Fiber Positioning Accuracy from Fiber Dithering
DESI-5572

Edward F. Schlafly

Lawrence Livermore National Laboratory

Commissioning Acceptance Review
March 17, 2020

Prepared by LLNL under Contract DE-AC52-07NA27344.

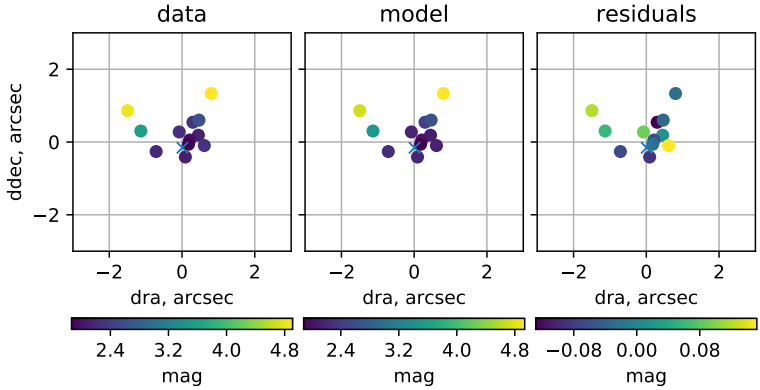
Fiber Positioning Accuracy: Requirements

- DESI must be able to position within a small fraction of a fiber diameter (107 μm) to avoid significant unnecessary light loss.
- Requirements, DESI-579:
  - IN.FPA.2003: < 10 μm 2D RMS positioning accuracy
  - IN.FPA.2004: < 35 μm 2D absolute positioning accuracy
- Assess performance via fiber dither analysis, locating light centroids relative to fibers
- We focus on the RMS accuracy
  - Fibers with large offsets are inevitable in the dither analysis (blends...)
- Plate scale of 70 μm/arcsec used to convert from arcseconds (measured in dither analysis) to microns

Fiber Positioning Error Contributions

- Positioner move precision (currently < 5 μm 2D, see Kevin's talk)
- FVC centroid accuracy (currently ~ 3 μm 2D, see David's talk)
- FVC-to-sky transformation
  - Largest current contribution, presently ~ 11 μm 2D
- The dither analysis here measures a mixture of all of these, but is most sensitive to the FVC-to-sky transformation

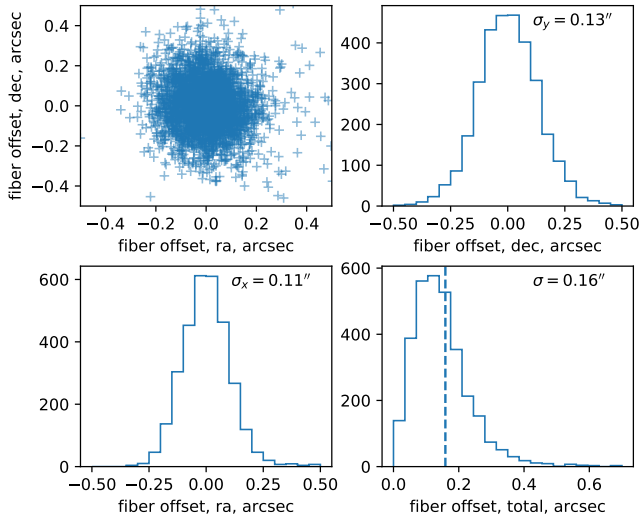
Fiber dither analysis



- Fibers dithered around the expected location of the source
- Centroid gives the location of the source
- Complications like varying FWHM, transparency, pointing are modeled
- $\sim 1\ \mu$m RMS precision in good conditions

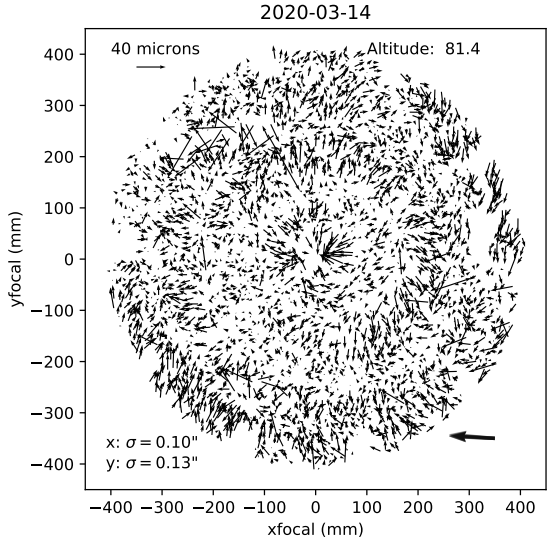
Fiber positioning accuracy results

- Results for one dither sequence
- 11 microns RMS (2D) (1.1× requirement)
- Arrows show derived fiber positioning errors
- High frequency, radial distribution; residual FVC-sky transformation error?
- Dramatic improvement
  - 10″ RMS on Jan 1
  - 1″ RMS on Jan 23
  - 0.4″ RMS on Feb 8
  - 0.16″ RMS on Mar 6



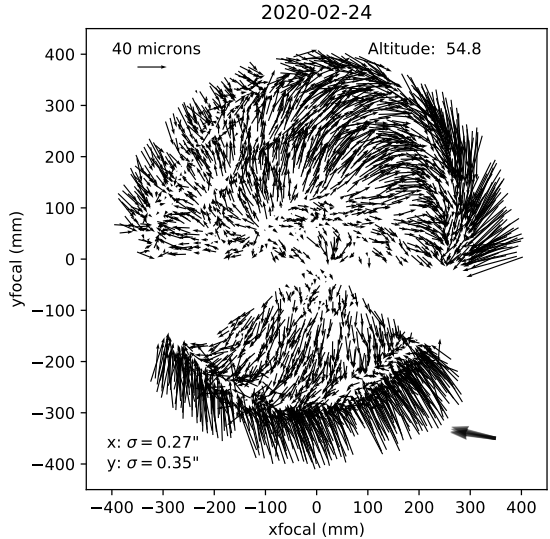
Fiber positioning accuracy results

- Results for one dither sequence
- 11 microns RMS (2D) (1.1× requirement)
- Arrows show derived fiber positioning errors
- High frequency, radial distribution; residual FVC-sky transformation error?
- Dramatic improvement
  - 10″ RMS on Jan 1
  - 1″ RMS on Jan 23
  - 0.4″ RMS on Feb 8
  - 0.16″ RMS on Mar 6



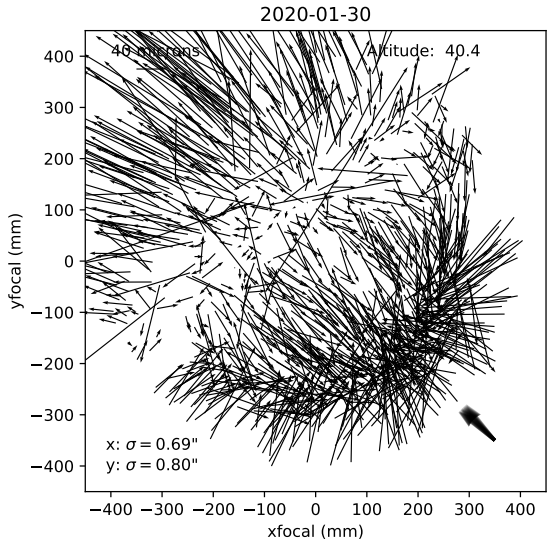
Fiber positioning accuracy results

- Results for one dither sequence
- 11 microns RMS (2D) (1.1× requirement)
- Arrows show derived fiber positioning errors
- High frequency, radial distribution; residual FVC-sky transformation error?
- Dramatic improvement
  - 10″ RMS on Jan 1
  - 1″ RMS on Jan 23
  - 0.4″ RMS on Feb 8
  - 0.16″ RMS on Mar 6



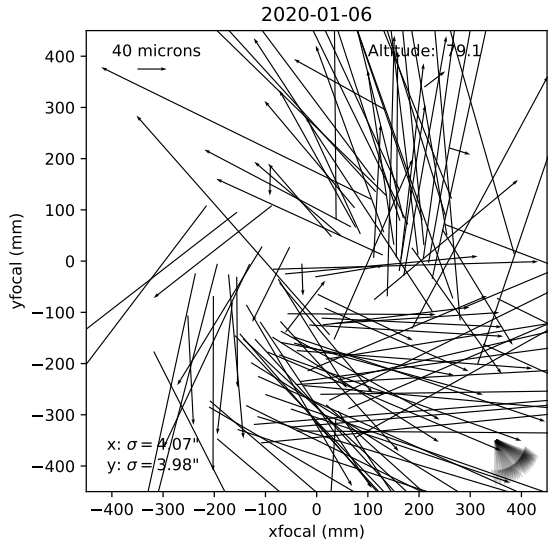
Fiber positioning accuracy results

- Results for one dither sequence
- 11 microns RMS (2D) (1.1× requirement)
- Arrows show derived fiber positioning errors
- High frequency, radial distribution; residual FVC-sky transformation error?
- Dramatic improvement
  - 10″ RMS on Jan 1
  - 1″ RMS on Jan 23
  - 0.4″ RMS on Feb 8
  - 0.16″ RMS on Mar 6



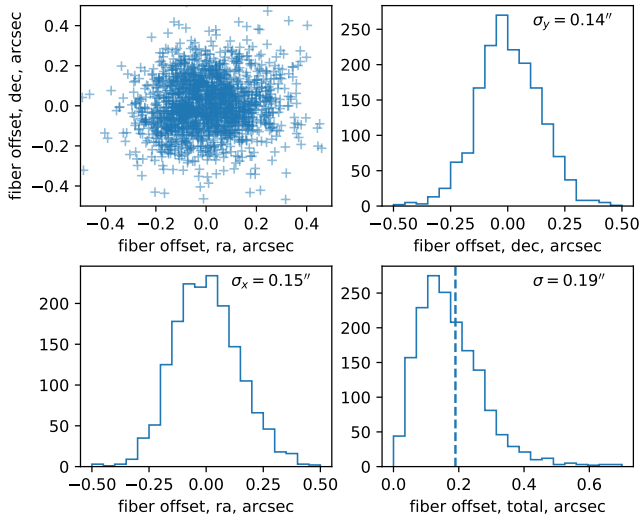
Fiber positioning accuracy results

- Results for one dither sequence
- 11 microns RMS (2D) (1.1× requirement)
- Arrows show derived fiber positioning errors
- High frequency, radial distribution; residual FVC-sky transformation error?
- Dramatic improvement
  - 10″ RMS on Jan 1
  - 1″ RMS on Jan 23
  - 0.4″ RMS on Feb 8
  - 0.16″ RMS on Mar 6



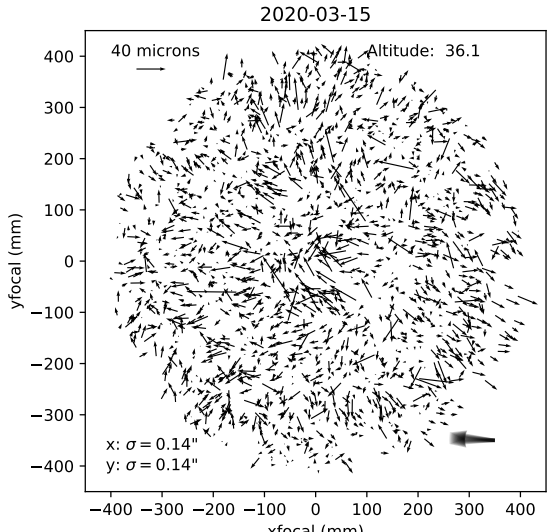
Positioning performance with elevation

- L3.3.2: fiber positioning requirement must be satisfied up to airmass 2
- Sequence at airmass 1.7 (54° from zenith)
- 13 μm 2D RMS
- Very similar performance to 11 μm 2D RMS at higher altitude
- Salt and pepper noise expected to come from uncertainty in dither analysis



Positioning performance with elevation

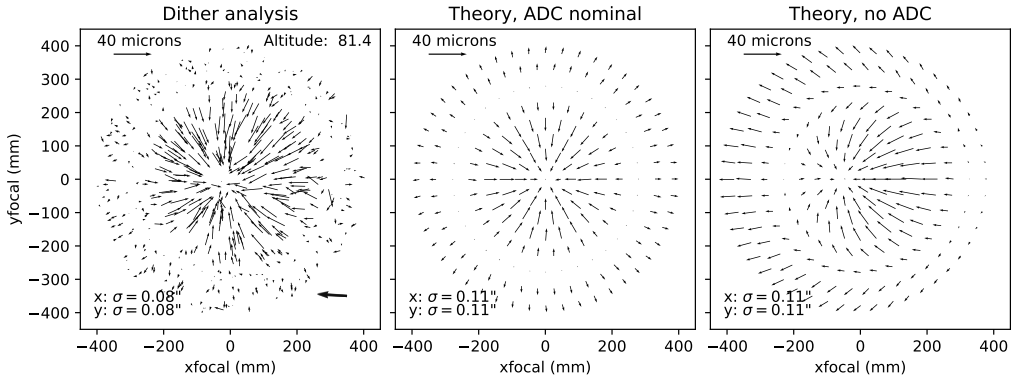
- L3.3.2: fiber positioning requirement must be satisfied up to airmass 2
- Sequence at airmass 1.7 (54° from zenith)
- 13 μm 2D RMS
- Very similar performance to 11 μm 2D RMS at higher altitude
- Salt and pepper noise expected to come from uncertainty in dither analysis



Testing the ADC via dither analysis

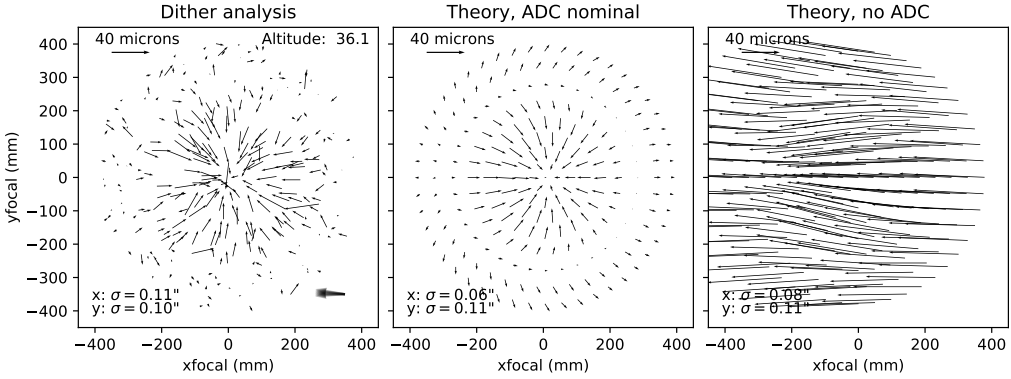
- The fiber dither analysis gives the centroid of the light in the focal plane.
- We can measure this centroid as a function of wavelength.
- The variation in centroid with wavelength tests both
  1. optical design
  2. ADC performance

Testing the ADC: 9° zenith distance



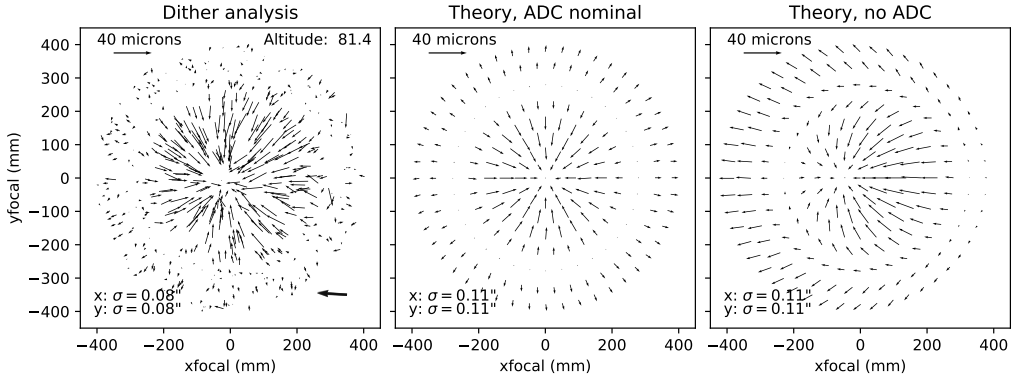
- Arrows point from Z centroid to B centroid
- Left: observed, middle: theory, ADC correctly positioned; right: theory, no ADC
- Good agreement between observed & correct ADC; the ADC is working.

Testing the ADC: 54° zenith distance



- Similar performance at 54° zenith distance
- $> 1''$ field shift would be present, absent an ADC!

Conclusion



- Transformation of FVC images → sky coordinates accurate to 0.16″ (11 μm 2D)
- 1.1× requirement (IN.FPA.2003)
- Similar performance for altitudes $> 30^\circ$
- Residuals well measured; could be incorporated into modeling