Building the control system to operate the Cryogenic Near Infrared Spectropolarimeter instrument for the Daniel K. Inouye Solar Telescope

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DKIST is the world’s largest ground-based solar telescope.
Under construction at Haleakala Observatory in Maui.
Operates in near-infrared (IR).
Will have 5 first light instruments.
Introduction: Cryo-NIRSP

- Under construction at the Institute for Astronomy at the University of Hawaii.

- Scientific aims:
  - Study the solar coronal magnetic field at near- to thermal- IR wavelengths over a large field of view.
  - Measure the full polarization state (Stokes IQUV) of spectral lines.
  - Will be able to study different solar phenomenon.
The Instrument

- **Cryogenic Near Infrared SpectroPolarimeter**
- Near-to-thermal-IR SpectroPolarimeter (SP) and Context Imager (CI).
- Critical optics are cryogenically cooled.
- Two IR cameras (1 for SP, 1 for CI).
  - Use Non-Destructive Readouts (NDRs)
  - Support 3 readout modes:
    - Fast up-the-ramp
    - Slow up-the-ramp
    - Line-by-line
The Instrument

- Delta Tau Power PMAC is used to move mechanisms and support real-time motion.
- Uses a polarizing modulator (to measure the Stokes angles), which supports 3 different modes:
  - Stepped
  - Continuous
  - Constant position
- Time Reference And Distribution System (TRADS) used for timing and synchronization.
The Software : Requirements

• Operational modes: CI, SP or CI+SP.
• Two primary task types: calibration & observes. Within these there are:
  – several calibration tasks (e.g. dark, gain, alignment, focus).
  – observe tasks.
• 3 different camera modes.
• 3 different modulator modes.
• A variety of different scanning patterns and configurations.
• Multiple wavelength filters and slit options.
The Software: Common Services Framework

• Built within the DKIST software framework using the Common Services model.

• Provides:
  – deployment
  – communication (notification, logging, connection & alarm services)
  – persistence support
  – application support
  – additional tools

• Uses a Container/Component Model
The Software: Structure

GUI
- Create a new Instrument Program (IP).
- Saves information to a DataSet Parameter (DSP).

Instrument Controller
- IP is submitted to the Instrument Controller (IC).
- This instigates the Instrument Sequencer (IS).
- The IS runs the IP by calling Jython scripts that call out to Java classes.

Instrument Sequencer
- IS manages the forwarding of instructions to the Mechanism Controller (MC), Polarizing Modulator Controller (PMC), Time Base Controller (TBC) and Detector Controller (DC).

TBC
DC
Camera Software System (CSS)
TRADS
CI
SP

MC
Power PMAC
Mechanisms

PMC
Modulator
Main Panel
-> IP Control
GUI : IP Control

- Instrument Program Control:
  - select task
  - observation mode
  - create a DSP
GUI: IP Control

**General Settings**

**CryoNIRSP Operation Mode**
- Spectrograph only
- Pickoff Mirror
- Pellicle
- Open

**Misc. Parameters**
- SP cold mask: On
- Feed relay Attenuation filter: Open
- FM2 Defocused delta: 

**Calibration Lamp**
- Continuum (ThAr)
- IR

**Wavelength**
- Filter: He I, Fe XIII
- Wavelength (nm): 1.080
- Order: 52
- Dispersion: 2.3874457016432... nm/mm

**Context Imager Filter**
- Wheel 1: 
- Wheel 2: 

Buttons:
- Save to Sequence
- Reset to Default
- Cancel Edits
**GUI : IP Control**

### General Settings

**Modulator**
- In: 0
- Out: 0

- **Spinning mode**: Stepped
- **Position angle (deg)**: 0
- **Modulation mode**: IQUV
- **Num. modulation states**: 8
- **Spinning rate (Hz)**: 1.120473

### Camera/Modulator Settings

**SP Camera**
- **Readout mode**: Fast UpTheRamp
- **Num. NDRs**: 1
- **Spectral binning**: 1
- **Spatial binning**: 1
- **Co-adds**: 1
- **Num. measurements**: 1
- **Exposure time (ms) for all frames of the ramp**: 100
- **Exposure rate (Hz)**: 1.12
- **Frame rate (Hz)**: 10.000000

**ROI (pixels):**
- Width: 2048
- Height: 2048
- Top-left position: 0, 0
GUI : IP Control

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<thead>
<tr>
<th>General Settings</th>
<th>Camera/Modulator Settings</th>
<th>Scanning Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telescope FOV</td>
<td>2.8' ○ 5' ○</td>
<td></td>
</tr>
<tr>
<td>Primary field scanning</td>
<td>FOV</td>
<td></td>
</tr>
<tr>
<td>Secondary field scanning</td>
<td>None</td>
<td></td>
</tr>
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**Spectrograph FOV Scanning**

- **Slit**: 52
- **Length**: 120''
- **Width on the Sun**: 0.15''
- **Pattern**: Raster
- **FOV**: Inner ○, Full ○, Restricted ○
- **1st Direction**: Horizontal ○
- **Step size (arcsec)**: 59
- **Num. scan positions**: 3
- **2nd Direction**: None ○
- **Step size (arcsec)**: 0
- **Num. scan positions**: 0
- **Restricted FOV center position**: 
  - Width: 0
  - Height: 0
- **Scanning overlap in spatial direction**: 0.00%
Running an observation

GUI

Instrument Controller

Instrument Sequencer

TBC

DC

Camera Software System (CSS)

TRADS

CI

SP

MC

Power PMAC

Mechanisms

PMC

Modulator
Running An Observation: The Setup Phase

- Mechanisms are moved to their defined positions by the Mechanism Controller.

- Camera/CSS set-up:
  - Creation of Data Acquisition Trees (DATs) – a structure to define when a camera should expose.
  - A DAT contains:
    - Camera configurations – parameters needed for the camera hardware.
    - Execution Blocks (EBs) – contains the timings.
Timing

• Primarily calculated within the tiers of an EB to define:
  – number of times to execute each tier.
  – the time that a single execution of a tier should take (a time slice).

• Must consider:
  – camera setup parameters.
  – synchronization with the spinning modulator.
  – synchronization with moving mechanisms if performing a scan (real-time motion).
Timing: Example

- Exposure time
- Camera setup/reset times
- Modulator move time
- Mechanism move time
Running an observation: **Execute phase**

- Involves submitting the configurations to the mechanisms/cameras:
  - real-time motion program is submitted to the MC.
  - global start time is calculated and submitted.
  - modulator configuration is submitted with rate, wait time, number of states, starting state etc.
  - submit to cameras the time to begin executing the DATs.
Conclusions

• The Cryo-NIRSP control and data processing system has been developed in line with the DKIST CSF to facilitate the complex design and operation of the instrument.

• Handles different observing modes, tasks, camera modes, scanning operations and modulator configurations.

• Combined with the data processing software it provides a full end-to-end solution allowing Cryo-NIRSP to function to its optimum ability.