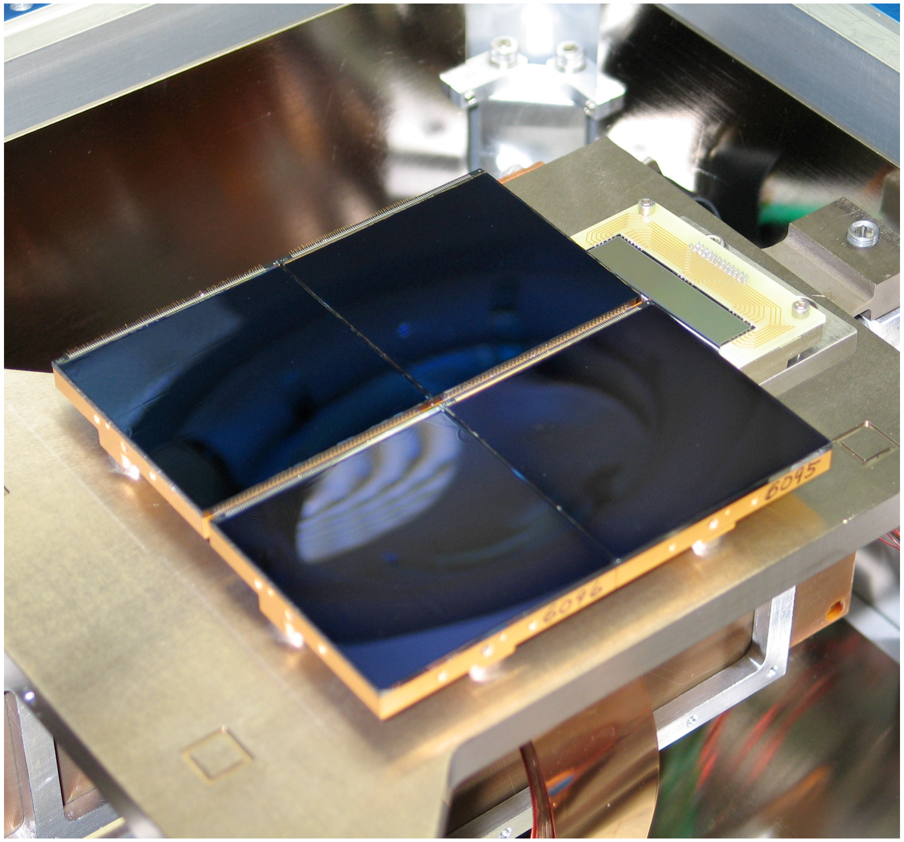
Optimizing Orthogonal Transfer Array CCDs for Science

David Sawyer[a], George Jacoby[a], Steve Howell[a], Daniel Harbeck[b]

[a]National Optical Astronomy Observatory, 950 N. Cherry Ave., Tucson, AZ 85719
[b]WIYN Observatory, 950 N. Cherry Ave., Tucson, AZ 85719

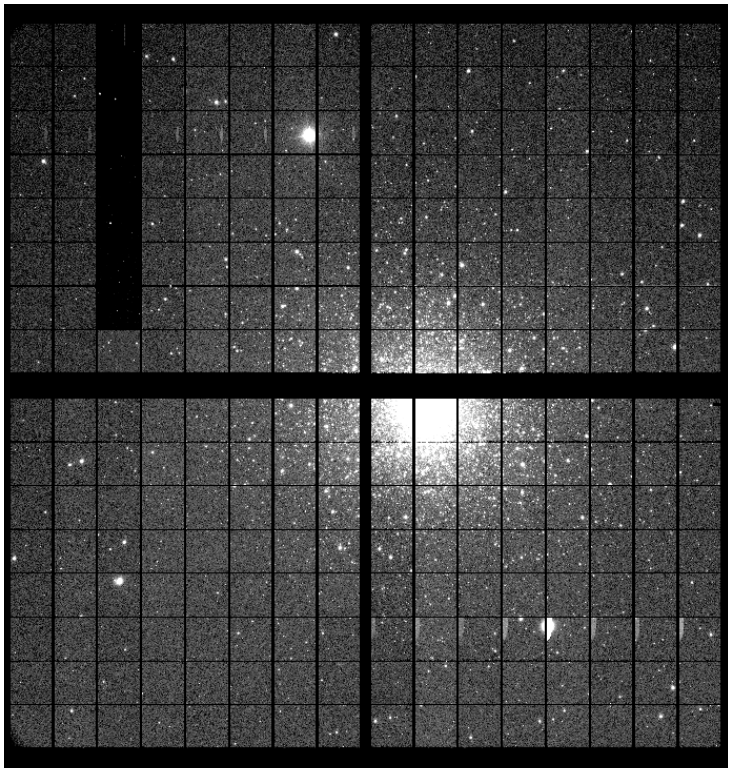
This poster details the OTA optimization lessons learned during the effort to prepare the ODI prototype instrument, QUOTA, for on-sky science observing and evaluation runs in August and October of 2008. Unlike typical CCDs, the OTAs need to be optimized for different operating modes, including fast guide star readout, charge shifting during science integration, and science readout. To achieve optimal performance for the different operating modes required evaluation of the various performance trade-offs, determining the best compromised solutions, and in some cases, dynamically changing voltages and waveform timing at the guide rates (20-30 Hz). This poster describes the performance issues encountered and describes the solutions implemented to produce successful scientific results.

QUOTA Test Camera



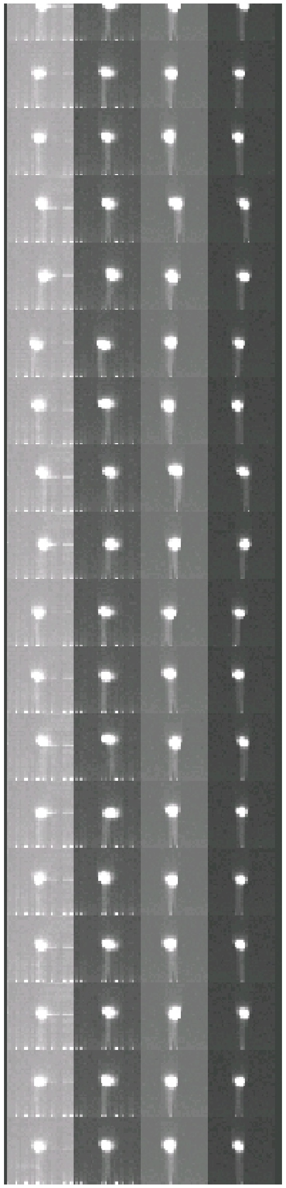
The image above shows four OTAs installed on the QUOTA focal plane. The image to the right is 120 sec exposure of M15 in the SDSS r' filter, taken 31 July 2008 using QUOTA. This image has overscan subtraction done, but no other post-processing.

- Prototype for WIYN One-Degree Imager
  - Used for evaluation of OTA detectors and understanding of operational issues
- Quad of OTAs (8K x 8K pixels)
- 64 Cells per OTA = 256 CCDs
- 32 Video Channels
- 30 Hz guide rate for up to 32 guide stars



OTA Operating Modes

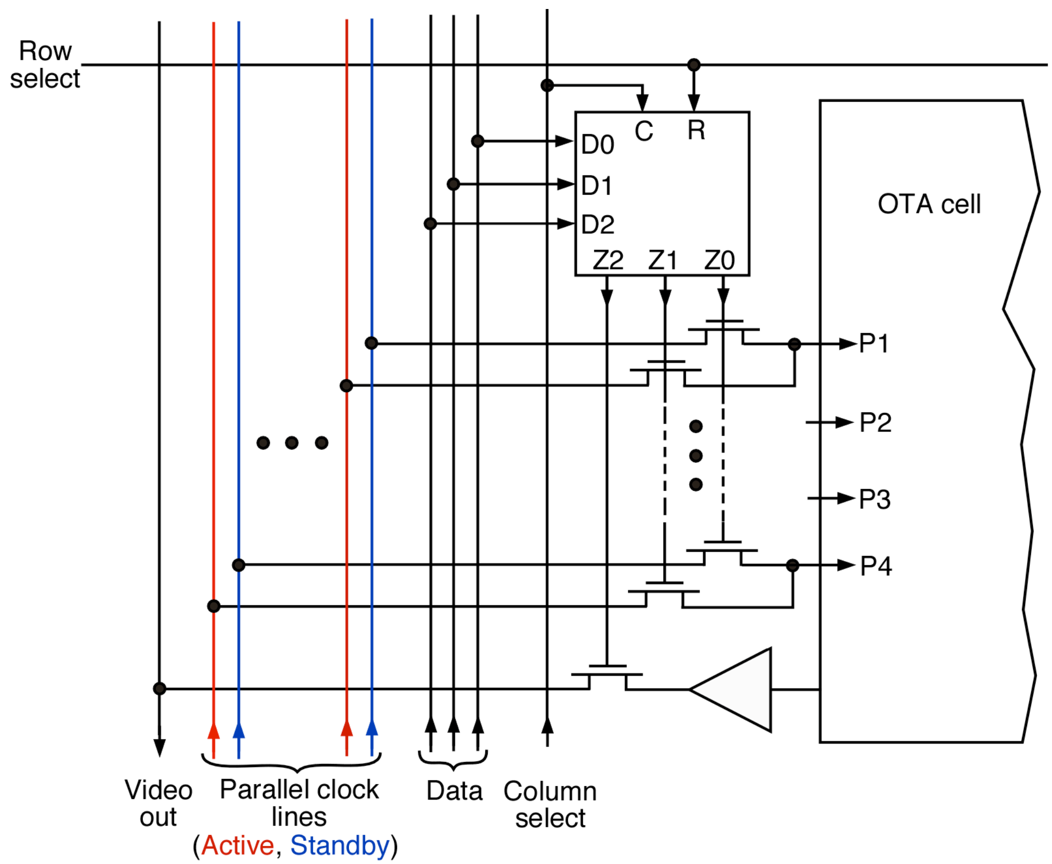
- Guide Mode
  - OTA cells containing guide stars are read out rapidly during science integration (8 GS per OTA maximum)
  - Typical guide parameters of 20 ms integration time, 2x2 binning, 64 x 64 pixel ROI => 20 Hz guide rate
  - After the guide integration, the guide ROI is rapidly shifted to output corner of the cell using horizontal (H) and vertical (V) parallel clocking, then
  - The guide ROI is read out using normal CCD clocking, except reverse serial clocking is used to clear the needed subset of the serial register
- Shift Mode
  - Occurs during the GS integration, typically takes 4 ms
  - After each GS readout centroids are measured and shift corrections are calculated, then
  - Shifts are applied to the science cells by clocking parallels in H and V.
  - Shifts applied to science cells can be different for each OTA (local) or common to all OTAs (global)
- Science Readout
  - At the end of the science exposure each OTA cell is readout as a normal CCD (32 cells at a time, 8 per OTA)



The Optimization Challenge: Parallel Clocks

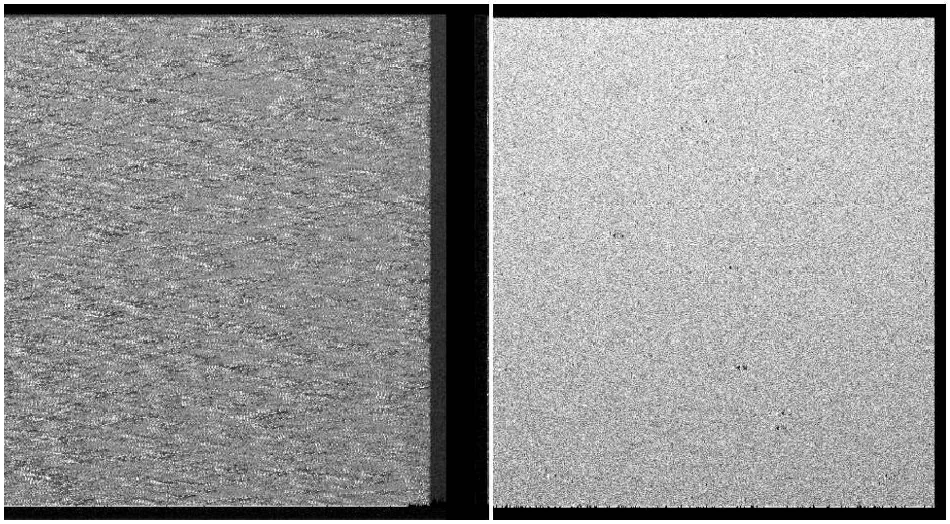
- The OTAs are very sensitive to the voltage and timing settings of the parallel clocks.
- The different operational modes of the OTA can produce different performance issues (and thus require different optimization solutions)
- The parallel-clock related performance issues encountered include:
  - Increased noise in science images from OT shifting (“shift noise”)
  - Horizontal banding in fast-read guide images
  - Poor vertical charge transfer efficiency
  - Excess charge in science images
  - Pass transistor glow

OTA Parallel Clock Control



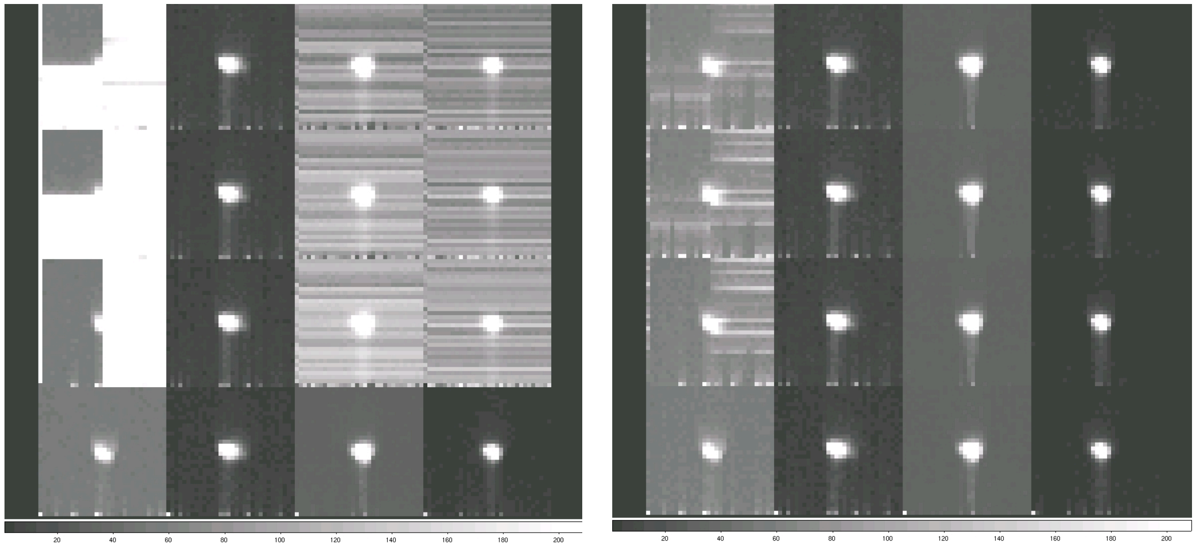
The parallel clocks have two states, active and standby, that are controlled through logic circuitry on the CCD. When a cell is in the active state the parallel clocks are connected to the clock drivers P1-P4. When in the standby state, the cell has the clock phases held in the charge collection state (P1=P4=Low voltage PL, P2=P3=High voltage PH).

Shift Noise



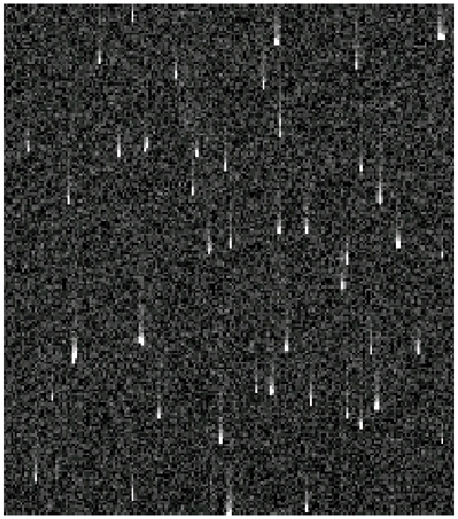
Comparison between a poorly optimized and well-optimized OTA science cell after integrations with OT shifting enabled. The cell on the left has the parallel clocks optimized for guiding (high voltage PH is set to 8V and/or the parallel clock overlap set to 3 us) and a Moiré-like noise pattern becomes evident. The cell on the right has PH increased to 10V and the parallel clock overlaps increased to 30 us. The higher PH voltage and longer overlaps needed to optimize the OT shifting are not desirable for the other OTA operating modes and so the values must be dynamically changed (optimized) for the different modes to avoid performance compromises.

Banding in Guide Frames



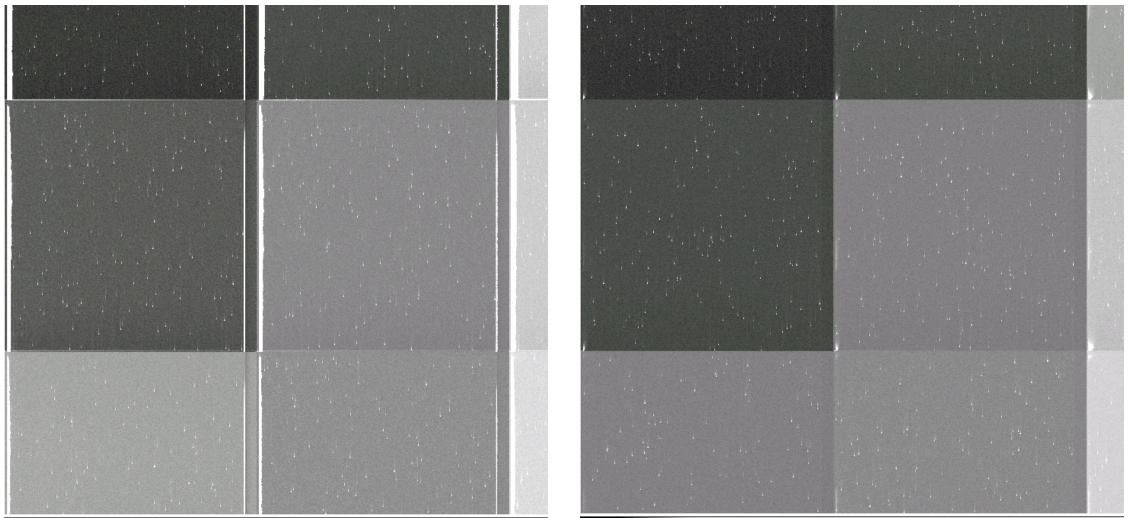
Comparison between guide star frames showing the horizontal banding that is generated during the fast parallel shifting of the guide box to the output corner of the OTA. The image on the left has the parallel voltages set to the OT shift optimized level (10V), whereas the image on the right has the parallel high voltages reduced by 1 volt. During initial OTA performance evaluation the OTAs were optimized by finding the best compromise voltage, but ideally the PH voltage should be adjusted dynamically depending on the OTA operational mode.

Vertical Charge Transfer



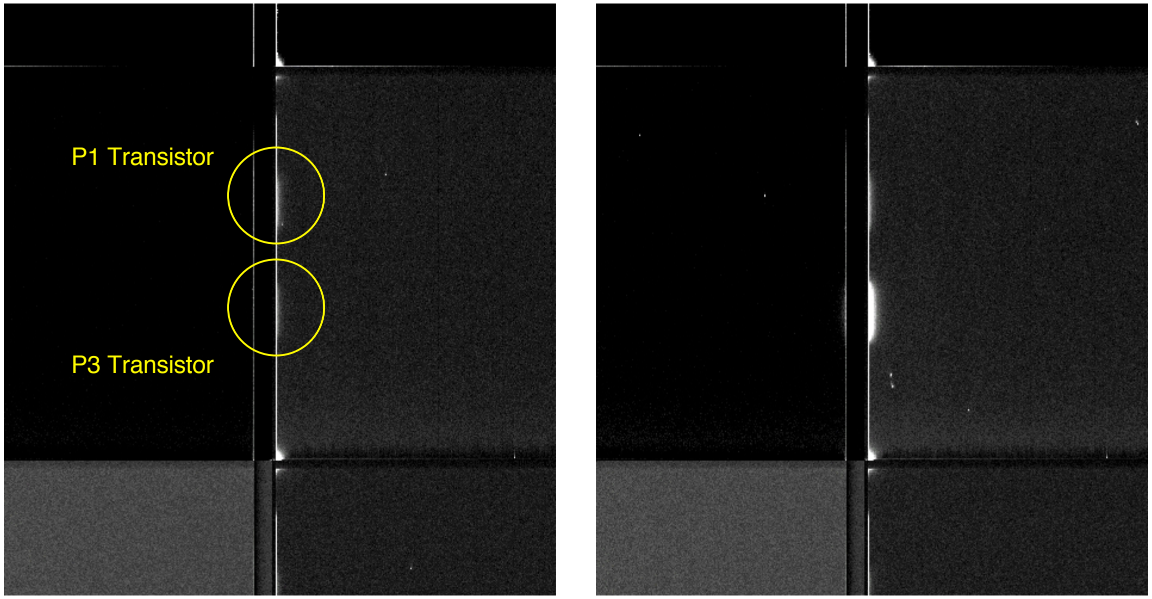
X-Ray images showing the effect of changing the high voltage setting of the parallel clocks (PH) on the vertical charge transfer efficiency. The image on the left has PH set to 11V, the image on the right has PH set to 8V.

Excess Charge



Images of OTA science cells showing the excess charge along the beginning columns of each cell that develops when the parallel clock high voltage is set to the OT shift optimization levels (10V) during science read out. The image on the right has PH reduced by 1V.

Pass Transistor Glow



Some OTAs exhibit glowing pass transistors. These images are 120 second dark frames showing close-ups of the left edge of an OTA cell where the pass transistors are located. The P3 pass transistor is connected to the parallel high (PH) voltage and becomes very evident when the high parallel voltage is increased from 8V (left) to 10V (right). The P1 pass transistor also shows a slight glow, but is connected to the parallel low (PL) voltage and thus is not affected by the change in PH. The output transistor glow evident in the bottom left corner of the cell is not related to parallels.

Tuning the OTAs: What we did to achieve science quality results

- Implemented dynamic parallel clock overlaps
  - Guide mode = 3 us overlap
  - Shift mode = 30 us overlap
  - Science readout = 10 us overlap
- Implemented dynamic serial clock overlaps (not discussed in this poster since this was for improved readnoise)
  - Guide mode = 300 ns
  - Science readout = 500 ns
- Adjusted PH voltages to best compromised static value (typically 8-9V) on a per OTA basis. We did not readily have the ability to dynamically change the clock voltages.
- In some cases, slight adjustments to the parallel low voltage (typically 1 V) was made to improve the performance.

Optimization Lessons Learned

- The OTA performance is very sensitive to the parallel clock settings.
- The OTAs can behave very differently for each of the operating modes (guide star readout, OT shifting, and science readout) and thus each mode must be optimized independently.
- All operating modes need to be evaluated when any voltage or timing change is made.
- Some OTAs are more sensitive to the parallel clock settings than others.
- Ideally, the parallel clock parameters should be changed dynamically by the CCD controller.
- Performance compromises may have to be made between the different operating modes.