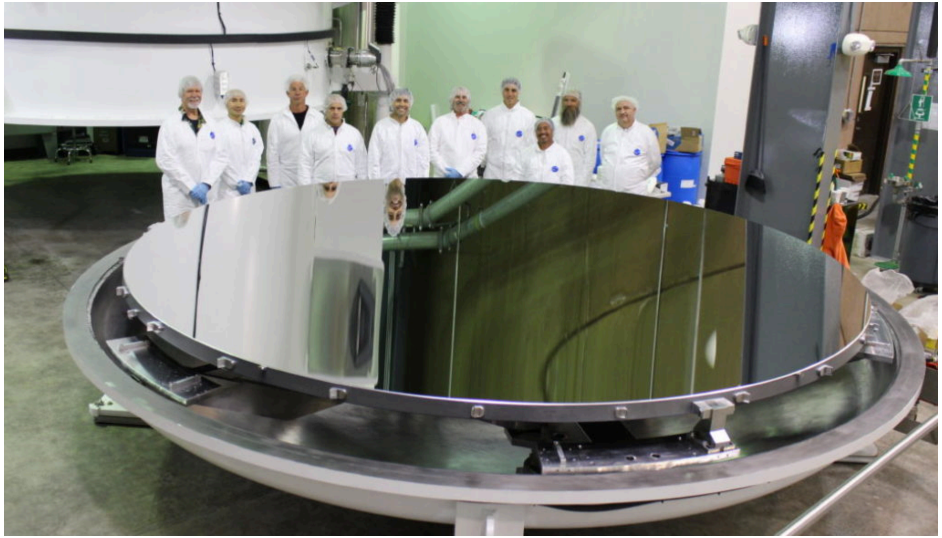
Dust accumulation at M1 in DKIST?

<u>DKIST M1 Requirement:</u> 20 Angstrom micro-roughness rms

<u>Coronal Working Group Assumption</u>: 12 Angstrom micro-roughness + 1 day dust

<u>Delivered M1 Performance</u>: 10.5 +/- 1.1 Angstrom rms

Final polish at U. of Arizona

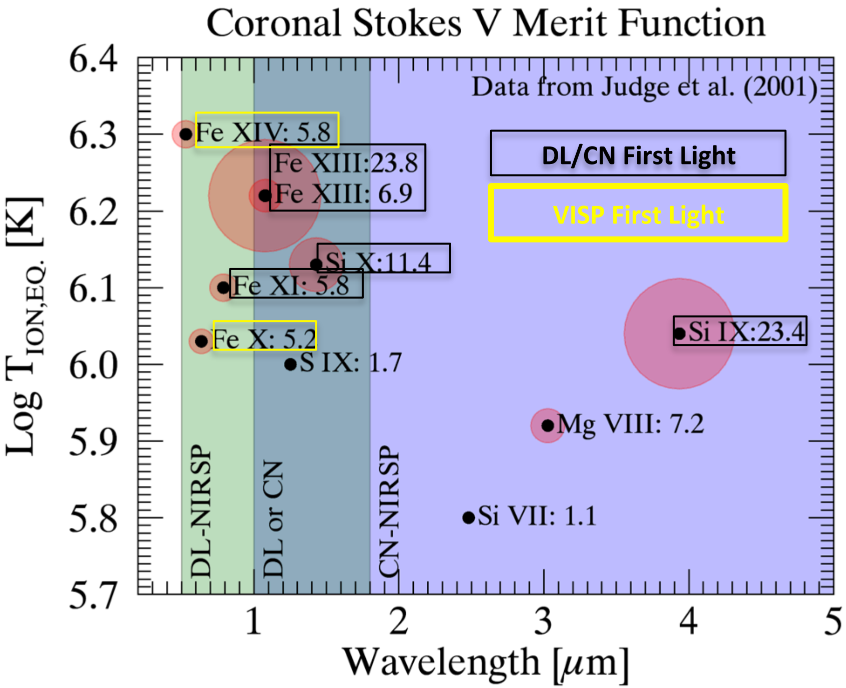


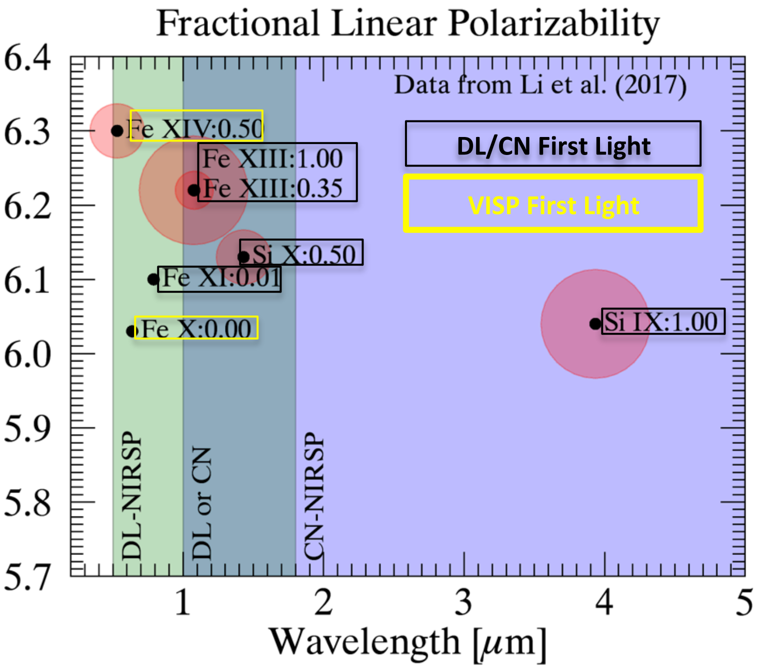
Aluminized at AMOS/MCF (April 2018)

NSF AURA NSO National Solar Observatory DKIST DANIEL K. INOUYE SOLAR TELESCOPE

Performance expectations vary by wavelength and spectral line

- We will use instrument performance calculators to estimate sensitivity for different lines.





Linear polarizability depends on atomic parameters, i.e. $W_2(J_l,J_u)$ from Landi Degl'Innocenti & Landolfi 2004 Table 10.1.

Using DKIST instrumentation for your coronal use case

- DKIST five first light instruments are complex, diverse, and **quickly** reconfigurable to support a very broad science portfolio.
- Users must understand and/or make decisions about:
  1. *Telescope field-of-view, coronagraphy, and pointing sequences*
  2. *Instrument lab rotation angle (solar image rotation)*
  3. *(Manually-changed) spectral distribution of light to instruments.*
  4. *Spectral/imaging/polarimetric capabilities of facility instruments*
  5. *Instrument parameters including domain coverage and SNR.*
  6. *Data rate/volume limits.*

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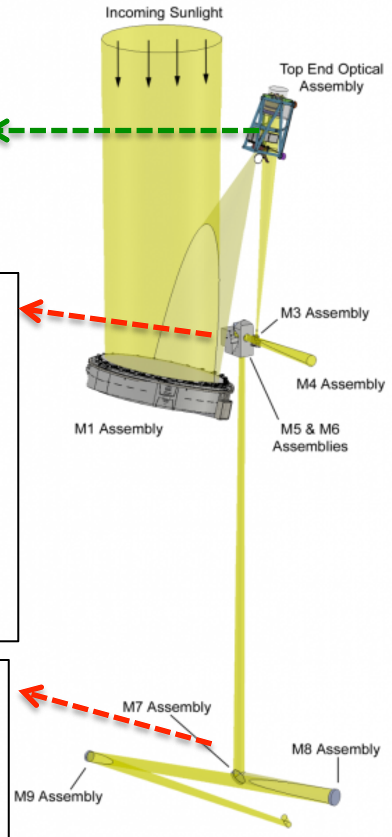
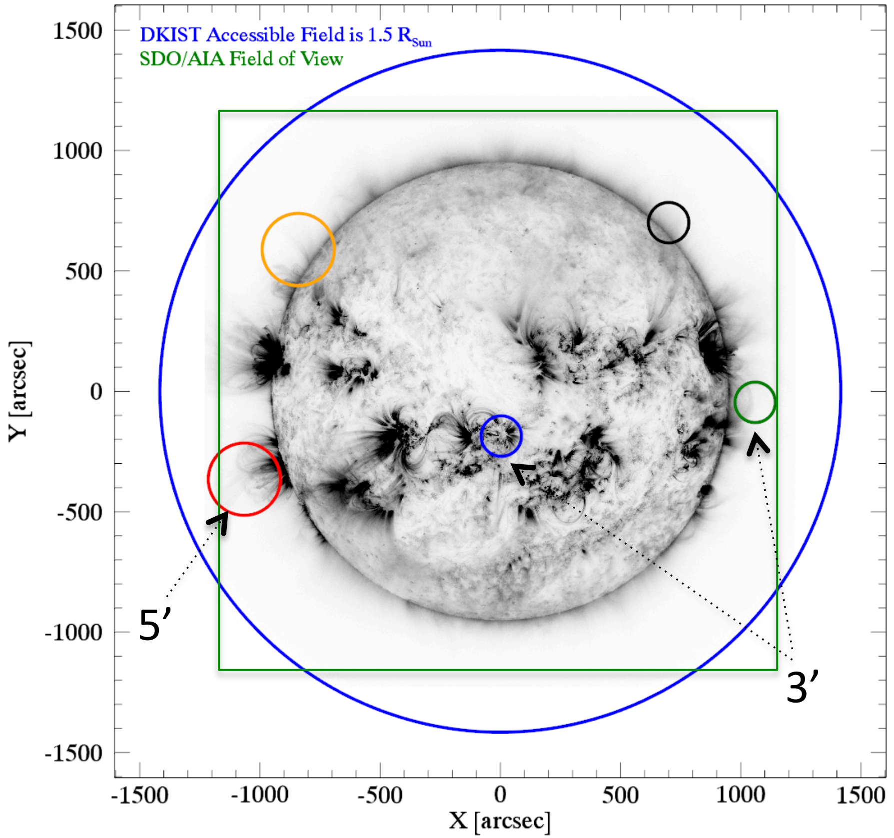
Field of View, Pointing Restrictions (R<1.5 R_{sun}), and Occulters

Prime field stop
"inverse occulter"
5 arcmin diameter

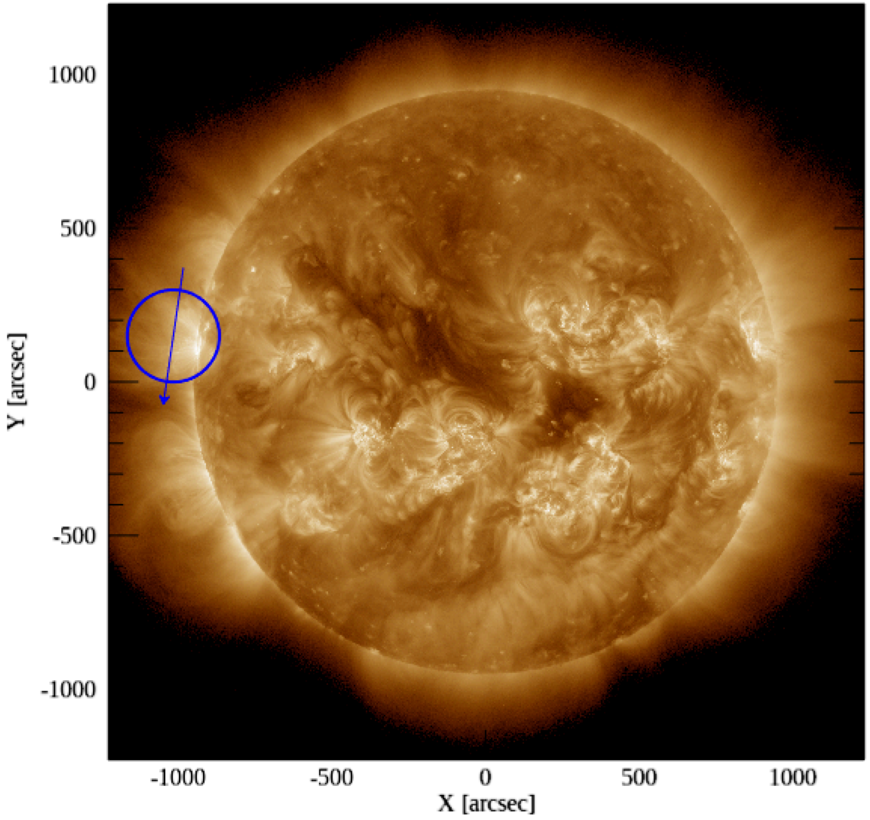
Gregorian focus (GOS): 2.8 and 5 arcmin apertures, limb occulters, and polarization calibration optics

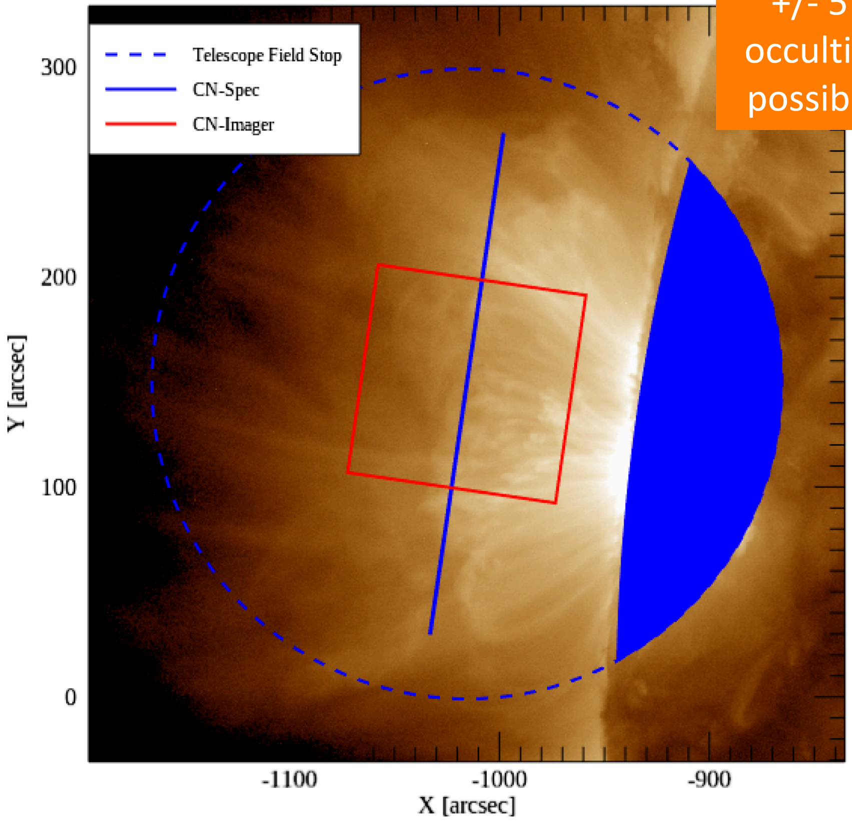
Instruments. Cryo-NIRSP can use 5′, others 2.8′ FOV





Cryo-NIRSP Example: 5 arcmin field-of-view with limb occulter (blue)

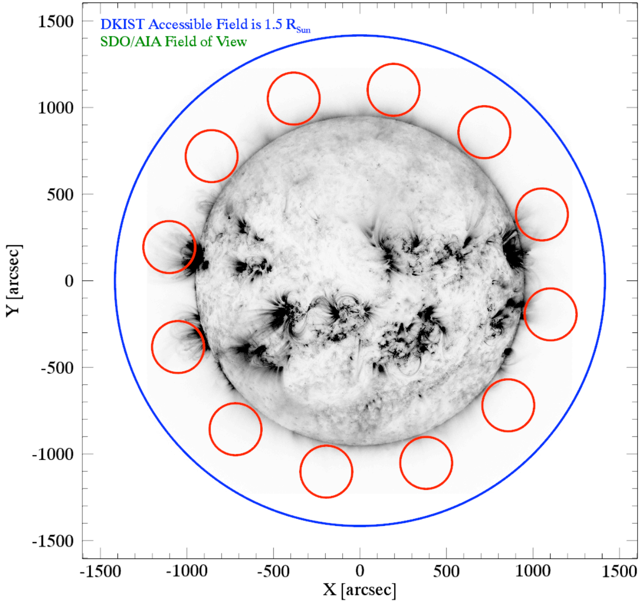




+/- 5” occulting possible.

Instruments have smaller instantaneous field of views, but most can scan field.

Automated execution of discrete pointing sequences



<u>Example use cases</u>

1. Obtain an overall FOV exceeding single-pointing (scanned) instrument FOV.
2. Perform a center-to-limb observation
3. Observe multiple regions in sequence
4. Observe discrete areas following solar limb around the Sun.

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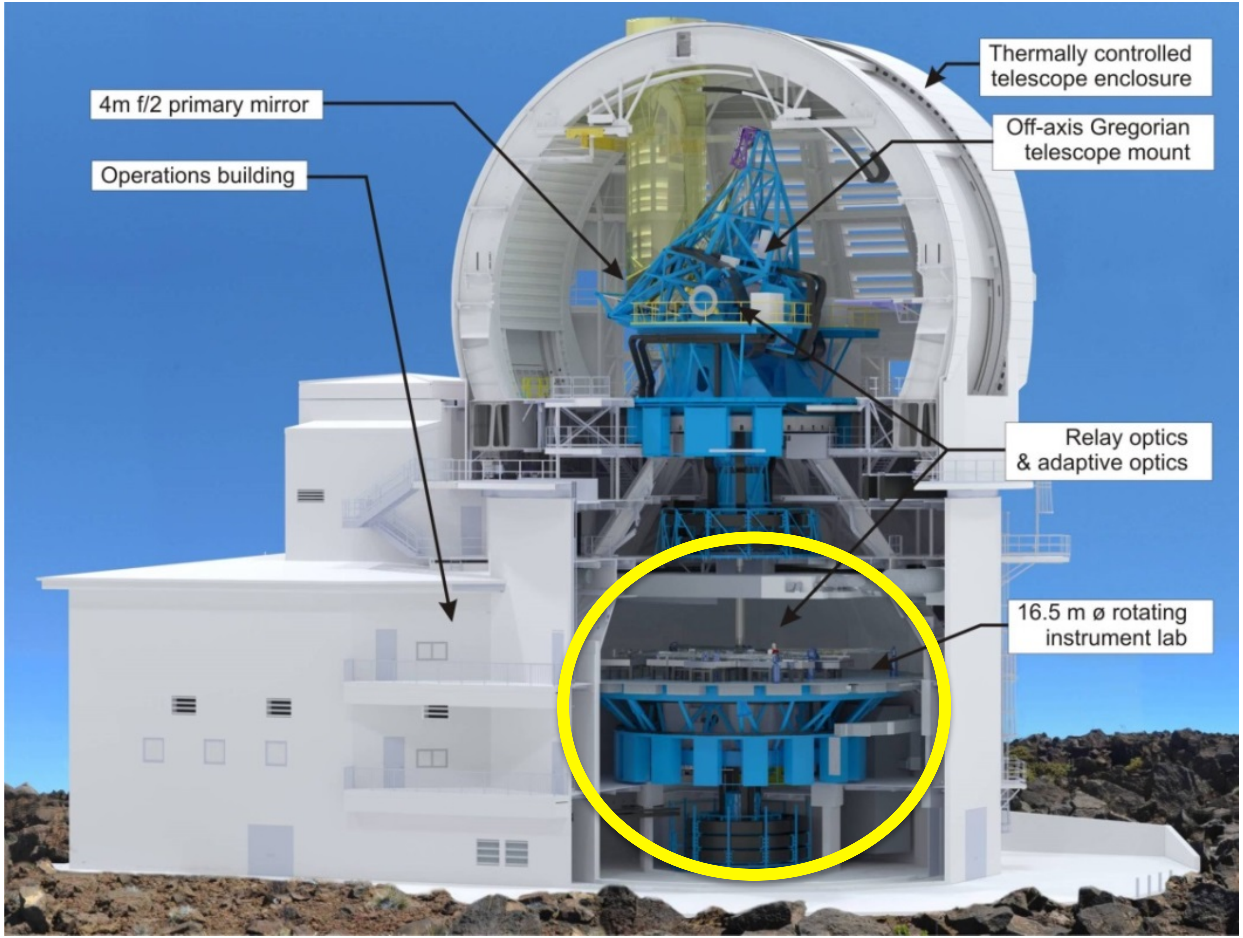


All instruments have fixed mountings in the Coudé instrument Lab.

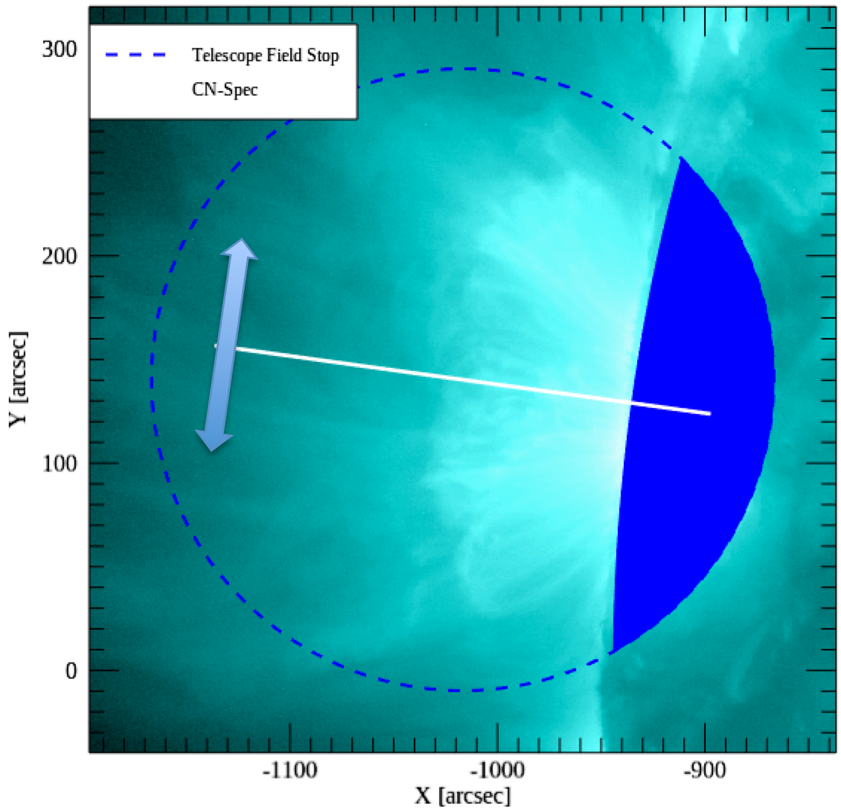
Coude lab rotation compensate alt/az induced image rotation.

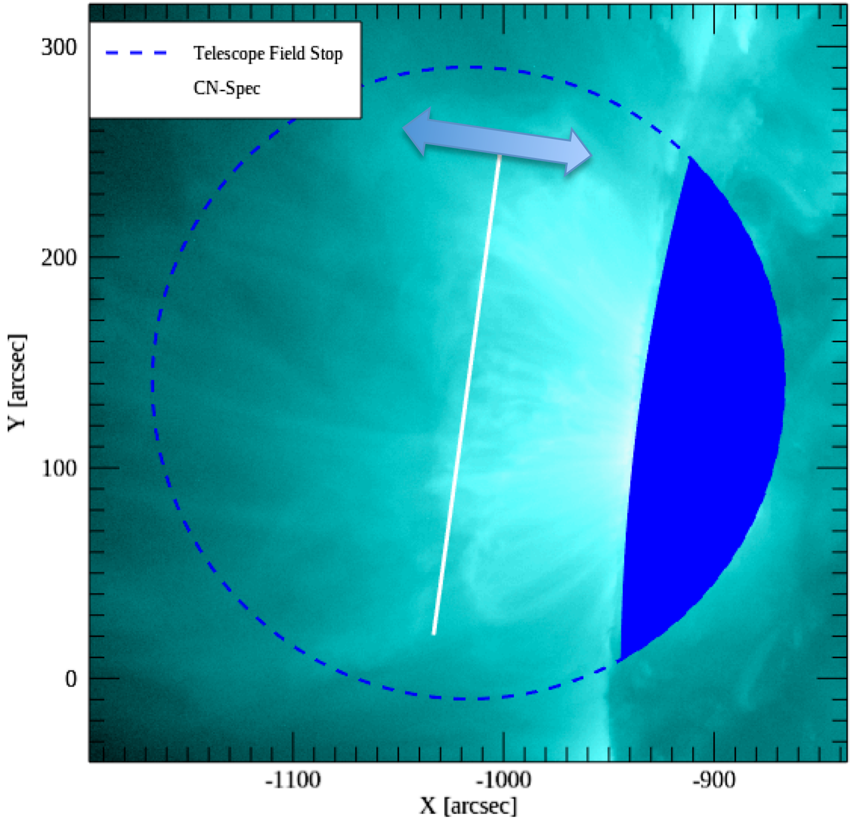
The target's angular orientation with respect to fixed instrument frame is controlled by the Coudé platform rotation offset angle.

Use cases:

- Slits aligned N/S or E/W
- Slits parallel/perpendicular to limb.
- Slits freely aligned parallel to filament axis, polarity inversion line, etc.

Cryo-NIRSP 4’ long coronal slit: Perpendicular/parallel to limb with occulter





*CN also has 2D scan patterns available

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Facility Instrument Distribution Optics (FIDO)

Case 1:

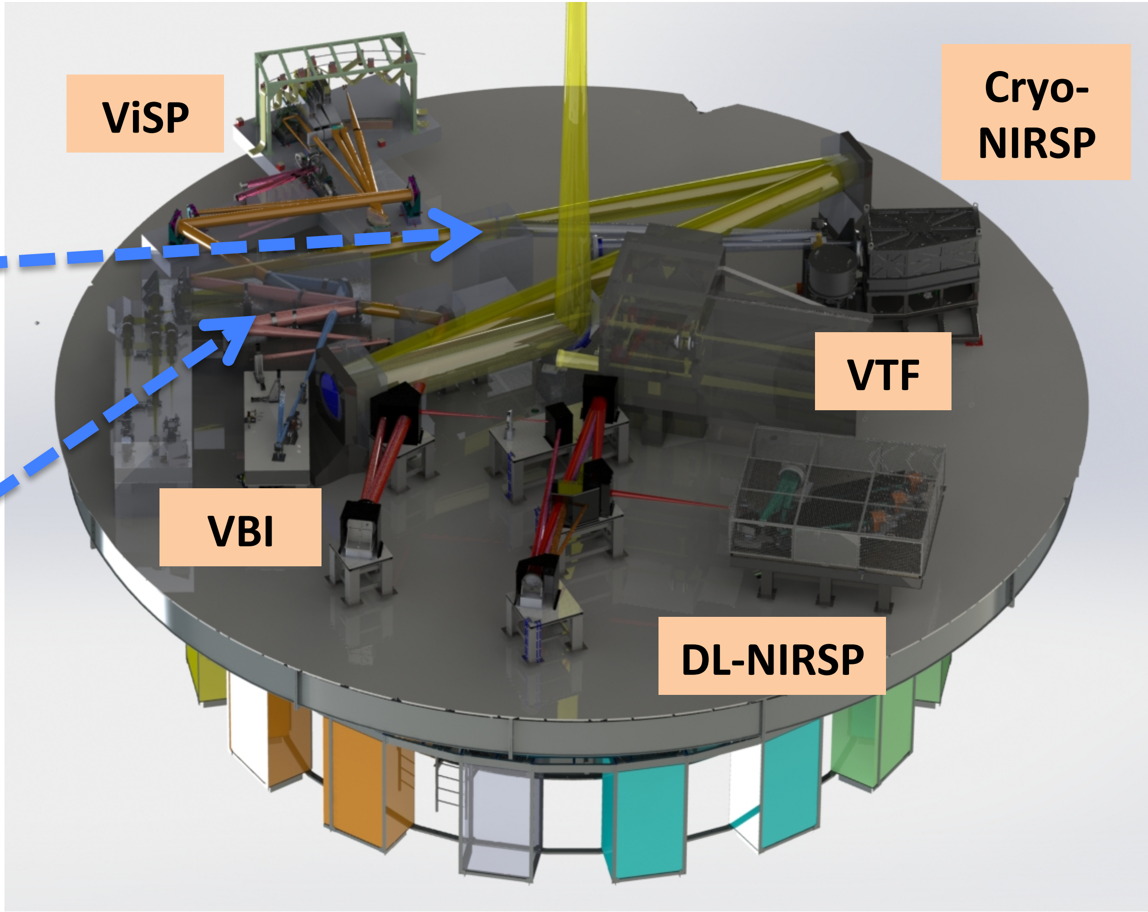
- Pickoff mirror M9a inserted
- Cryo-NIRSP operates alone
- No other instruments

Case 2:

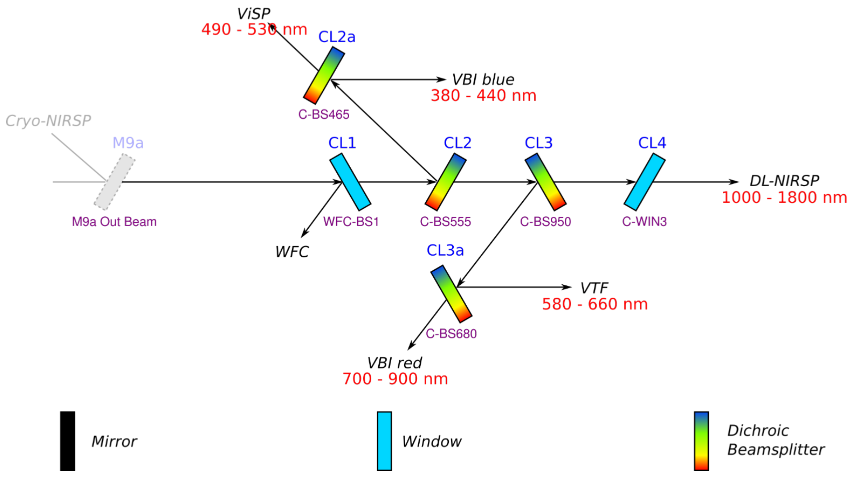
- Pickoff mirror M9a out
- Cryo-NIRSP receives no light
- Series of manually interchangeable dichroic beamsplitters determines distribution to post-AO inst.

Insertion/removal of M9a takes ***tens of minutes.***

Beamsplitters changes: ~1 day



FIDO concept: “All or no light in a wavelength band”

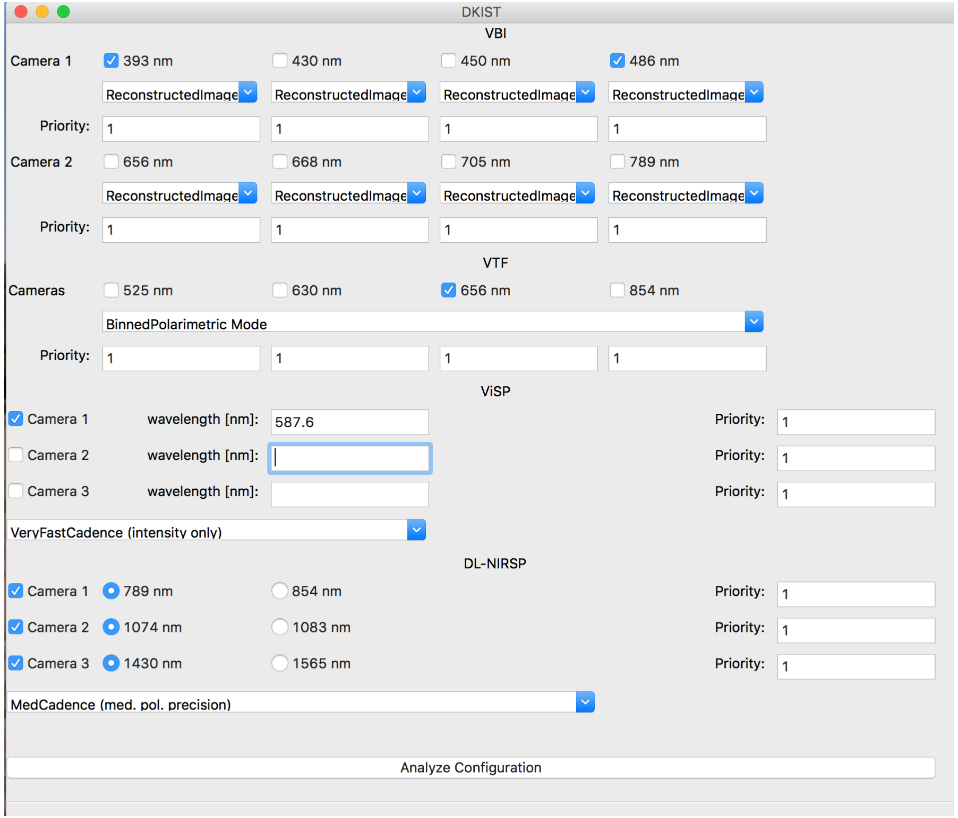


FIDO Schematic

Available optics for distribution

Name	Reflected Band	Transmitted Band	Comment
C-BS465	380 – 440 nm	490 – 1800 nm	Default: CL2A
C-BS555	380 – 530 nm	580 – 1800 nm	Default: CL2
C-BS680	380 – 660 nm	700 – 1800 nm	Default: CL3A
C-BS643	380 – 630 nm	656 – 1800 nm	
C-BS950	380 – 900 nm	1000 – 1800 nm	Default: CL3
C-WIN1		380 – 900 nm	Transmission band AR coat
C-WIN2		380 – 1800 nm	Uncoated front surface
C-WIN3		500 – 1800 nm	Transmission band AR coat Default: CL4
C-MIR1	380 – 1800 nm		Protected Silver coat

FIDO Beam Splitter Calculator



Within the distributed file of IPCs, there is the FIDO Beam Splitter Calculator.

Allows one to test whether spectral/ instrument selection can be achieved by FIDO.

Also gives preliminary estimate of data rates.

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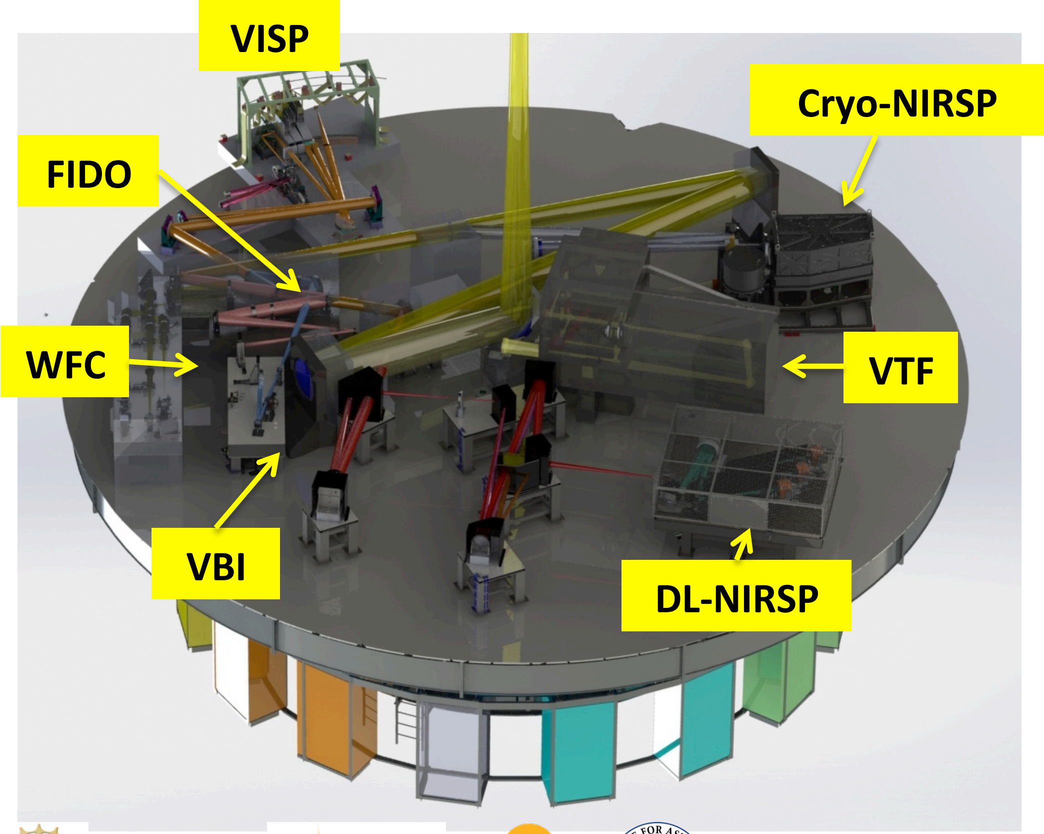
DKIST Facility Instruments



Cryogenic Near-Infrared Spectropolarimeter (Cryo-NIRSP) – UH/IfA
PI: J. Kuhn

Diffraction Limited Near-Infrared Spectropolarimeter (DL-NIRSP) – UH/IfA
PI: H. Lin

Visible Tunable Filter (VTF) – KIS
PI: O. vd Luehe

Visible Spectropolarimeter (ViSP) – HAO
PI: R. Casini

Visible Broadband Imager (VBI)– NSO
PI: F. Woeger

Instrument Overview (details at dkist.nso.edu/CSP/instruments):

Instrument Name	Type	Accessible λ Range*	Analogs
Cryogenic Near IR Spectro-Polarimeter **(Cryo-NIRSP, or CN)**	Cryogenic slit-scanning spectropolarimeter and context imager	1000 – 5000 nm	CYRA (BBSO)
Diffraction-Limited Near IR Spectro-Polarimeter (**DL-NIRSP**)	Integral Field Unit spectropolarimeter	500 – 900 nm 900 – 1350 nm 1350 – 1800 nm	SPIES, GRIS-IFU
Visible Tunable Filter **(VTF)**	Etalon-based 2D imaging spectropolarimeter	520 – 870 nm (590 – 870 nm)	IBIS, CRISP, GFPI, HMI
Visible Spectro-Polarimeter (**ViSP**)	Slit-scanning spectropolarimeter	380 – 900 nm	SPINOR, Hinode/SP, IRIS
Visible Broadband Imager (**VBI**)	Narrowband Imaging	390 – 550 nm 600 – 860 nm	Hinode/BFI; ROSA

*Selection of narrowband filters limits spectral line available for all except ViSP

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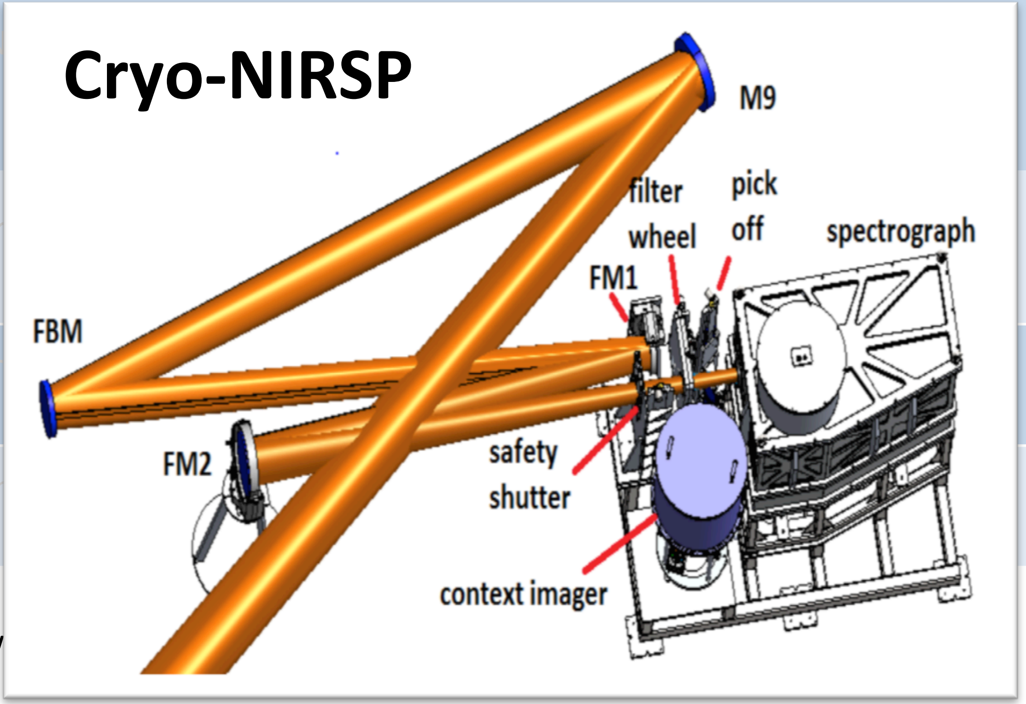
Visible Tunable Filter **(VTF)**			IBIS, CRISP, GFPI, HMI
Visible Spectro-Polar **(ViSP)**			SPINOR, Hinode/SP, IRIS
Visible Broadband Im **(VBI)**			Hinode/BFI; ROSA



*Selection of narrow

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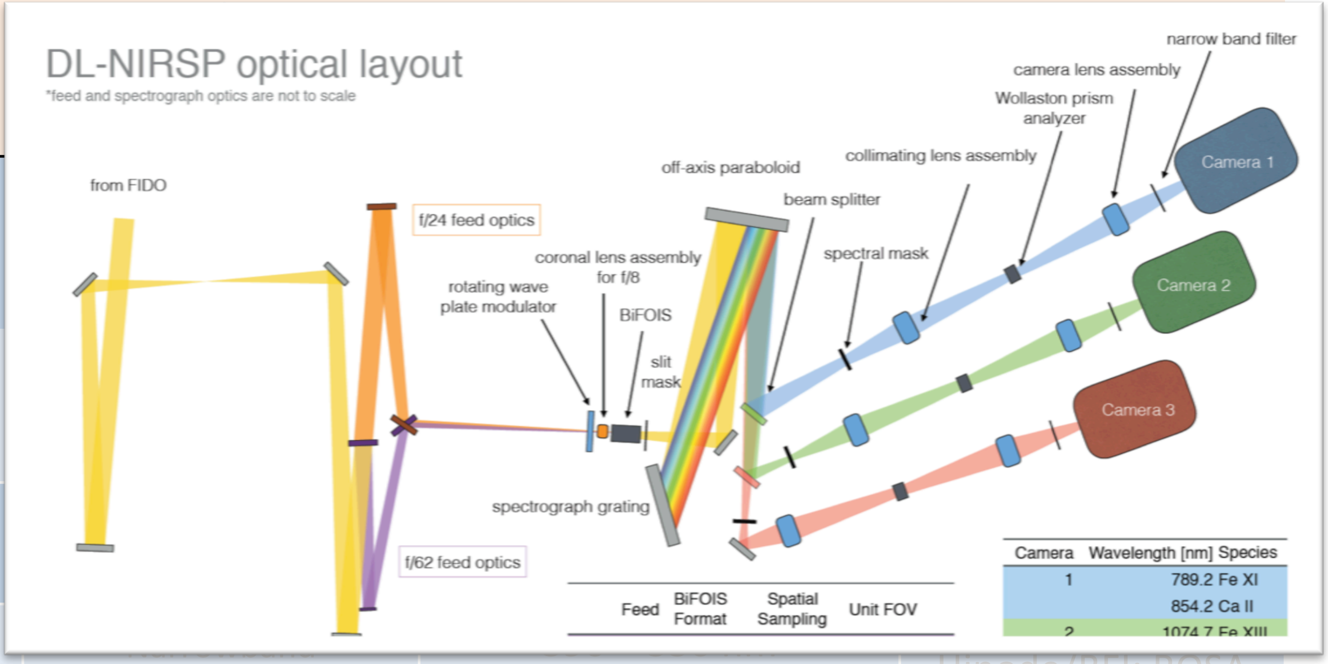
Visible Tunable Filter **(VTF)**			
Visible Spectro-Polarimeter **(ViSP)**			
Visible Broadband Imager **(VBI)**	Imaging	600 – 860 nm	Hinode/BFI; ROSA



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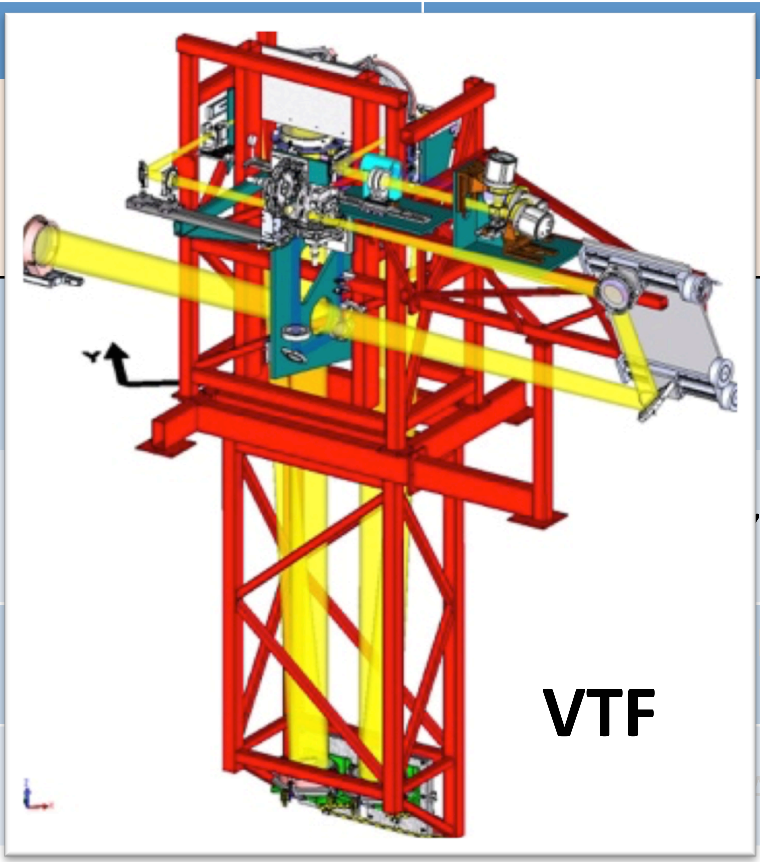
Visible Broadband Imager **(VBI)**	Narrowband Imaging



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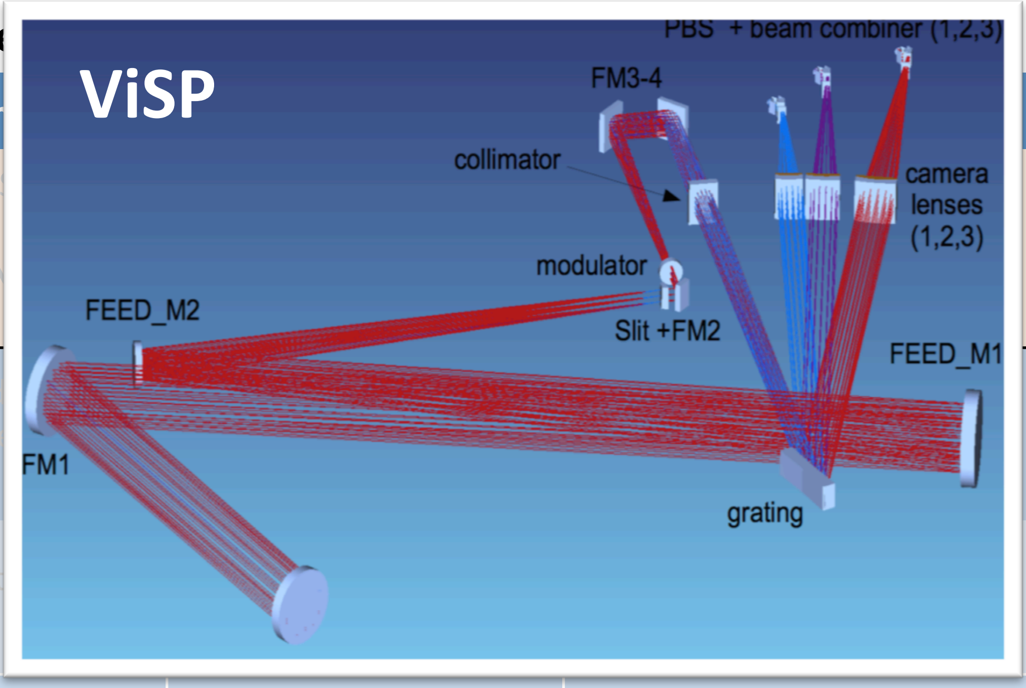
Instrument Ove



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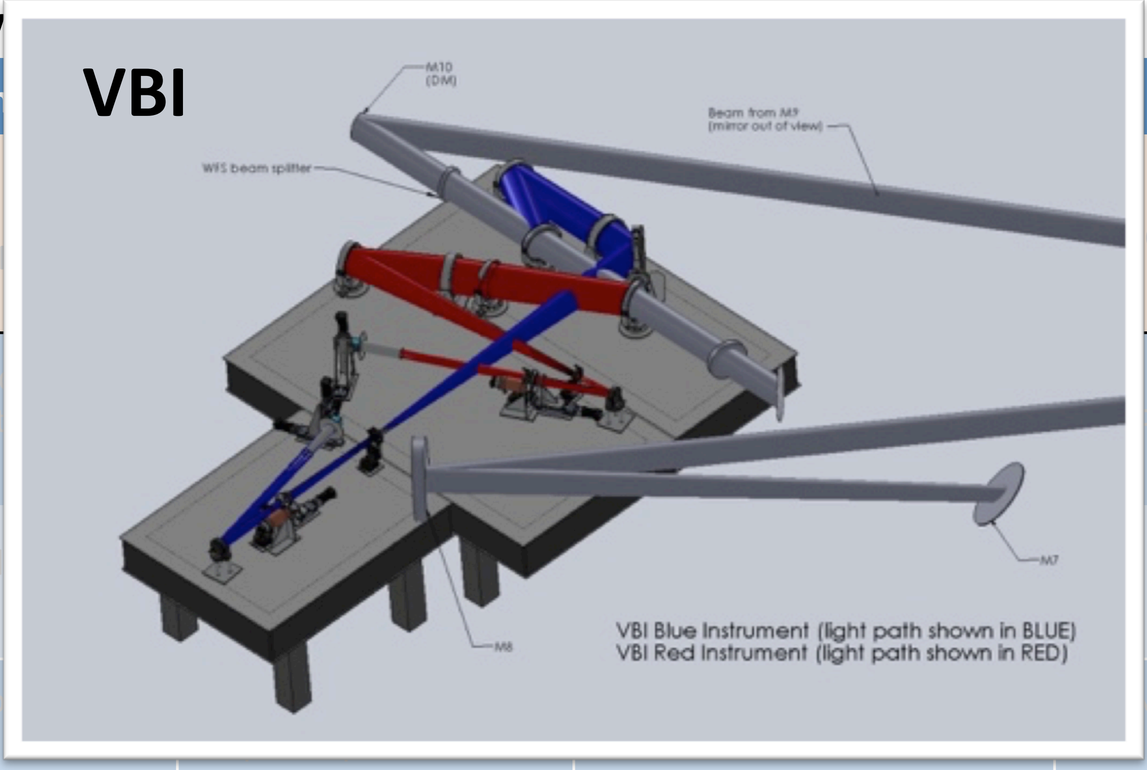

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Visible Tunable Fi **(VTF)**			S, CRISP, GFPI, HMI
Visible Spectro-Po **(ViSP)**			IOR, Hinode/SP, IRIS
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Instrument Summary Table (available at dkist.nso.edu/CSP/instruments)

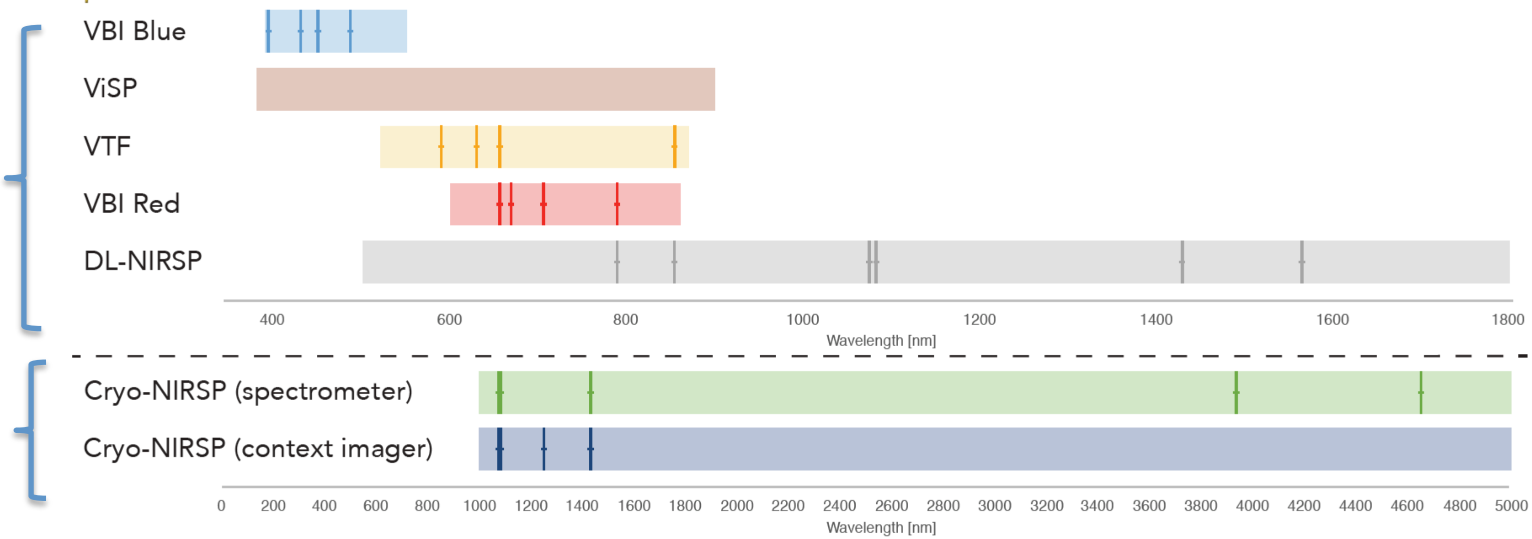
	Instrument type	Spectral range	Spectral resolution	Spatial sampling	Maximum Instantaneous Field of View	Maximum Sampled Field of View	Peak Cadence	Analogous Instruments
Visible Broadband Imager ***VBI (Blue)***	High Cadence, High Resolution Imager	390–550nm (sequential filter sequencing)	N/A	0.011″	45″ x 45″	2′ x 2′ (sequential field sampling)	3.2 sec (reconstructed) 0.03 sec (raw images)	ROSA, Hinode/BFI *High cadence, high spatial resolution*
Visible Spectropolarimeter ***ViSP***	Scanning Slit Spectropolarimeter	380-900nm (3 spectral windows at a time)	>180,000	0.0195″ (arm 1) 0.0236″ (arm 2) 0.0295″ (arm 3) [sampling along slit]	*5 slits* *Width x Length* 0.028″ or 0.041″ or 50″ (arm 1) 0.053″ or x 60″ (arm 2) 0.106″ or 75″ (arm 3) 0.214″	Slit length x 2′	0.5-10 sec per slit position (polarimetry) 0.02-0.2 sec per slit position (intensity-only)	SPINOR, Hinode/SP, IRIS, GRIS *Scanning spectrograph, high spectral fidelity*
Visible Tunable Filter ***VTF***	Fabry Perot Imaging Spectropolarimeter	520-870nm (sequential scans through multiple spectral lines)	FWHM 6-8 pm	0.014″	60″ x 60″	60″ x 60″	Typical scan times per spectral line: 0.5-2 s (intensity only); 2-10 s (polarimetry)	IBIS, CRISP, GFPI *Imaging spectropolarimeter*
Visible Broadband Imager ***VBI (Red)***	High Cadence, High Resolution Imager	600–860nm (sequential filter sequencing)	N/A	0.017″	69″ x 69″	2′ x 2′ (sequential field sampling)	3.2 sec (reconstructed) 0.03 sec (raw images)	ROSA, Hinode/BFI *High cadence, high spatial resolution*
Diffraction Limited Near Infrared Spectropolarimeter ***DL-NIRSP***	Integral Field Unit Spectropolarimeter	500–900nm 900–1350nm 1350-1800nm (1 filter band per channel)	125,000	0.03″ (high res) 0.077″ (mid res) 0.464″ (wide field)	2.4″ x 1.8″ (high res) 6.16″ x 4.62″ (mid res.) 27.84″ x 18.56″ (wide)	2′ x 2′	Depends on resolution and and total field of view. E.g. 6s for one tile, on-disk, high resolution, full polarimetry	SPIES *True Imaging Spectropolarimeter: simultaneous 2D FOV and spectral information using fiber-fed IFU*
Cryogenic Near Infrared Spectropolarimeter ***Cryo- NIRSP***	Scanning Slit Spectropolarimeter	1000-5000nm (1 filter band at a time. About 70 s to switch filters)	100,000 on-disk 30,000 off-limb	0.12″ [along slit] (no Adaptive Optics)	*2 slits* 0.15″ x 120″ slit 0.5″ x 240″ slit	4′ x 3′ (near limb) 5′ round (off-limb)	Heavily depends on signal to noise. Maximum frame rate is 10 frames per second e.g. 1s per slit position near-limb/ chromosphere	CYRA (BBSO) *Cryogenic, scanning spectrograph, novel diagnostics*
Cryo-NIRSP ***Context Imager***	Imager	1000-5000nm (1 filter band at a time, with fast switching time to support sequential observations during a single-band spectrograph scan.)	N/A	0.052″ (no Adaptive Optics)	100″ x 100″	4′ x 3′ (near limb) 5′ round (off-limb)	Heavily depends on signal to noise. Maximum frame rate is 10 frames per second e.g. 1s per slit position near-limb/ chromosphere	CYRA (BBSO) *Cryogenic, scanning spectrograph, novel diagnostics*

This table is meant to give an idea of the capabilities of the DKIST first light instrument suite. It cannot capture the large trade space that is provided by the flexibility of the instruments. For more information, visit http://dkist.nso.edu/CSP/instruments

DKIST First Light Instrument Filters

Post-A0
2.8’ Field Stop
Co-operate*

2.8’ or 5’
Field Stop
Only CN



VBI Blue

Ca II K	393.327nm
G-band	430.52nm
Continuum	450.287nm
H-beta	486.1nm

ViSP

Access to entire spectral range between 380-900 nm

VTF

Na D	589.6nm
Fe I	630.25nm
H-alpha	656.3nm
Ca II	854.2nm

VBI Red

H-alpha	656.282nm
Continuum	668.423nm
Ti O	705.839nm
Fe XI	789.186nm

DL-NIRSP

Fe XI	789nm
Ca II	854.2nm
Fe XIII	1074.7nm
He I	1083nm
Si X	1430nm
Fe I	1565nm

Cryo-NIRSP

Fe XIII	1074.7nm
Fe XIII	1079.7nm
He I	1083 nm
Si X	1430nm
Si IX	3935 nm
CO	4651nm

Cryo Context

Fe XIII	1074.7nm
He I	1083nm
J Band	1250nm
Si IX	1430nm

Up next: Samples of possible coronal observations with DKIST

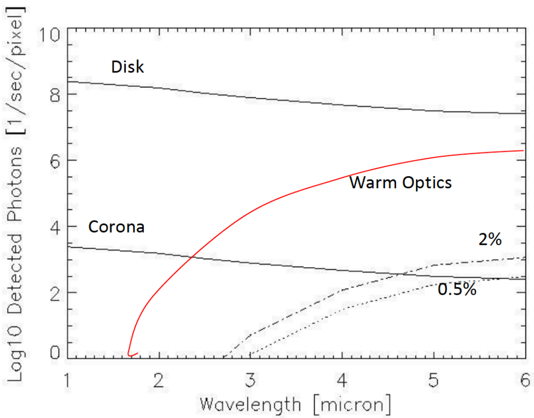
Disclaimer: Examples are purely illustrative. They do not cover the full range of instrument use, nor even necessarily the primary use cases of a given instrument.

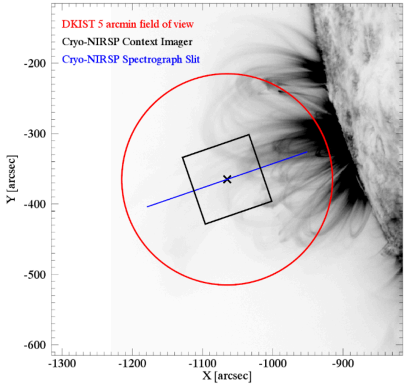
Cryo-NIRSP: Cryogenic Coronal Spectropolarimetry

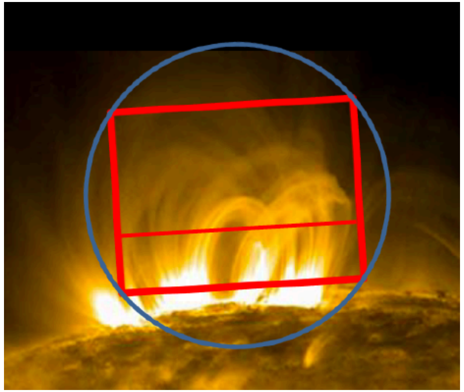
Cryo-NIRSP	
Fe XIII	1074.7nm
Fe XIII	1079.7nm
He I	1083 nm
Si X	1430nm
Si IX	3935 nm
CO	4651nm

Cryo Context	
Fe XIII	1074.7nm
He I	1083nm
J Band	1250nm
Si IX	1430nm

Pioneering low background, high-dynamic-range coronal spectropolarimetry out to 5 microns. Most extensive coverage of infrared coronal lines with high efficiency.







Example 1:

Si IX 3.9 um slit-scanned spectropolarimetry

3’ x 4’ region, 1’’ samples, 5G sensitivity near limb, 15G at 1.5 solar radii, 3 hr scan

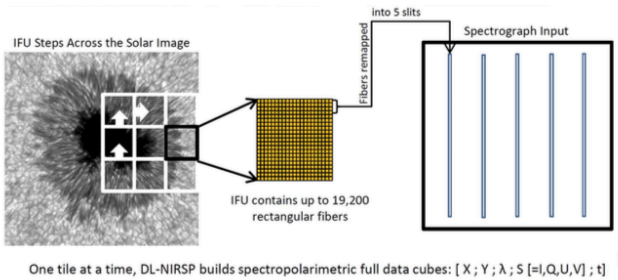
Different species (e.g. Fe XIII pair) observable in sequence with ~70 second spectrograph reconfiguration time (calibration overhead TBD). Context imager field always centered on slit.

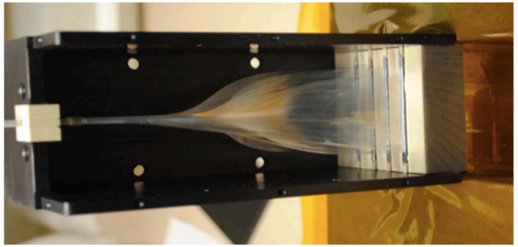
DL-NIRSP: Multi-band Integral Field Coronal Spectropolarimetry

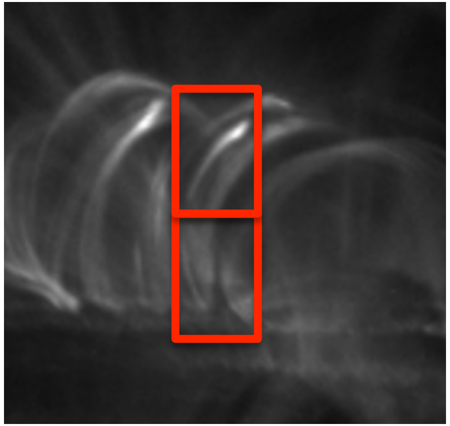
DL-NIRSP	
Fe XI	789nm
Ca II	854.2nm
Fe XIII	1074.7nm
He I	1083nm
Si X	1430nm
Fe I	1565nm

More filters recently added:
Fe XIV 530.3 nm
He D3 587.6 nm
Fe I 630.2 nm
Fe XIII 1079.8 nm

Fiber-optic based integral field spectropolarimetry with up to three simultaneous channels. Instantaneous spectrograph coverage over a 2D field.







- DL-NIRSP wide-field mode consists of 60 x 40 IFU with 0.464'' samples. (FOV: 18.6'' x 27.8'')
- 2D scanning for up to 2' x 2' FOV for single telescope pointing.
- Example: 1 x 2 scan pattern, total FOV 18.6'' x 55.7'', 16 sec integration (SNR ~50), 33 sec cadence.
- Resolve MHD wave propagation/dynamics and do temporal coadding for magnetic field inference.

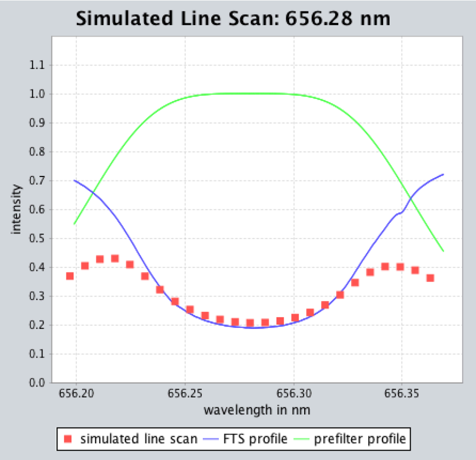
VTF: Cool Coronal Dynamics

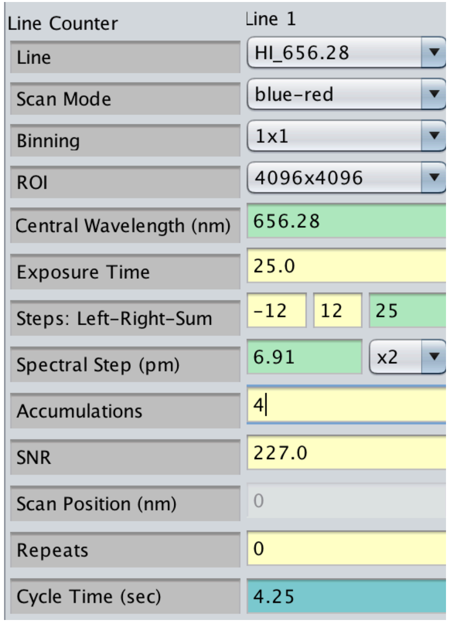
VTF

Na D	589.6nm
Fe I	630.25nm
H-alpha	656.3nm
Ca II	854.2nm

- Thermal coverage of VTF does not include hot coronal plasma.
- High-cadence imaging spectro(polarimetry) of cool lines (H-alpha and Ca II)
- Prominences; coronal rain; post-flare cooled loops.

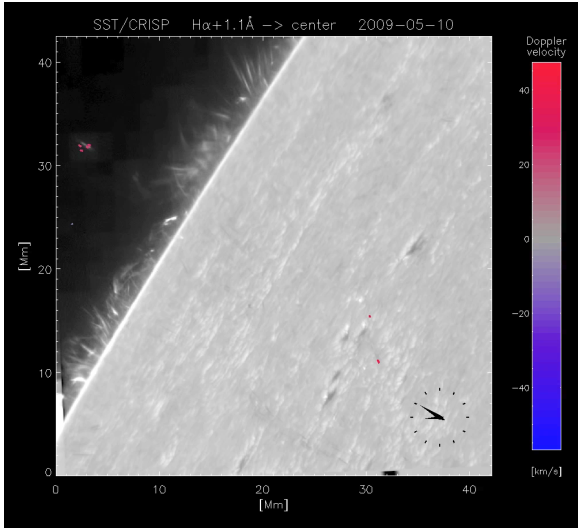
VTF FOV: 60’’ x 60’’ (no scanning)





Example: H-alpha spectroscopy (+/- 34 km/sec) in 4.25 sec

Coronal rain observed by SST/CRISP 60’’ x 60’’ FOV (Antolin et al. 2012)



ViSP in the Corona

ViSP

Access to entire spectral range between 380-900 nm

- VISP science cases emphasize photospheric/chromospheric/prominence science.
- Attractive coronal science includes diversity of visible line diagnostics.
- Increase of scattered light in visible; Zeeman sensitivity reduced.
- IPC does not give coronal estimates (but some capabilities can be assessed).

Example 1: Simultaneous scan of three coronal lines 0.214'' slit width (widest), 1'' scan step, 5 sec total integration 100'' scan width → 9 minutes to map				FOV along slit	Telescope + ViSP transmission	Spectral Resolution
Fe XIV	Log T ~ 6.3	530.3 nm	'Green' line	75''	1.23%	90000
Ca XV	Log T ~ 6.65	569.4 nm	'Yellow' line	60''	1.85%	89000
Fe X	Log T ~ 6.05	637.5 nm	'Red' line	50''	0.73%	79000

Example 3:
2MK FIP Effect

S XII 761.2 nm
Fe XV 706.2 nm

Example 2: Ca XV density line ratio sit and stare 0.214'' slit width (widest), a few seconds of int per step				FOV along slit	Telescope + ViSP transmission	Spectral Resolution
Ca XV	Log T ~ 6.65	569.6		75''	2.26%	78000
Ca XV	Log T ~ 6.65	544.6		60''	2.34%	75000

VBI in the Corona: Direct Multi-Thermal Coronal Imaging

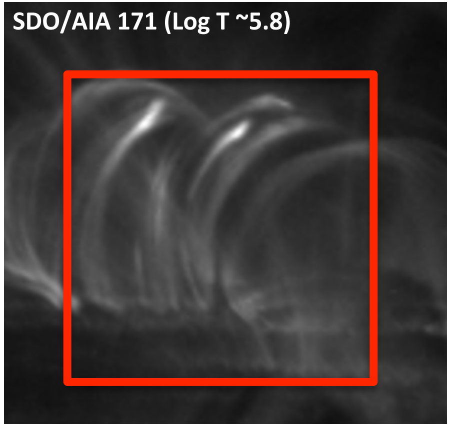
VBI Blue

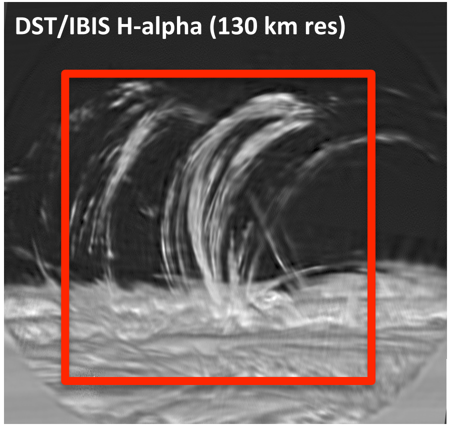
Ca II K	393.327nm
G-band	430.52nm
Continuum	450.287nm
H-beta	486.1nm

VBI Red

H-alpha	656.282nm
Continuum	668.423nm
Ti O	705.839nm
Fe XI	789.186nm

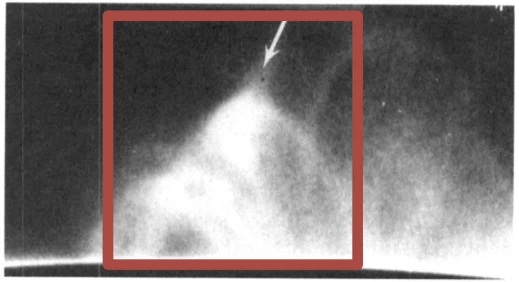
Key targets: Bright post flare loops and other cooling loops





VBI-red 69'' x 69'' FOV
(Field sampling to 2' x 2')
0.017'' spatial sampling

VBI-red coronal filter
Fe XI 789.2 nm (Log T ~ 6.13)
1 to a few second cadence
(no off-band subtraction)



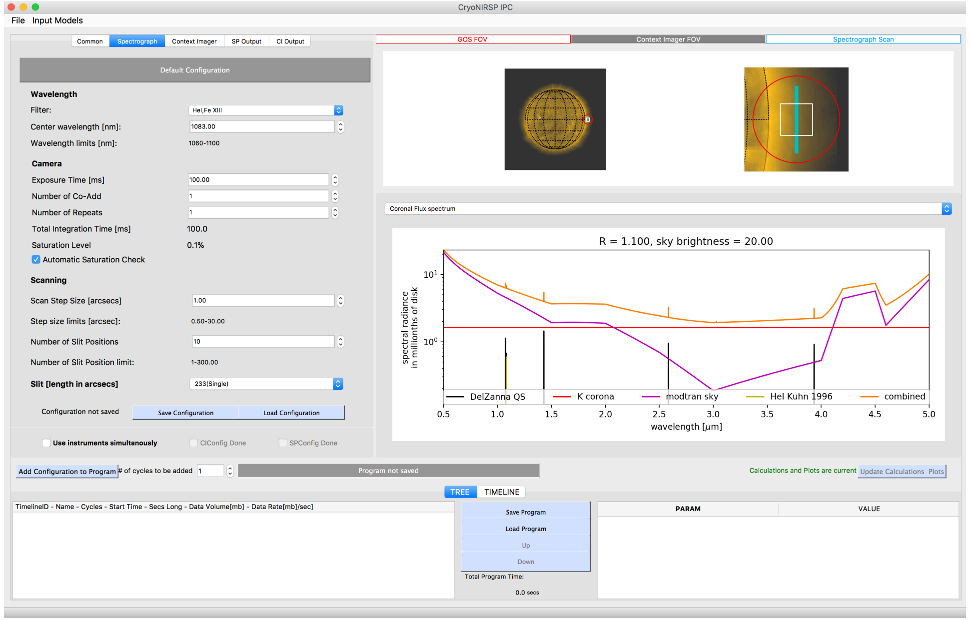
Direct imaging of green line from Sac Peak (20 cm Coronal One Shot) Airapetian and Smartt, 1995, ApJ

Using DKIST instrumentation for your coronal use case

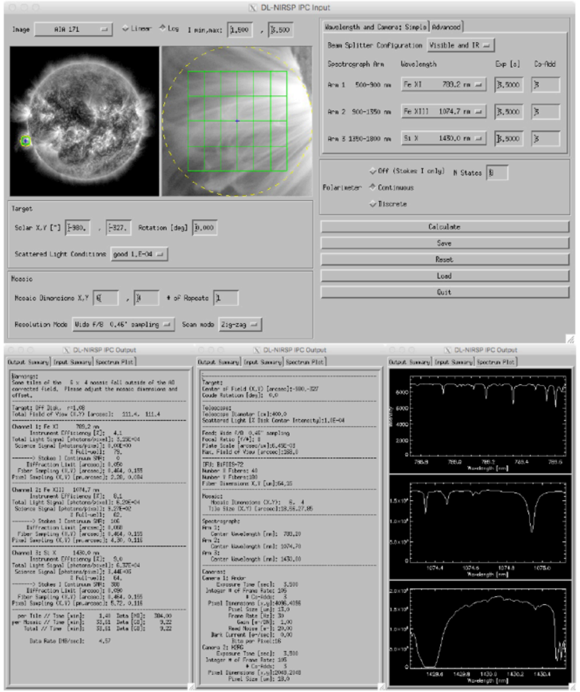
- DKIST five first light instruments are complex, diverse, and *quickly* reconfigurable to support a very broad science portfolio.
- Users must understand and/or make decisions about:
  1. *Telescope field-of-view, coronagraphy, and pointing sequences*
  2. *Instrument lab rotation angle (solar image rotation)*
  3. *(Manually-changed) spectral distribution of light to instruments.*
  4. *Spectral/imaging/polarimetric capabilities of facility instruments*
  5. ***Instrument parameters including domain coverage and SNR.***
  6. *Data rate/volume limits.*

Estimate signal-to-noise (and observable errors) using Instrument Performance Calculators (IPCs)

Every instrument has an IPC for potential users.



Cryo-NIRSP IPC



DL-NIRSP IPC – Coronal Example

IPCs will be discussed further after coffee break.

Summary / Next Steps

- DKIST provides diverse coronal capabilities in support of its broad science mission.

dkist.nso.edu/CSP/instruments

- Resources are available to help you tailor the experiment for your use case.

DKIST Instrumentation Suite and Configuration

View | Edit | Revisions | Grant

Instrumentation Suite Overview

The DKIST (**DKI Solar Telescope in a Nutshell**) will offer a combination of state-of-the-art instruments with imaging and/or spectropolarimetric capabilities covering a broad wavelength range. This first-light instrumentation suite will include:

- **Cryogenic Near-InfraRed Spectro-Polarimeter (Cryo-NIRSP)**: a cryogenic slit-based spectropolarimeter for coronal magnetic field measurements and on-disk observations up to 4.7 microns.
- **Diffraction-Limited Near-InfraRed Spectro-Polarimeter (DL-NIRSP)**: a fiber-fed two-dimensional spectropolarimeter.
- **Visible Broadband Imager (VBI)**: a rapid broadband filtergraph for high-spatial and -temporal resolution imaging.
- **Visible Spectro-Polarimeter (ViSP)**: a slit-based dual-beam spectropolarimeter for sensitive and accurate multi-line spectropolarimetry.
- **Visible Tunable Filter (VTF)**: a double Fabry-Pérot based imaging instrument for high-spatial resolution spectroscopy and spectropolarimetry.

Extra slides

Modeled mirror/dust scattering at 1000 nm (TN-0013)

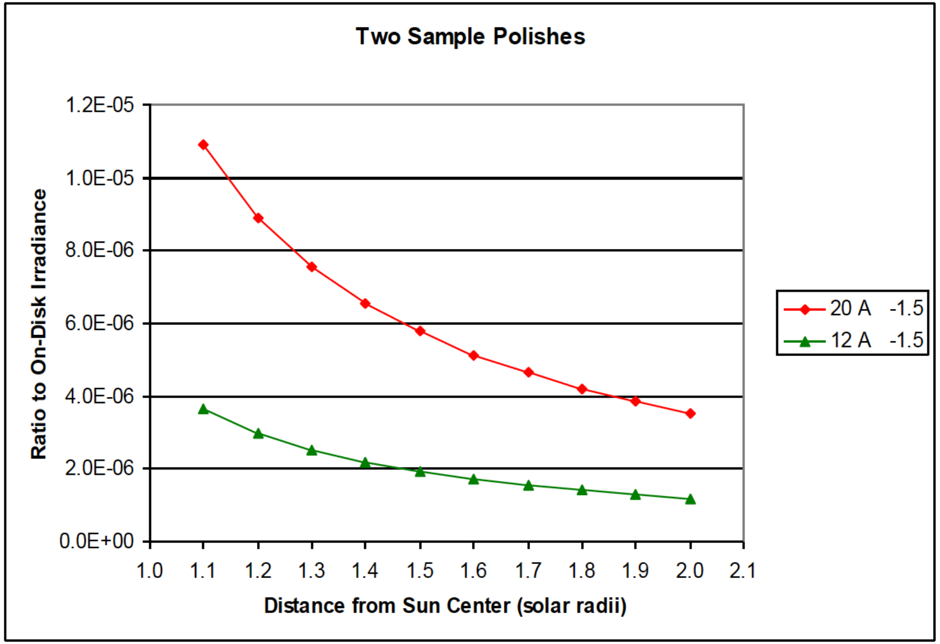
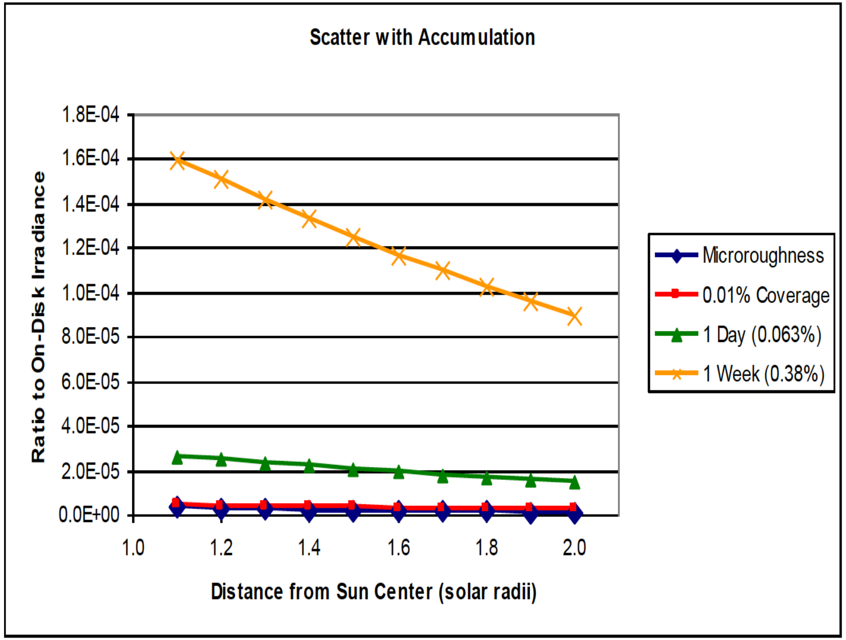


Figure 10. The figure shows the impact of scattered light due to microroughness for two different mirror polishes as a function of limb position. Both presume a slope of –1.5.



ure 15. The figure shows the effects of dust accumulation on the primary mirror after one day and one week, assuming the UKIRT accumulation rate of 0.002 percent per hour.

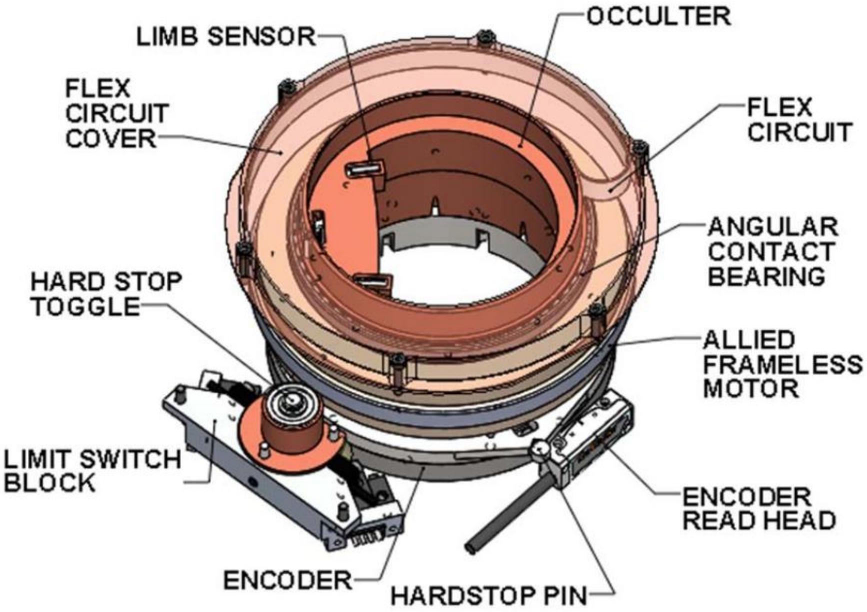
DKIST M1 Requirement: 20 Angstrom micro-roughness rms

Dust accumulation at M1 in DKIST?

<u>Sample</u> FIDO distributions for coronal use cases.

All light to Cryo-NIRSP	**VBI-Blue::** *Ca K 393.3 nm* *H-beta 486.1 nm* **VISP::** *He I D3 587.6 nm* **VTF::** *H-alpha 656.3 nm* **DL-NIRSP::** *Fe XI 789 nm* *He I 1083.0 nm* *Si X 1430 nm*	**VBI-Blue::** *Ca K 393.3 nm* **VISP::** Fe XIV *530.3* Ca XV *569.4* *Fe X 637.5* **DL-NIRSP::** *Fe XI 789 nm* *Fe XIII 1074.7 nm* *Si X 1430 nm*	**VBI-Blue::** *Ca K 393.3 nm* **VBI-Red::** *Fe XI 789 nm* **VISP::** Fe XIV *530.3 nm* Ca XV *569.4 nm* *Fe X 637.5 nm* **DL-NIRSP::** *Fe XIII 1074.7 nm* *Si X 1430 nm*

Limb Occulters and Limb Tracking



Limb occulters at Gregorian Focus are used to block disk light when observing coronal lines near the limb.

Two limb occulters available:

2.8 and 5 arcmin diameter

Consist of occulting segment and two limb sensors reading position of solar limb.

Active driving of secondary mirror stabilizes limb location on occulter.

+/- 5” occulting possible.