The MROI fast tip-tilt correction and target acquisition system

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Outline

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   - Thermal design
   - Electronics design
   - Software design
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   - Opto-mechanical testing
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MROI fast tip-tilt system
System Role

- One system per UT, mounted on Nasmyth optical table
- Uses “visible” light 350–1000 nm; other colours sent to beam-combining laboratory
- Fast tip-tilt correction using UT actuated secondary mirror
  - Tip-tilt zero point on FTT camera defined at start of night as part of interferometer automated alignment
- Narrow-field (60″) target acquisition
- Integrated with MROI supervisory control system
Key Requirements

- Acquisition and fast tip-tilt correction modes
- **Limiting sensitivity** $\geq 16^{th}$ magnitude
- **Zero-point stability** $\leq 0.060''$ on sky for $\Delta T = 5$ °C
- $T - T_{\text{ambient}} \leq 2$ °C for components on Nasmyth optical table; power consumption $< 250$ W
- Time-varying objective point for dispersion compensation and/or off-axis reference star
- Continuous streaming of diagnostic data to ISS
Design Overview

[Diagram showing the MROI fast tip-tilt system]

- Telescope beam
- Corner-cube reflector mount
- ECF alignment beam
- Dichroic mount
- Focusing optic
- Detector
- Tip-Tilt Control System HW & SW
- Local Archive
- Laptop
- FIT Actuator Controller
- ISS Data Collector
- Unit Telescope Mount
- ISS

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• Transmissive design with custom cemented triplet lens
  • Angular stability tolerance $20 \times$ that for OAP mirror
  • Temperature-dependent focal length compensates for expansion of steel table top
Opto-mechanical design (i)

- Monolithic, symmetric mounts
- “Material compensation” to keep lens centred in its mount
- Construct mounts from Aluminium alloy to minimize thermal equilibration time
  - Costs of invar not justified, worse thermal conductivity almost cancels lower CTE
Opto-mechanical design (ii)

- Common baseplate to mitigate effects of Nasmyth table deformations
- Separate camera mount to avoid transmitting heat and vibration to optics
- Baseplate and camera mount have kinematic interfaces to Nasmyth table to accommodate differential expansion
• Camera thermal enclosure:
  • Maintains camera above 0 °C and non-condensing, surface temperature within 2 °C of ambient
  • Uses convenient electronics cabinet cooling loop
  • Mechanically isolated from camera mount
• In UT enclosure electronics cabinet:
  • Rack-mount PC
    • Andor camera interface PCI card
    • Analogue/digital to fast tip-tilt mirror controller
  • EMCCD Peltier power supply
  • $2 \times$ USB Labjack analogue/digital I/O
    • Each includes $I^2C$ bus to temperature and humidity sensors
  • Custom interface circuit board
  • Power supply
Software components

- **Environment controller**  Thermal control/monitoring of camera enclosure
- **System controller**  Hard real-time fast tip-tilt loop closure, target acquisition
- **Control/display GUI**  Live image/monitor data display, data recording
- **Analysis GUI**  Data visualization and analysis
System controller real-time architecture

- Based on Xenomai — kernel-space and user-space hard real-time contexts that coexist with Linux
- Open-source Andor driver modified to provide parallel real-time access to pixel data
- Uses floating point in user-space real-time context
Camera readout testing

- We have measured frame rate, latency, noise for preliminary $23 \times 23$ pixel custom readout mode
- Andor are developing a $32 \times 32$ pixel version
  - Larger FoV to accommodate field rotation when using off-axis reference object
  - Andor report 1 kHz frame rate and $\sim 1$ ms latency
  - Latency is consistent with our model for the readout timing
- We have measured total interrupt and compute latency as insignificant 38 $\mu$s
### Individual component testing

<table>
<thead>
<tr>
<th>Element</th>
<th>Degree of freedom</th>
<th>Measured motion</th>
<th>Required stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dichroic/mirror mount</td>
<td>Piston stability</td>
<td>100 nm</td>
<td>&lt; 500 nm</td>
</tr>
<tr>
<td>Dichroic/mirror mount</td>
<td>Tilt stability</td>
<td>≤ 100 nm</td>
<td>45 nm</td>
</tr>
<tr>
<td>Lens mount</td>
<td>Shear stability</td>
<td>≤ 250 nm</td>
<td>~ 350 nm</td>
</tr>
</tbody>
</table>

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• R is reference beam port
• 1 & 2 are intermediate test ports
• 3 is output port to FTT camera
• Large excursions when $\Delta T$ between optical table top and bottom skins changes rapidly

• At other times, for several-degree temperature changes, motion is $\sim 2 \times$ requirement
Conclusions

- Prototypes of critical system components have been built and tested
- Laboratory test results validate design approach
  - Optomechanical stability within (at least) factor 2 of demanding requirements already demonstrated
  - Preliminary test results predict 43 Hz closed loop bandwidth
- Final design and fabrication of first system underway
- Preliminary version of real-time control software complete and working

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