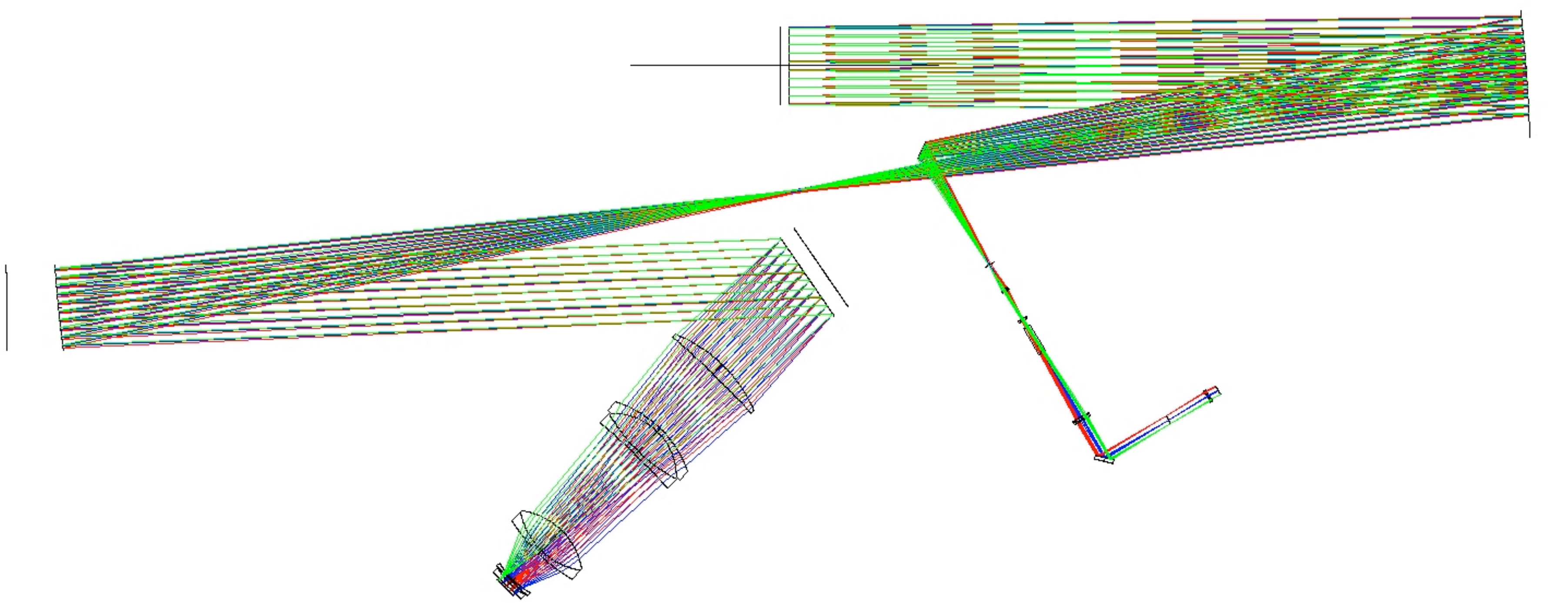
THE HRS
Pre and post HET Wide Field Upgrade

Topics for this presentation

- **State of the HRS performance (throughput-centric)**
- **The HRS Input Upgrade and HRS completion projects**
- **The planned HRS blue arm**

The current HRS optical layout

- The current HRS configuration is shown below for reference
- The echelle grating is top center, the white pupil collimator and pupil transfer mirrors are at extreme right and left, the cross disperser grating is below the echelle, and the camera and detector are at left center
- New pre-slit optics (to be discussed) are shown at lower right



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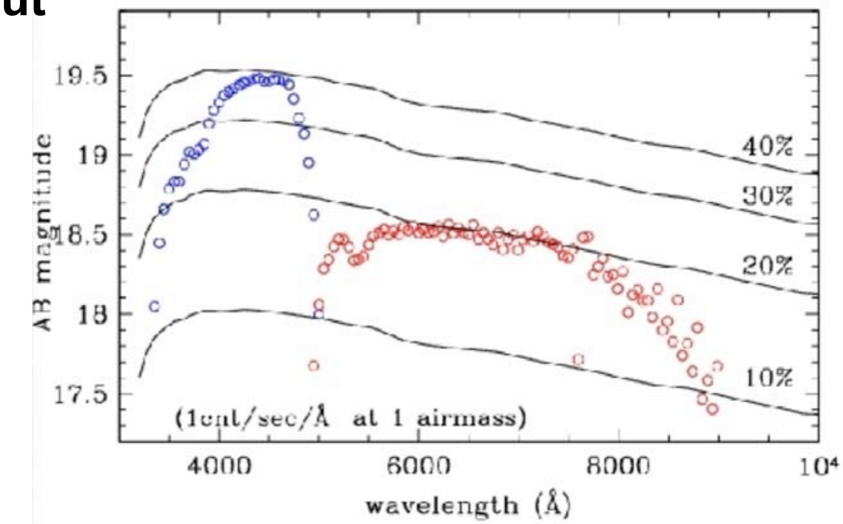
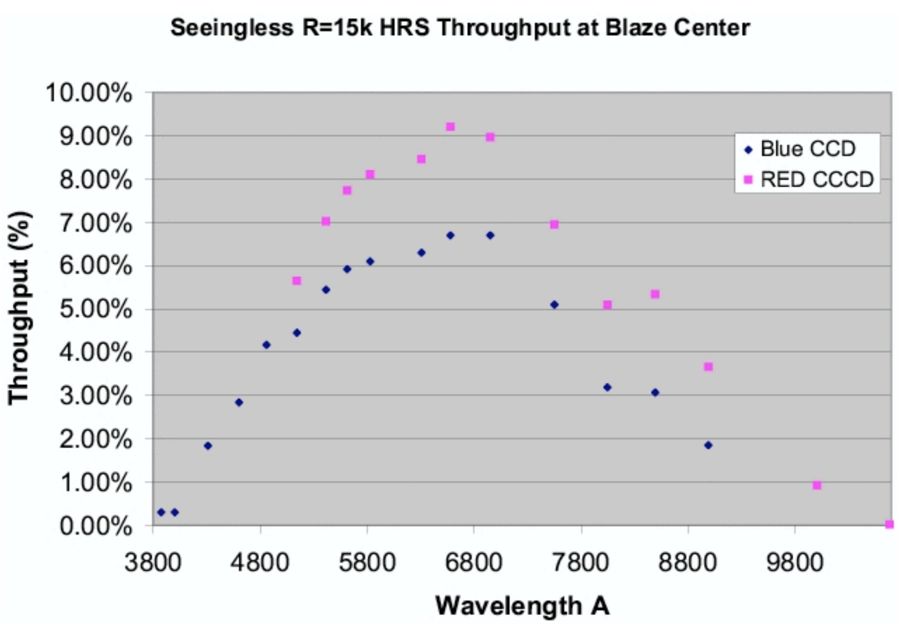
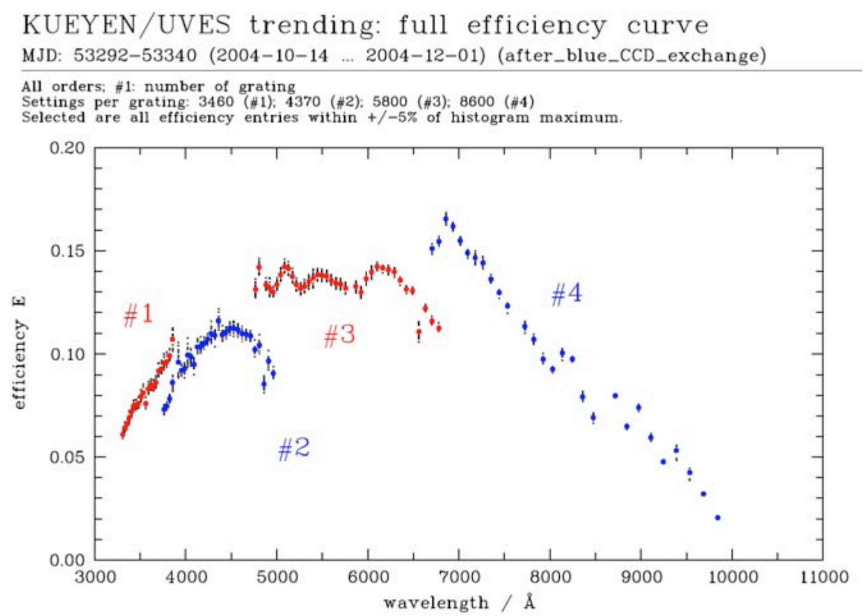
Current HRS Throughput

- HRS focal-plane-to-CCD throughput is poor relative to MIKE on Magellan (prism cross-dispersers), and UVES on VLT (grating cross-dispersers)
- The HRS throughput shown is before recent fixes and upgrades, and is for the lowest resolving power (no slit losses)
- N.B. HRS data includes telescope (<0.69)

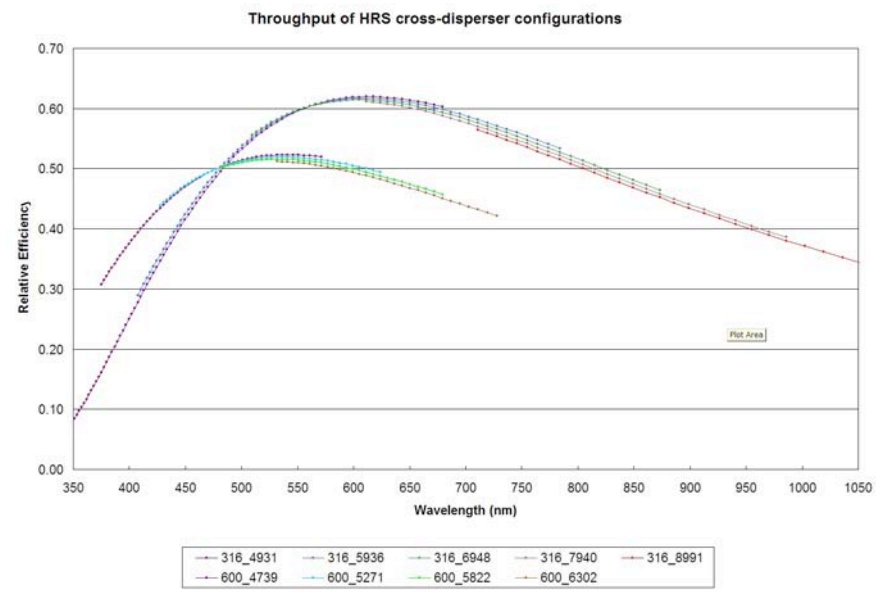


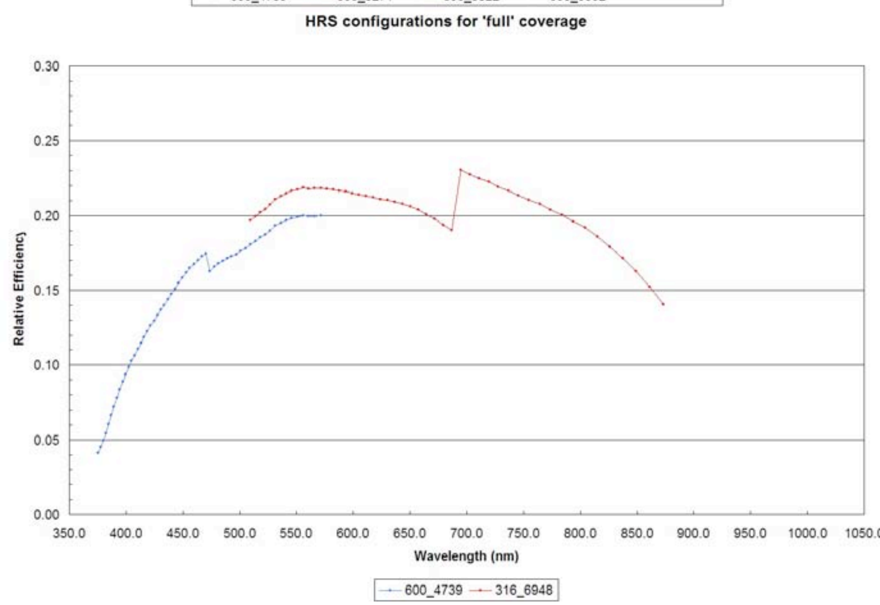




Efficiency problems

- **Detailed modeling has been done to determine efficiency expectations from fiber to CCD (see figures)**
- **The three significant causes of low throughput are**
  - **the current HET image quality and throughput**
  - **the HRS cross dispersers**
  - **the HRS slit losses (the major problem at high resolution)**
- **HRS has two cross dispersers, the 600 gv/mm grating for the blue, and the 316 gv/mm grating for the red**



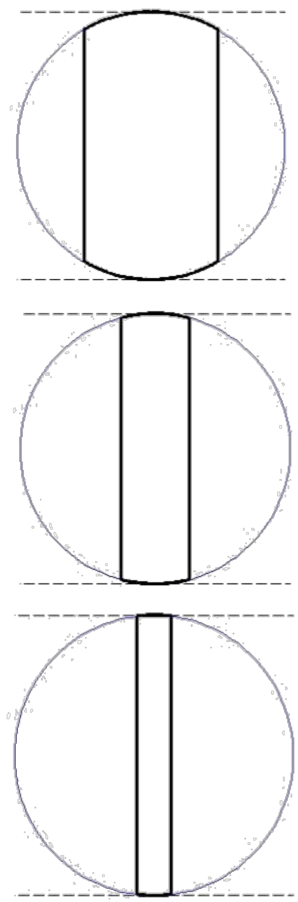


Slit losses: the current HRS fiber-feed modes

Current HRS fiber-slit configurations:

- **R=15,000**
  - 2” fiber with 2” slit (R~18,000)
  - 3” fiber with 2” slit
- **R=30,000**
  - 2” fiber with 1” slit
  - 3” fiber with 1” slit
- **R=60,000**
  - 2” fiber with 0.5” slit
  - 3” fiber with 0.5” slit
- **R=120,000**
  - 2” fiber with 0.25” slit
  - 3” fiber with 0.25” slit

The exit slit which sets the resolving power causes a loss of throughput



R = 30K (2” fiber)

62% throughput

R = 60K (2” fiber)

32% throughput

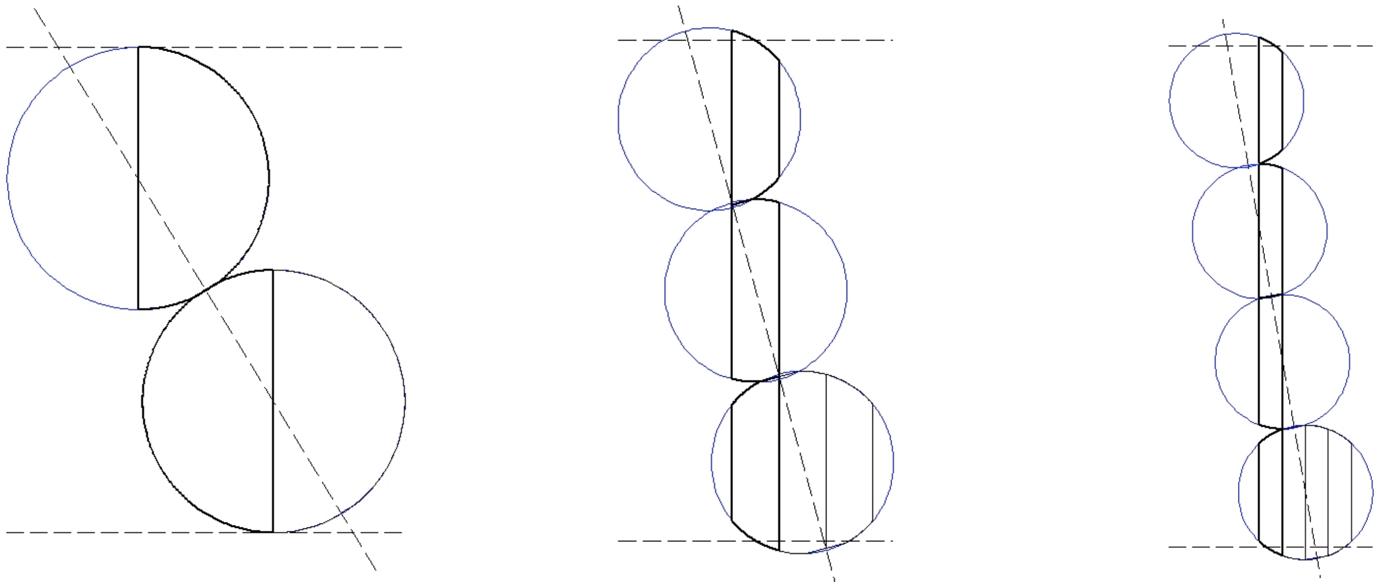
R = 120K (2” fiber)

16% throughput

HRS Input Upgrade: the image slicers

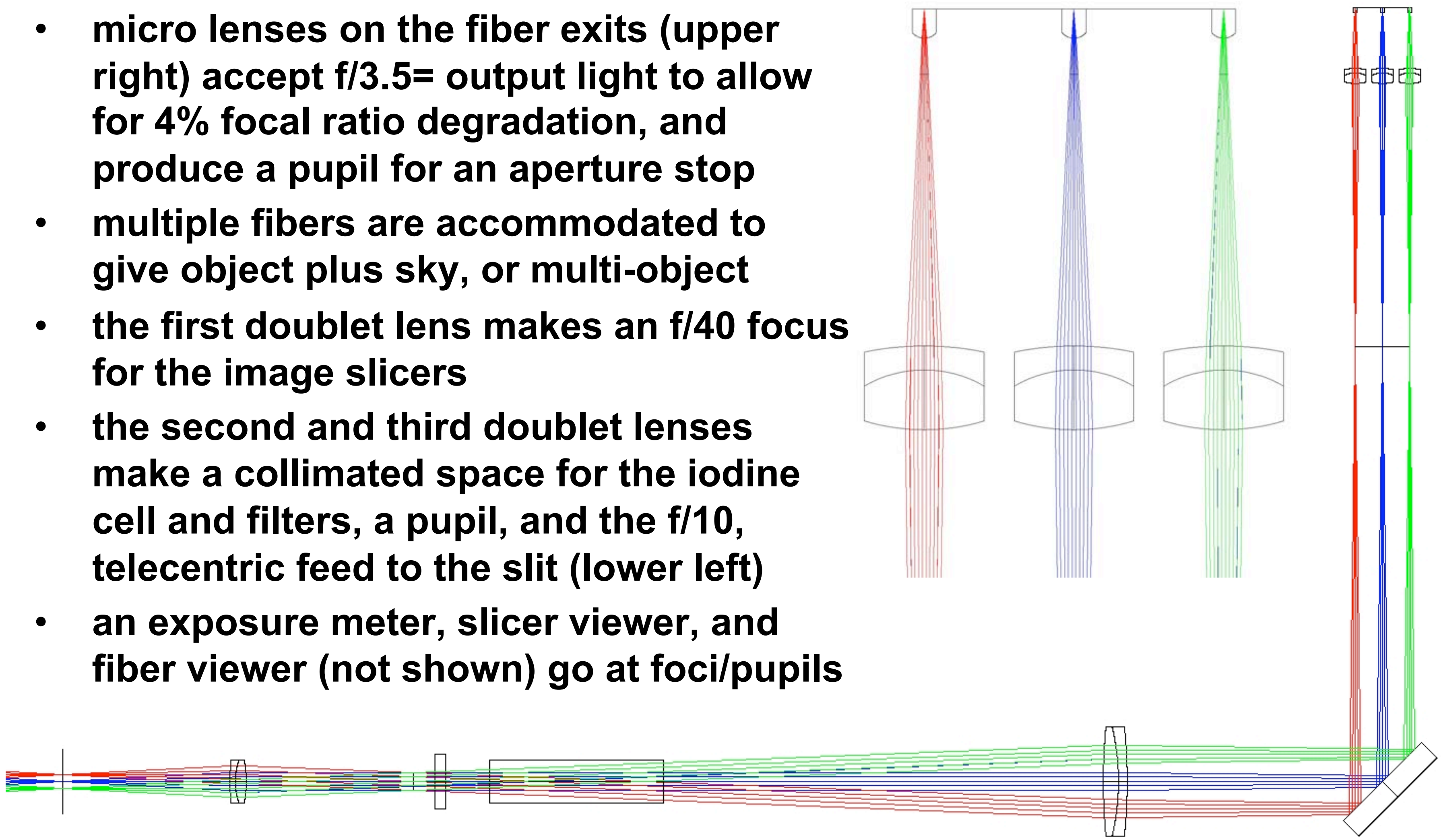
- The image slicer design is very dependent upon mean HET IQ and fiber size, and the interorder separation delivered by the cross dispersers
- The 3 arcsec fibers will be retired, and new fibers installed with 2 arcsec and 1.45 arcsec diameters.
- Slicers shown are for the current cross disperser interorder separation

R=30K, 2” Fiber	R=60K, 2” Fiber	R=120K, 1.45” Fiber
3.9” height, 1.5x gain	5.3” height, 3x gain	5.4” height, 4x gain



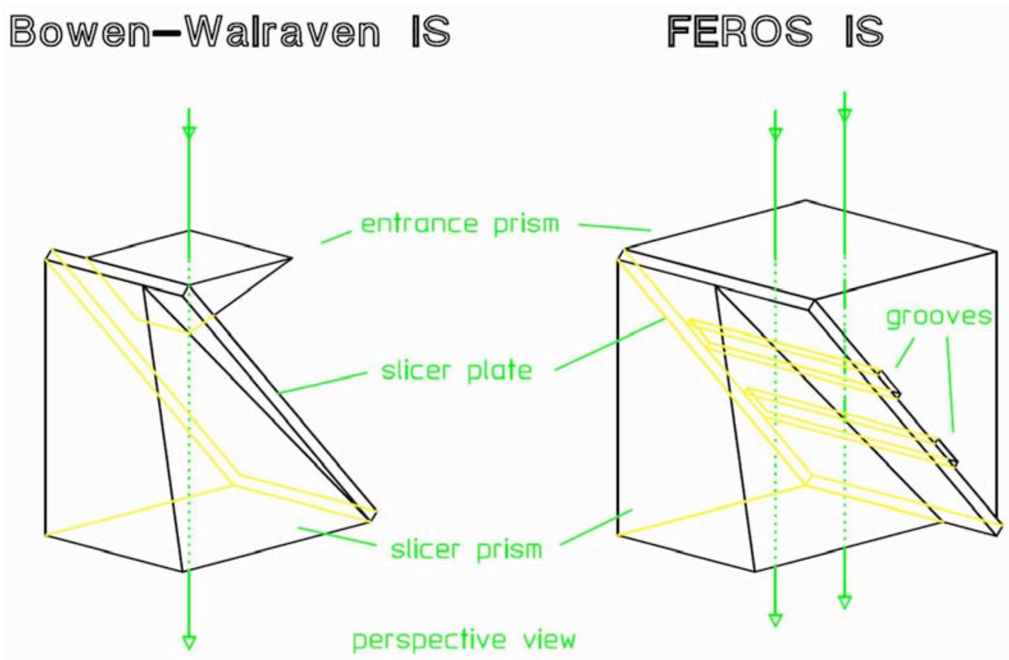
HRS Input Upgrade: preslit optics

- micro lenses on the fiber exits (upper right) accept f/3.5= output light to allow for 4% focal ratio degradation, and produce a pupil for an aperture stop
- multiple fibers are accommodated to give object plus sky, or multi-object
- the first doublet lens makes an f/40 focus for the image slicers
- the second and third doublet lenses make a collimated space for the iodine cell and filters, a pupil, and the f/10, telecentric feed to the slit (lower left)
- an exposure meter, slicer viewer, and fiber viewer (not shown) go at foci/pupils

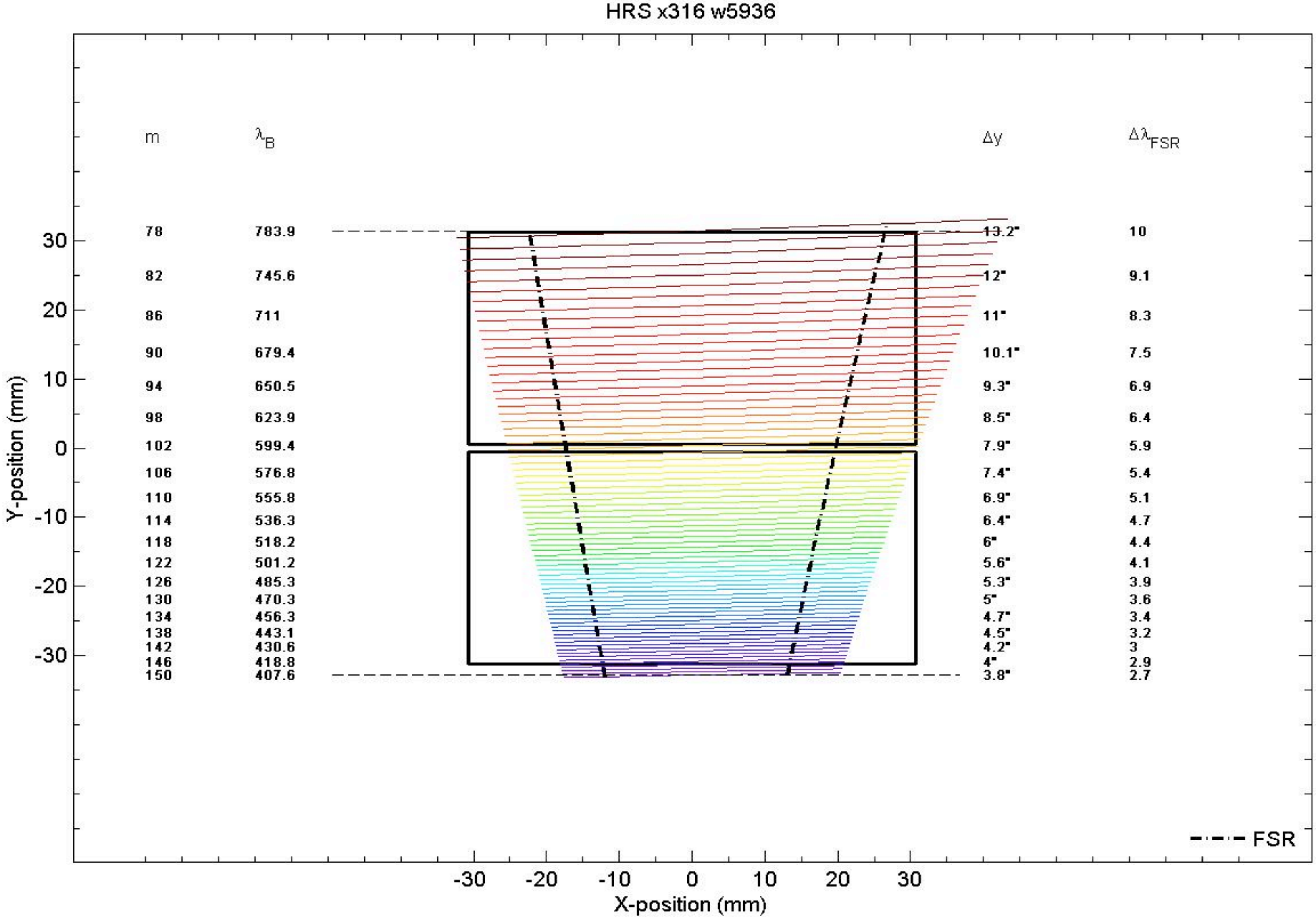


HRS upgrade motivation: improve throughput!

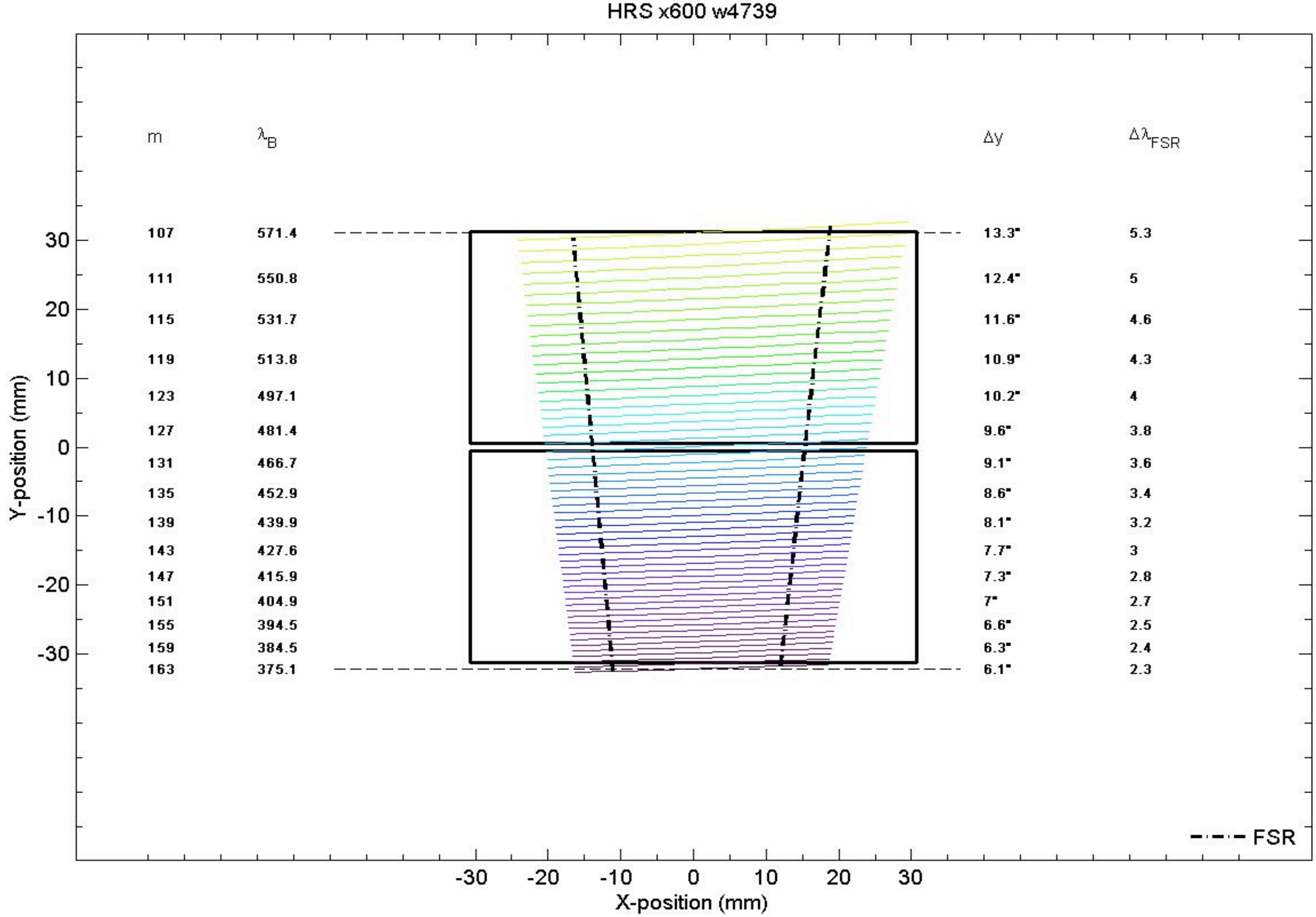
- Use fiber output slicers as done with FEROS, bHROS, and UVRES
- Optimize slicers for the HET and HRS performance parameters
  - Seeing distribution, resolving powers, wavelength coverages, and diffraction order separation as a function of wavelength
- Design based upon enhanced Bowen-Walraven, total internal reflection image slicers



316 gv/mm cross disperser - 5936 A configuration

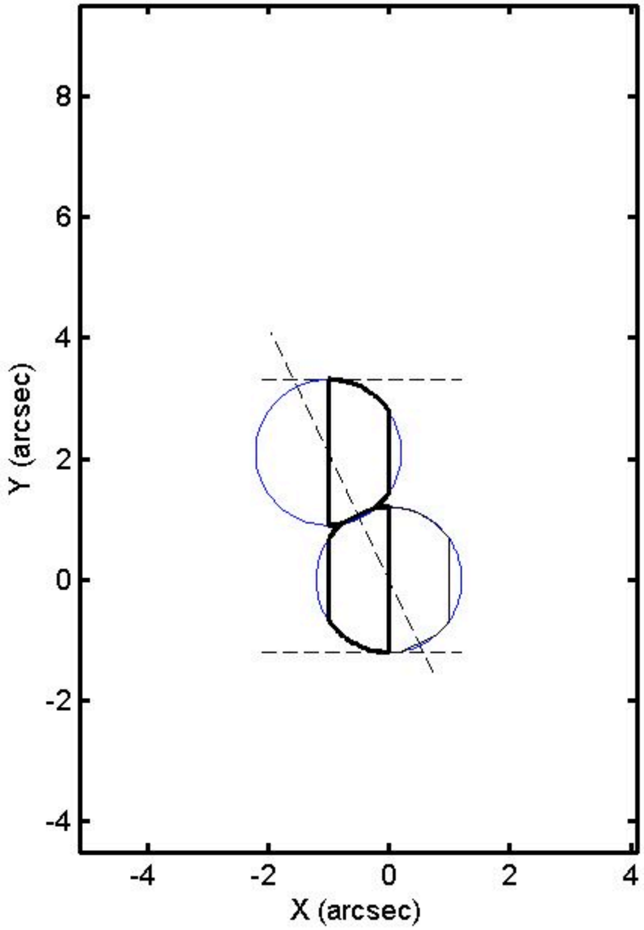


600 gv/mm cross disperser - 4739 A configuration



Slicers for R=30,000 and R=120,000

R=30,000
W=1.0”, D=2.4”, H_{tot}=4.7”



R=120,000
W=0.25”, D=1.5”, H_{tot}=9.1”

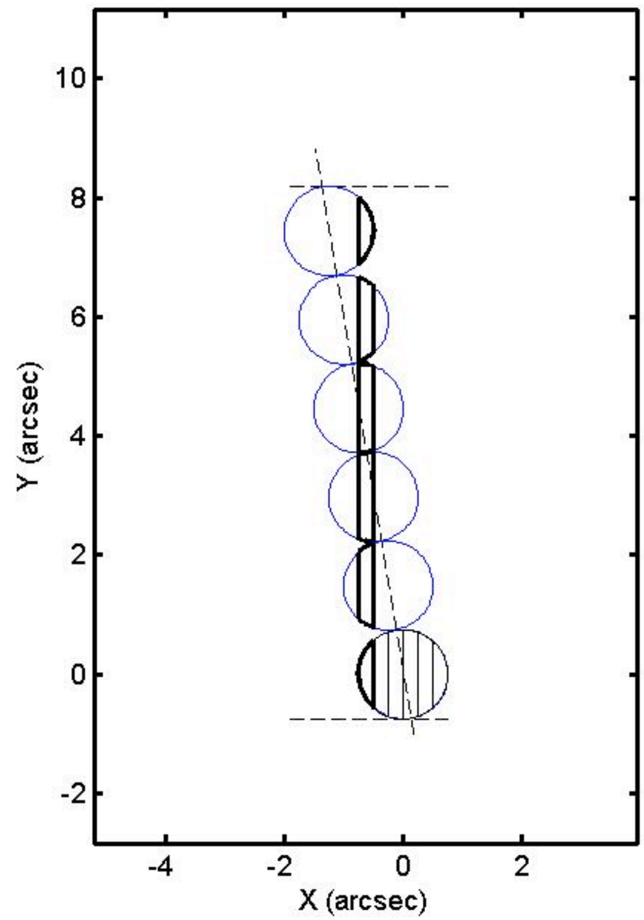


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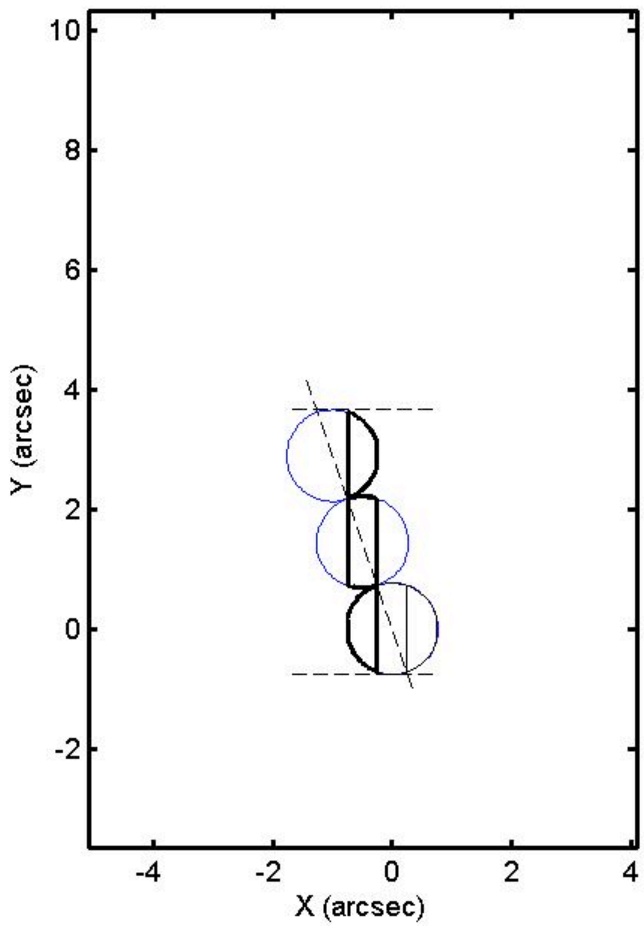
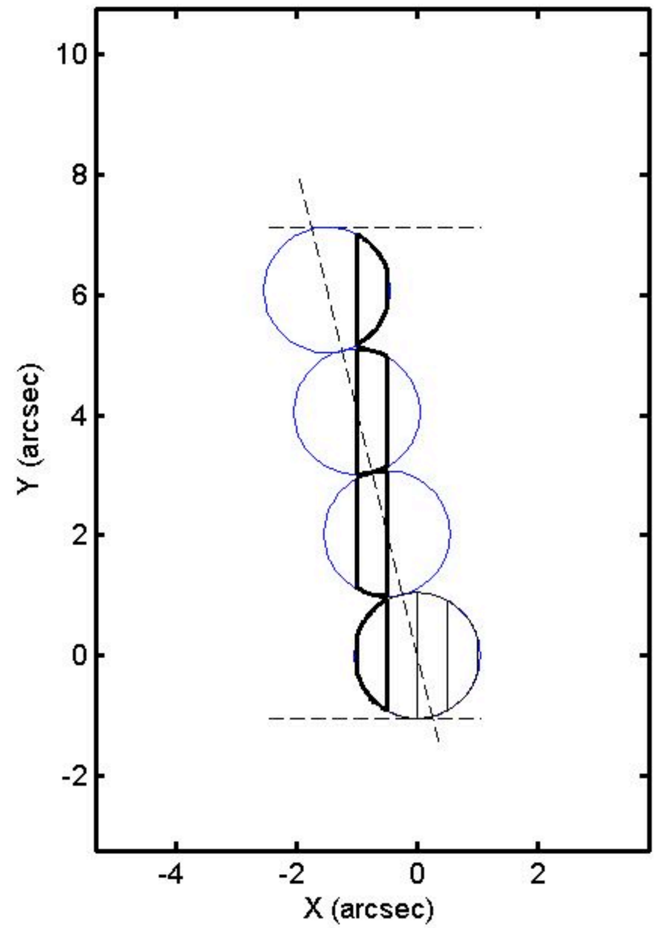
Image slicers for different fiber sizes at R=60,000

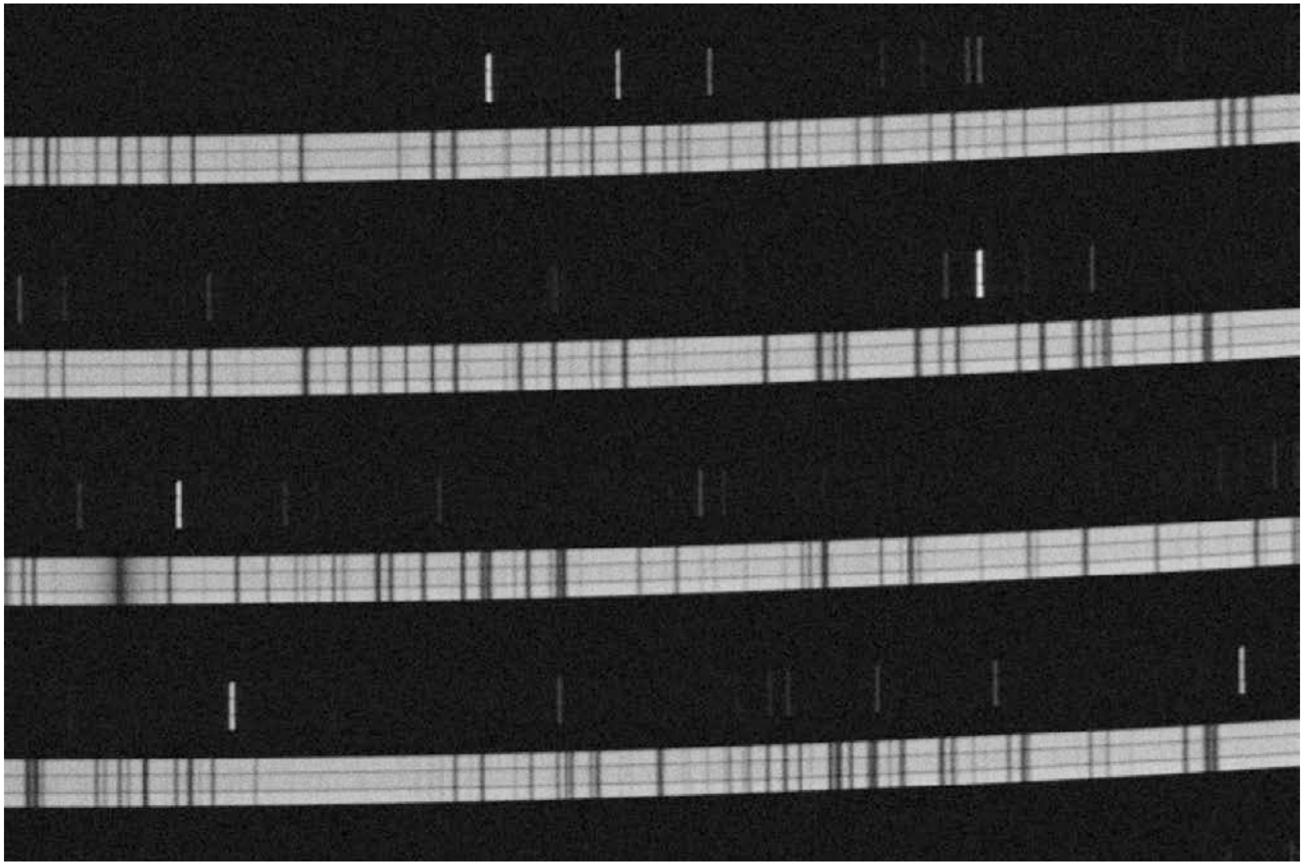
Object + sky
W=0.5”, D=1.5”, H_{tot}=4.7”



Object only
W=0.5”, D=2.1”, H_{tot}=8.5”



The SALT HRS image slicer design

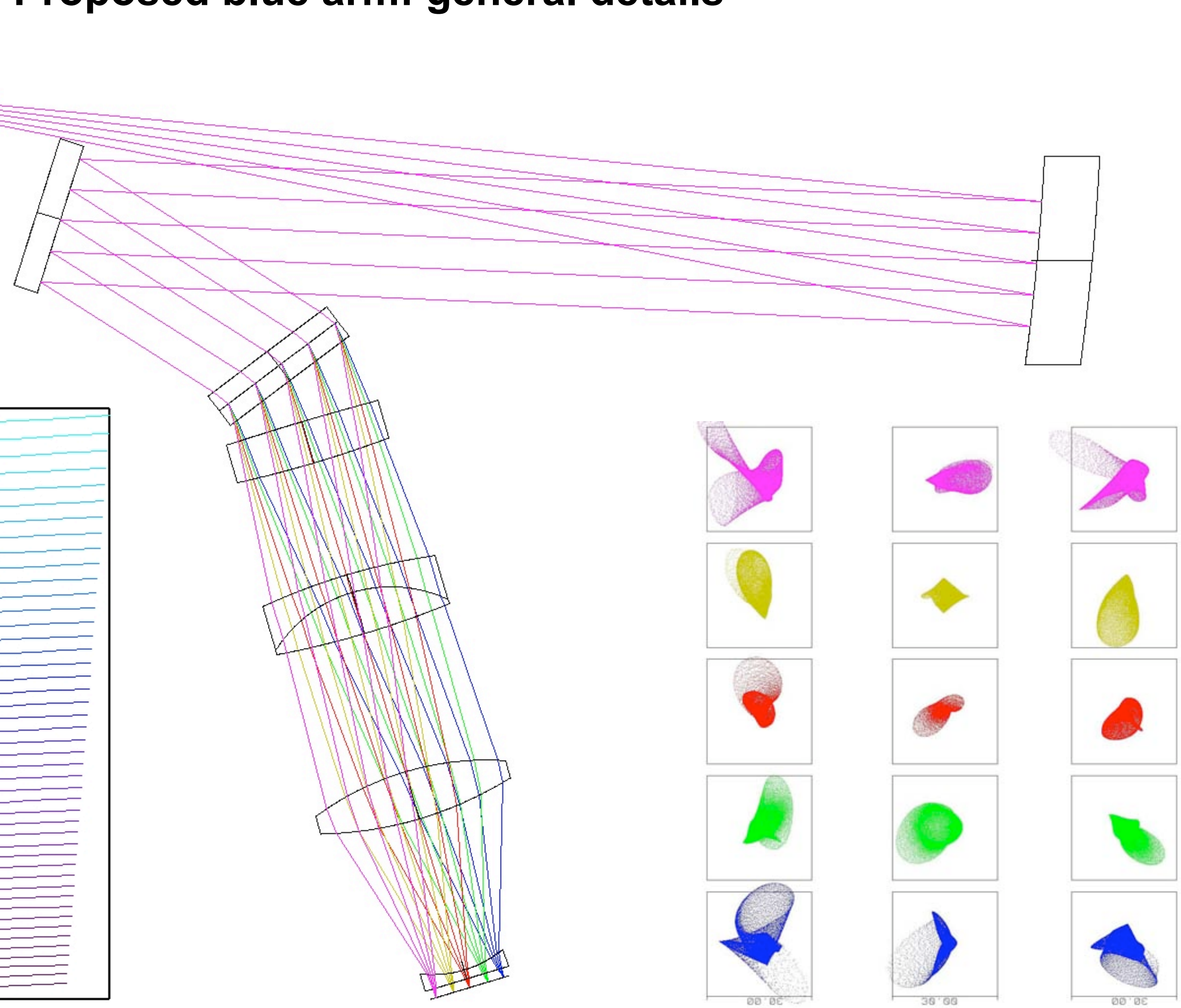


- A synthetic spectrum image by Stuart – generated for the SALT HRS with a 3-slice image slicer, 1-D spectrum input to Zemax with SALT HRS optical design, and simultaneous Th-Ar calibration

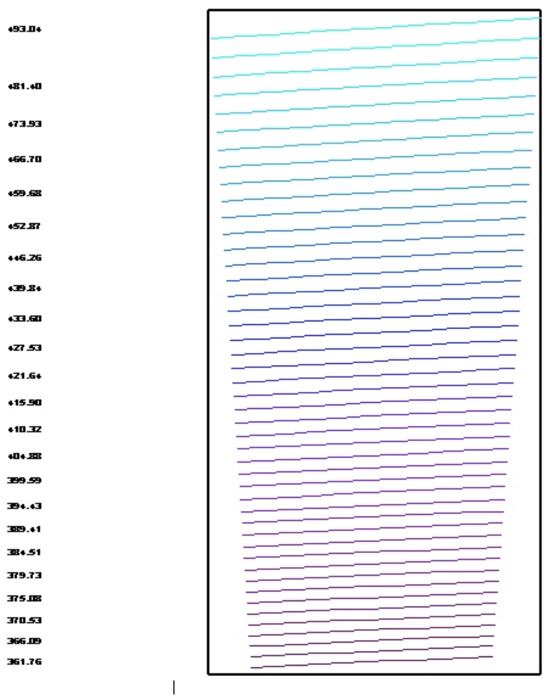
Proposed HRS Blue Arm

- **The original HRS proposal was for a two arm spectrograph. The NSF requested a significantly reduced budget, and so HRS was reduced to a single arm spectrograph.**
- **A blue arm has been designed (Stuart Barnes) so that the HRS Input Upgrade can accommodate it. Its details are:**
  - **the echelle will be shared between arms (cf. two echelles in MIKE and UVES)**
  - **the current arm will become the red arm, and will be configurable**
  - **the split between arms is at 495 nm so that the iodine cell bandwidth is entirely in one arm – the red arm**
  - **the blue bandwidth is 360 – 495 nm, and is a fixed format**
  - **it uses a VPHG cross disperser for efficiency (75-85%, cf. 50-60%)**
  - **uses a single 2k x 4k CCD with 15 micron pixels. The coating will be a gradient coating with optimized QE at each wavelength.**
  - **pupil demagnification is used to simplify the camera (cf. 2dcoude).**

Proposed blue arm: general details



- **2-pixel spot boxes showing 360-495 nm**
- **2k x 4k CCD**



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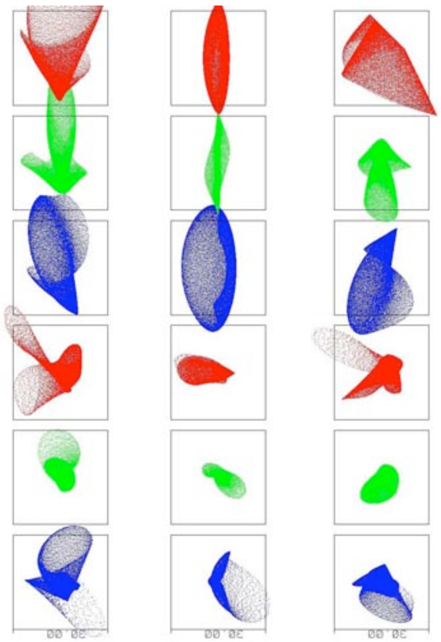
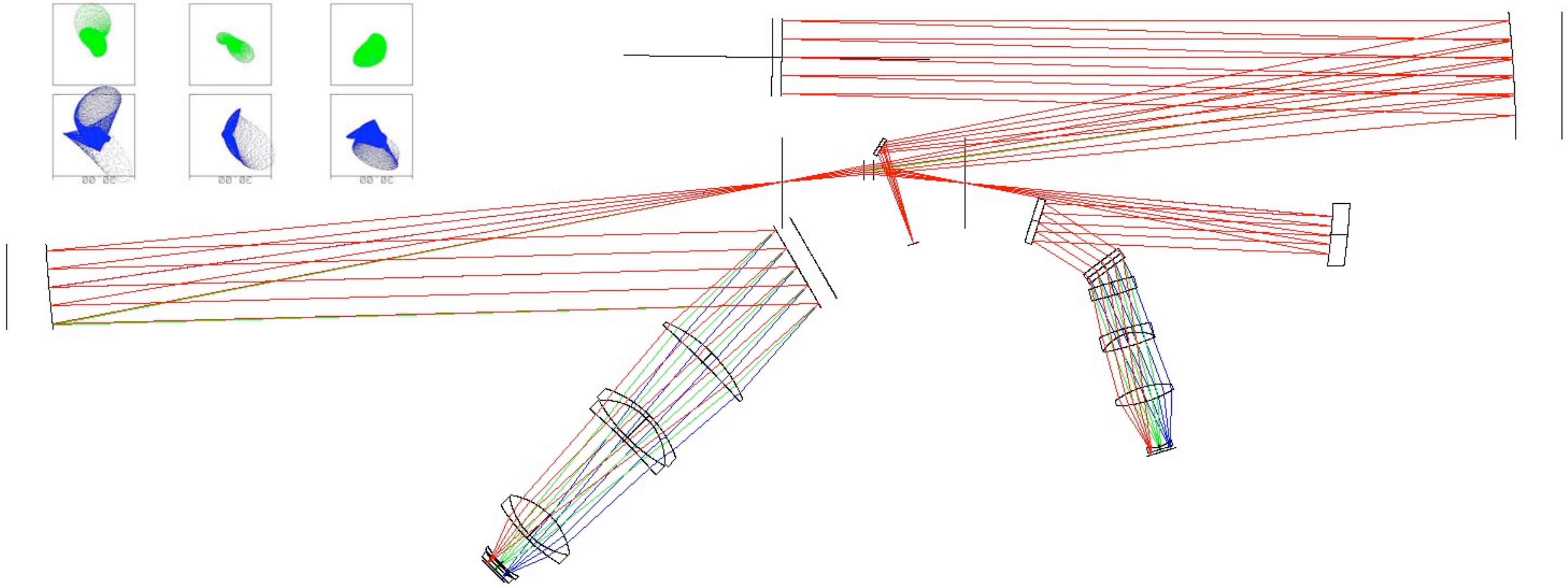
Proposed blue arm: layout in HRS

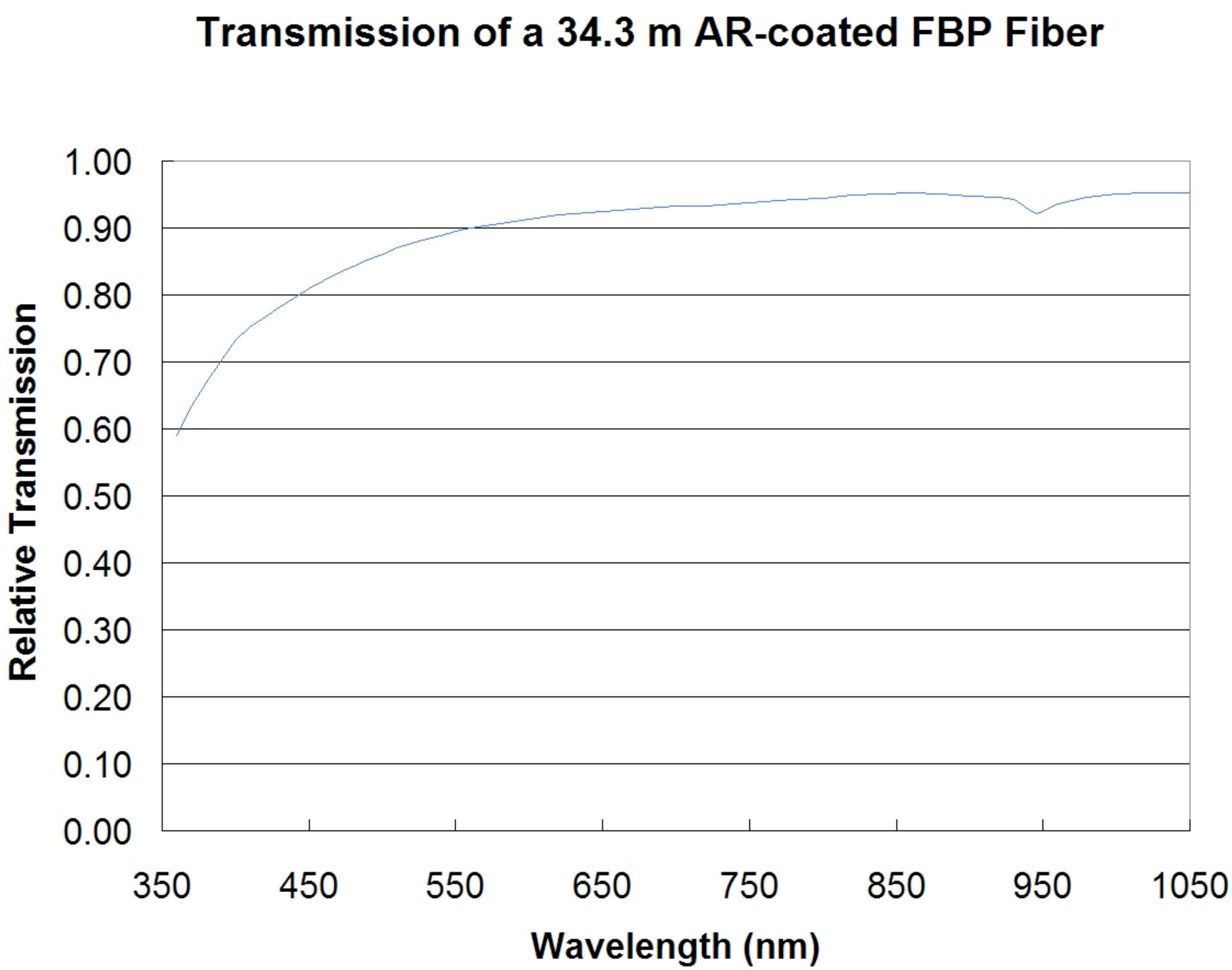


- the dichroic before the intermediate focus splits the light at 495 nm, blue reflected to the right, red transmitted straight through
- the preslit optics must fit between the arms
- the bottom three rows of spots are the blue camera, and the top three are the red camera



Proposed blue arm: fiber transmission

- fiber transmission at 360 nm is ~59% for AR-coated fiber ends
- the input and output microlenses will be AR coated and coupled to the fibers with a refractive index matching compound



HRS stability issues

Stability

- **HRS temperature changes cause wavelength shifts on the detector equivalent to 238 m/s per C°**
- **HRS pressure changes also cause wavelength shifts equivalent to 91 m/s per mbar (hPa). Note the mean atmospheric pressure at HRS is 800 mbar. Pressure shifts set the *good enough* limit on temperature control for velocities**
- **The HRS is now temperature controlled to ~ ±0.2 C° over long periods, and ~ ±0.01 C° over multi-hour periods. Our intent is to achieve ±0.01 C° long term stability**
- **For precision radial velocity observations, an iodine cell is used to calibrate for pressure and residual temperature changes**

The HET performance

The role of the HET in HRS performance (key points):

- **HRS is competing against HiRES, UVES, and MIKE that are fed by telescope with median delivered image quality between 0.6 and 0.8 arcseconds.**
  - **improving HET monochromatic image quality from ~1.65 to <1. 2 arcseconds will result in a 1.5x gain for 1.5 arcsec fibers, 1.34x gain for 2 arcsec fibers**
  - **the ADC will improve the polychromatic image quality over the HRS bandwidth from 1.2 arcsec dispersion to <0.2 arcseconds (~1.4x at ends of bandwidth for 1.5 arcsec fibers)**
  - **The WFU was conceived in part to address this**
- **HET throughput is also low**
  - **the reflectivity and scattering of the 5 HET mirrors (91 M1, 4 SAC) is poor, lowering throughput and raising the sky brightness. This continues to be addressed.**

Summary of HRS needs

In order to improve HRS competitiveness, HRS & HET need to:

- Improve HET image quality and throughput via:
  - improved median monochromatic image quality
  - high throughput and low background from HET optics
  - an ADC to correct the polychromatic image quality
  - compensation for the site image motion
- Improve HRS throughput
  - fed HRS through image slicers and new fibers
  - higher throughput cross dispersion
  - optimized blue arm
- Improve stability through
  - repeatable mechanisms for configuration changes
  - an exposure meter
  - through-fiber calibration
  - higher performance temperature control