Precision Angle Monitors (BCAMs) for Real-Time Telescope Alignment

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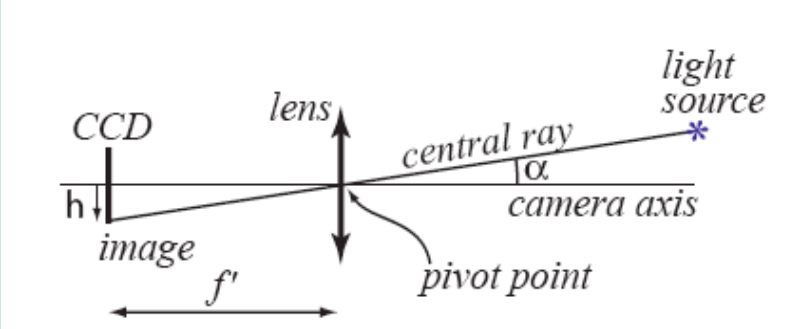
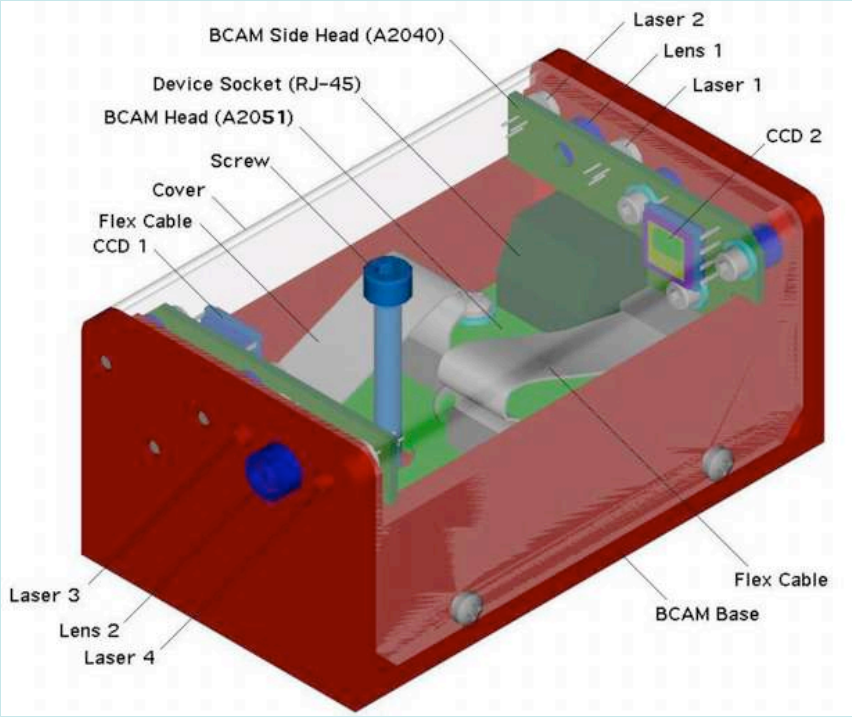
Motivation

- The Blanco mirror is known to move in its cell.
  - Repairs and modifications being undertaken to address this problem.
  - Want to verify that these are successful.
- Real-time information on the relative position and tilt of the mirror and camera can allow us to adjust the camera position and recover the best possible seeing.
- General desire to understand the instrument as well as possible.

A Possible Solution: Angle monitoring with BCAMs

- Brandeis CCD Angle Monitor
- Developed for alignment of ATLAS muon system; also used at ALICE (100's of devices in system).
- Basic BCAM contains:
  - CCD camera
  - Pair of red lasers
  - Sockets for kinematic mount
  - DAQ interface
- Pairs of BCAMs image each others' lasers and monitor the spot positions.
- 5 μrad angular resolution, i.e. 25 microns at 5 meters
- Can fit in small openings and look down narrow corridors.





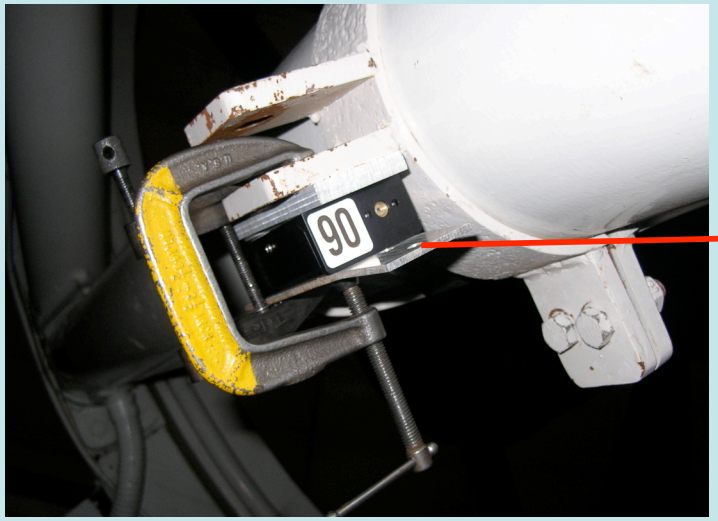
Other BCAM details

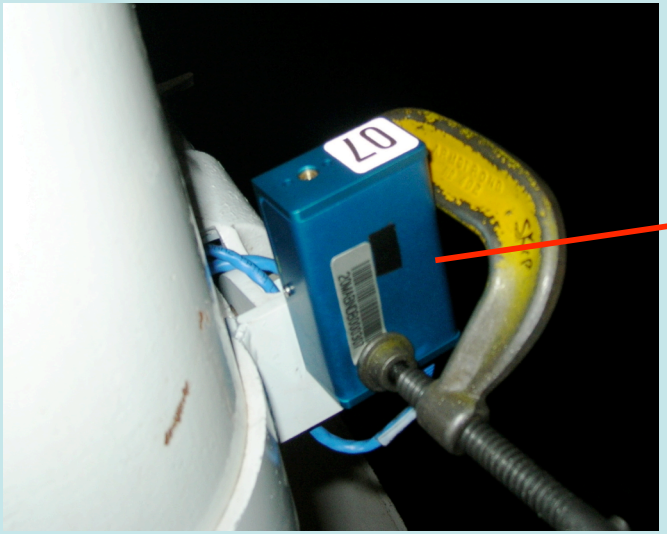
- 72 mm focal length lens
- 344 x 244 10 μm pixels on CCD
- Lasers flash for ~1.5 μs at configurable intervals (5 seconds to hours).
- Centroid-finding precision on CCD of ~0.4 μm
- Relatively easy to align… field of view of camera is 30x40 cm at 10m.
- Can in principle hook hundreds of BCAMs into a single system.
- Cost about $300 each.
- Other devices plug-and-play with the same DAQ system:
  - RASNIKs
  - Temperature sensors
  - Scalable: 5500 devices in the ATLAS monitoring system.

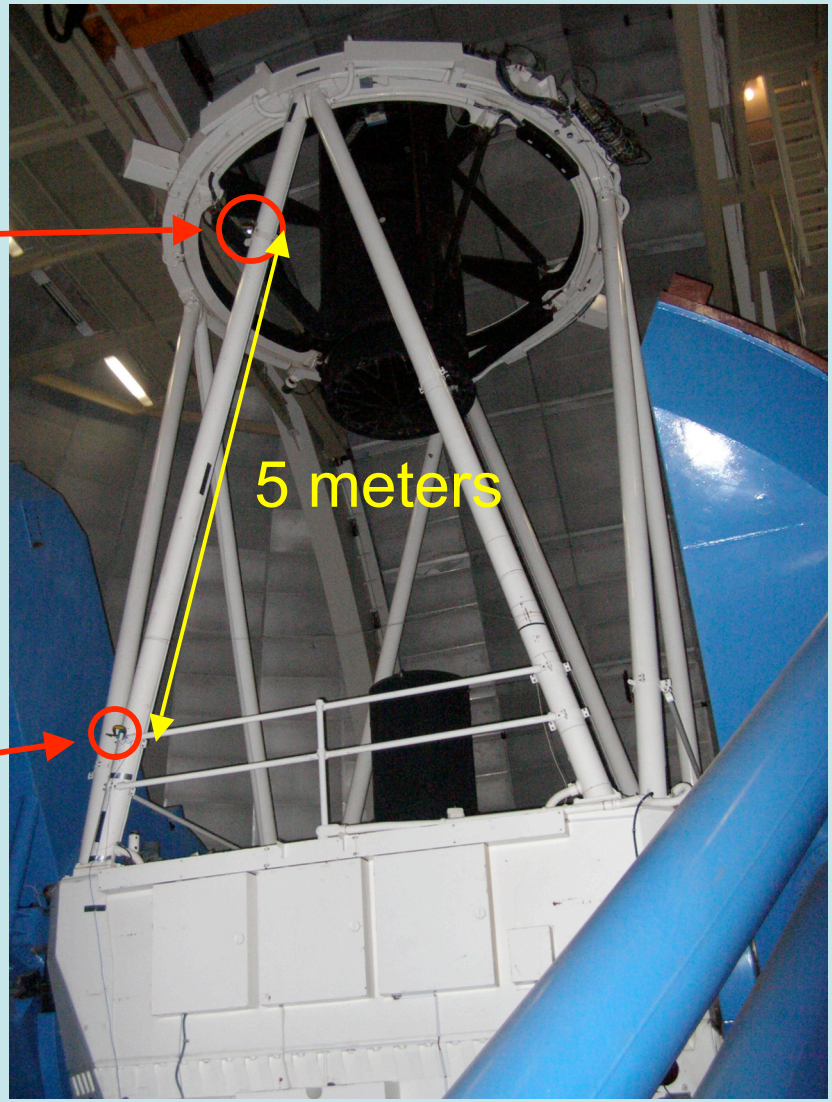
Goals of the Aug. 2005 Mayall Tests

- Establish a proof-of-principle that we can make these devices work.
- Try to measure something that will move!
- Not possible to attach to optical elements on this occasion--chose a support truss that was likely to show some deflection as telescope pointing changes.

BCAM Setup at Kitt Peak

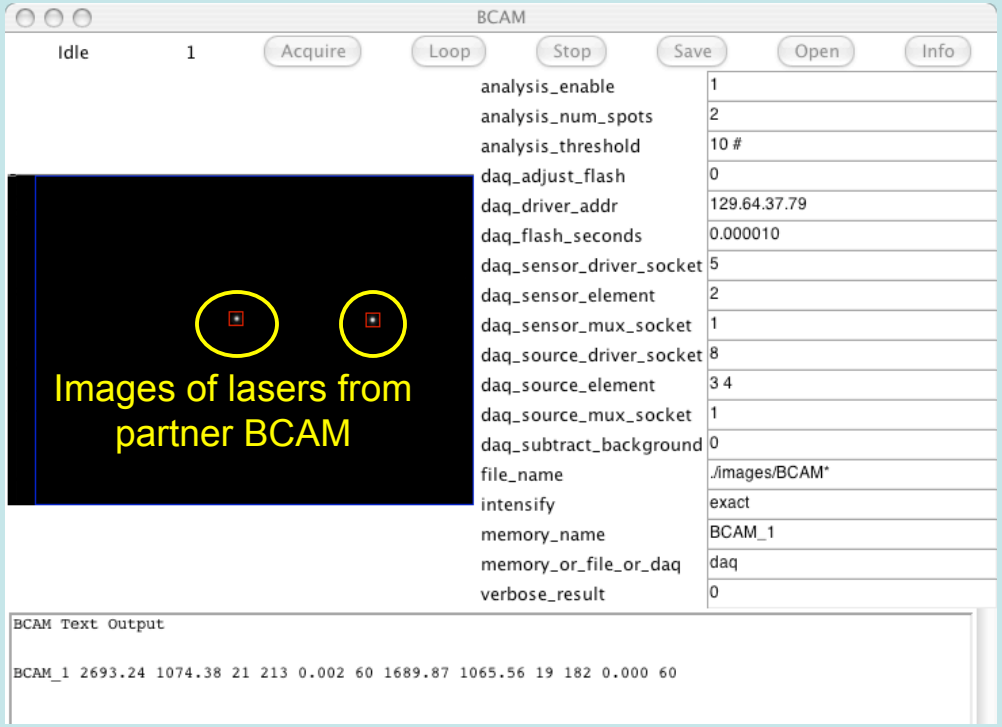






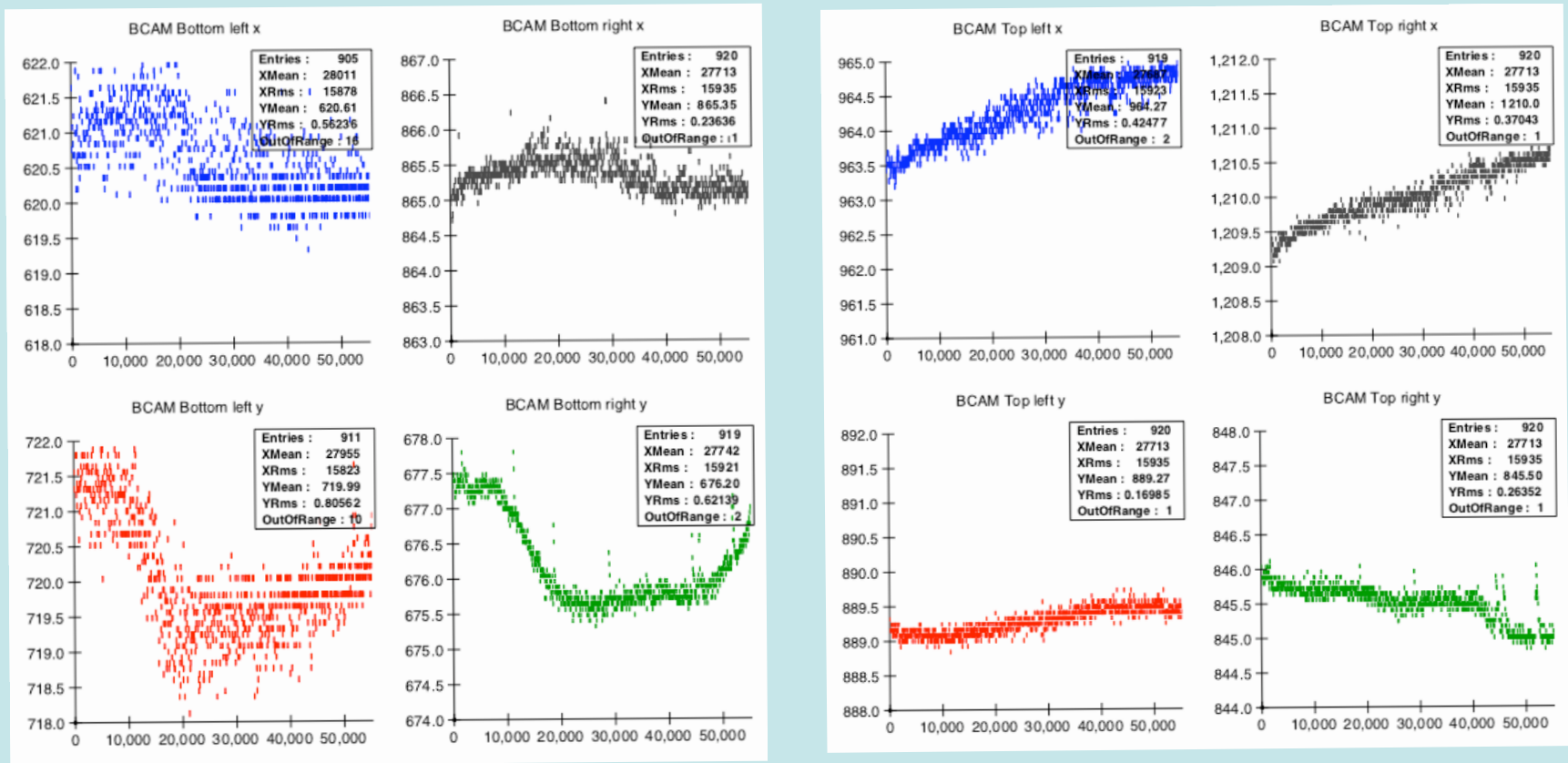
Ethernet-based DAQ system: configuration, operation, and analysis from anywhere in the world

DAQ hub in Cassegrain cage



First test: watch as the telescope remains stationary overnight

Position on CCD (microns)



Time (s)

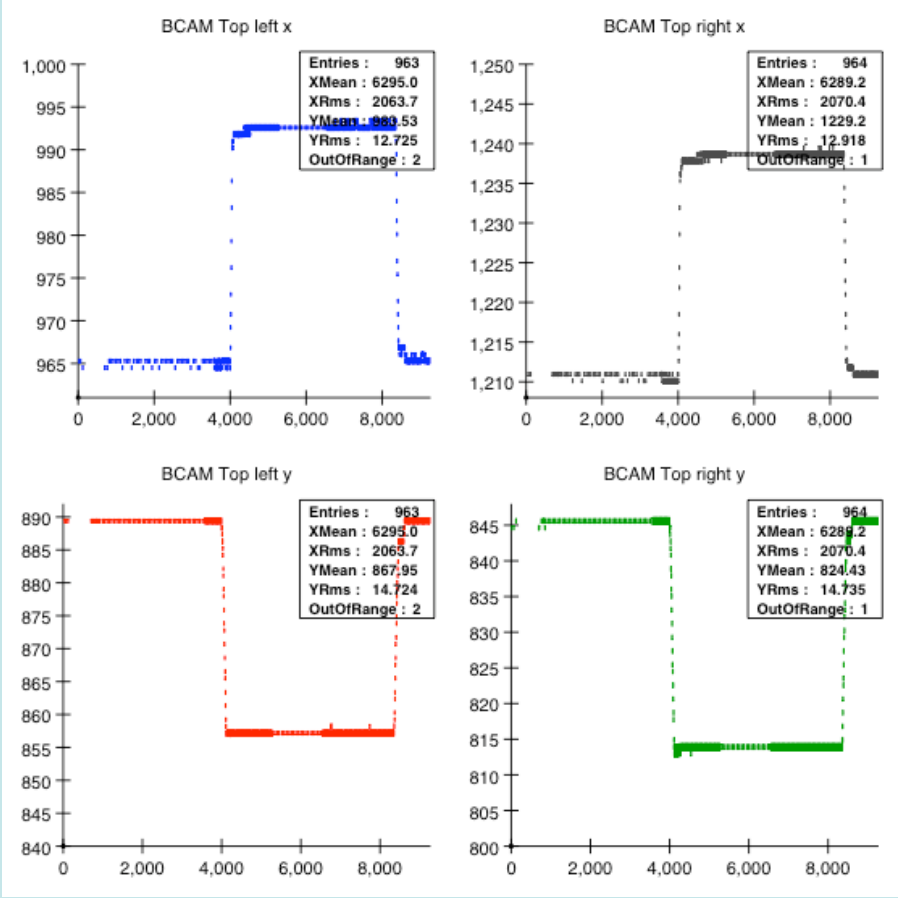
1 μm on CCD ≈ 50 μm relative motion between BCAMS

x = radial, y = transverse to truss

Sensitive to motion at the ~10-15 micron level with one pair of BCAMs

Next: Move the telescope around

- Begin with pointing at eastern horizon
- Slew to zenith, sit there for ~1 hour, then rotate back.
- Note difference in vertical scales: movements of about 2mm.
- Truss returns to original position; no “sticking”.

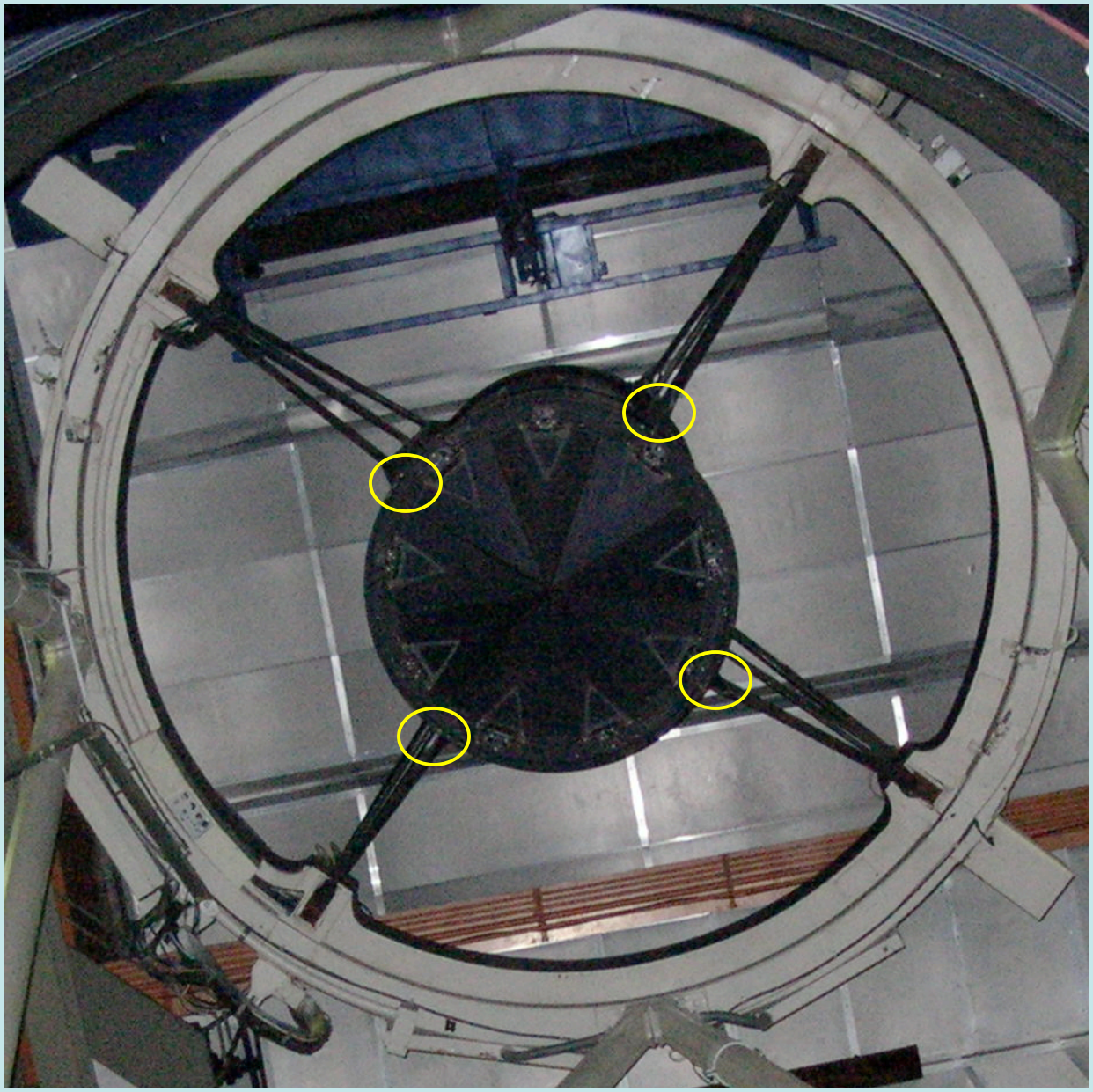


October 2005 visit to CTIO

- Very useful to see the instrument in a disassembled state
- Identified possible locations for BCAMs
- Made contact with key scientific/technical staff.

Could place BCAMs around this ledge

BCAMs on chimney base could watch BCAMs placed beneath spiders



Summary and Next Steps

- BCAMs successfully operated and used to measure interesting behavior of the Mayall support structure.
- Over anticipated lever arm at CTIO, expect to be sensitive to displacements on the order of 10 microns.
- It is desirable to apply this technique to the optical axis itself
  - Mount some on the chimney base.
  - Mount a few more on the prime focus cage.
- Need to define requirements on optical-mechanical alignment.

Implementation Issues

- Use offline (to establish range of motion) or during observing (between exposures) to provide feedback for corrector alignment?
- How many devices and where?
  - Should follow from alignment requirements
  - Surveys can establish the most critical degrees of freedom to measure.