DKIST: TELESCOPE, INSTRUMENTATION AND OPERATIONS IN A NUTSHELL

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- Renamed/dedicated in December 2013.
- NSF funded MREFC project.
- PI Institute: NSO.
- Co-PIs: HAO, NJIT, UH/IfA, University of Chicago.
- DKIST will be operated in a rather different way than today’s ground-based telescopes: tests on this are being conducted at DST!

Construction Project ends in Summer 2019: Largest solar ground-based telescope.
DKIST will replace existing national solar facilities of the NSO
NSO Facilities

Dunn Solar Telescope
Sacramento Peak, New Mexico
Visible wavelengths

McMath Pierce Telescope
Kitt Peak, Arizona
Infrared wavelengths

With DKIST: consolidation of the AZ and NM sites,
NSO move to Boulder, new Headquarters
(by 2017).
Overview: General Properties

- 4-m aperture
  - Unprecedented spatial resolution.
- All reflective design
  - Exploitation of un-explored wavelengths in the IR.
- Off-axis Gregorian optical design
  - Scattered light reduction downstream.
  - Allows limiting FOV to 5 arcmin in prime.
- Integrated active and adaptive optics.
- Integrated polarization calibration equipment.
- Set of facility-class instruments
  - Covering broad wavelength range (allows up to 28 microns).
  - Mounted on a rotating platform.
  - Multi-instrument operations.
Construction Schedule and Site

- Start: Dec 2012.
- End: Summer 2019 after IT&C.
- Instruments:
  - Science Verification Phase for each instrument.
Construction Schedule and Site

- Ground-breaking: November 2012.
- Start: December 2012.
- End: Summer 2019 after IT&C.
- Instruments:
  - Science Verification Phase for each instrument.
Telescope Mount and Optical Path

**Telescope Mount**
Off-axis: structure more similar to 8-m telescope
5 arcsec pointing accuracy (open loop)

**Enclosure environment**
Active/passive ventilation
Air scavenging
Dehumidification

**Coude environment**
“Clean” lab space

**Coude Rotator**
Rotating instrument platform
16-m diameter

Gregorian Optical Station

Primary Mirror

Coude Transfer Optics

Incoming Sunlight
Top End Optical Assembly
M3 Assembly
M4 Assembly
M5 & M6 Assemblies

Azimuth axis
Elevation axis

M1 Assembly
M7 Assembly
M9 Assembly
M8 Assembly
Coudé Level: Facility Instruments

- **VBI**: Visible Broadband Imager (NSO); **DL-NIRSP**: Diffraction-Limited Near-Infrared SpectroPolarimeter (IfA); **Cryo-NIRSP**: Cryogenic Near-Infrared SpectroPolarimeter (IfA); **VTF**: Visible Tunable Filter (KIS); **ViSP**: Visible Spectropolarimeter (HAO).
Coudé Laboratory

Very different to instrument labs or instrument platforms currently used at GB solar facilities!

- Thermally controlled environment ("clean room"): room is not "open" (like at the DST, VTT, Gregor, SST, NST).
- Access to the room is "controlled"!
- Telescope, AO, and instruments are controlled from a separate control room (via the Observatory Control System OCS provided user interfaces).
- Access to the room during science observations is "prohibited" (internal seeing, thermal stability).
- Changing the light-beam distribution to instruments from standard to customized configurations: difficult manual task, has to be scheduled and planned for! Beam-splitters/mirrors are heavy pieces of glass (50 kg)!
VBI: Visible Broadband Imager

- Wavelengths: 390-860 nm.
- Two separate arms: VBI red and VBI blue.
- 4 interference filters per arm.
- Filter widths (FWHM): 0.05–0.6 nm.
- Spatial FOV: optical design allows for 2 x 2 arcmin (squared).
  - VBI Blue: 45.2 x 45.2 arcsec.
  - VBI Red: 69 x 69 arcsec.
- Field sampling capability.
- Frame rate: up to 30 HZ (raw, full detector).
- Spatial resolution: quasi-real time image reconstruction (speckle technique ≈ diffraction-limited spatial resolution).
- Filter wheel movement repeatability: +/-0.05 mm.
- Filter wheel move time: 0.54 s (goal: 0.34 s)

Rapid Interference Filter Imager (NSO)

Purpose/Mission: Record images from the DKIST telescope at the highest possible spatial and temporal resolution at a number of specified wavelengths in the range from 390-860 nm.

Opportunity: Fast flare dynamics and study of small-scale processes

In Fabrication and Testing Phase

Filters: Blue: CaII K 393.4 nm, G-Band 430.5 nm, blue continuum at 450.4 nm, Hβ 486.1 nm. Red: Hα 656.3 nm, red continuum at 668.4 nm, TiO 705.8 nm.
VTF: Visible-Tunable Filter

Double Fabry-Perot Spectropolarimeter (KIS)

**Purpose/Mission:** Spectrally isolate narrow-band images of the Sun at the highest possible spatial and temporal resolution from the DKIST telescope.

- **Wavelengths:** 520 - 870 nm.
- **Two channels:** narrowband and broadband.
- **Spectral resolution (narrowband):** 3pm@550 nm.
- **Spatial FOV:** 1 arcmin (circular).
- **Frame rate:** up to 30 Hz (full detector).
- **Spatial resolution:** 0.03arcsec@500 nm.
- **Dual-beam spectropolarimeter (two detectors).**

Opportunity: spectral investigations chromosphere/photosphere (much like IBIS/CRISP today)

Progressing through Preliminary Design Phase
ViSP: Visible Spectro-Polarimeter

- **Wavelengths**: 380-900 nm (goal: up to 1600 nm)
- **Simultaneous spectral ranges**: three spectral arms.
- **Spatial resolution**: 2 x telescope resolution.
- **Spatial FOV**: 2 x 2 (scanning) arcmin capable (currently: 1.15 x 2 arcmin max).
- **Resolving Power**: 180,000 (3.5 pm)@630 nm (met everywhere with proper slit, grating, etc.).
- **Temporal resolution**: 10 sec per slit position (SNR dependent)
- **Slit move time**: 200 ms.
- **Slit slew velocity**: 2 arcmin in 30 sec.
- **Dual-beam spectropolarimeter** (single detector).
- **Setup time**: 1 arm in 10 min.

**Slit-Based Spectropolarimeter (HAO)**

**Purpose/Mission**: Provide precision measurements of the full state of polarization simultaneously at diverse wavelengths in the visible spectrum and fully resolving the spectral profiles of lines originating in the solar atmosphere.

**Opportunity**: Impact polarization diagnostics

**Progressing through Critical Design Phase**
DL-NIRSP: Diffraction-Limited Near-Infrared SP

Fiber-Fed 2D Spectropolarimeter (UH/IfA)

Purpose/Mission: Analysis of recording of the full polarization state of spectral lines originating on the Sun in the near infrared wavelength region.

- Wavelengths: 900 – 2500 nm.
- Dual-beam spectropolarimeter (single detector).
- Two IFU’s (Integrated Fiber Units):
  - High-Res Mode: f/62 beam, 80 x 60 (0.03 arcsec sampling) imaging array: 2.4 x 1.8 arcsec.
  - Mid-Res Mode: f/24 beam, 80 x 60 (0.077 arcsec sampling) imaging array: 6.16 x 4.62 arcsec.
  - Low-Res Mode: f/24 beam, 60 x 40 (0.464 arcsec sampling, corona) imaging array: 27.84 x 18.56 arcsec.
- Spatial FOV: 2.8 x 2.8 arcmin (circular).
- Field scanning mirror to sample larger FOV.
- Field scanning move time: ≤100 ms.
- Field scanning slew time (120 arcsec): 1.3 sec.

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

Opportunity: Chromospheric magnetic fields, full 2D spectroscopy of flares.

Progressing through Critical Design Phase
Cryo-NIRSP: Cryogenic Near-Infrared SP

- Wavelengths: 1000 – 5000 nm.
- Resolving power: 30,000 (corona); 100,000 (on-disk).
- Spatial FOV and sampling:
  - Corona: 4 x 3 (scanning) arcmin (0.5 arcsec sampling).
  - On-disk: 90 x 90 arcsec (0.15 arcsec sampling); in 90 sec.
- Frame rate: ≥ 10 Hz.
- Dual-beam spectropolarimeter (single detector).
- No AO!
- Filter wheel: < 60 sec (next position).
- Scan mirror: < 200 ms (next position).
- Context viewer (interleaved).

Cryogenic Slit-Based Spectropolarimeter (UH/IfA)

**Purpose/Mission**: Study of solar coronal magnetic fields over a large field-of-view at near- and thermal infrared wavelengths by measuring the full polarization state of spectral lines originating on the Sun.

**Filters**: Fe XIV 530 nm, Fe X 637 nm, H I 656 nm, Fe XI 789 nm, Fe XIII 1075 nm, He I 1080 nm, S IX 1252 nm, S i X 1430 nm, Fe IX 2218 nm, CO 2326 nm, S i X 2580 nm, Mg VIII 3028 nm, Si IX 3935 nm, CO 4651 nm.

**In Fabrication Phase**
Operations

- Science operations: moving away from traditional PI mode with fixed time allocation but implementation of an efficient observing model.
  - Service mode operations in addition to classical/PI mode (access mode).
  - NSO is currently experimenting this new mode at the DTS for fixed periods (Cycle1/2/3).
- Solar Service mode operations: proposals/experiments (ranked) only executed when solar conditions (target availability), weather conditions, and instrument configurations are suitable.
- In service mode or access mode the facility will offer different programs: Regular, synoptic, survey, and target of opportunity.
- Standard operations (mostly): light-beam to instruments is fixed and instruments are operated to produce standard data sets.
- DKIST is expected to reach out for new users (NSF’s “open sky policy” is assumed for now).
- DKIST is expected to make data available to the broader solar community (data center, calibrated data and derived data products).
How to get access?

- Everybody can apply! Application is not restricted to being affiliated with partner institutions of the DKIST.
- Proposal application and review process.
- A TAC with international, NSO, and partner representatives will evaluate proposals based on a scientific merit and technical feasibility assessment; Proposals will be ranked (and likely grouped).
- It is required that a special proposal preparation and submission tool (Proposal Architect, PA/ProArc) is used that will be made available.
- Proposal solicitation will happen at least twice per year.
- PI can apply for service or access time and different programs: standard, synoptic, survey, Target of Opportunity; coordination possible for all of those programs.
Questions

- How is planned for a target?
- How fast can the target be changed? Depends (e.g. on the compromises one is willing to accept):
  - During execution of observations and data acquisition (maybe the fastest way to do it): telescope GUI and WFC GUI is active and target can be moved while data acquisition is still progressing; new AO lock-point needs to be identified and acquired; data is “incoherent”, metadata out of sync; issues with data pipeline. Time scales pretty much like at current telescopes (e.g. DST) couple of minute(s).
- How fast can be changed from one experiment to the next in general?
  - No change in light beam distribution: really hard to estimate.
    - Instrument dependent, depends on whether different lines/spectral regions are involved and those have been prepared for in the morning. Best case scenario: maybe couple minutes; there are always some manual steps involved like fine-tuning the pointing position and identifying an AO lock point.
  - Different light-beam distribution: not on the same day.
Construction of the DKIST is progressing on schedule.

Open-access to the community (NSF’s open-sky policy assumed) offering service mode operations and PI mode operations via a proposal process.

DKIST will offer a first-light facility instrument suite (multi-instrument operations) with unique opportunities.

Data sets/calibrated data from facility class instruments served to the community through NSO’s DKIST Data Center in Boulder, CO.