iLocater

Moving from design to fabrication

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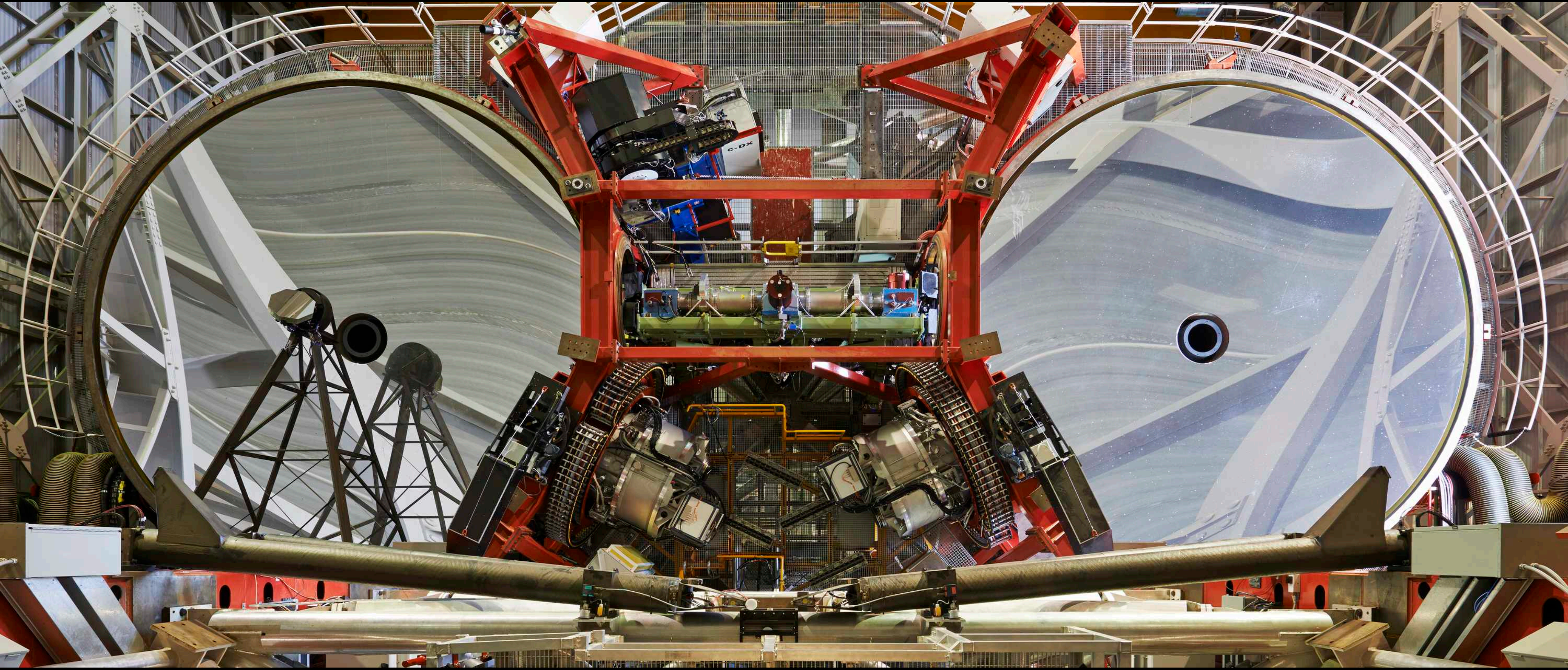
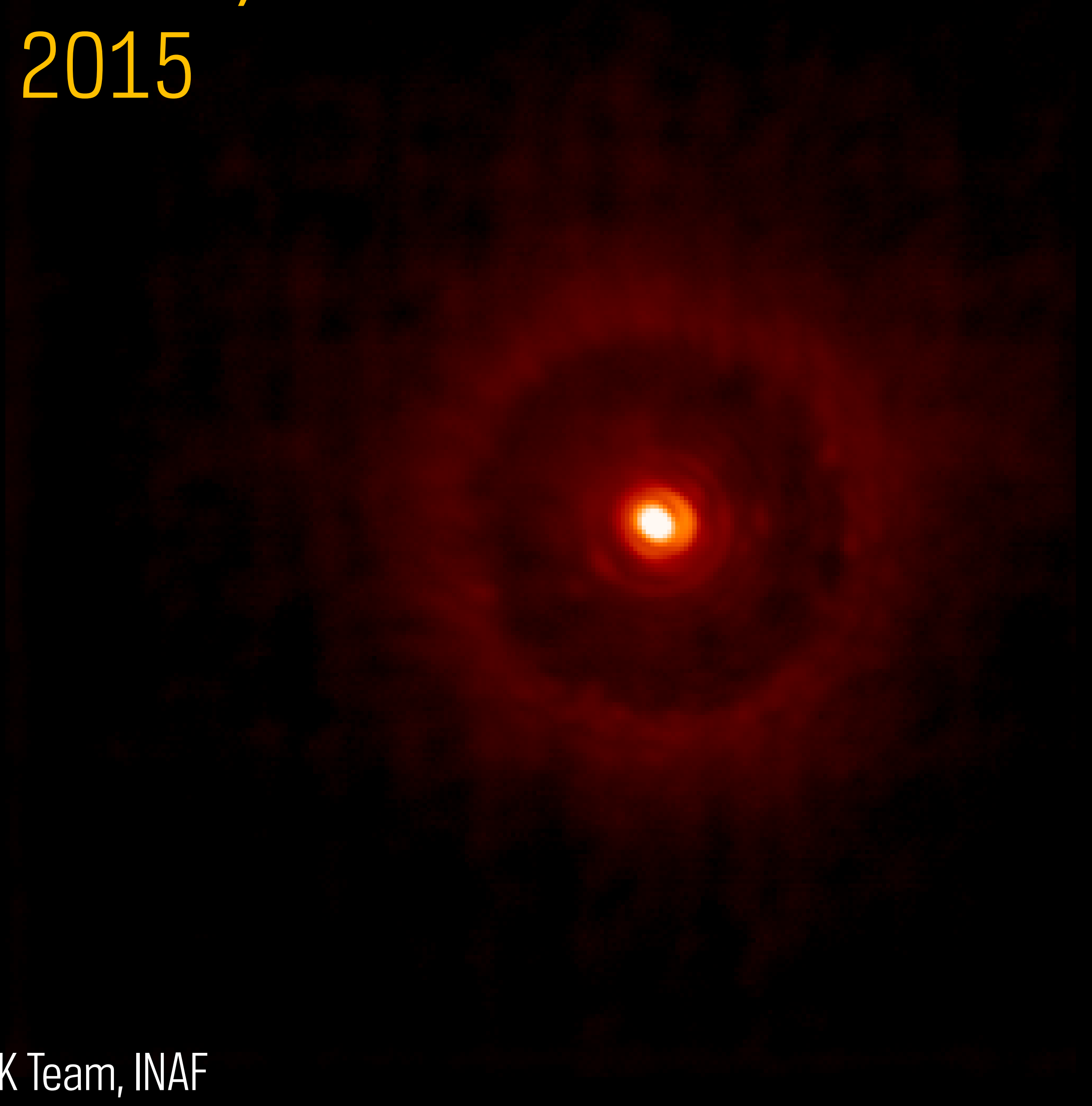
iLocater

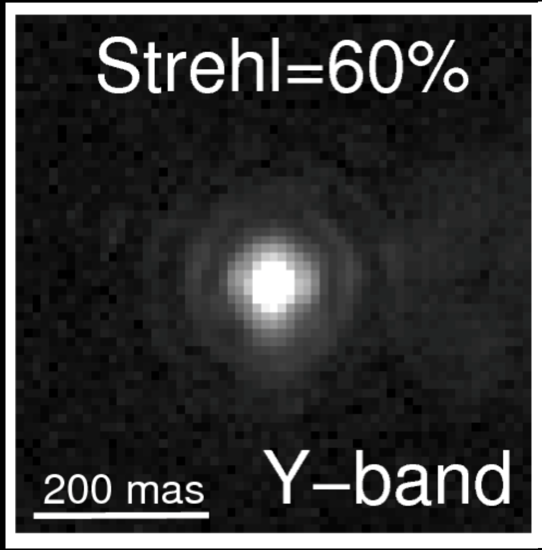


HIP 48455 (V=3.85)
February 13, 2015

Raw FWHM=34 mas
λ=630 nm (6% bandpass)
f=990 Hz, 300 modes
Seeing=0.8″

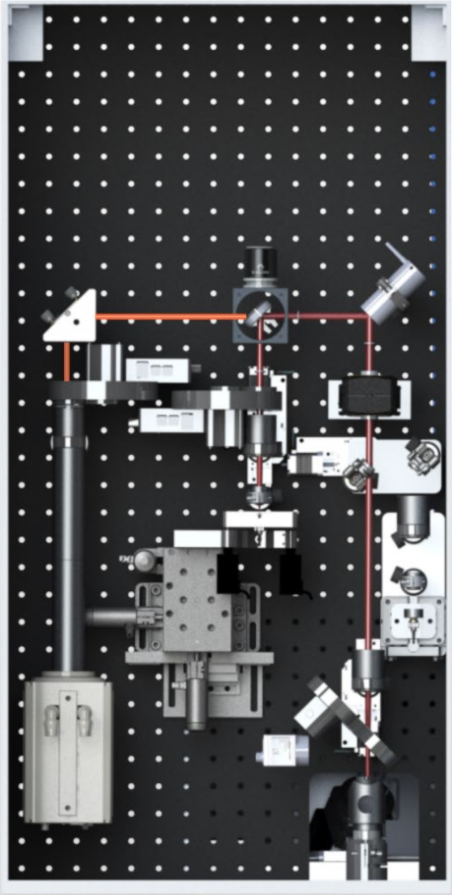
Strehl ratio: >30%

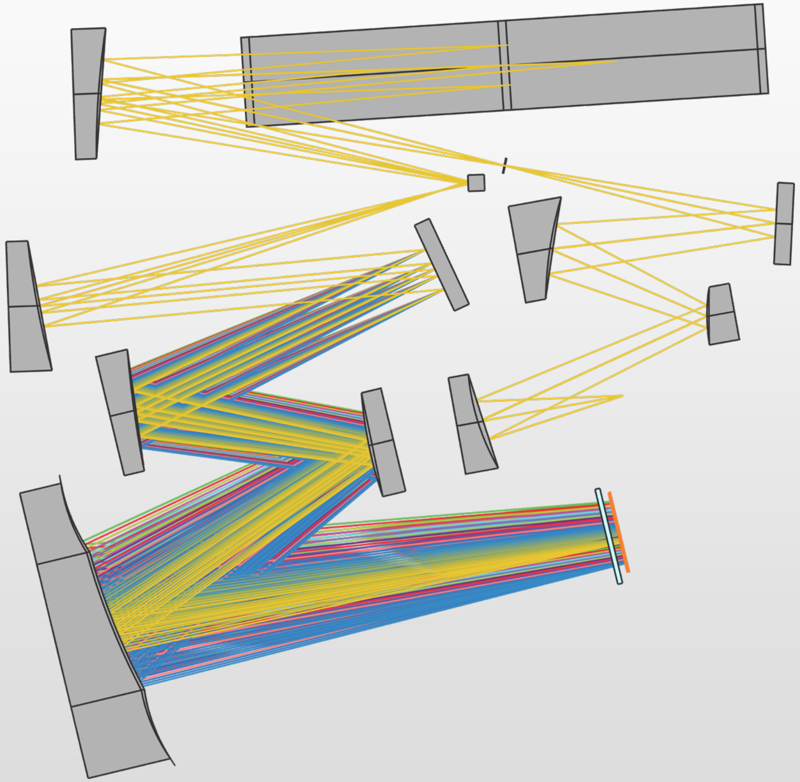


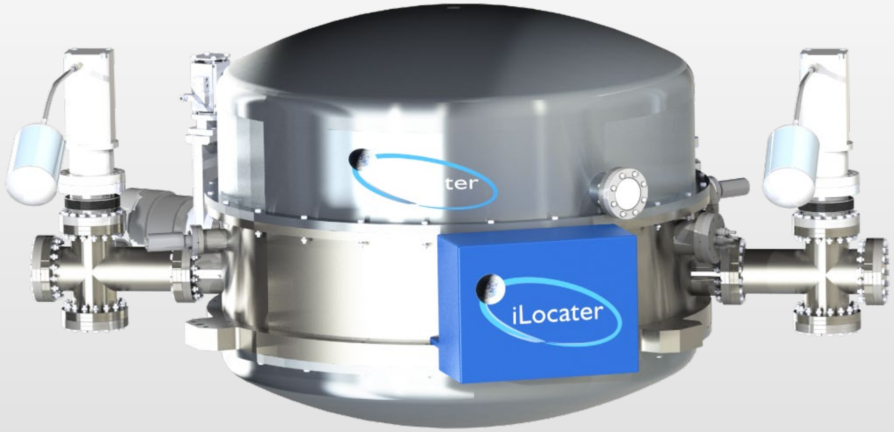


Data Courtesy of SHARK Team, INAF

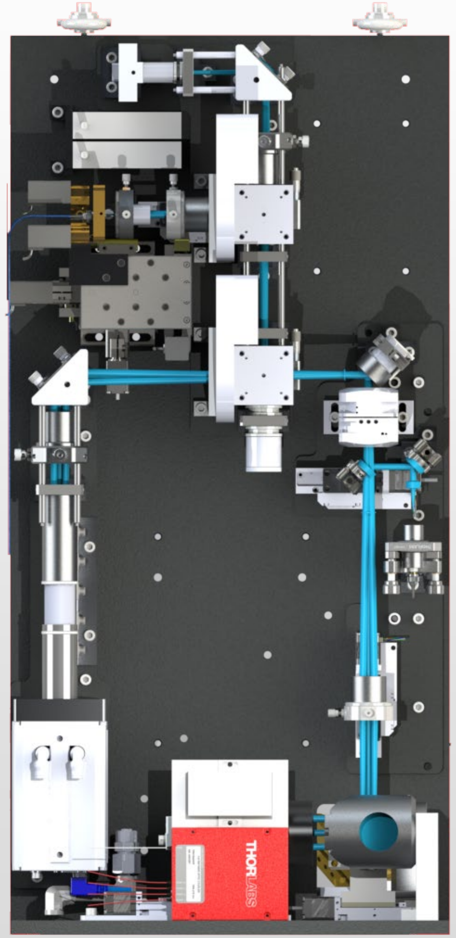
Where were we at EPRV3?

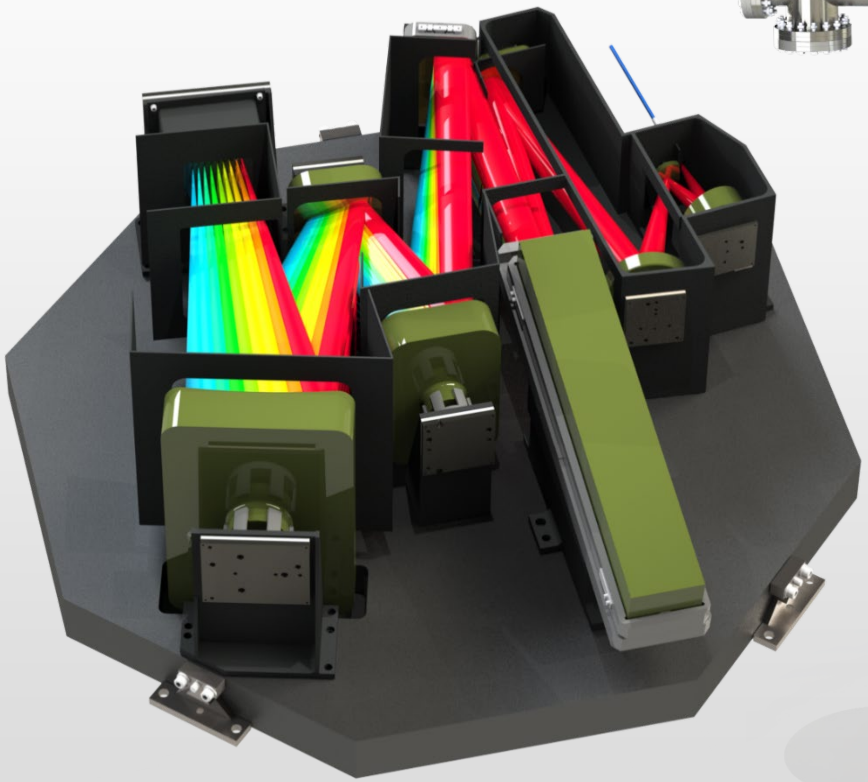


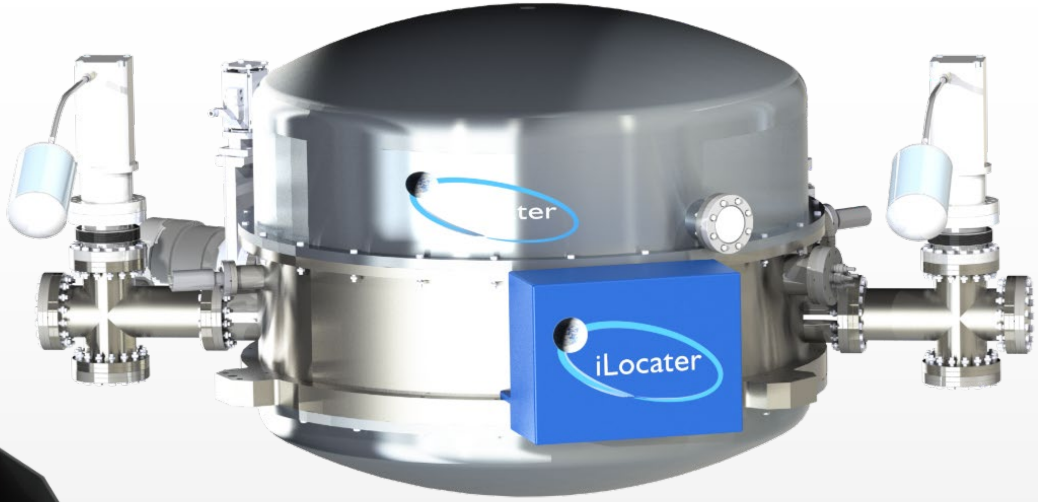


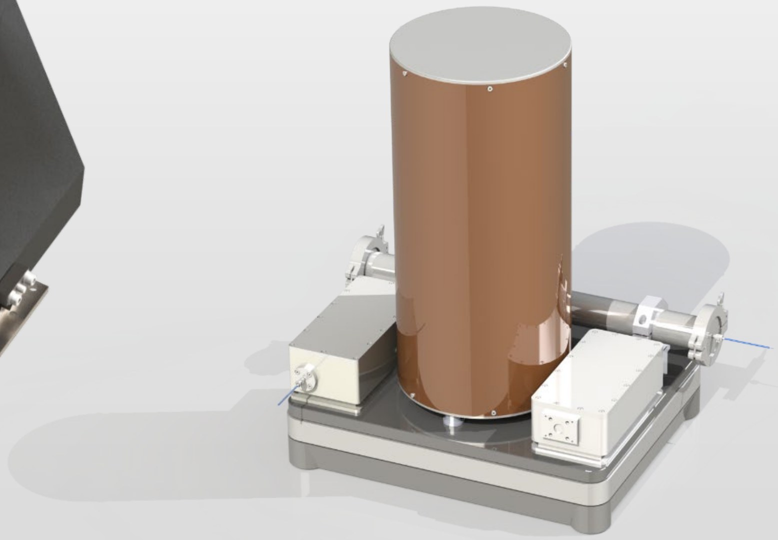


Where are we today?







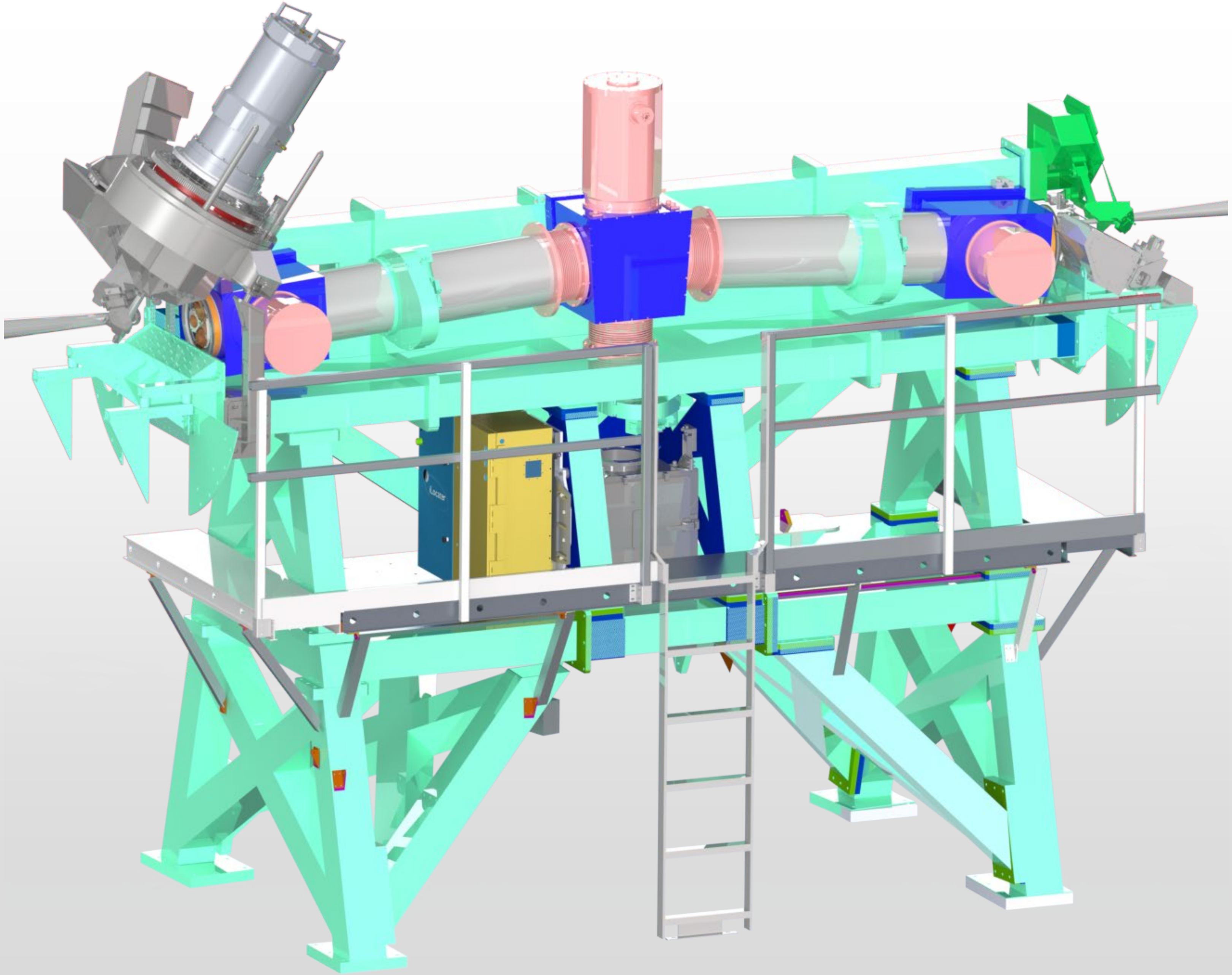


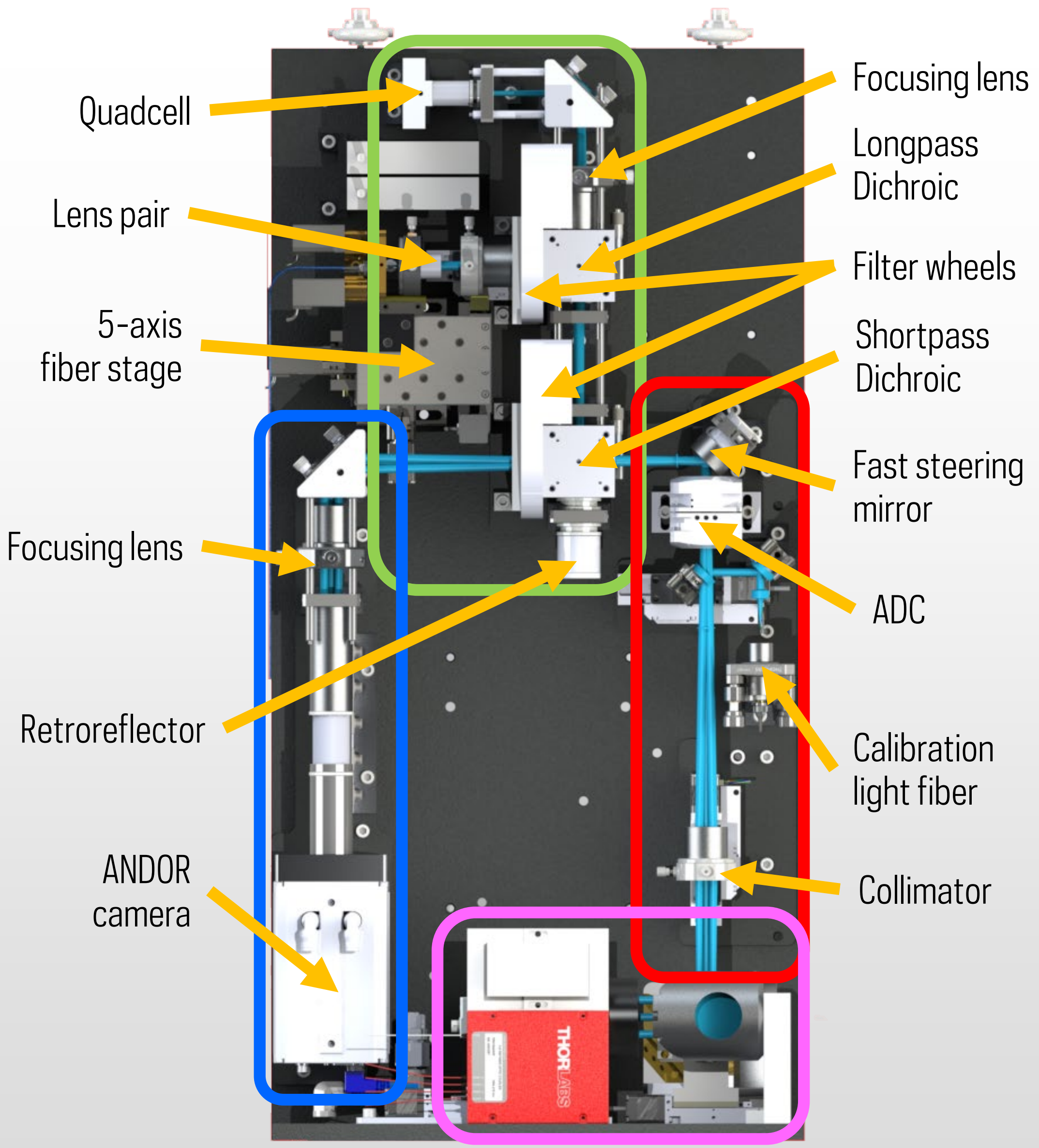
Acquisition Camera Design

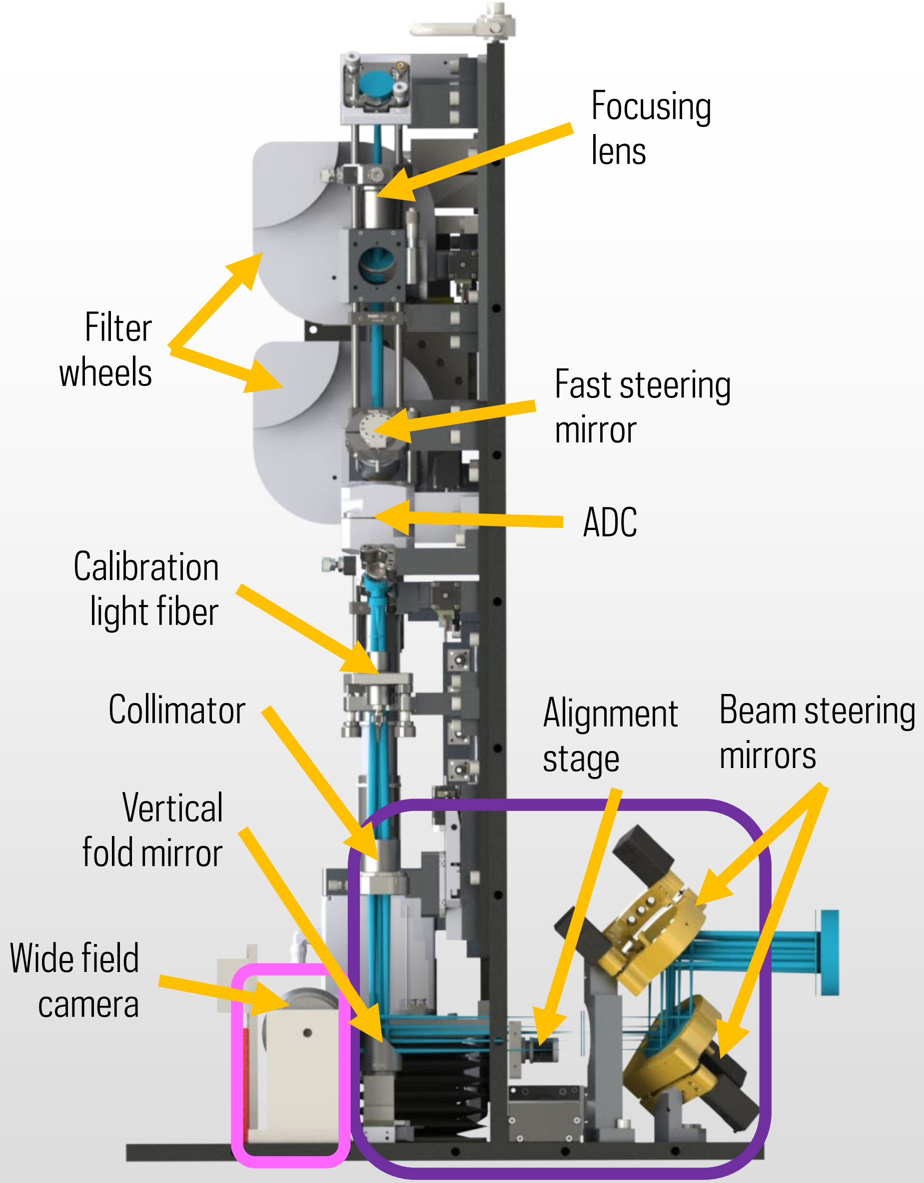
How do you get light into a single-mode fiber?

- To efficiently couple light into a single-mode fiber – you're trying to match the incident beam to the spatial mode of the fiber as closely as possible.

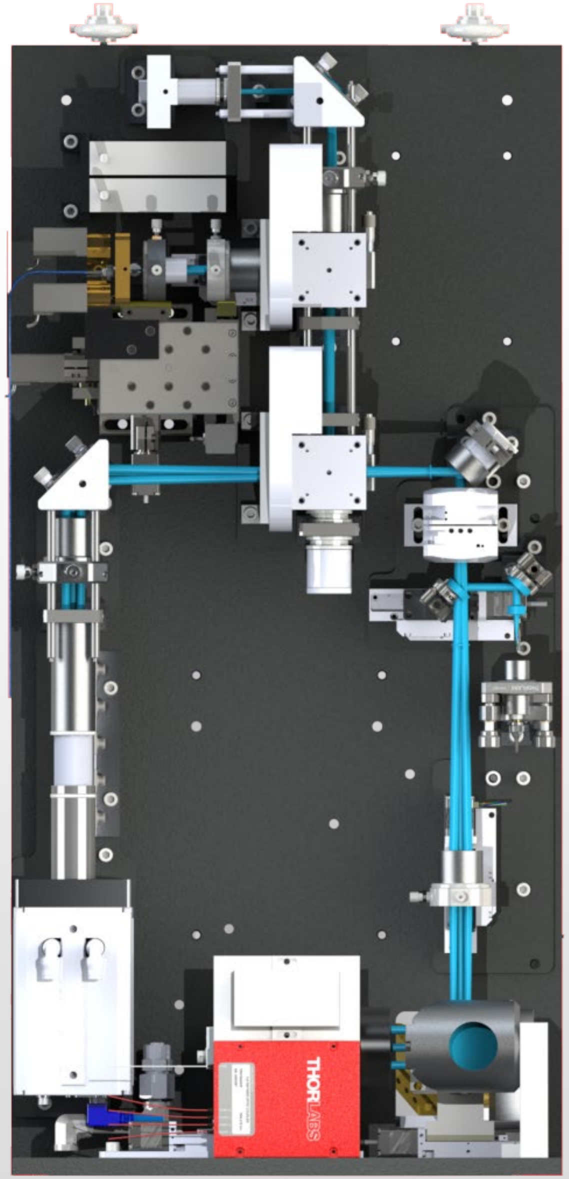
- To do that, you need to:
  - Scale so the $1/e^2$ diameter of Airy disk PSF matches the mode field diameter of your fiber.
  - Don't exceed the NA of the fiber
  - Have a 'flat' wavefront
  - Have very good atmospheric dispersion correction
  - Have a stable beam

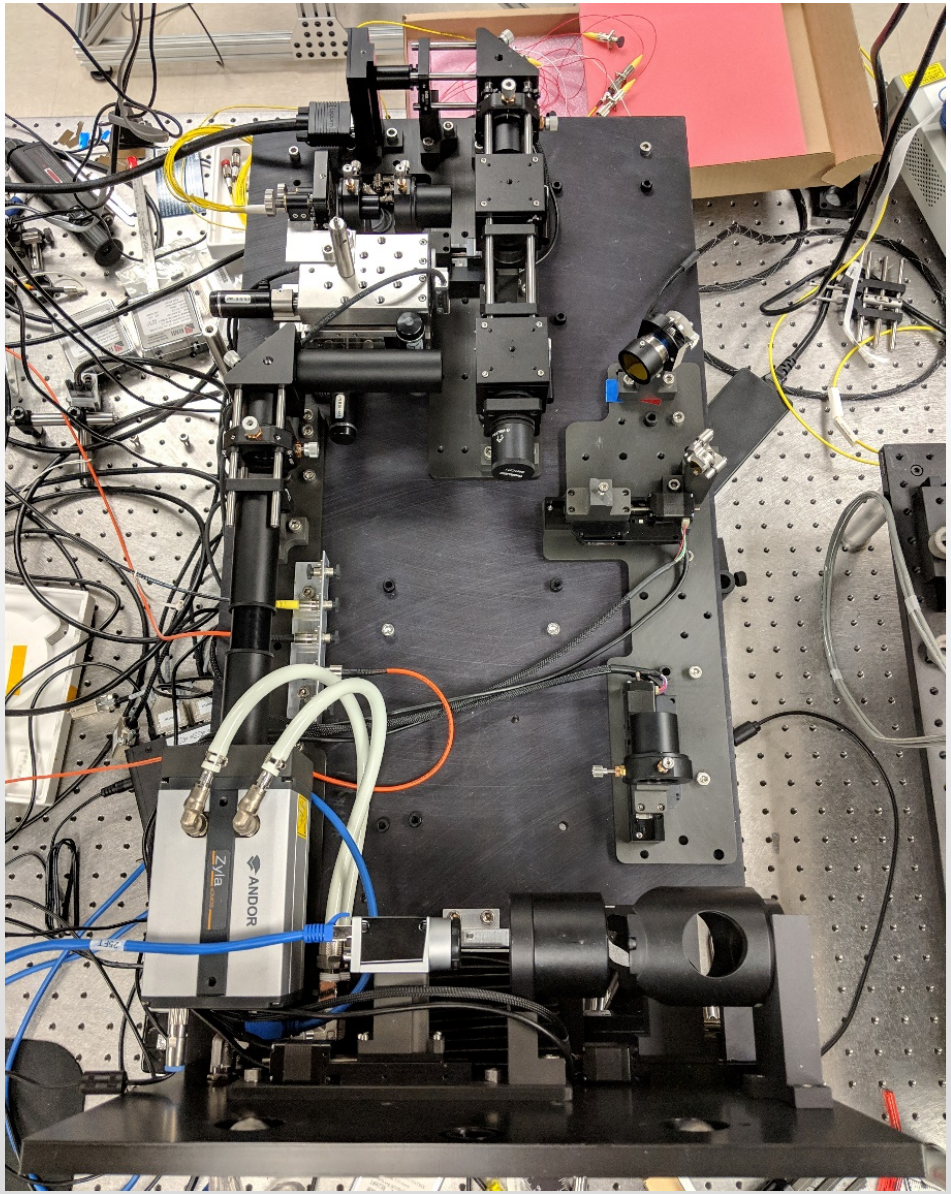


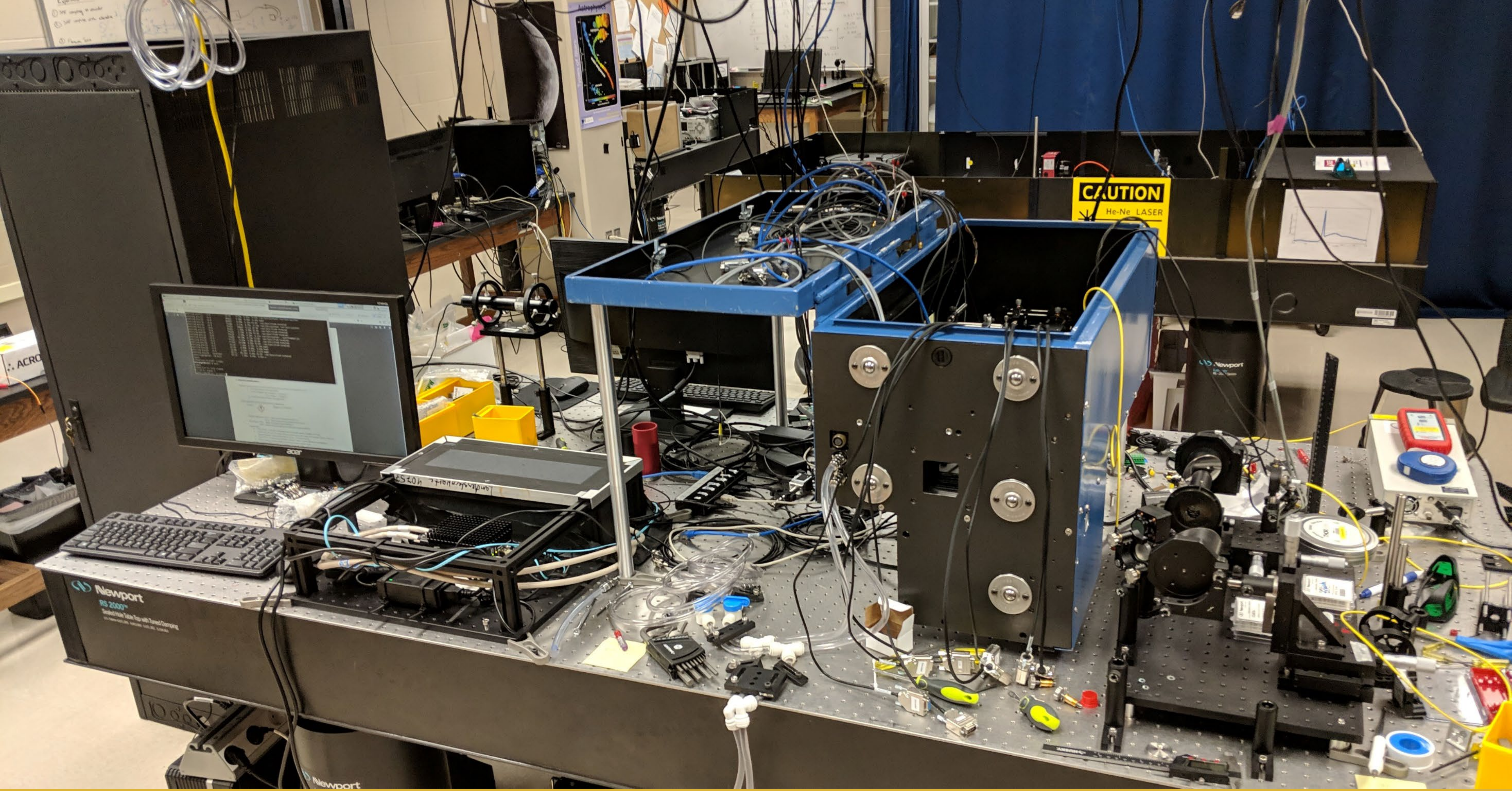




Collimator plate
WFC plate
Fiber channel/ quadcell plate
Fine guide / ANDOR plate
Beam steering optics


THORLABS


ANDOR
Zyla


CAUTION
He-Ne LASER
Newport
RS 2000
acer

Spectrograph Design

Single-mode fiber fed spectrograph = Gaussian beam spectrograph

- Single-mode fibers are small
  - Output a spatially stable Gaussian beam profile
    - Two polarization modes
  - Fibers are small enough to be considered a point source rather than an extended source (slit/multi-mode fiber)
    - Working in 'diffraction-limited' system if you want to maintain PSF profile
  - Spectrograph design completely decoupled from telescope

- It is important to maintain optical quality through the entire system
  - Aberrations broaden instrument profile ⇒ degradation in effective optical resolution
  - All surfaces have to be high-quality to achieve this
  - All surfaces have to be 'oversized' to accommodate Gaussian beam profile

iLocater spectrograph design has been built from the ground up to ensure this performance.

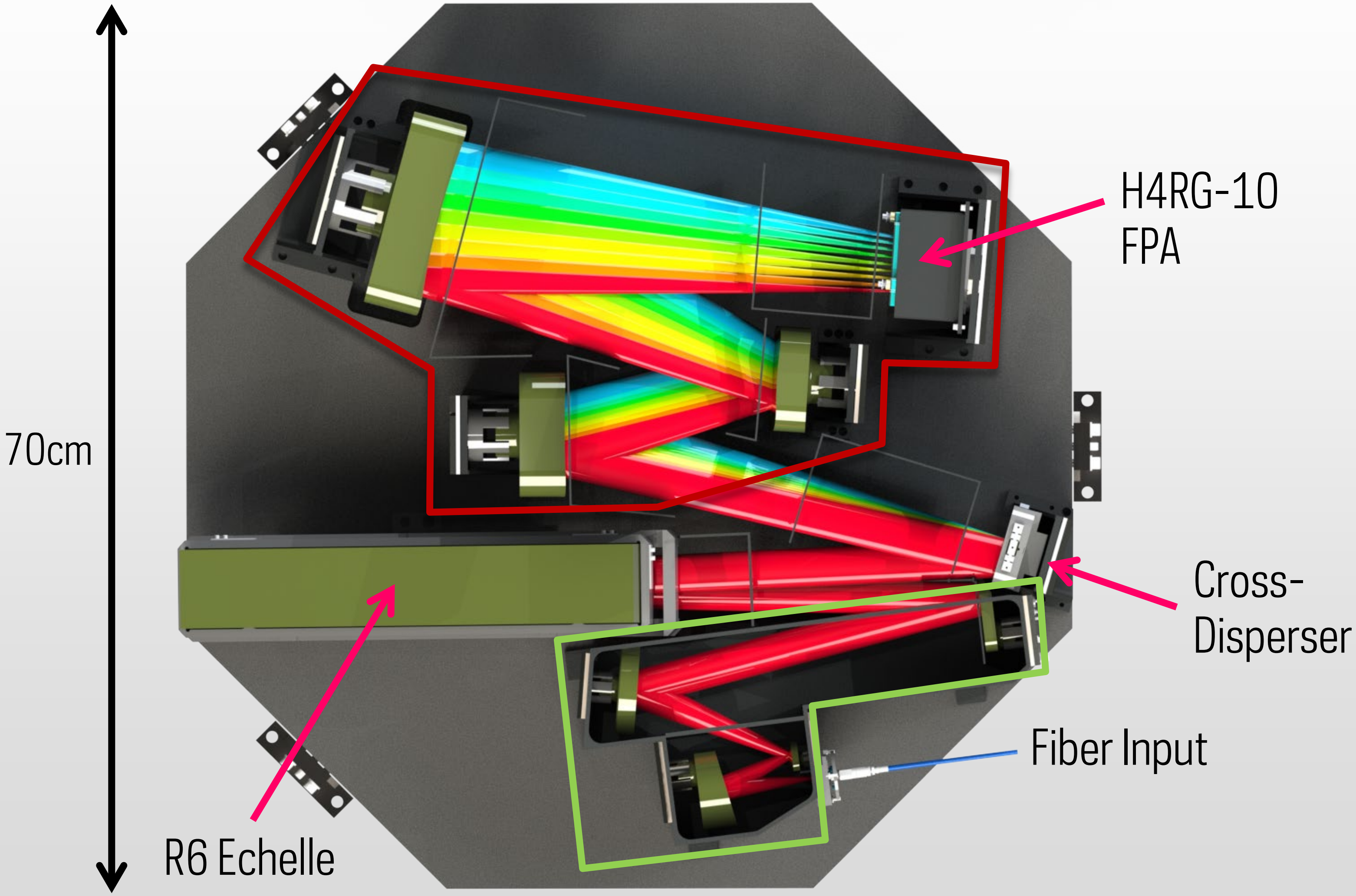
Spectrograph optical design – upgrades/changes

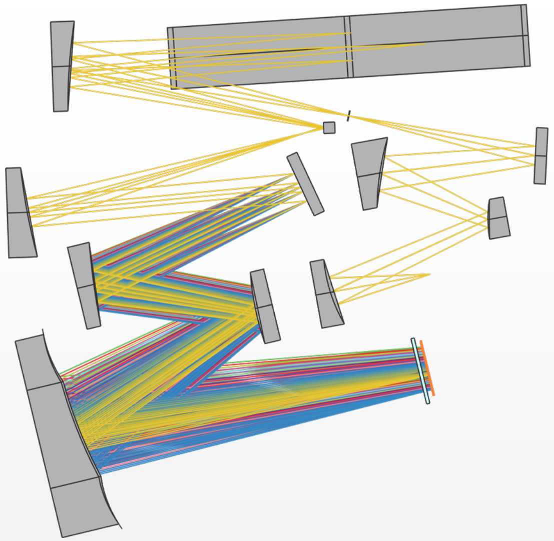
Following PDR – revisited spectrograph architecture to ensure performance of as built system would deliver the performance expected.

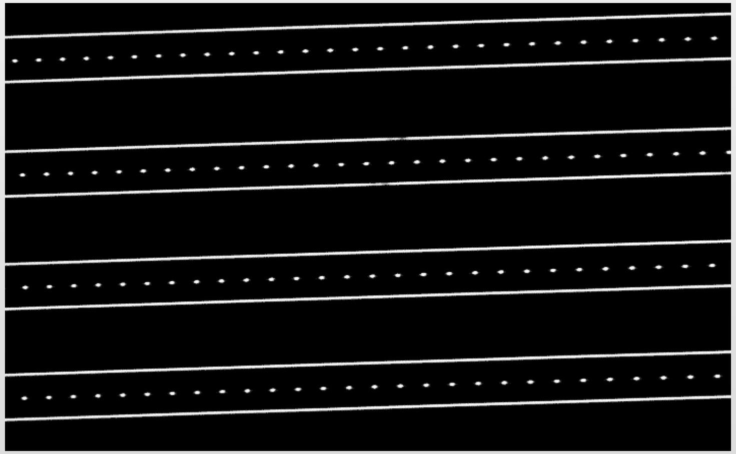
Three sources of concern identified:

- Design residual wavefront error
- Grating surface figure
- Ellipticity/rotation of PSF at detector focal plane

Spectrograph optical design – upgrades/changes

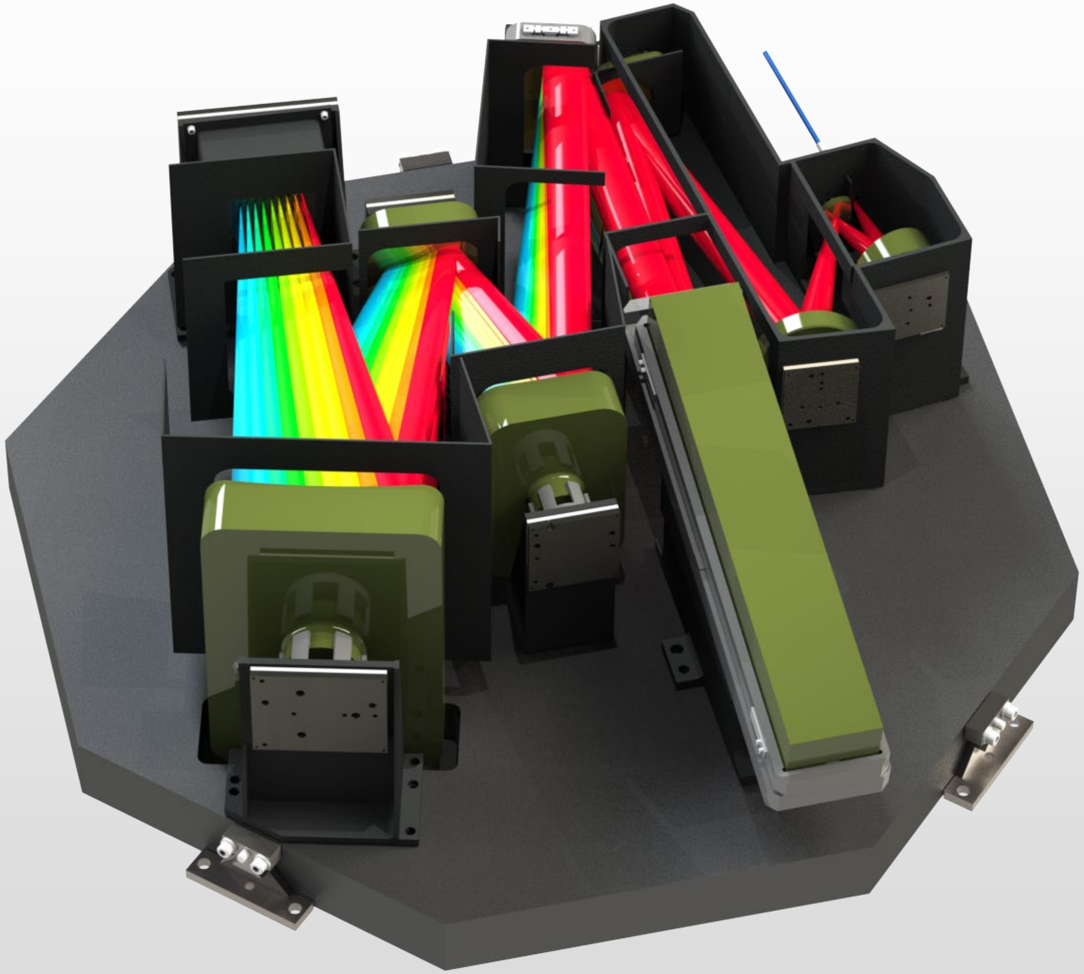


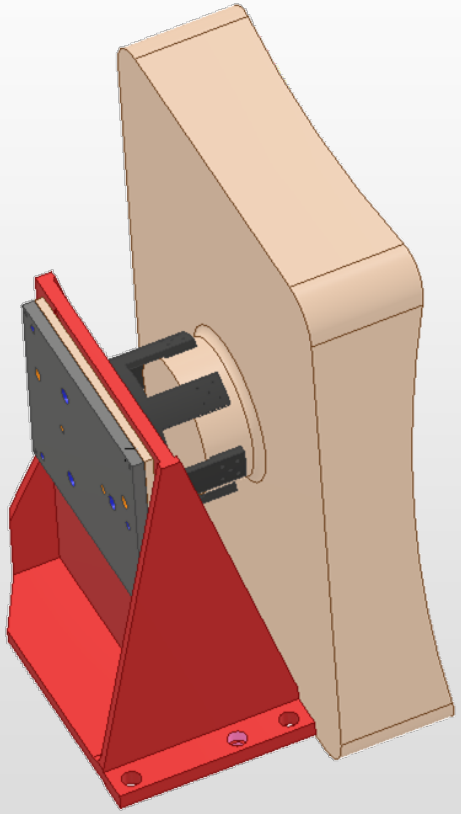


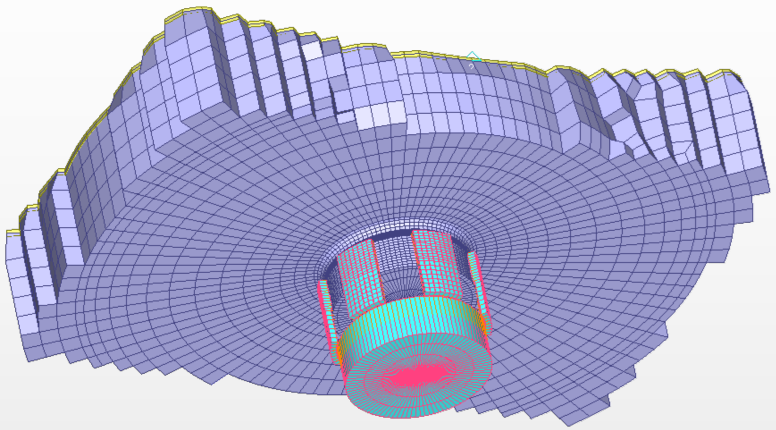


Bandpass: Y- and J-bands: 0.97-1.27μm
Orders: 117-152

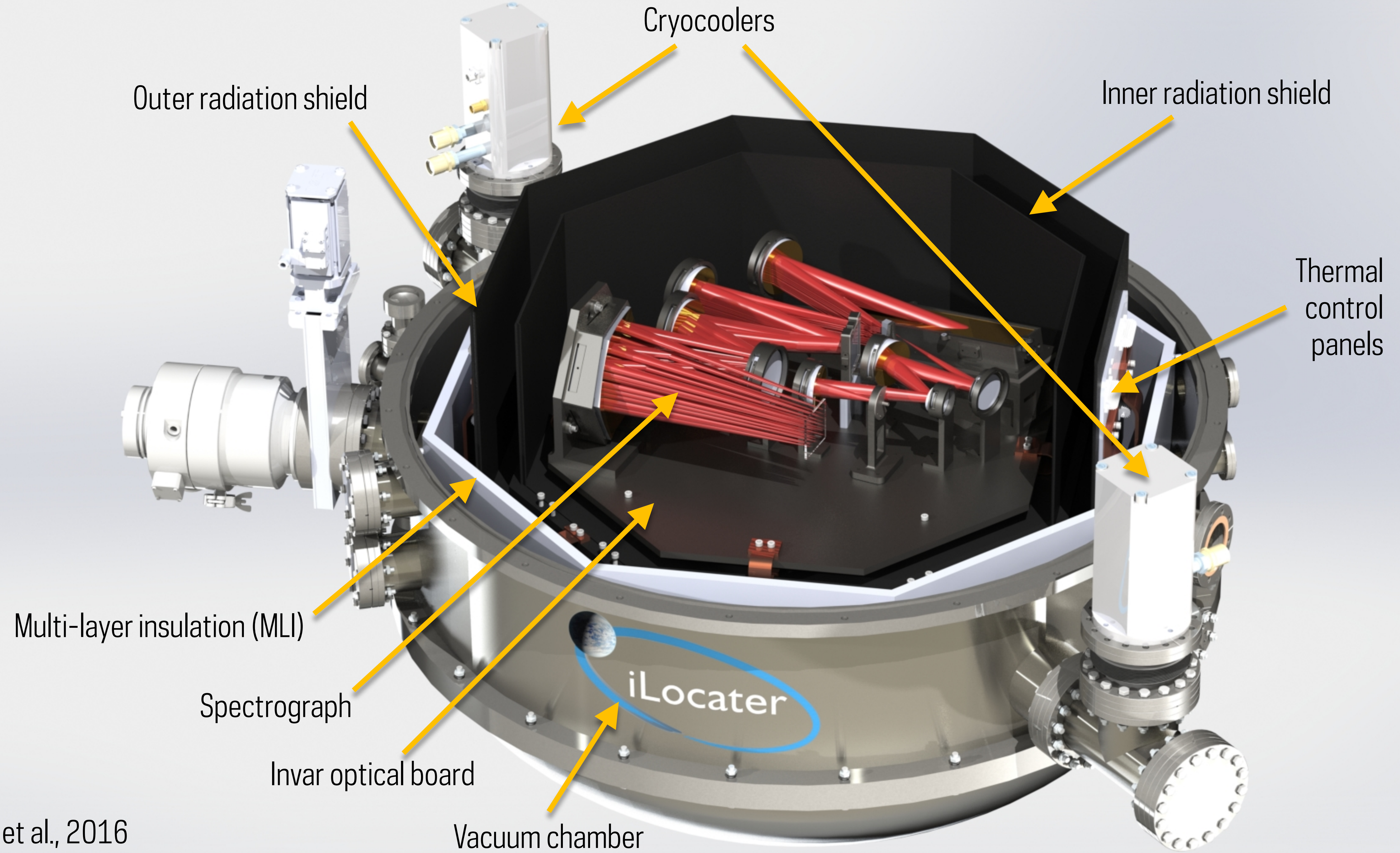
Spectrograph optical design – optomechanics







Error Term	Zernike	Residual RMS (waves @ 632.8nm)
Raw		0.01319
Piston	-6.93E-03	0.01176
Tip	1.03E-05	0.01176
Tilt	-2.58E-02	0.00137
Focus	-1.74E-03	0.00096
Astig1	-1.20E-06	0.00096
Astig2	-8.66E-04	0.00093
Coma1	5.15E-06	0.00093
Coma2	5.15E-06	0.00093



Crass et al., 2016

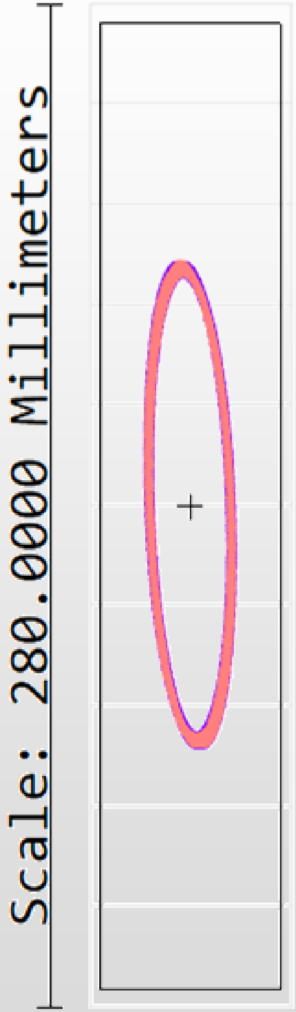
Spectrograph optical design – Gratings Study

COTS gratings

- "Cheap"
- Surface figure - only guarantee $\lambda/2$ @ HeNe (goal $\lambda/4$)
    - Dominates wavefront error budget

Need for custom gratings

- Gratings study to assess best solution
    - R4, R6, R8+…
    - Impact of gamma angle



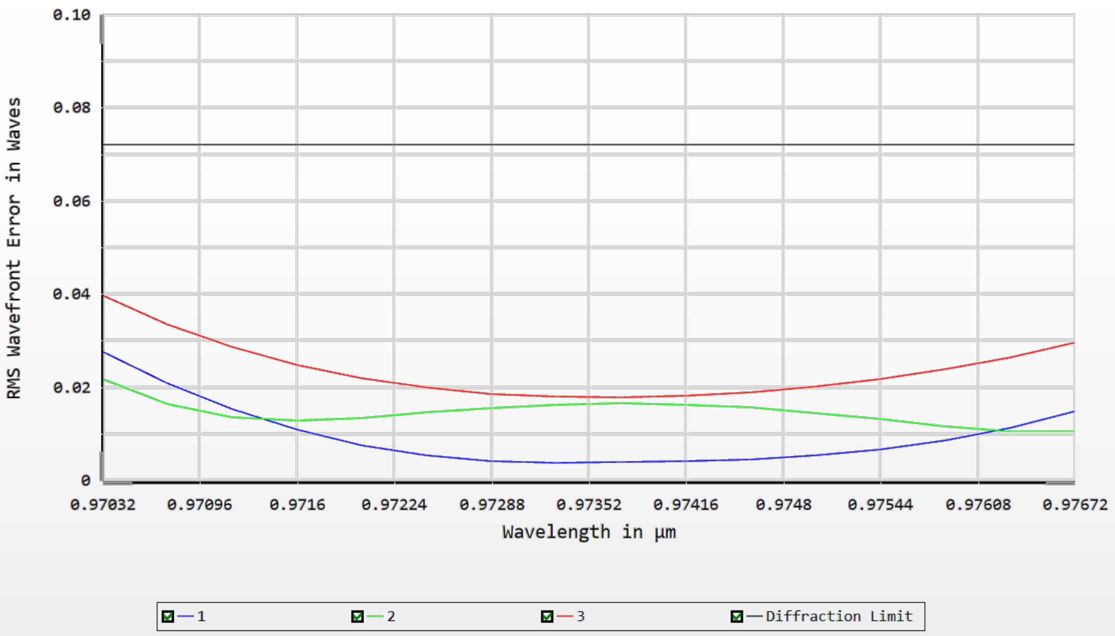
Spectrograph optical design – Gratings Study

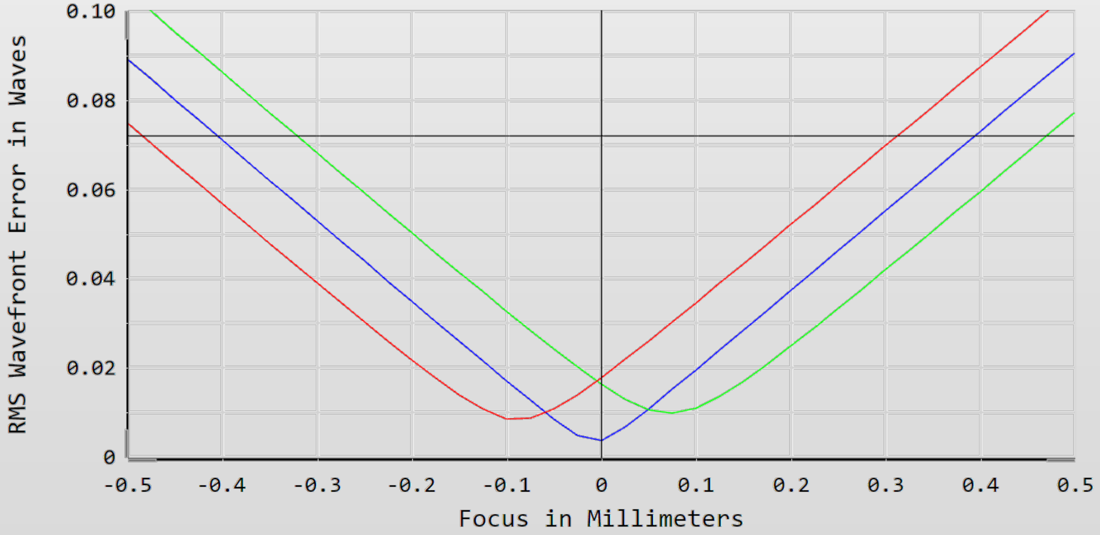
- The higher the gamma angle onto your grating, the more elongated and rotated the PSF
  - Decreases spectral resolution
- Set upper limit of gamma at 2.5 degrees
  - Poses challenges for separating incident and outgoing beams
  - Final design: 2 degrees

- Custom Grating Fabrication
  - Design uses same characteristics as Richardson R6
  - Will be fabricated in silicon through either:
    - E-beam lithography and silicon etching
    - Precision direct ruling

Optical performance

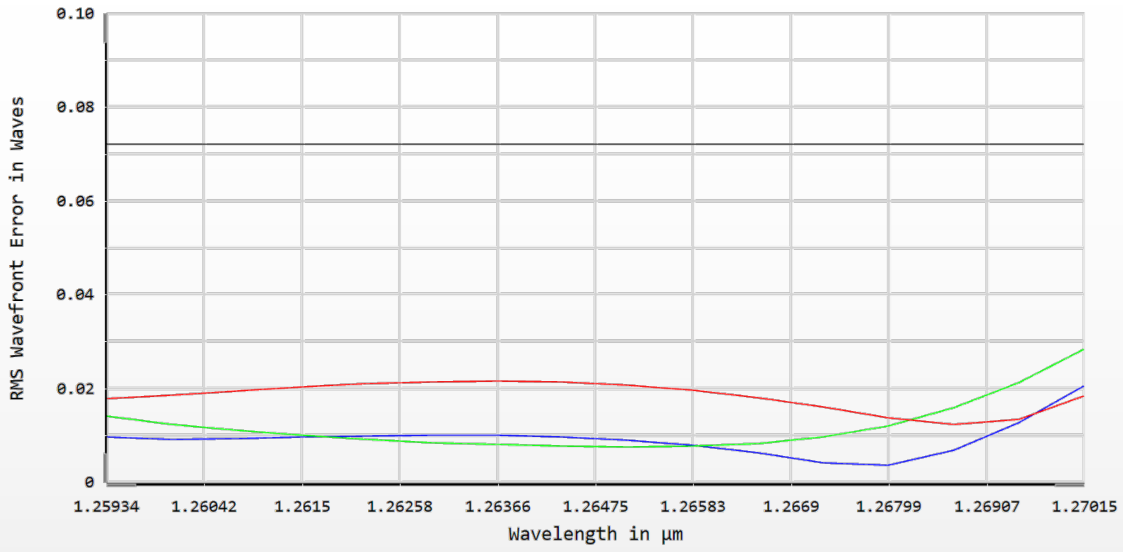
Short wavelengths

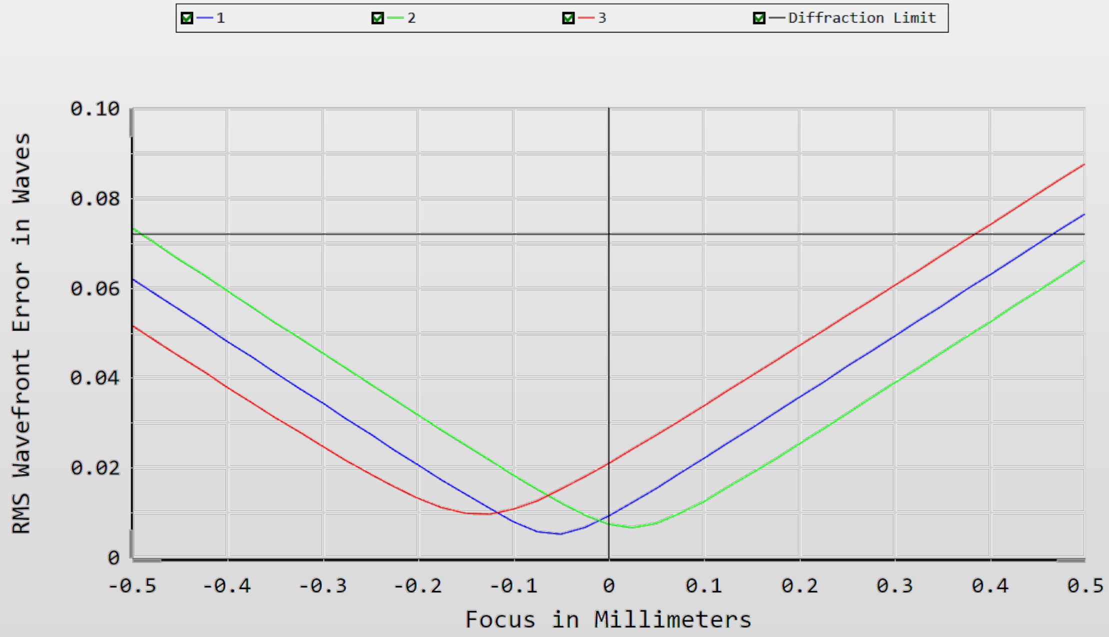




Optical performance

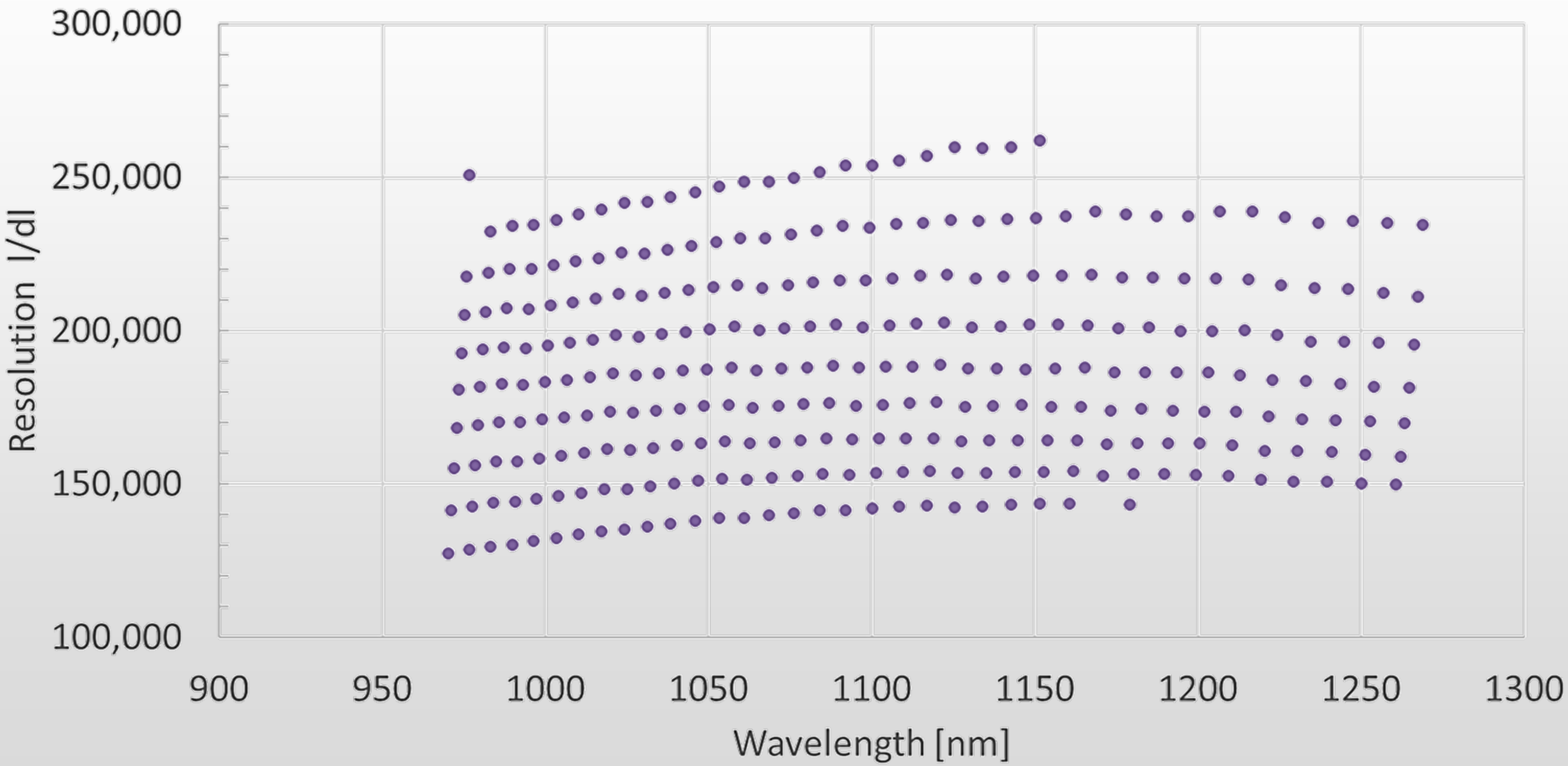
Long wavelengths





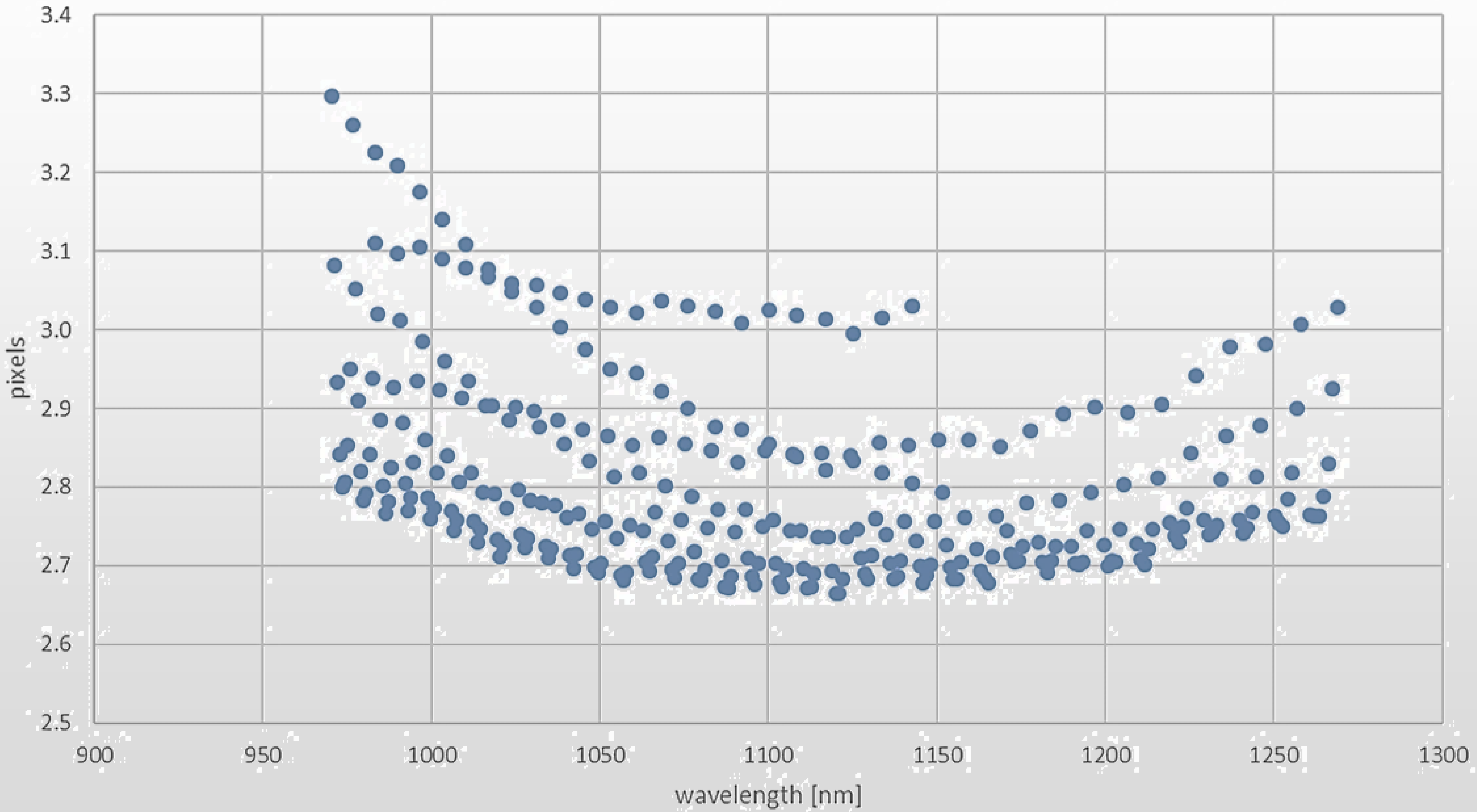
Spectrograph Resolution

Resolution			
Median:	189,400	Minimum:	131,900
Mean:	193,600	Maximum:	273,600

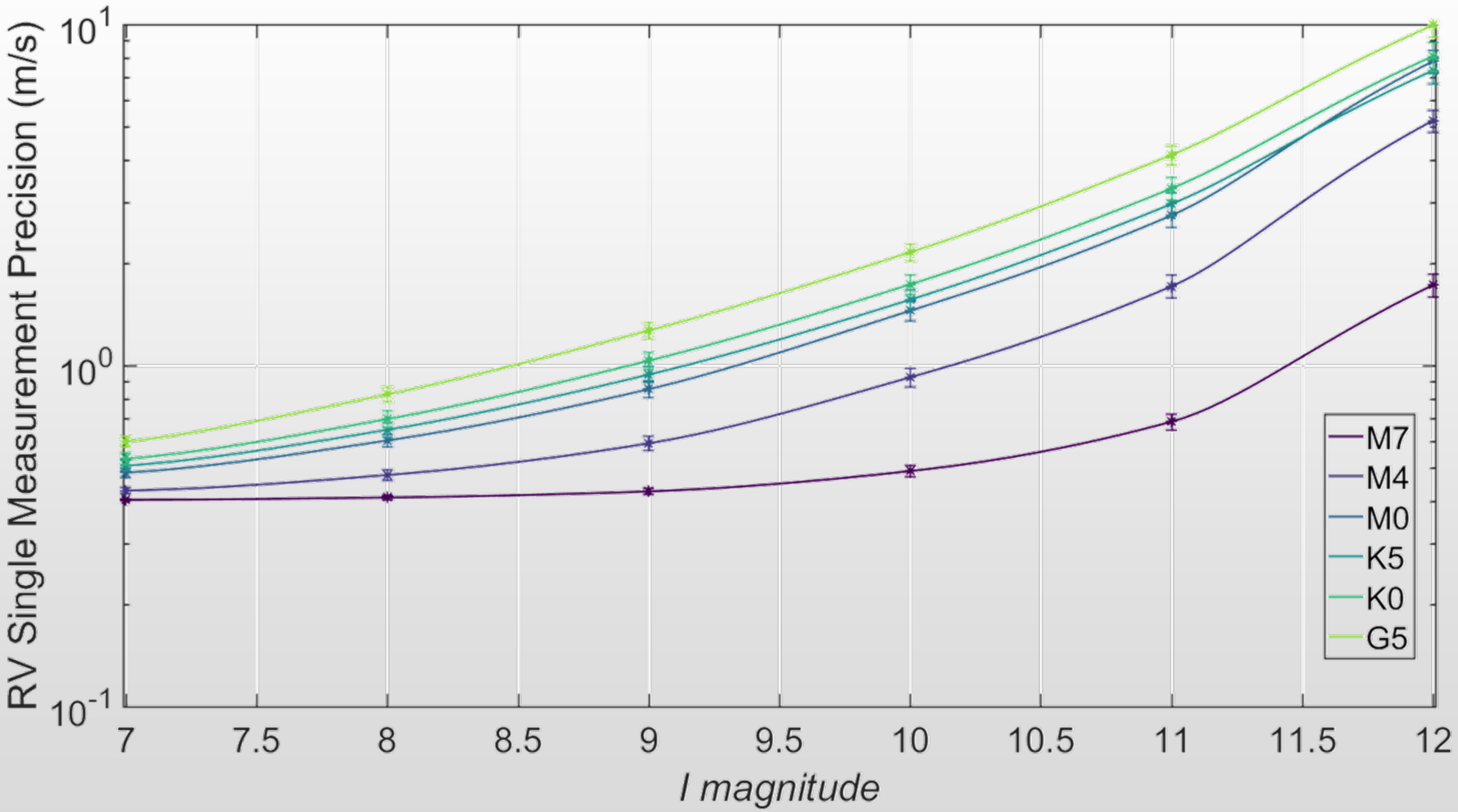


Spectrograph Pixel Sampling

Pixel Sampling/Resolution Element			
Median:	2.69	Minimum:	2.62
Mean:	2.73	Maximum:	3.17



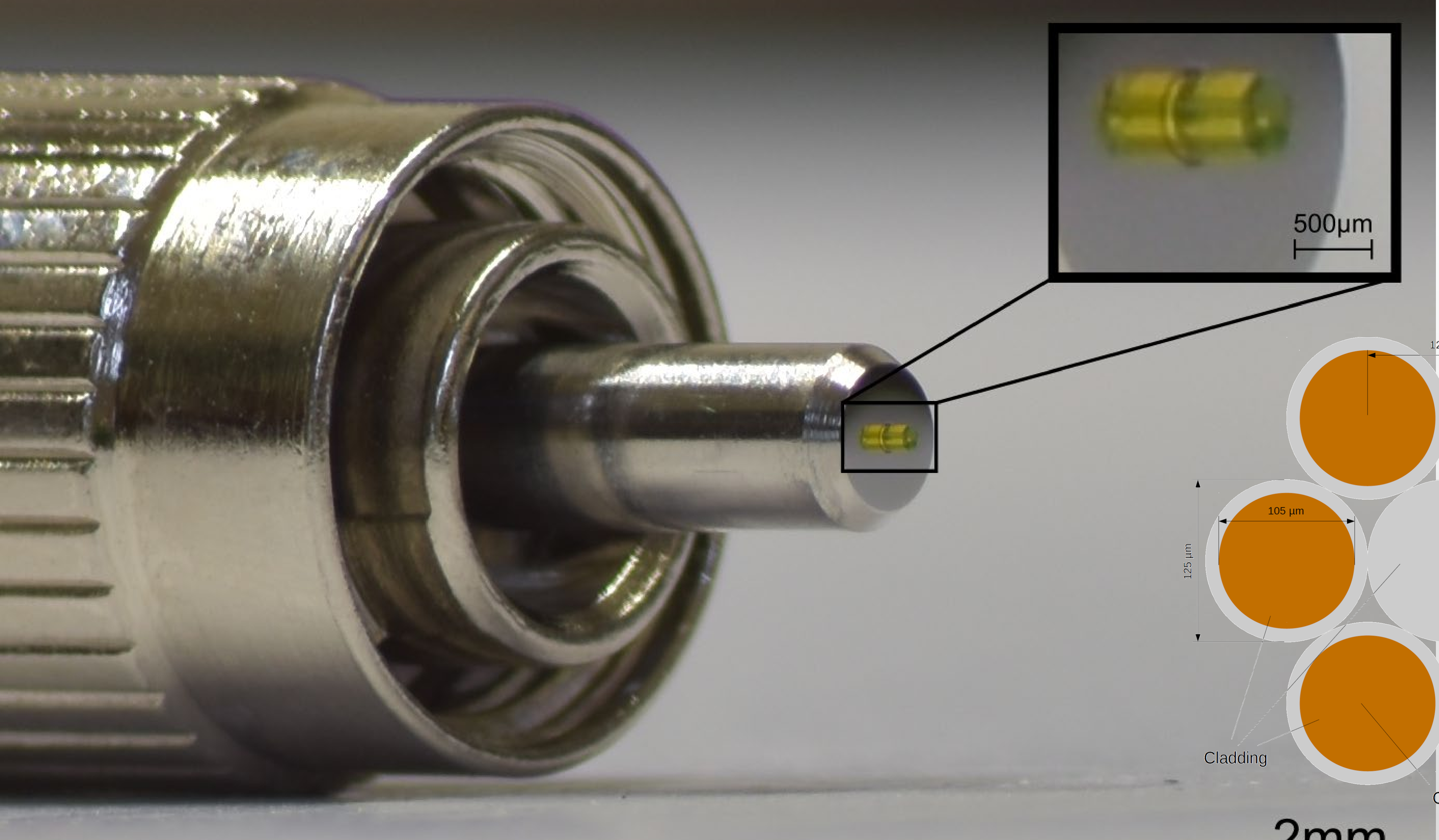
Single-measurement precision

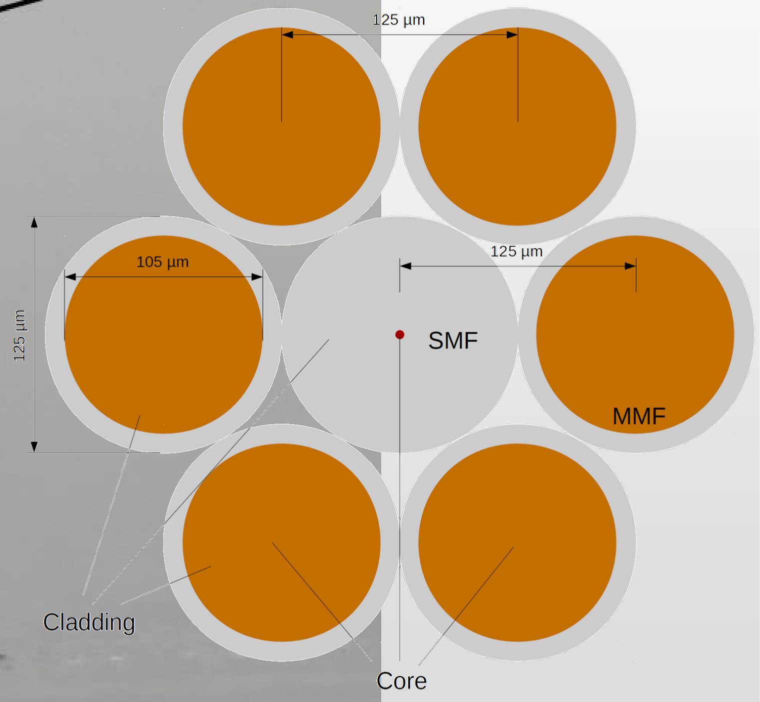


Selected Science Programs

- Studies of close-binary systems

- Simultaneous programs with other LBT instruments
  - SHARK high contrast/resolution imaging at NIR/visible
  - PEPSI: R=270,000, λ=0.384-0.913μm
  - iLocater: R=190,000, λ=0.97-1.27μm





https://arxiv.org/abs/1808.03190

Summary

- iLocater is moving rapidly from design to fabrication
- Prototype SX fiber injection system will be delivered to the telescope this semester and tested on-sky
- Spectrograph design – built from the ground up to ensure its suitability for RV science
  - High resolution ⇒ possibility to measure line asymmetries
  - Build about to commence

Resolution	
Median: 189,400	Minimum: 131,900
Mean: 193,600	Maximum: 273,600

Pixel Sampling/Resolution Element	
Median: 2.69	Minimum: 2.62
Mean: 2.73	Maximum: 3.17

Bandpass: Y- and J-bands (0.97-1.27μm)