Outline

• Introduction
  • Science & Science Ops.
  • Schedule
  • Software overview
    • Platforms, OS, Languages
    • Architecture

• Functionalities
  • Alignment (mechanical at installation)
  • Imaging/Nulling
  • Standby

• Special issues
The Instrument
LBTO Software Workshop

LBTO Software Workshop

LBTI: Imaging Exo-solar Planetary Systems

With the advent of large telescopes and progress with associated technology, planets around other stars are now detectable, both in principle and in reality. In order to further this search, NASA and The University of Arizona are undertaking the construction of the LBT Interferometer (LBTI). The project will use the Large Binocular Telescope as a testbed to develop nulling and Fizeau interferometry for this purpose. The Large Binocular Telescope will be the world largest and most sensitive telescope on a single mount with an aperture of 23 meters edge-to-edge. Nulling interferometry is a technique which cancels the overwhelming glare from a star by interference of light. This allows the detection of nearby planets or dust disks which would otherwise be obscured by the much brighter star. The technique is being studied in preparation for NASA’s Terrestrial Planet Finder Mission. The project is currently in the construction phase. In addition to searching for extrasolar planets the instrument will enable ultra-high resolution, wide-field imaging, allowing the LBT to create images with ten times the resolving power of the Hubble Space Telescope.

The LBTI instrument will be constructed and operated by the University of Arizona, Steward Observatory and funded by NASA through the Navigator Program at the Jet Propulsion Laboratory.

Simulated Geosynchronous Satellite Images

3-D Model of the LBTI

Instrument Highlights

- Observes giant planets, zodiacal dust as markers for presence of terrestrial type planets
- Enables Ultra-high resolution Fizeau Imaging (10x HST) on LBT
- Diffraction Limited Imaging at 1.0µm to 13µm
- 256x256 SiAs BIB Array (8-25µm), 50µm pixel pitch
- 1k x 1k HAWAII Array (3.5-5µm), 18µm pixel pitch
- Instrument commissioning in early 2008
- 100µJ Photometric Sensitivity @13µm
- 40x60 arc-second FOV in Imaging mode

Telescope Highlights

- Two 8.4m, f/1.1 Borosilicate Primary Mirrors
- 22.8 meter x8.4 meter effective aperture
- Tertiary Flats (2), 50x64cm, 4 degrees of freedom
- Adaptive Secondaries (2)

Adaptive Optics Highlights

- 911mm diameter, 1.6mm thick
- 672 Voice coil actuators
- 336 DSPs (60 GigaMAC computational power)
- 2.6kW Power consumption
- Glycol/H2O cooled to within 1°C of air temperature
- 1KHz Closed loop operations
Operations Overview

- Run as PI instrument
  - Always instrument scientist
  - Limited automation
- PI Science Program (NIREST)
  - Small team of observers
- NASA GO (Guest Observing)
  - Queued Observing program executed by Instrument Scientist
Schedule

• 2006
  • MMT Prototype testing
    • Software, Hardware, Techniques, Procedures
  • UBC Testing in the lab - Present - mid ’07
    • Internal software

• 2007
  • Fabrication of Nulling imager
  • IIF Software interface testing

• 2008
  • Delivery to Mt Graham in Jan ’08
  • Commissioning

• 2009 - 2017
  • Science Ops
Software Overview

• **Specifics**
  
  • *Industrial PC Based platforms*
    
    • *Primarily Linux OS*
    
    • *Some Windows black boxes*
  
  • **Language**
    
    • *C with mix of C++*
    
    • *TCL/TK, Perl*
    
    • *IDL (Limited use)*
Modes

- Initial Alignment
- Fizeau Imaging
- Nulling
- Standby

considered the same for this presentation
Initial Alignment

- Completed during the installation of LBTI on telescope
- Will require manual control of Active optics and other facility functions
  - Expect to accomplish this with engineering staff and TO/AAO support
- This flow diagram describes all modes of observing
- Let’s take a closer look at the 2 groups

Diagram Key

- LBTI Internal or LBTI-Facility interaction
- Facility Task (no LBTI)
Preparation

Observatory activities and tasks that are transparent to LBTI

- Internal wLBTI Alignment
- AO Systems Check
- Open Dome

Confirmation of bi-directional communications with IIF + others subsystems

The Instrument will require verification that tasks have been accomplished (TO/AOO interaction or status flags) to continue into observing phase

Directs the beam to central station, loads custom parameters and presets to optimize observing (e.g. pointing model). May be a command from LBTI controller.

Requirement:
Status related to “state of the observatory” available to instrument controller.
The Instrument will require verification that tasks have been accomplished (TO/AOO interaction or status flags) to continue into observing phase.
**Observe (Phase Control)**

**Internal adjustment of path length.**

- **Close Phase Loop**
- **Dither**
  - AGWs Stage moves
  - Open/Close AO Loop
  - Hexapod move
- **Nod**
  - wLBTI stages
  - Open/Close AO Loop
  - Mount move
- **Offload Path length**
  - AGW Z stage
- **Chop Enable**
- **Chop**
  - AO Shell move
- **Offload Disable/Modified**
- **AO Arbitrator**
- **Beamswitching (Chop Nod)**
  - wLBTI stages
  - Open/Close AO Loop
  - Mount move

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**Science Observing Actions (non-sequential)**

- Telescope/AO Preparation
- LBTI Internal Calibration/Setup
- LBTI/LBTO Coms Check
- Select LBTI
- Acquire Object
- Align System/Close AO Loop
- Close Phase Loop
- Observe
- Telescope/AO Preparation

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* Master = SX
Slave = DX

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LBTO Software Workshop - October 2-6, 2006
Observing Tasks

Dither

Chop

Nod

Beam switching

Path-length Offloading
Standby

- Monitoring
  - *Request some reflected memory to store key parameters so that Obs. Personnel can read the “State of the Instrument” to determine if any action needs to be taken*
  - *Could have a monitor window on any workstation*

- Maintaining readiness
  - *Could (should?) have lockout mode that would protect systems from inadvertently being turned on/off*

- Suggest that Observatory generate policies for this type of mode
<table>
<thead>
<tr>
<th>When</th>
<th>Item</th>
<th>Task</th>
<th>Timing Req.</th>
<th>Response</th>
<th>Systems Involved</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Select LBTI</td>
<td>Slow</td>
<td>ACK, Flag</td>
<td>Active optics (tertiary), wLBTI, Other?</td>
<td>Sets the LBTI as the observing instrument directing the beam into the central instrument position, adjusting other parameters that may be tailored for LBTI (e.g. pointing model)</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Collimate</td>
<td>N/A</td>
<td>N/A</td>
<td>AOS, AAOS</td>
<td>Facility “canned” routine</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Stealth Mode</td>
<td>Slow</td>
<td>Facility data</td>
<td>Facility, TO, AOO</td>
<td>Shut down noisy systems (e.g. blowers, chillers) to enable high sensitivity nulling. Can be accomplished initially via TO &amp; AO Operator.</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>LBTI Com Check</td>
<td>Slow</td>
<td>ACK</td>
<td>IIF, AAOS, TCS, wLBTI</td>
<td>Checks for com to targeted subsystems</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Align Science Array</td>
<td>Slow</td>
<td>N/A</td>
<td>Hexapod, wLBTI stages</td>
<td>Co-align WFSs and science arrays. May require access to WFS images.</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Science Array Focus</td>
<td>Slow</td>
<td>Completed request</td>
<td>AAOS, Hexapod</td>
<td>Fine tune focus via wLBTI z-axis stage (i.e. move WFS camera</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Nod</td>
<td>Medium</td>
<td>ACK, Complete</td>
<td>TCS, AAOS</td>
<td>Move the star off Science array FOV. Similar to Dither but for larger movements. Requires opening and closing AO loop</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Chop</td>
<td>Fast</td>
<td>N/A</td>
<td>AAOS, wLBTI</td>
<td>Trigger synchronized chop of DX &amp; SX secondaries</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Chop Enable/Disable</td>
<td>Slow</td>
<td>Ready</td>
<td>AAOS, wLBTI</td>
<td>Perform setup for chopping</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Dither</td>
<td>Medium</td>
<td>wLBTI stages</td>
<td></td>
<td>Scan object across Science array while maintaining AO loop closure</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Disable/Modify Offload</td>
<td>N/A</td>
<td>ACK, Flag</td>
<td>AO Arbitrator?</td>
<td>Disable optical offloading maintaining static mirror configuration. We would want to have this with adjustable parameters to specify which optics to enable or disable. Directed to AO Arbitrator?</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>Offload Path length</td>
<td>Slow</td>
<td>ACK</td>
<td>AAOS, Hexapod</td>
<td>Correct the path-length difference between SX &amp; DX sides. This occurs when LBTI path-length correction bandwidth reaches/nears limits.</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Beam switching</td>
<td>Medium</td>
<td>ACK</td>
<td>AAOS</td>
<td>Switch between the chopped stellar images within the science array FOV</td>
</tr>
</tbody>
</table>

**Notes:**

- **Timing:**
  - N/A = Don’t care
  - Slow = 10s < t < 1s
  - Medium = 1s < t < 0.1s
  - Fast = 0.1s < t < 0.001s

  **Abbreviations:**

AAOS = Adaptive Optics Sys.
AOS = Active Optics Sys
TCS = Telescope Control Sys
wLBTI = LBTI WaveFront Sensors (== AGW units)
Telemetry Data

- **Vibration**
  - 100 Hz or better

- **Standard Items**
  - *Time, pointing, weather, tracking errors, etc...*
  - *State of the observatory*
    - e.g. Dome open, cooling fan speeds, stealth fans

- **Tech Viewing Camera and WFS images**
  - *WFS for alignment purposes (not continuous)*
  - *Tech Viewing Camera continuously*
  - *Sub-Full frame rate (~2-15Hz)*