FIU optical design status 5/11/18

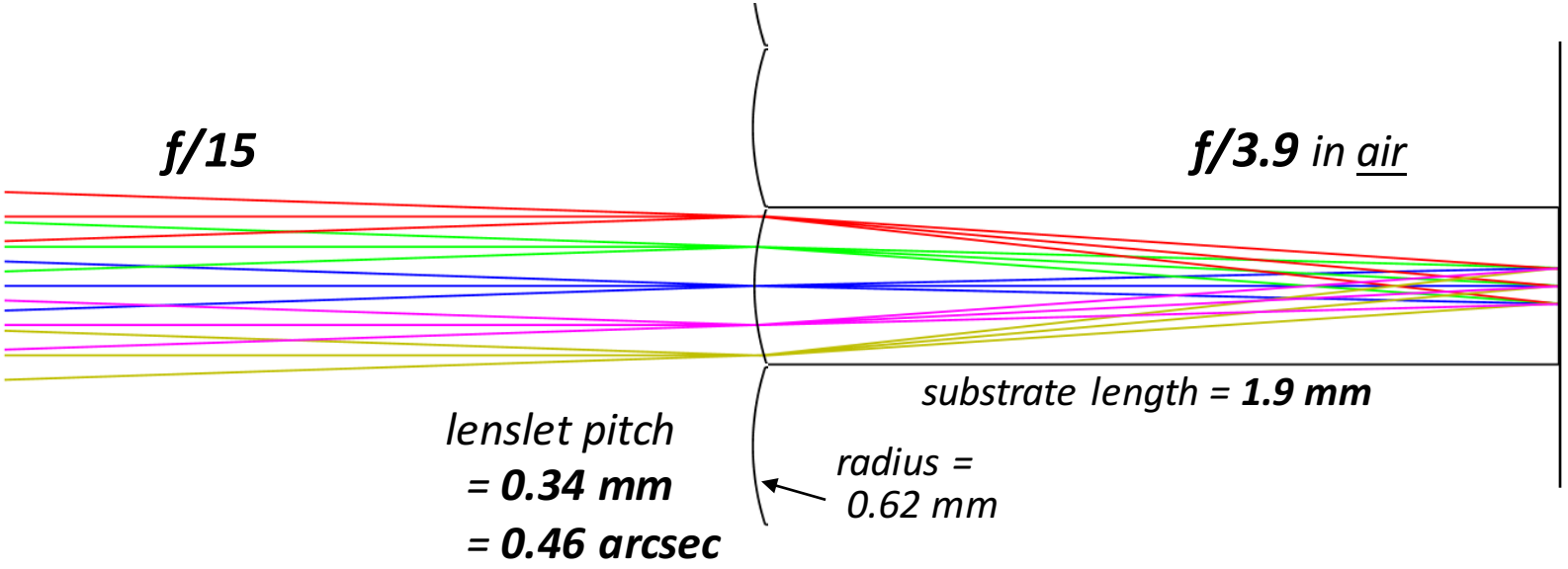
- Previously (Jan 2018) we've modeled Keck telescope as first-order optic, and used a narrow bandpass, for initial simple assessment
- Updated models to include real Keck telescope and 360-980 DESI bandpass
- Changed lenslet pitch 370 to 340 um (0.51 to 0.46 arcsec) to fit pupil image into 107um fiber core with margin
- Noted that new K1 tertiary likely limits FOBOS to use on K2

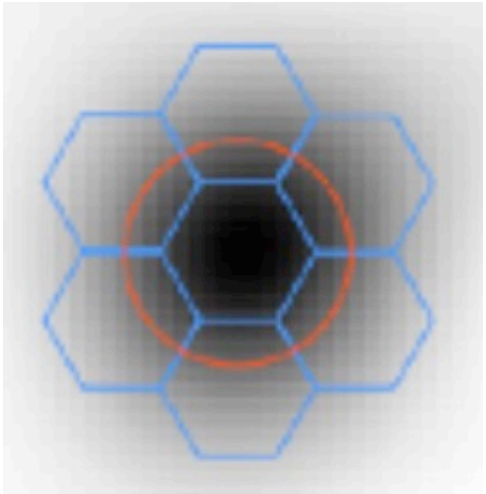
Optical Design

- Current assumed parameters:
  - 20’ FOV
  - 360-980nm bandpass
  - 0.46 asec lenslet pitch
  - f/3.9 input to fibers

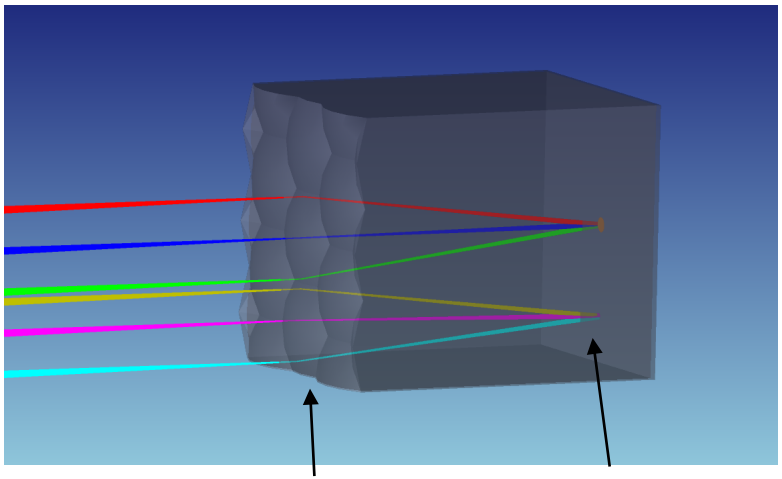
- Modeled Keck focal plane in Zemax with 7x1 lenslet array
- Assumed no foreoptics initially
- Explored optical performance across the full focal plane, and over positioner patrol radii of 18mm
  - FIU aligned to best position (focus) and orientation (pointing at incoming rays) at center of patrol disk

FIU (no foreoptics)



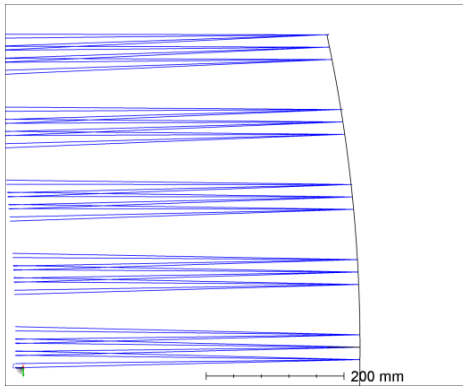


arrangement of 7x lenslets

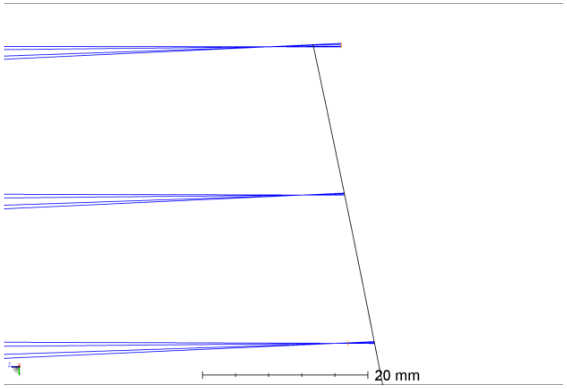


Rays reaching lenslets

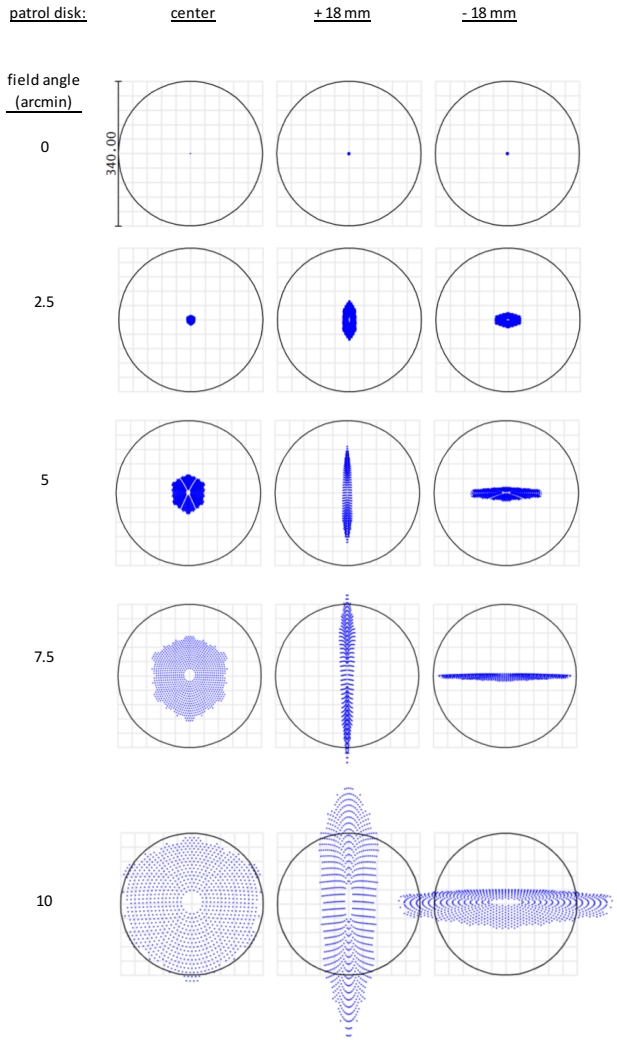
focal surface 0 to 10 amin



at 10 amin: ± 18 mm patrol disk



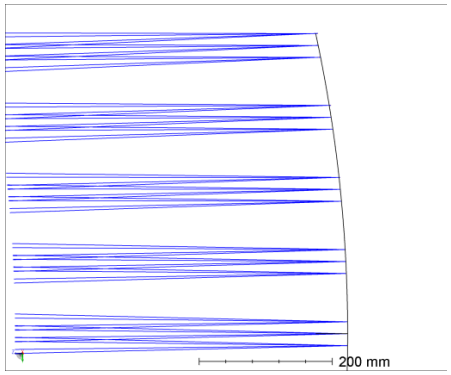
plots of image spots at different locations across the field
(circle = 340 microns, width of lenslets)



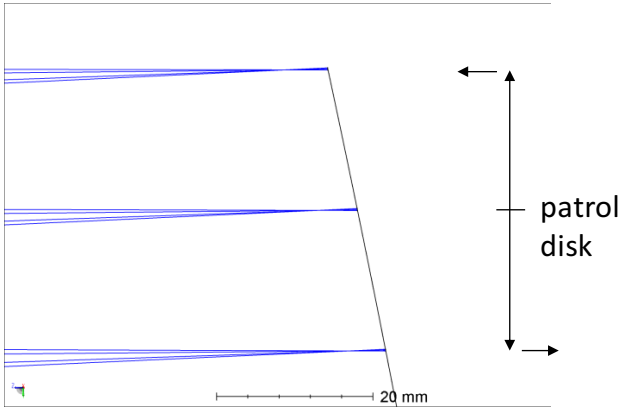
- *Model object as point source*
- *Astigmatism from Keck telescope goes as square of the off-axis field*

Rays reaching lenslets

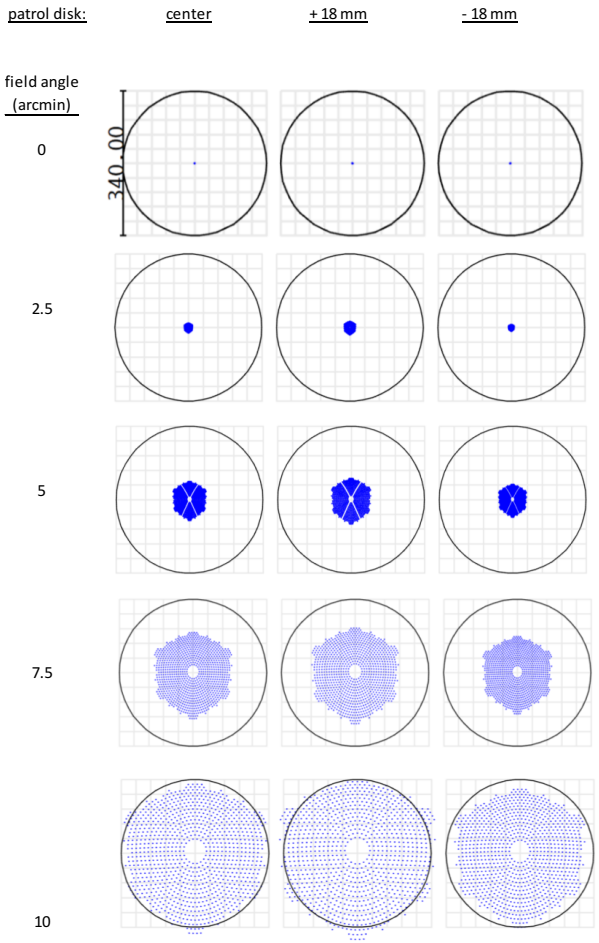
focal surface 0 to 10 amin



at 10 amin: ± 18 mm patrol disk



plots of image spots at different locations across the field
(circle = 340 microns, width of lenslets)



- *Allow refocusing (piston) across the patrol disk*

Initial conclusions

- Microlenses are feasible to couple Keck focal plane to 107 micron fibers
- Astigmatism degrades image quality at edge of 20’ FOV (i.e. throughput loss)
  - pistoning robotic positioners would be highly desirable
  - tilting positioners not necessary
- All light that reaches lenslets does also reach fiber core

Foreoptics theory

- Foreoptics are not obviously needed by FOBOS FIU
  - image magnification may not be needed: intrinsic telescope plate scale okay, lenslet size is manufacturable
  - telescope image telecentricity seems acceptable to FIU design
  - foreoptics likely can't fix telescope astigmatism

- Benefits of removing foreoptics include
  - less complicated FIU
  - avoids their dispersion/aberration & lens misalignment effects

Future steps

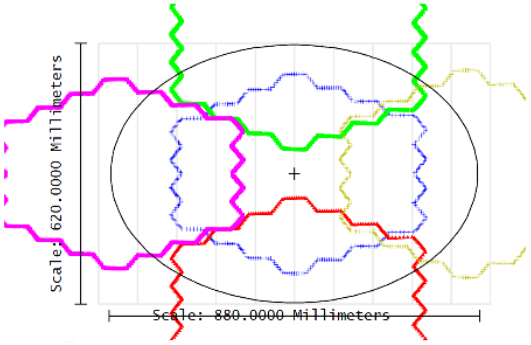
- assess loss at best focus due to astigmatism
  - convolve blur function with extended source and include all 7x lenslets
- how reduce astigmatism?
- Incorporate correction into ADC?
  - quick attempt unsuccessful

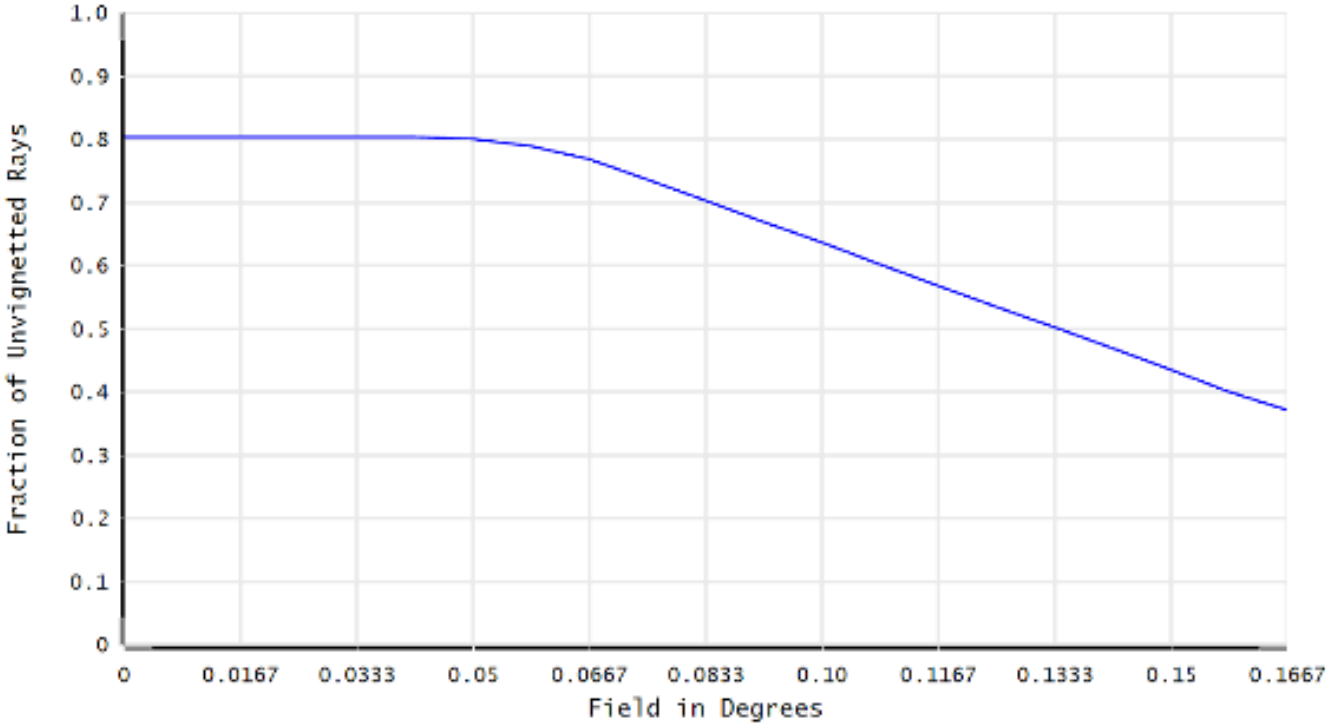
BACKUP

Future Keck 1

- Keck 1 currently being implemented with new, smaller tertiary mirror (DM3), which significantly vignettes 20’ FOV of FOBOS
- FOBOS would probably have to go on K2

beam footprints on tertiary of ±10’ fields



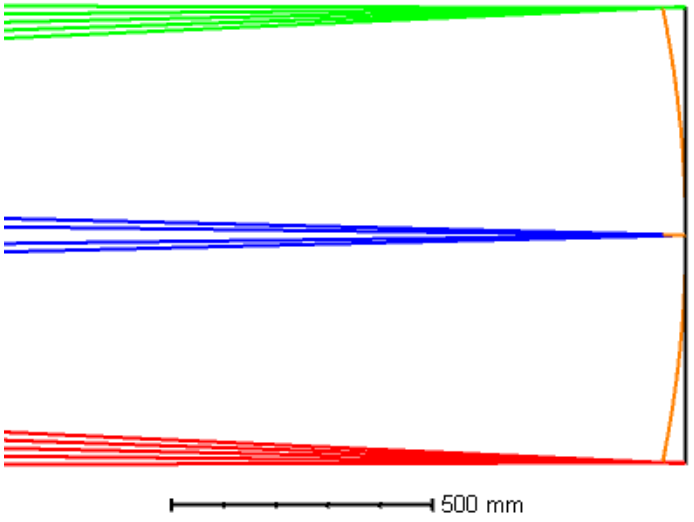


Field arcmin	Fraction	normalized
0.0	0.804	1.000
0.5	0.804	1.000
1.0	0.804	1.000
1.5	0.804	1.000
2.0	0.804	1.000
2.5	0.803	0.999
3.0	0.801	0.996
3.5	0.789	0.982
4.0	0.768	0.956
4.5	0.736	0.916
5.0	0.702	0.874
5.5	0.669	0.833
6.0	0.637	0.792
6.5	0.602	0.749
7.0	0.568	0.706
7.5	0.534	0.665
8.0	0.502	0.624
8.5	0.469	0.583
9.0	0.436	0.542
9.5	0.401	0.499
10.0	0.372	0.463

Keck focal surface

- Focal surface curved, R = 2.1m
  - sag = 44mm at edge of FOV
- Aberration: spot size 230um rms diam = 0.31 asec rms diam at edge of FOV
  - entirely astigmatism, goes as field^2
- chief ray angle = 0 to ±1.25deg, varies linearly
- exit pupil = 19.95m before focus
- f/15.2
- distortion = 0.01%
- achromatic

- Fibers should be positioned and angled to follow position and angle of focal surface rays (DESI and WFOS do this)

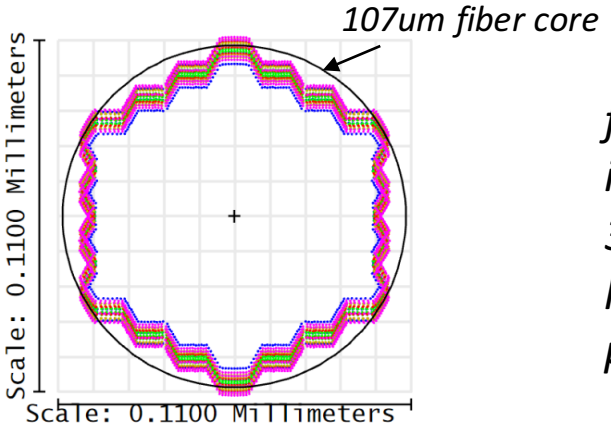


20’ = 0.86m

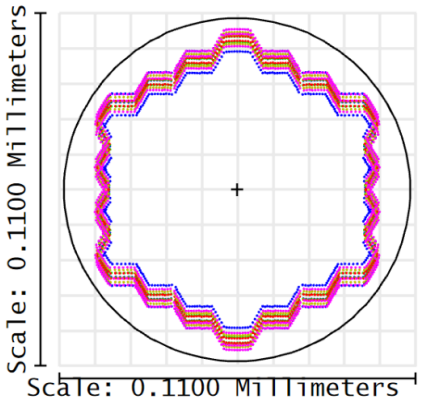
Design update

- On-axis design previously had lenslet pitch = 370 um (0.51 arcsec)
- implementing full bandpass introduces chromatic aberration, and means that can't fit pupil image into 107um fiber core with margin (for f/3.9 beam)
- changed lenslet pitch 370 to 340 um (0.46 arcsec), now fits
  - includes some margin for misalignments
  - IFU now covers 3 x 0.46 asec = 1.4 asec

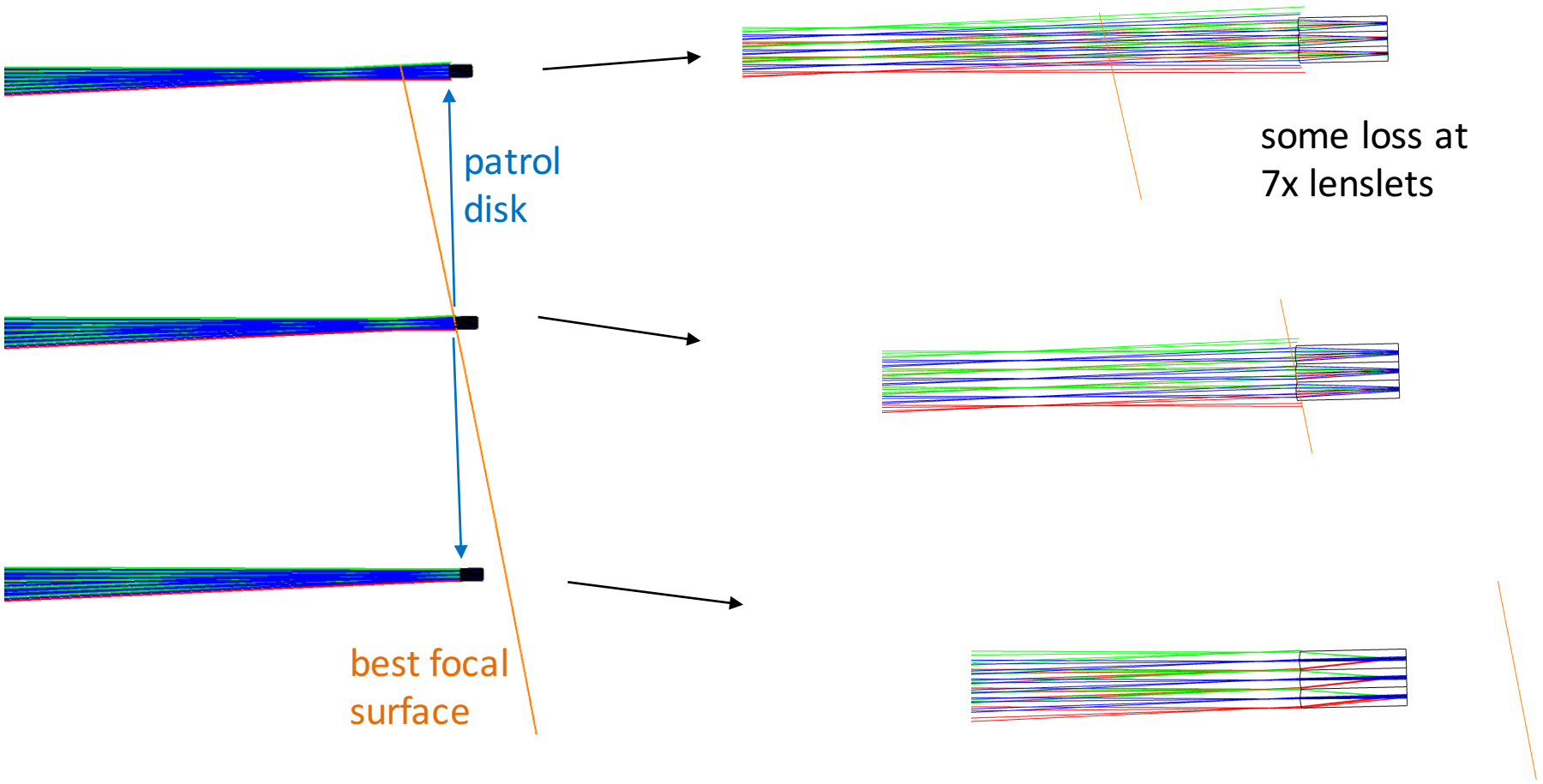
fiber image, 370um lenslet pitch



fiber image, 340um lenslet pitch



throughput, off-axis



- *FIU aligned to best position (focus) and orientation (pointing at incoming rays) at center of patrol disk*
- *best focus and tilt change over patrol disk*