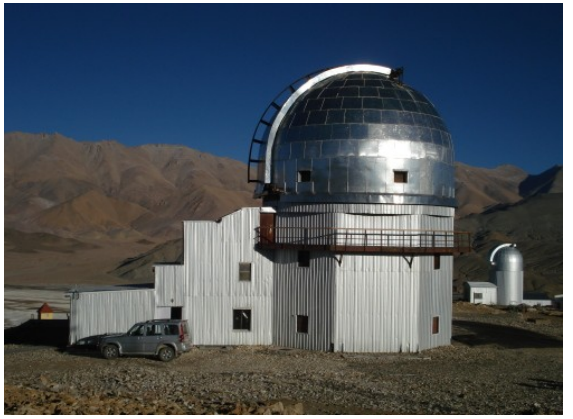
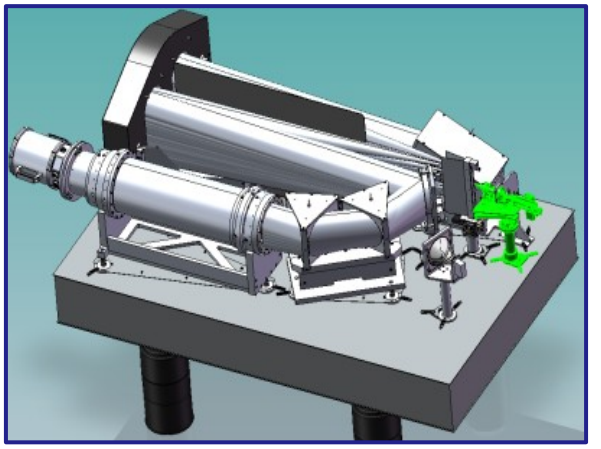
Hanle Echelle Spectrograph (HESP)

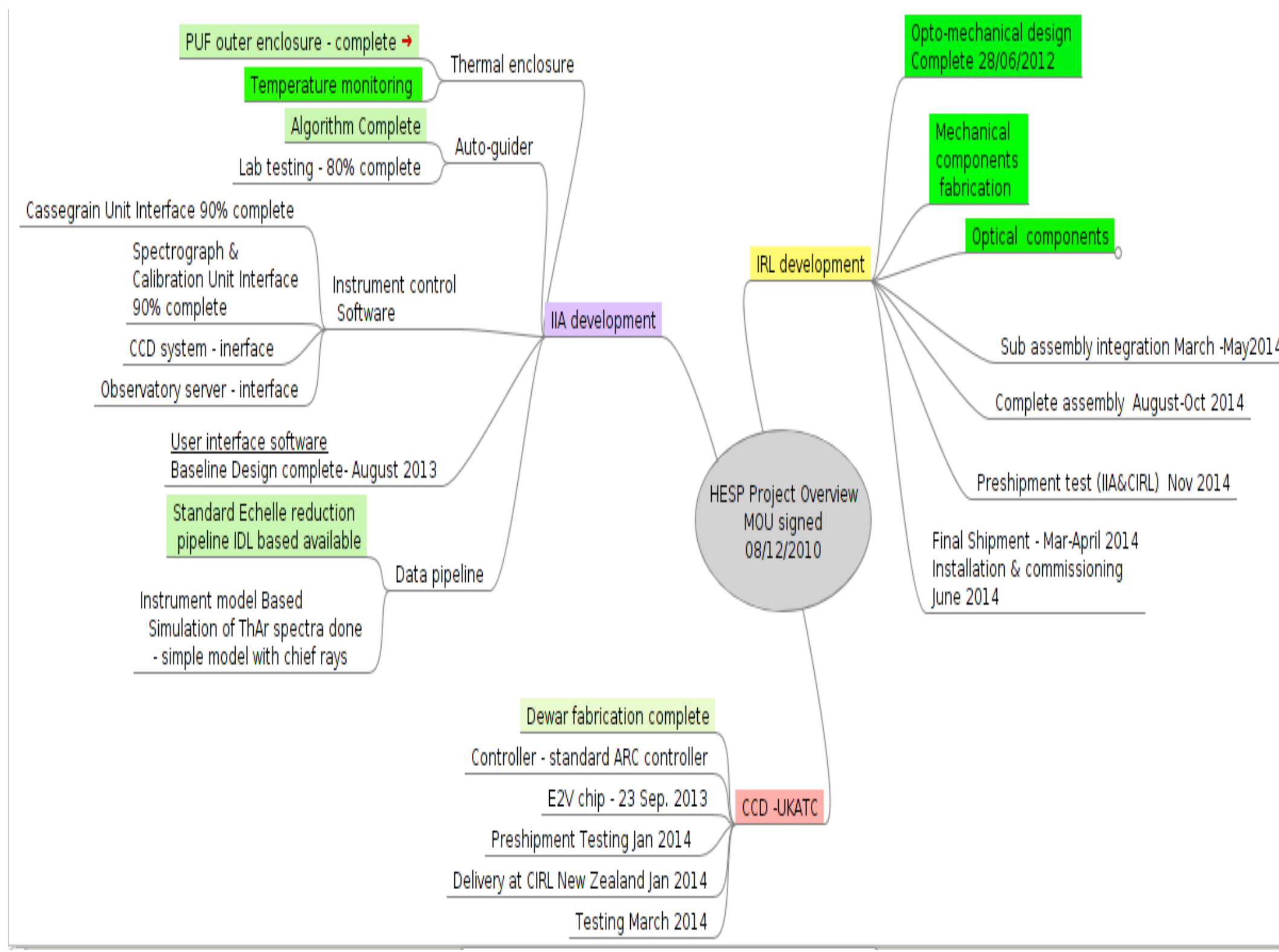


- Bench mounted High resolution echelle spectrograph fed by Optical Fiber

- Second generation instrument for HCT



The project is a technical collaboration between Indian Institute of Astrophysics (IIA), Bangalore and Industrial Research Limited, New Zealand where both partners work in close interaction


HESP Project Overview
MOU signed
08/12/2010
IIA development
Thermal enclosure
PUF outer enclosure - complete
Temperature monitoring
Auto-guider
Algorithm Complete
Lab testing - 80% complete
Instrument control Software
Cassegrain Unit Interface 90% complete
Spectrograph & Calibration Unit Interface 90% complete
CCD system - inerface
Observatory server - interface
User interface software
Baseline Design complete- August 2013
Data pipeline
Standard Echelle reduction pipeline IDL based available
Instrument model Based Simulation of ThAr spectra done - simple model with chief rays
IRL development
Opto-mechanical design Complete 28/06/2012
Mechanical components fabrication
Optical components
Sub assembly integration March -May2014
Complete assembly August-Oct 2014
Preshipment test (IIA&CIRL) Nov 2014
Final Shipment - Mar-April 2014
Installation & commissioning
June 2014
CCD -UKATC
Dewar fabrication complete
Controller - standard ARC controller
E2V chip - 23 Sep. 2013
Preshipment Testing Jan 2014
Delivery at CIRL New Zealand Jan 2014
Testing March 2014

HESP specifications

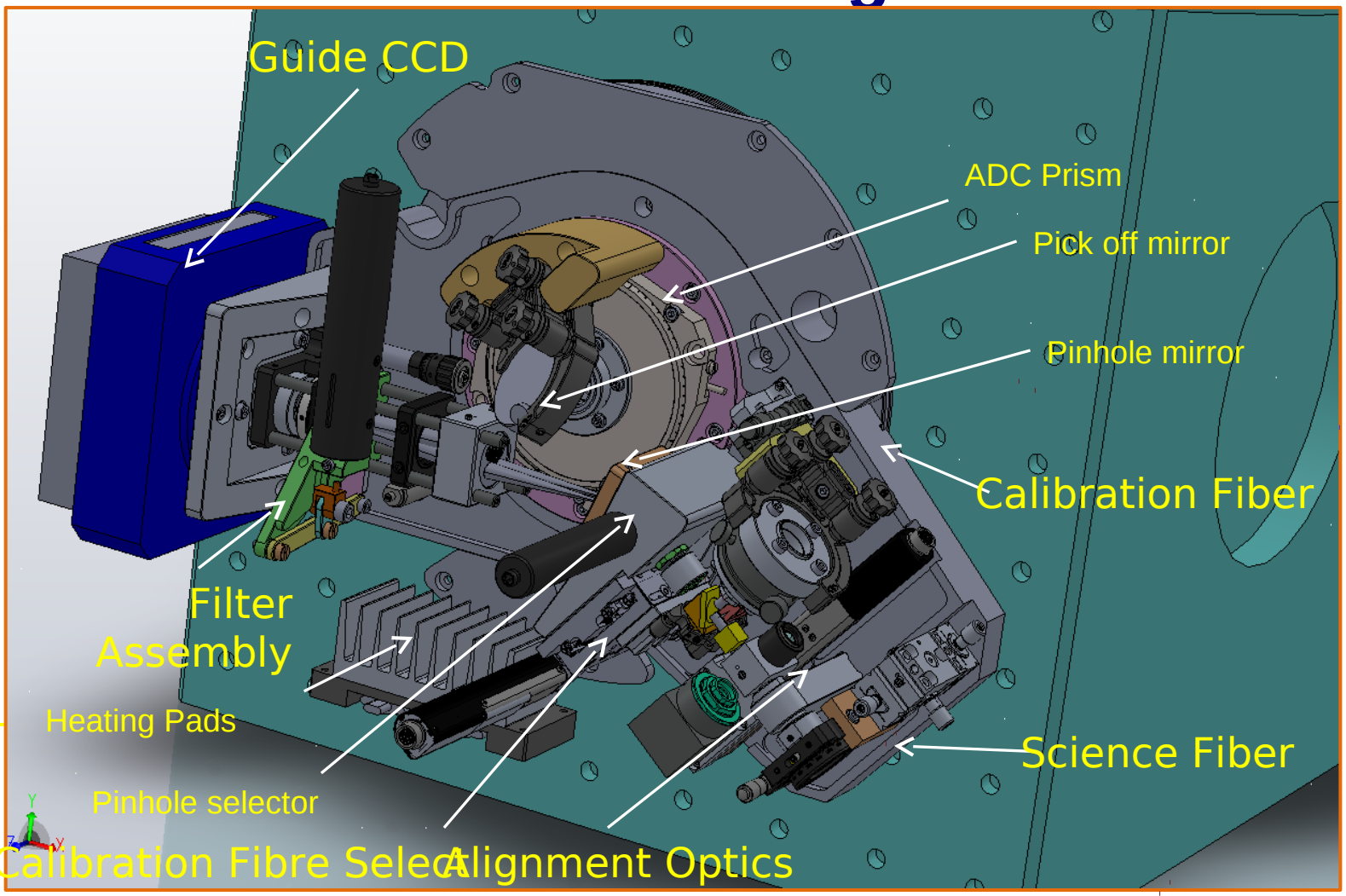
- ✓ Spectral resolution
  - ✓ R = 30000 (unsliced fiber)
  - ✓ R = 60000 (with image slicer)
- ✓ Continuous wavelength coverage: 350-1000nm in single exposure with 4Kx4K Detector format of 12mm square pixel
- ✓ Mechanical stability 200 m/s
- ✓ Radial velocity accuracy 20m/s (ThAr reference mode)
- ✓ Total system Efficiency > 20% (including telescope and detector in the range 400-700nm)
- ✓ Double fiber mode to record the star and calibration/sky spectra simultaneously for high precision RV measurements
- ✓ A minimum inter-order separation of 400 μm on the detector

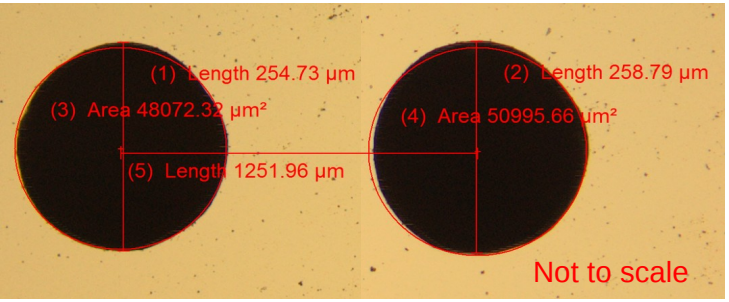
Faintest limit ~12mag (@R=60000 S/N ~15)

HESP Module

- **Cassegrain Unit**
  - Attached to the side port of HCT instrument cube
    - Launching telscope beam into optical fiber
    - Auto guiding setup
      - Atmospheric Dspersion Corrector
      - Pihole mirror /Optical fiber (Science)
      - Calibration fiber
      - Alignment Optics
      - Auto guiding camera
- **Calibration Unit**
  - Located in Spectrograph Laboratory
    - Feeds cassegrain unit with flux from calibration source (Th/Ar, Neon, Hallogen/Tungston)
      - Optical fiber (Calibration)
      - ND filter/Color Balancing filters
      - Fiber selector (00,01,10,11)
- **Spectrograph**
  - Input optics
  - Image Slicer
  - Collimator
  - Echelle Graing
  - Slit mirror

HESP Cassegrain Unit





Two pinholes
250mm
(Sky/object) 2.85”

1.25mm
separation

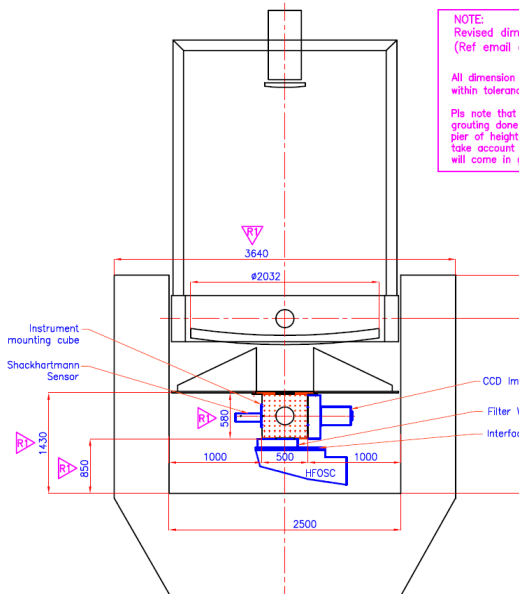
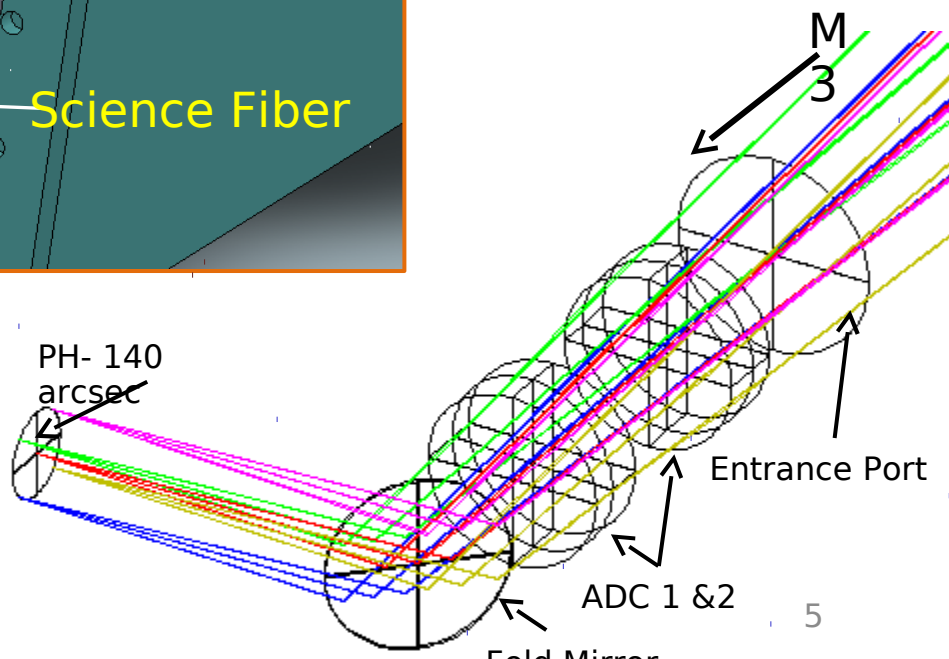
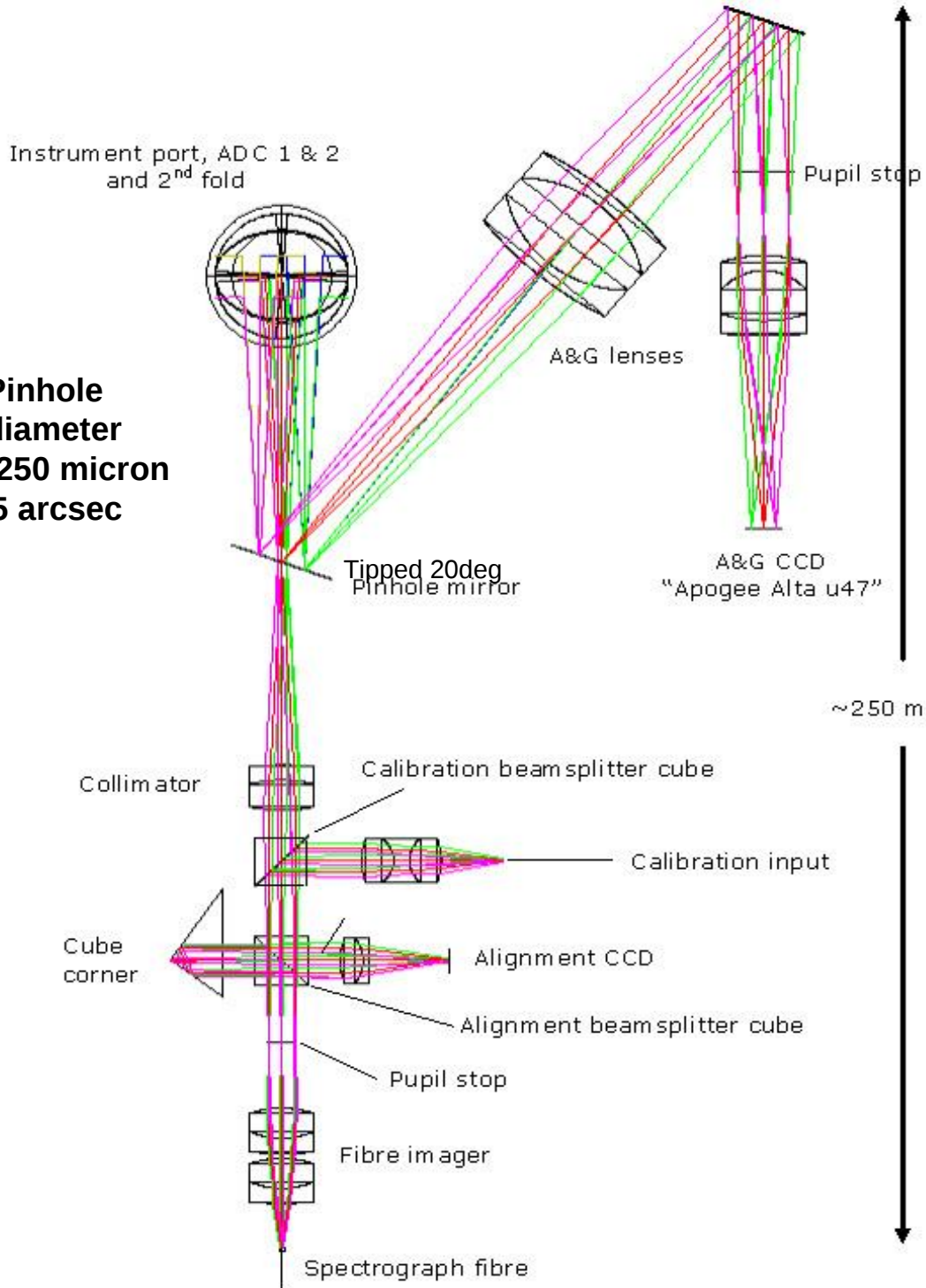


Image scale at the pinhole mirror is 87mm per arcsecond



Cassegrain input optics



- Pinhole diameter -250 micron 2.85 arcsec

Auto guiding options

- Guiding the target star -the spillover annular ring
- Offset guiding within 100x100”
- Using HCT autoguider -offset field
- Image scale – 0.15”/pixel (6pixels)

F/9.2 HCT ➔ F/3.6 at fiber feed to minimize FRD losses

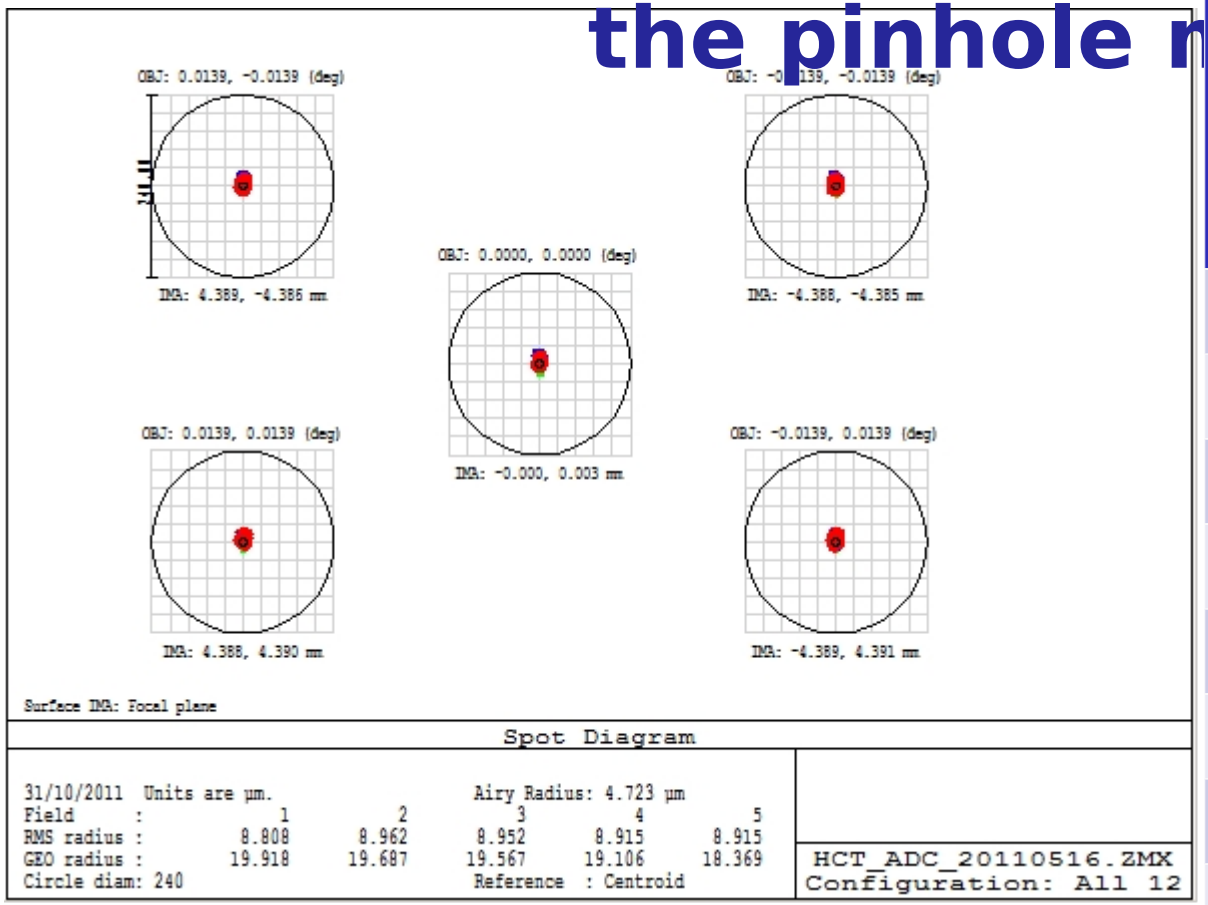
100micron fiber core - 2.85”

5mm Collimated beam

Alignment Optics

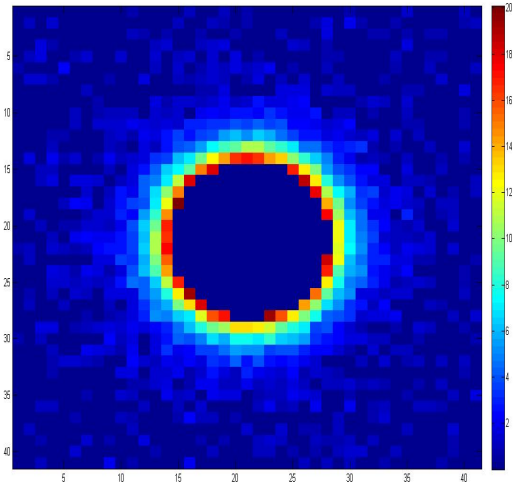
Calibration Fiber feed

Spot diagrams at F/9 telescope focus – the pinhole r



Seeing disk diameter (arcsecs)	Flux through 0.25 mm = 2.85 arcsec diameter pinhole
0.25	1.00
0.5	0.99
0.75	0.97
1.0	0.93
1.25	0.90
1.43	0.86
1.5	0.83
1.75	0.75
2.0	0.67

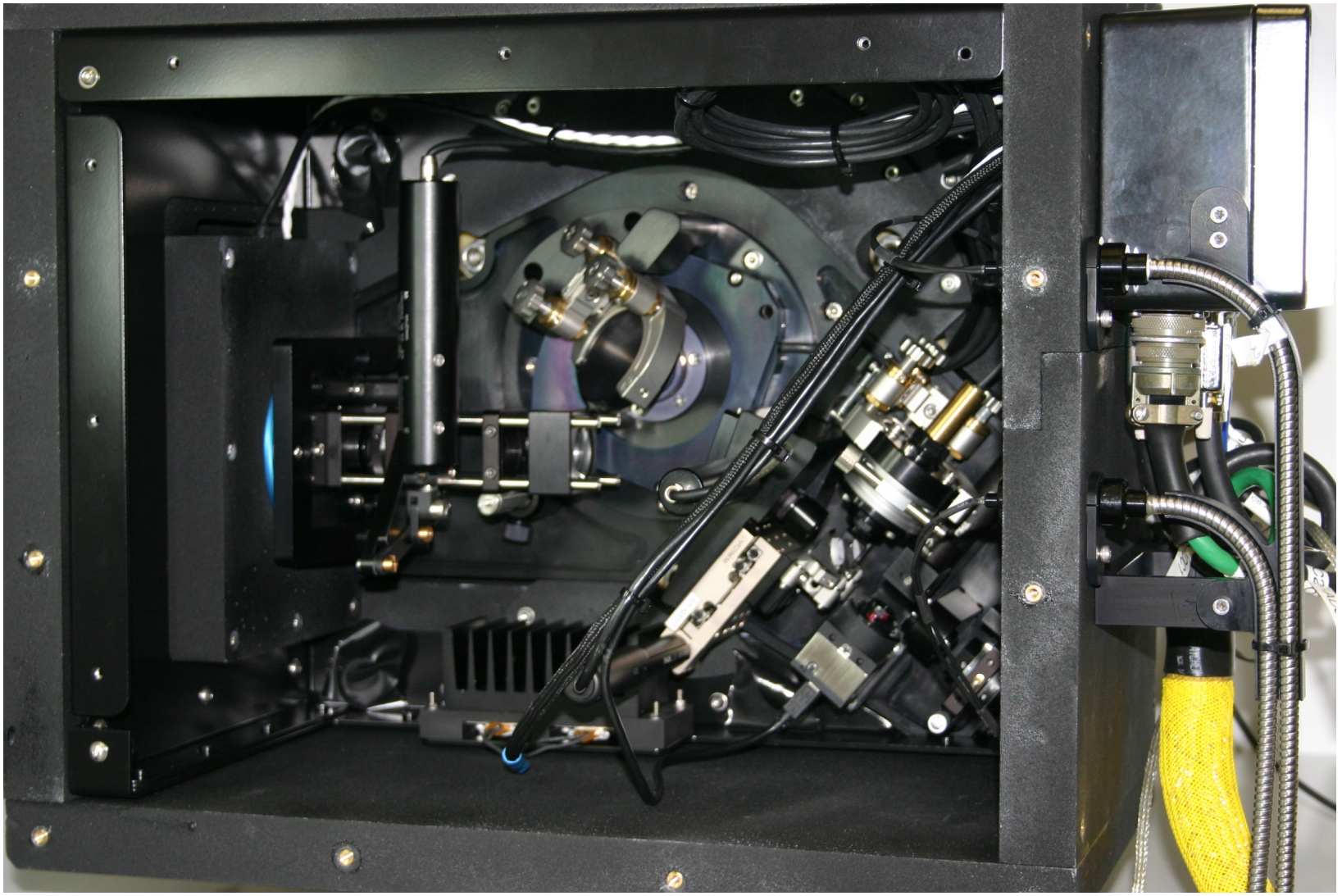
- 12 zenith angles from 0 to 70 degrees are combined and overlaid in each spot diagram.
- The circle diameters are 0.25 mm (equal to the pinhole diameters) or 96% of a projected fibe diameter.
- This is for the square 100 arcsecond field



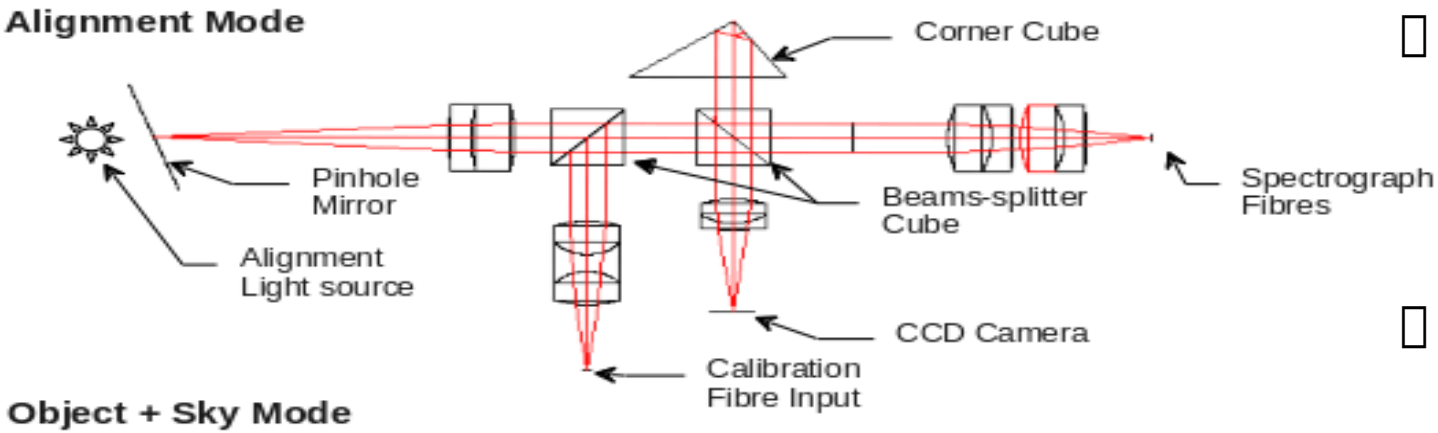
Simulated image at the detector of guiding unit for 1.43” seeing

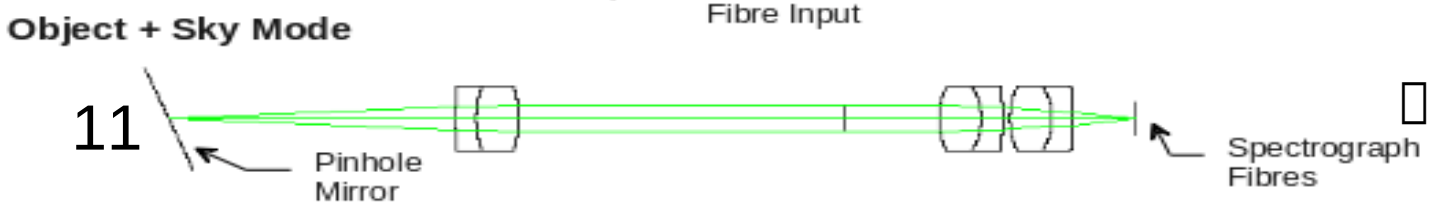
11 mag object

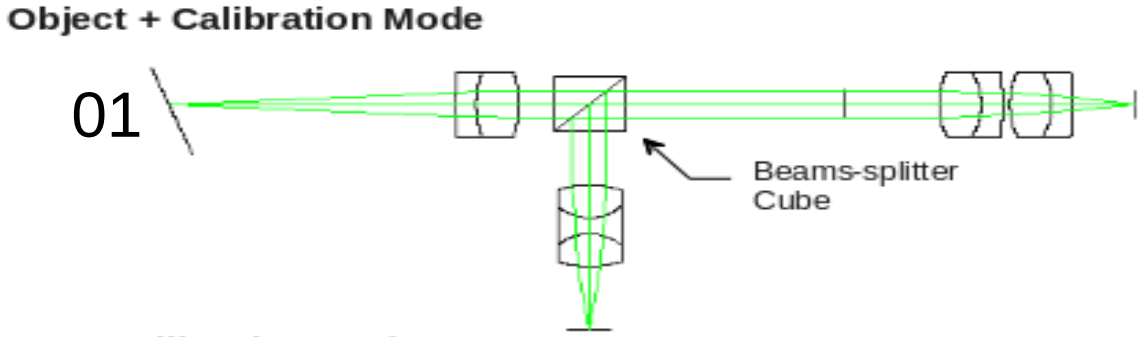
HESP Cassegrain Unit

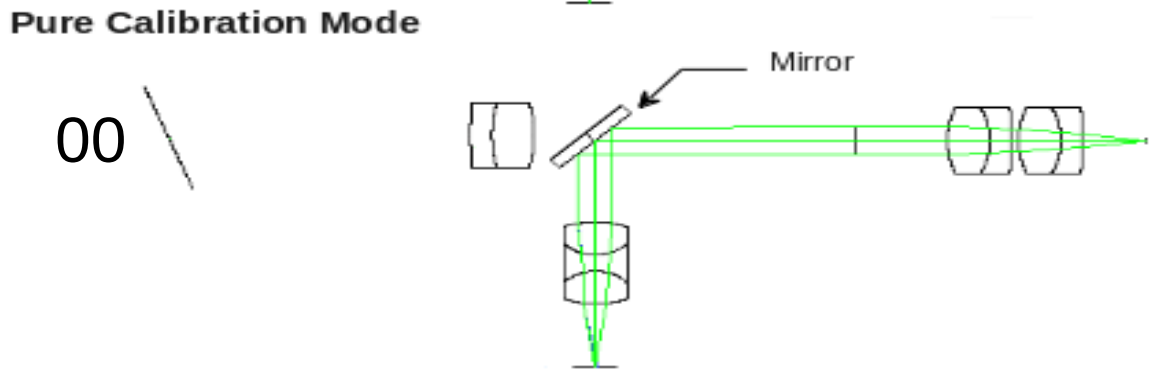


HESP operating modes





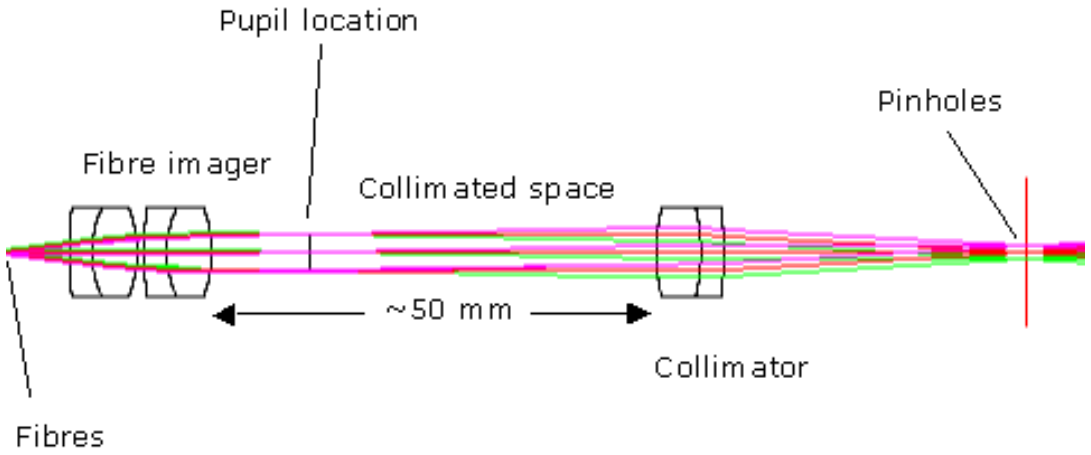


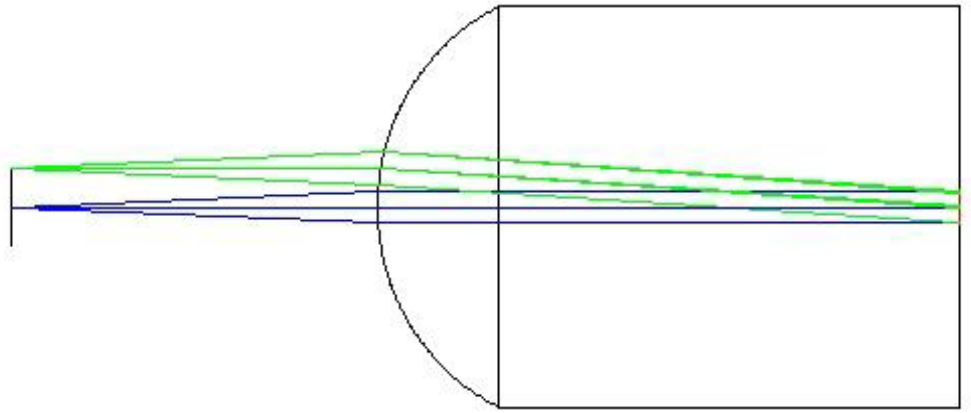


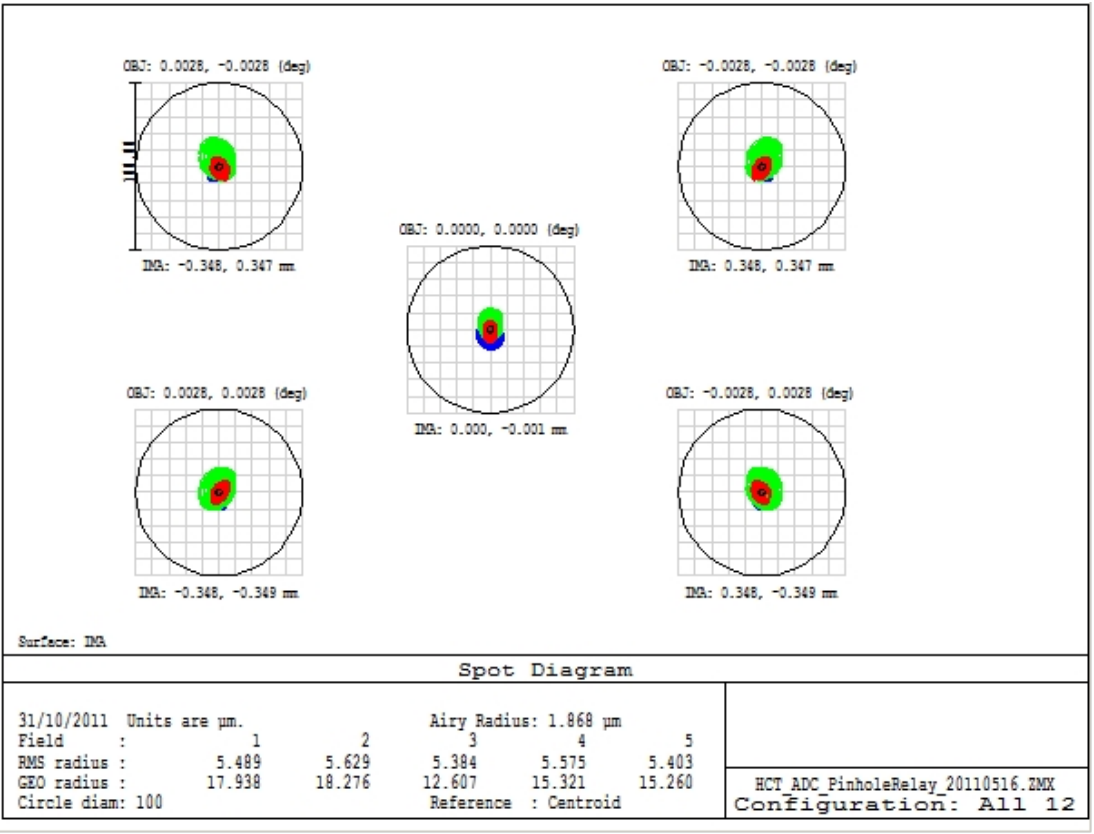
- Alignment mode allows pinholes, calibration and science fibres to be precisely aligned.
- Object and Sky mode is for pure observation.
- Object and Calibration mode is for simultaneous recording of object and calibration spectra for precision.
- Pure calibration mode is for calibration exposures between observations.
- Calibration fibre outputs will be at f/3.6.

Shutter behind Pinhole selects Fiber
00: Calib-Calib
01: Object-Calib / 10: Calib – Object
11: Object - Sky

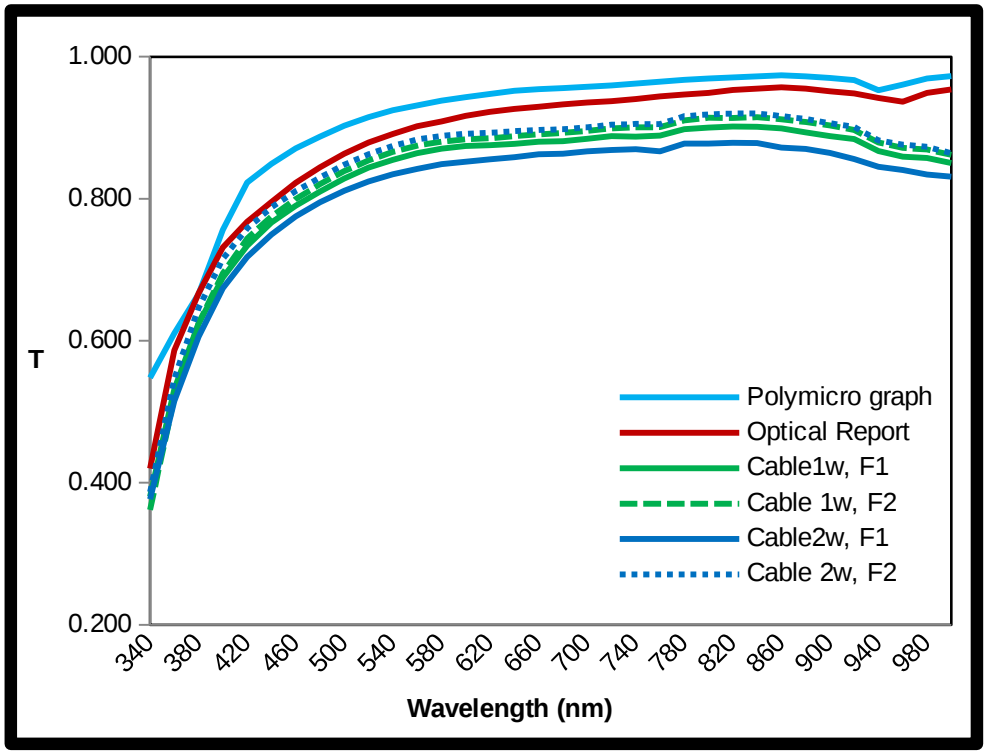
HESP Pinhole - Fiber Coupling







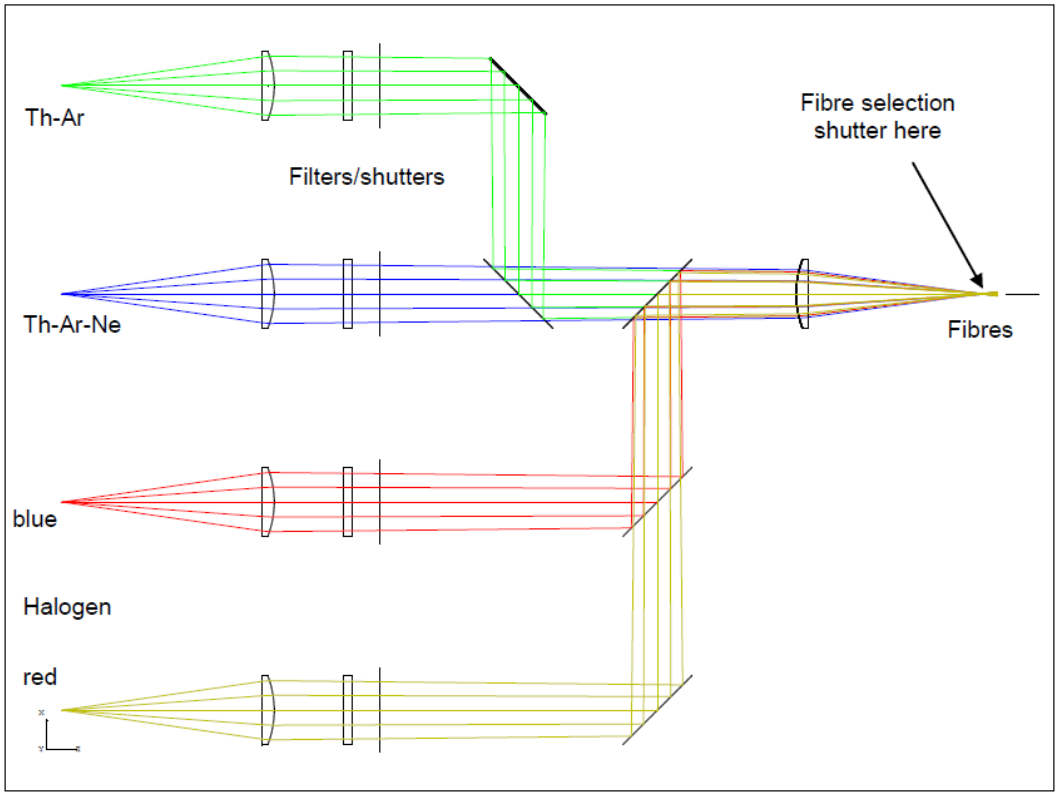
Coupling Efficiency : ~85%



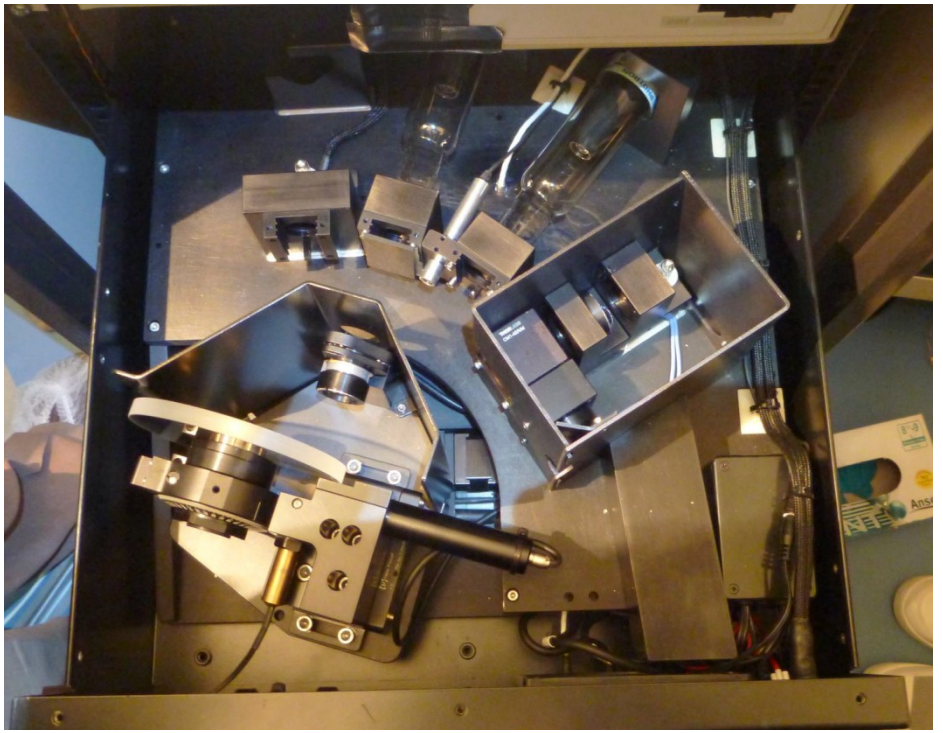
HESP Calibration unit

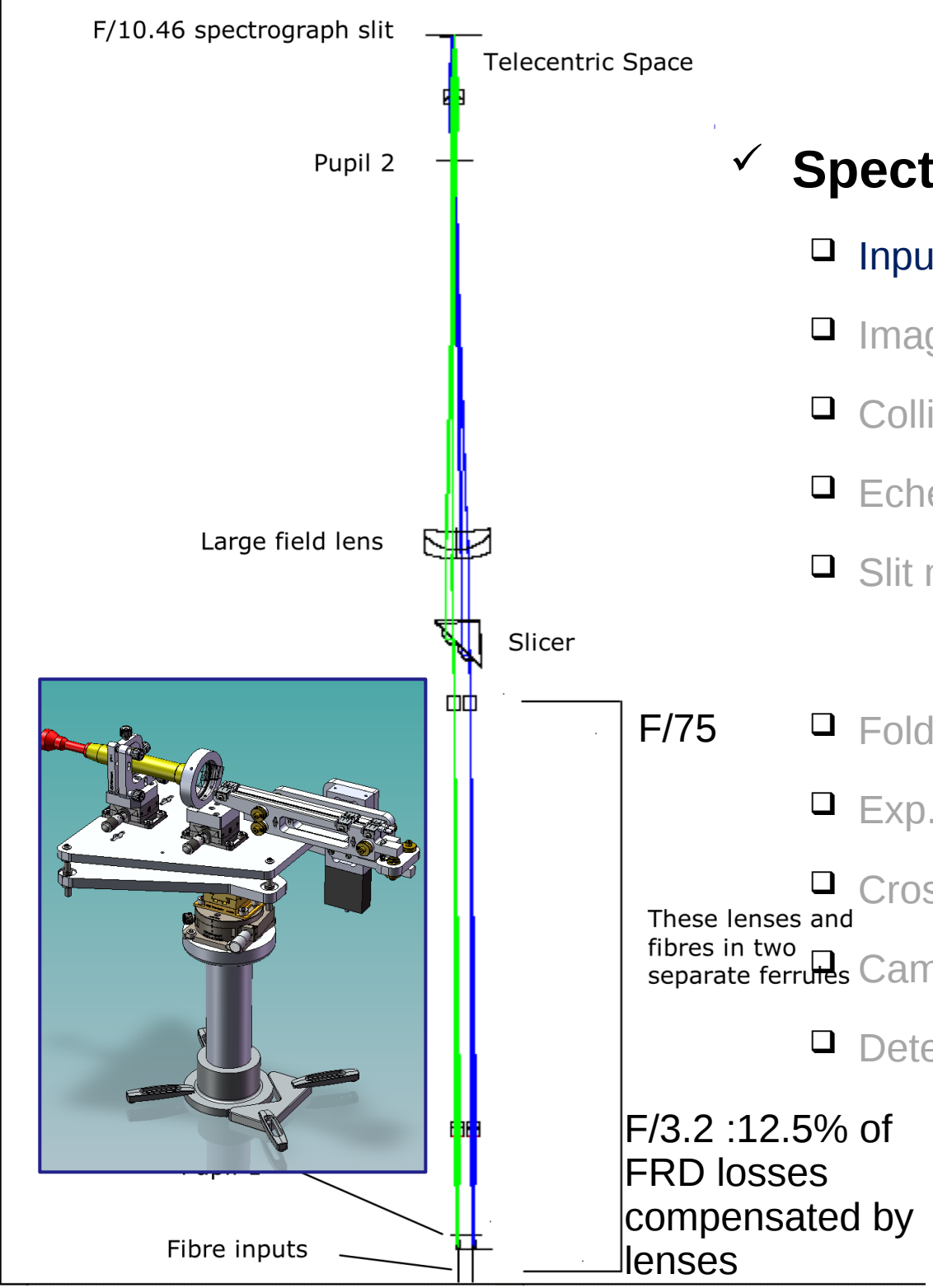
- ✓ **Wavelength calibration:** Th/Ar, Neon
- ✓ **Flat Fielding:** Hallogen/Tungston
- ✓ **Alignment :** Laser

ND Filter : OD 4

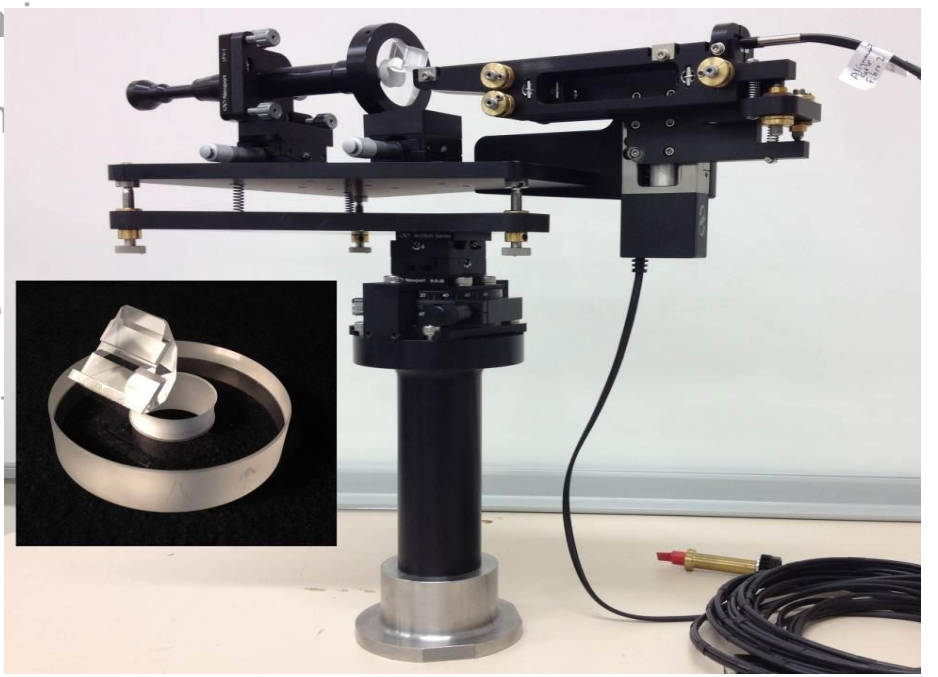


- ✓ **Calibration Unit**
  - ❑ Located in Spectrograph Laboratory
    - ❑ Feeds cassegrain unit with flux from calibration source
      - ❑ Optical fiber (Calibration)
      - ❑ ND filter/Color Balancing filters
      - ❑ Fiber selector (00,01,10,11)

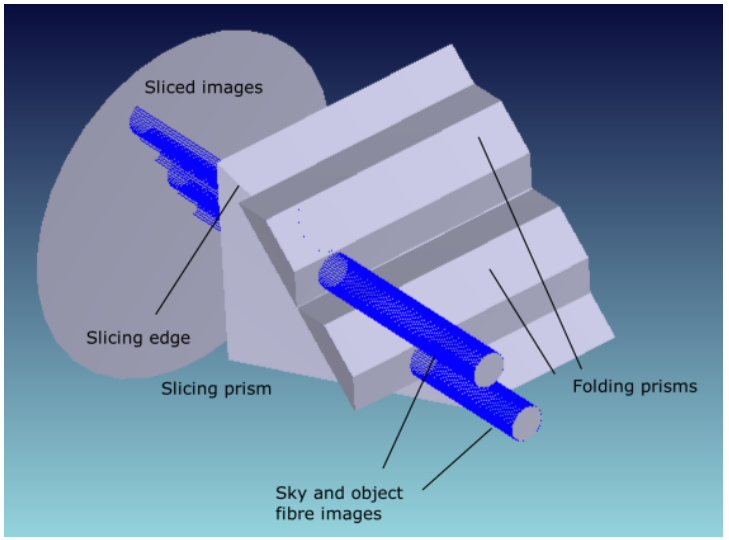


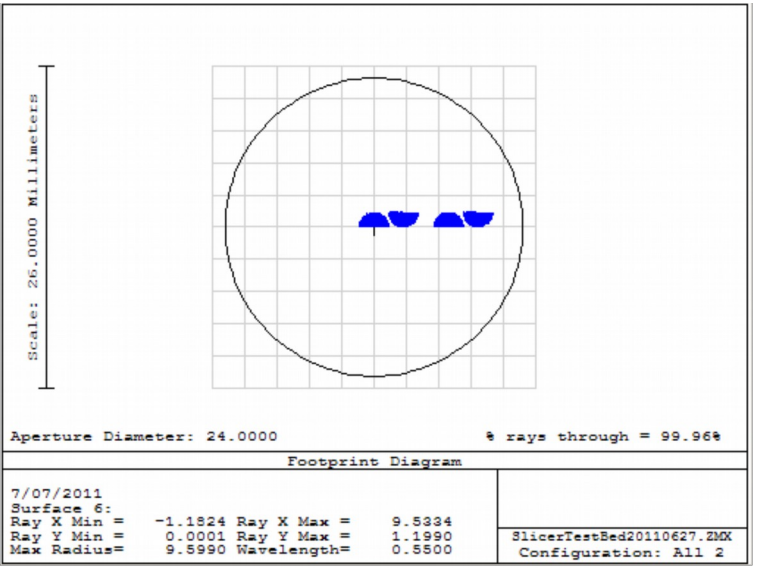


- ✓ **Spectrograph**
  - ❑ Input optics
  - ❑ Image Slicer
  - ❑ Collimator
  - ❑ Echelle Graing
  - ❑ Slit mirror
  - ❑ Fold m
  - ❑ Exp. m
  - ❑ Cross
  - ❑ Came
  - ❑ Detec

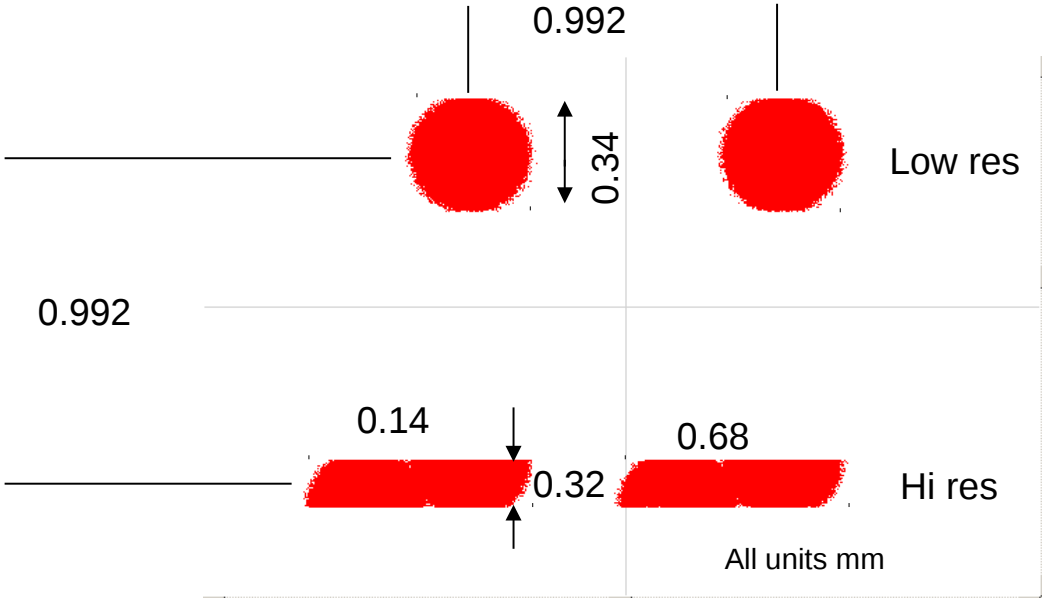


HESP Image Slicer

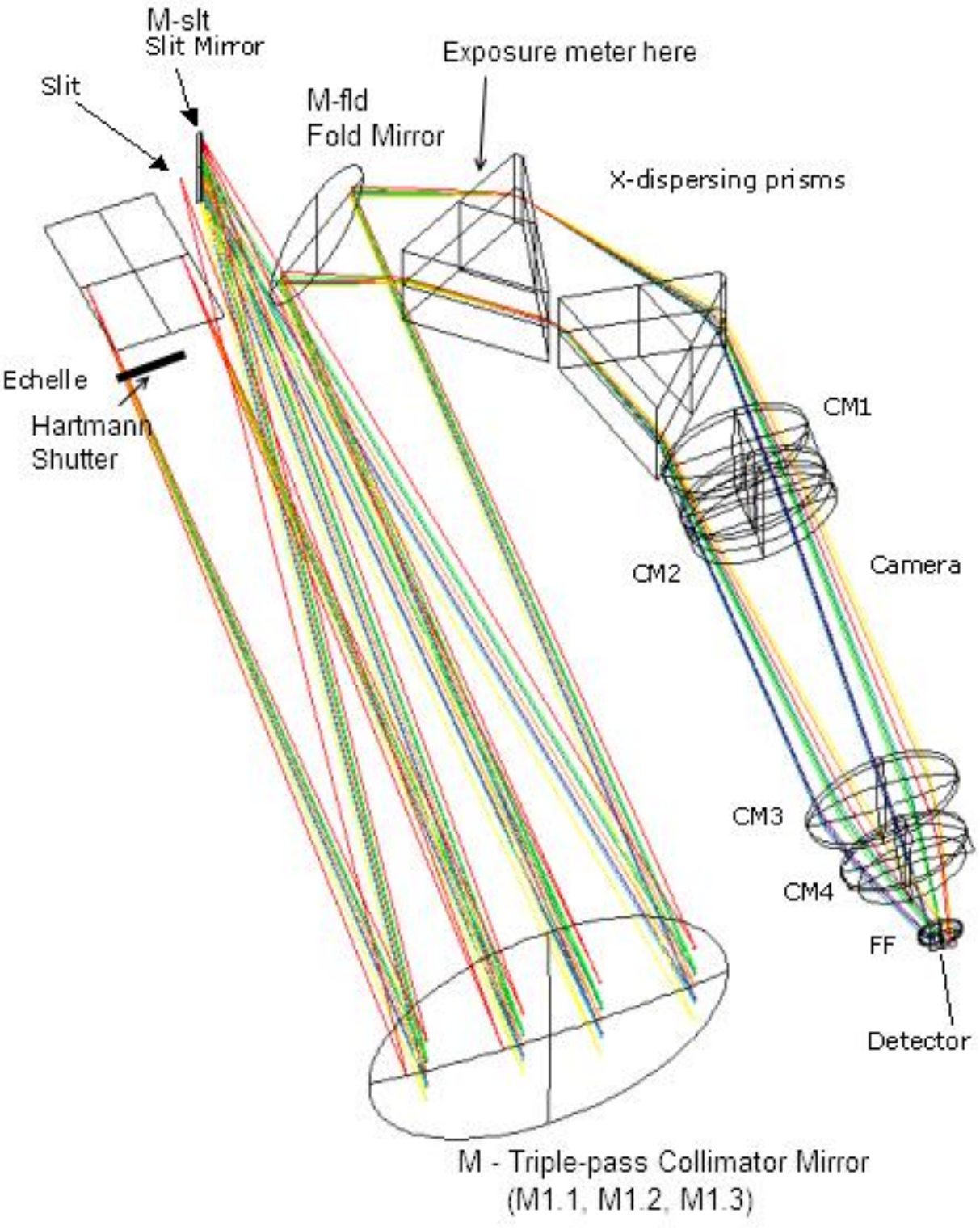




- The pre-slicer optics convert the fibre outputs to be f/3.2 to f/75 for the slicer.
- Slicer and Fold Prisms
- Folding prisms are made separately and cemented to the Slicer prism.
- Overall length and width are of the order of ~13 mm.
- Slit : *340x340mm for Hi Res/ 140x680mm Lo Res*



Efficiency:
~85%



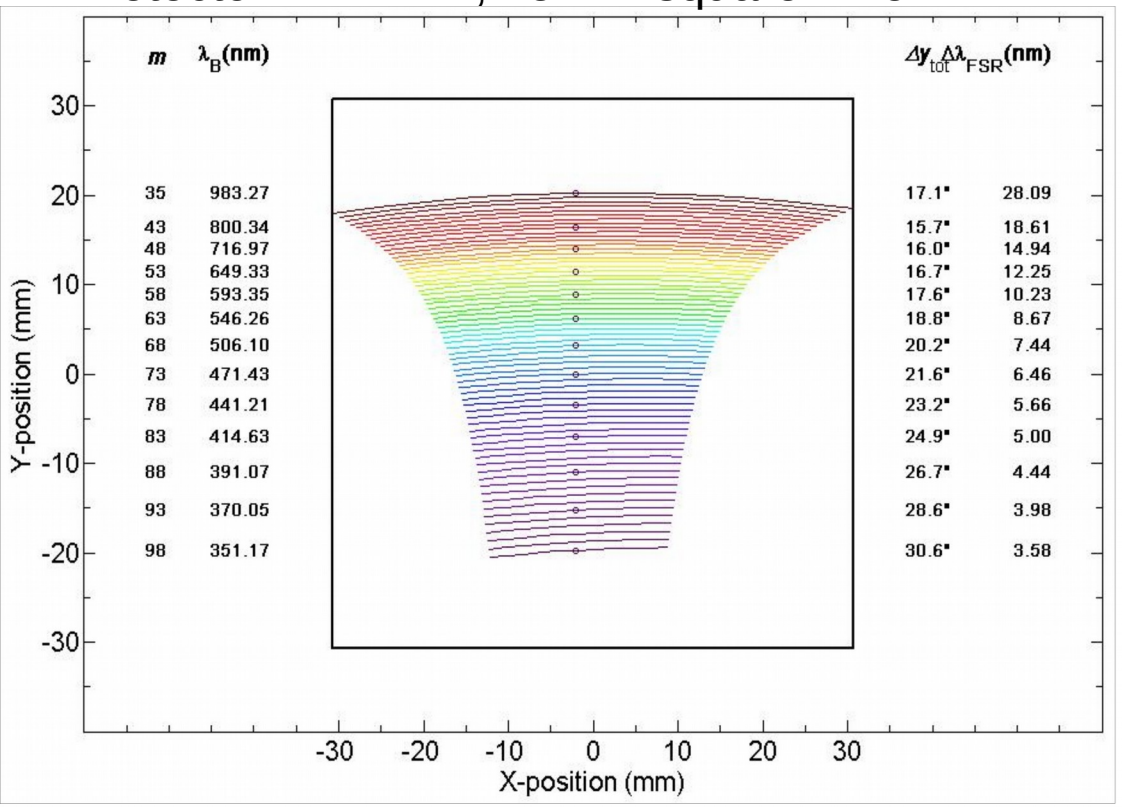
Spectrograph optical Layout

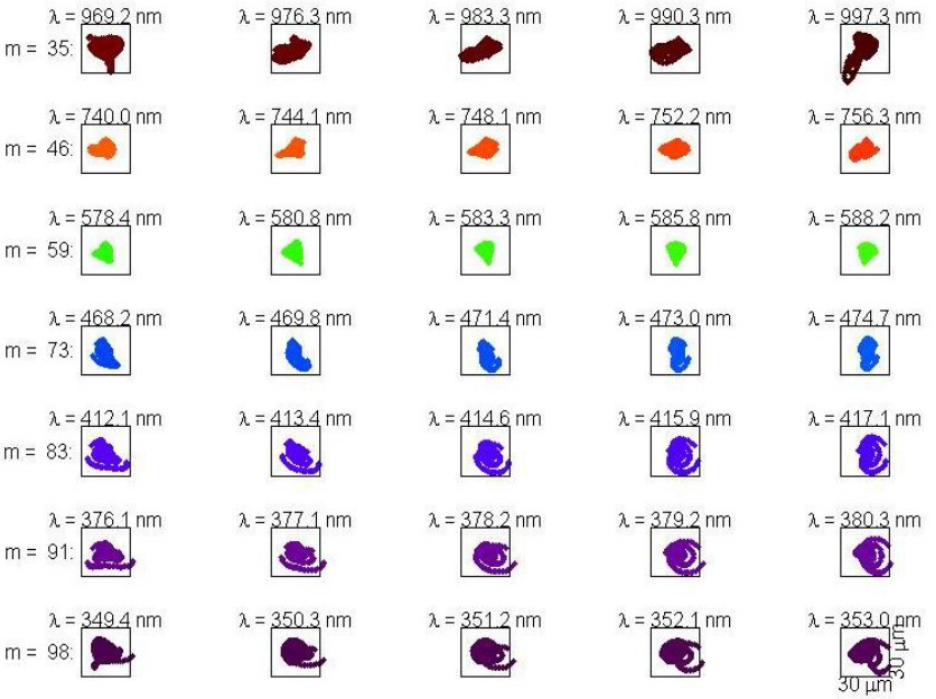
- Echelle grating :
  - Blaze angle: 65deg (R2.15)
  - Groove Frequency: 52.67l/mm
  - Size: 220x420x74mm
- Collimator :
  - F Ratio: 10.45
  - Beam size: 177mm
  - Focal length : 1850mm
- Prisms
  - Apex angle : 55deg
  - Material: BSL-7Y
- Camera
  - Six Elements
    - CM1.1 Ohara FPL51Y
    - CM1.2 N-BAK2 schott
    - CM1.3 OharaFPL51Y
    - CM2.1 FSL-5Y Ohara
    - CM3.1 BSL7Y Ohara
    - CM4.1 FPL51Y
  - Focal Ratio: 2.7
  - Flat Fieldner

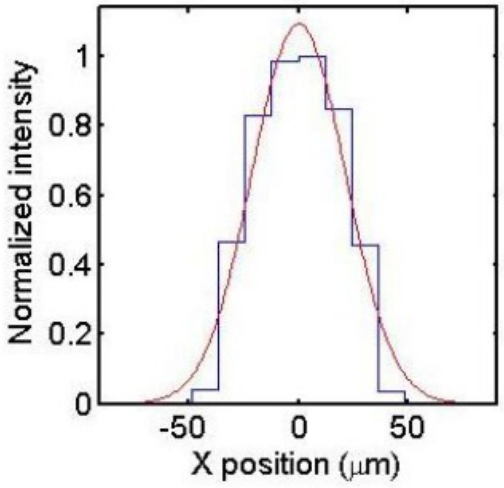
Spectrograph Integrated on Optical Bench

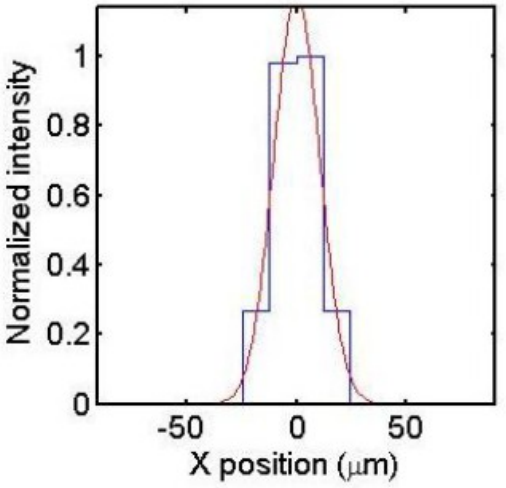
HESP Spectral Format/ Image Quality

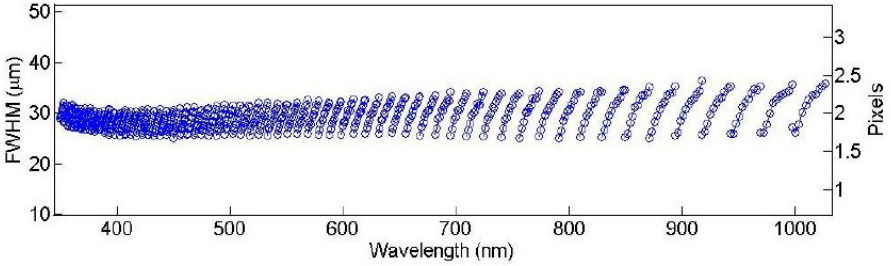
Detector: 4K x 4K , 15mm square Pixel

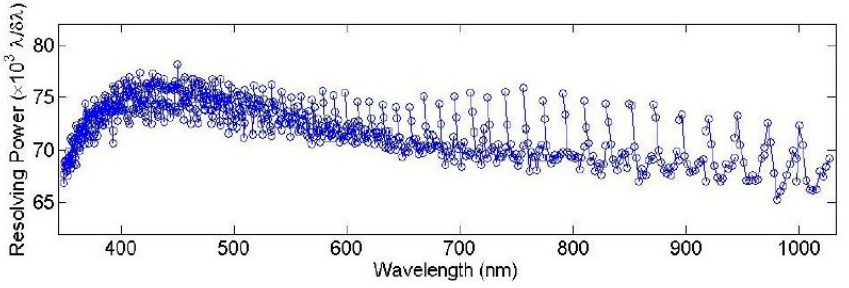












HESP Detector

e2v technologies

PROPOSAL

ATC graded-AR CCD231-84

Document :	e2v-PR-1096
Issue :	1
Page :	4 of 8
Date :	23 Nov 2012

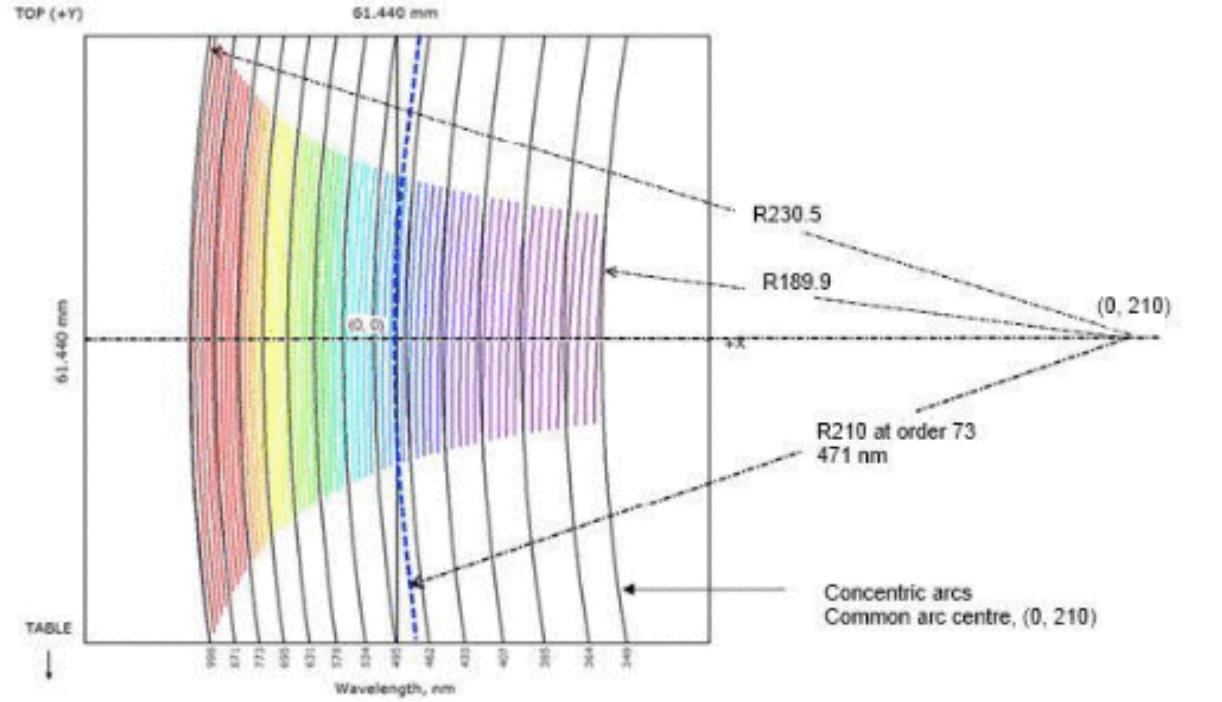


Figure 1. Wavelength map

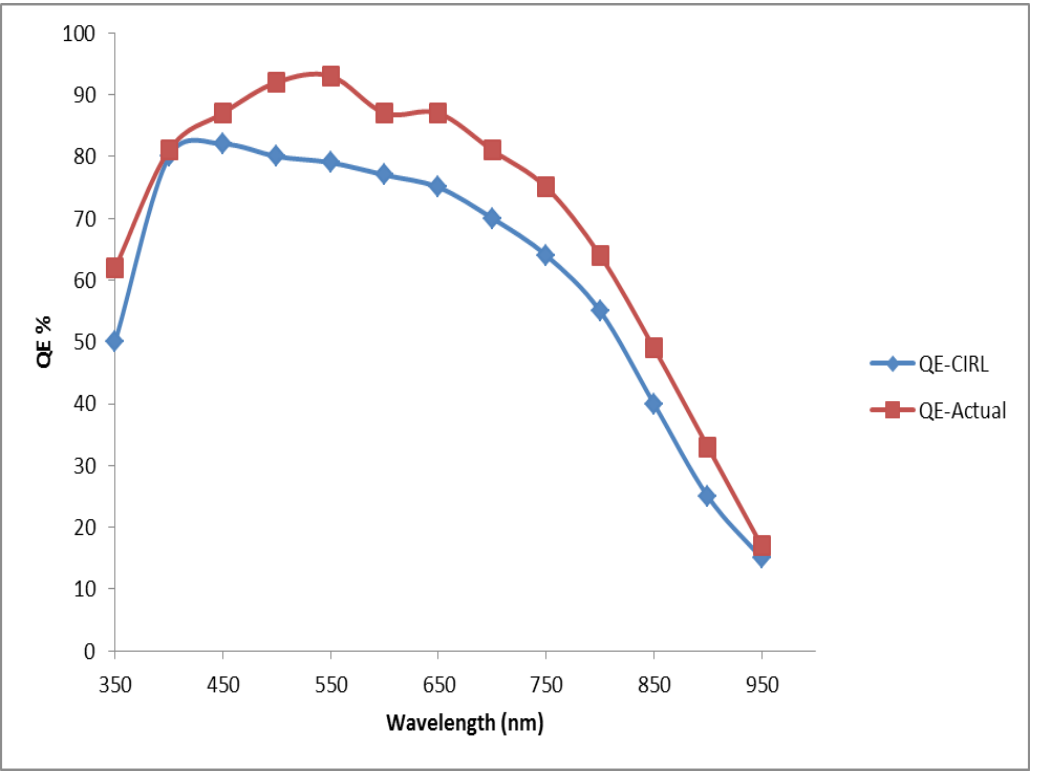
The coating orientation has not been specified. The figure below gives a proposed orientation on the device. If an alternate orientation is required (ie rotated 90 degrees) then this must be agreed at contract placement.

Y=0 = row-zero of CCD = connector-1 end of CCD.
X=0- column-zero of CCD.
Centre of device is X, Y = 2048, 2048 nominal.

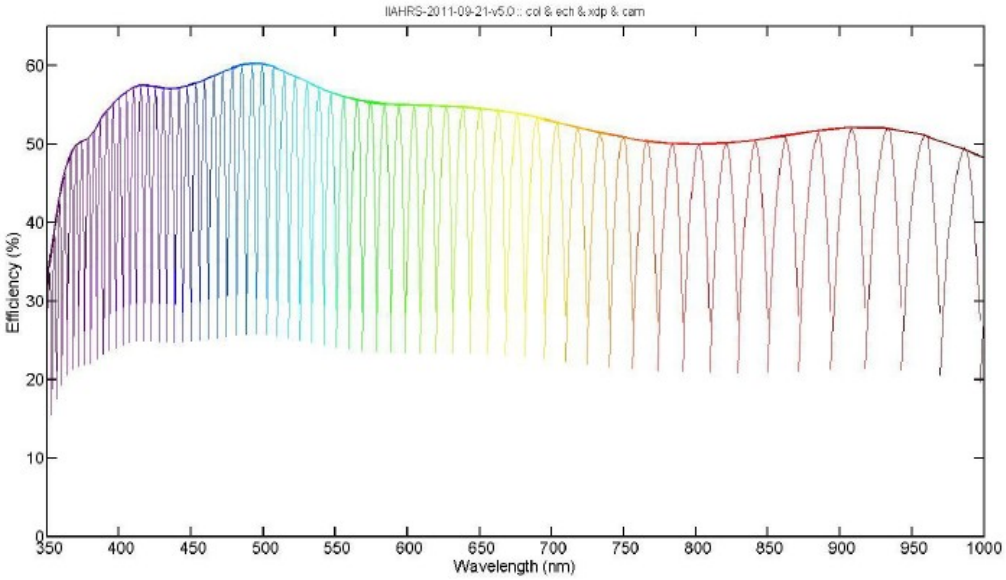
The proposed coating orientation is with the red end at the X=0 side (ie near amplifiers E, H).

- **4kx4k E2V 231-84**
- **Custom AR graded**
- **Back illuminated**
- **Standard silicon device**
- **15Micron pixel size**
- **4-readouts**
- **1MHz, 50kHz– readout speed**
- **System gain-1.20,2.50 e-/ADU**
- **Read noise – 3.8,4.2e-**
- **Fringing < 1% 900nm**

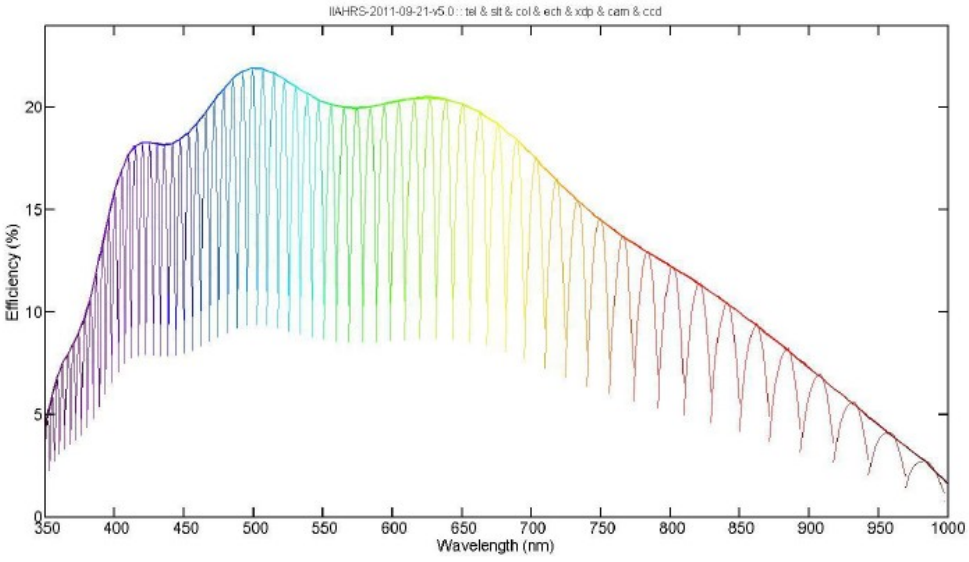
Detector QE



Spectrograph Efficiency Slit to Focal Plane

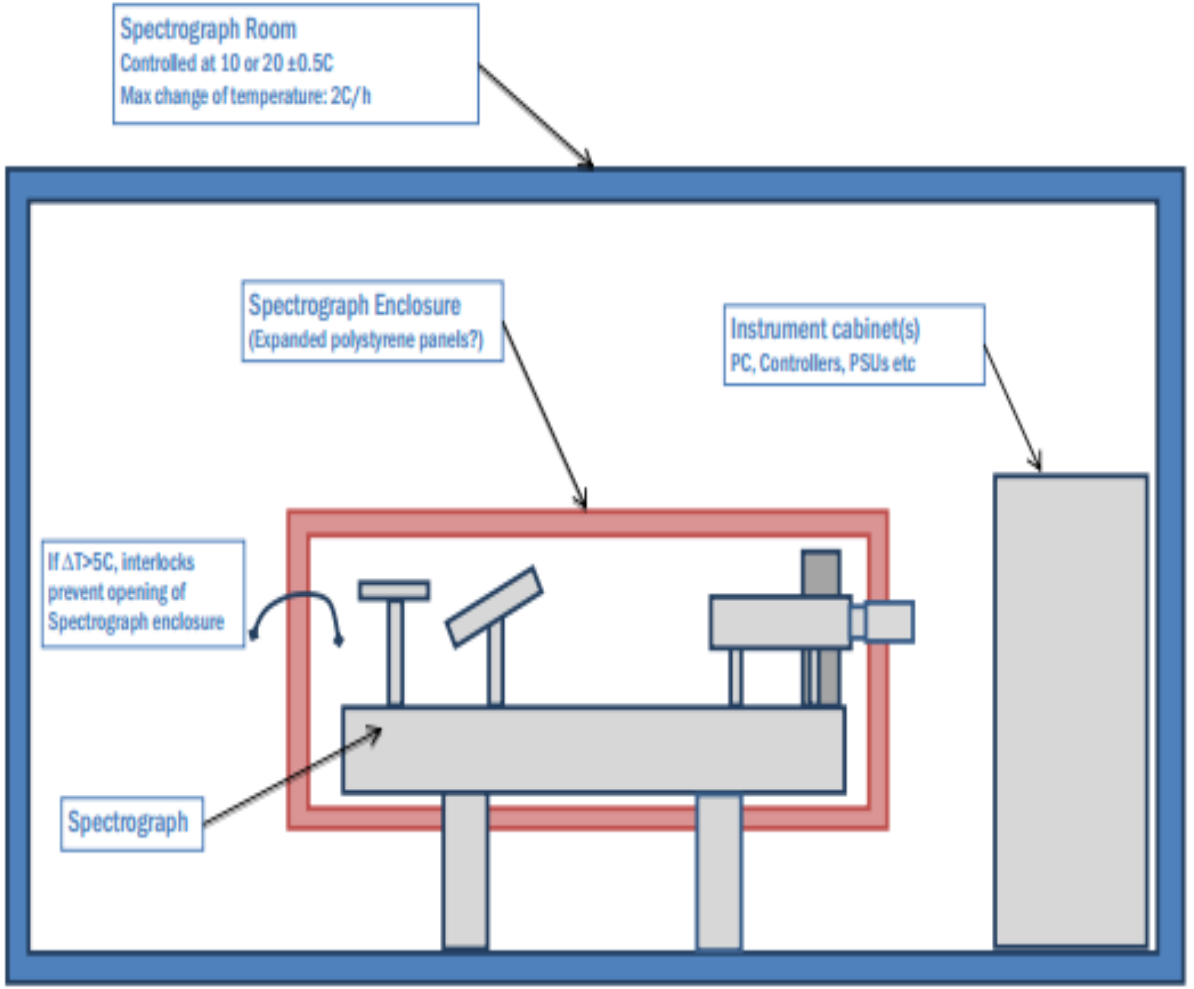


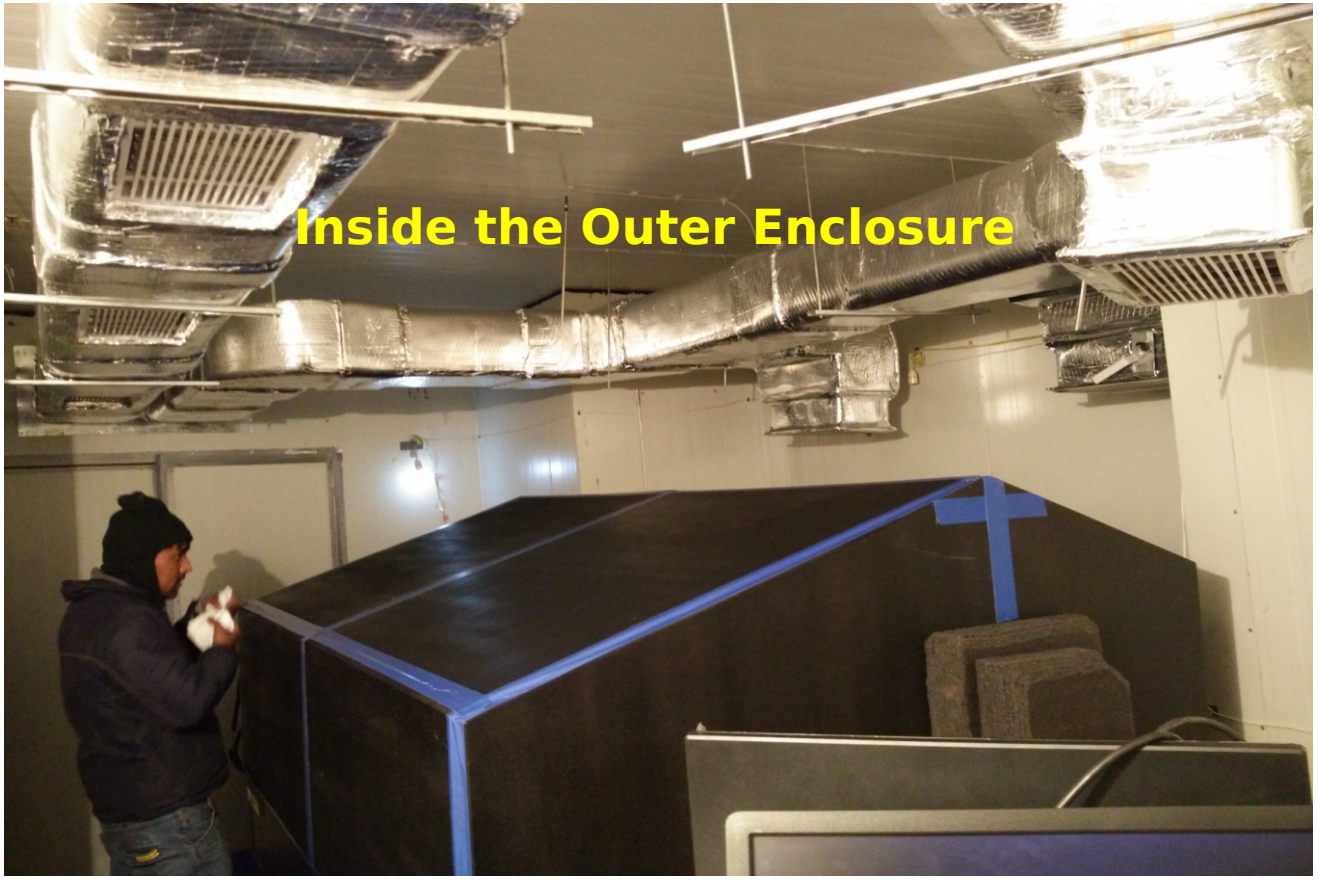
Spectrograph + Telecope Efficiency



Efficiency : 20%
450nm to 700nm

HESP Thermal Enclosure : Concept

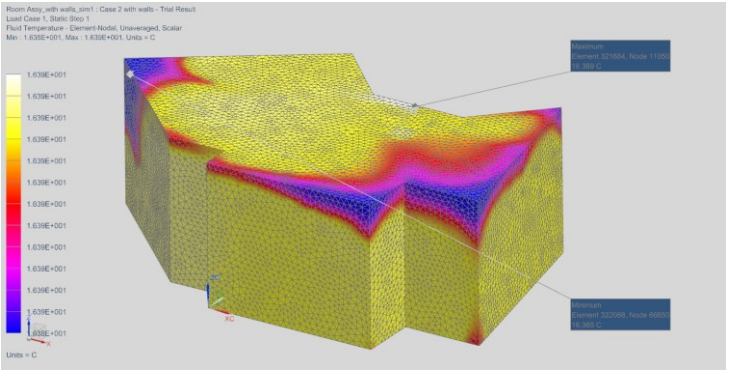



Inside the Outer Enclosure

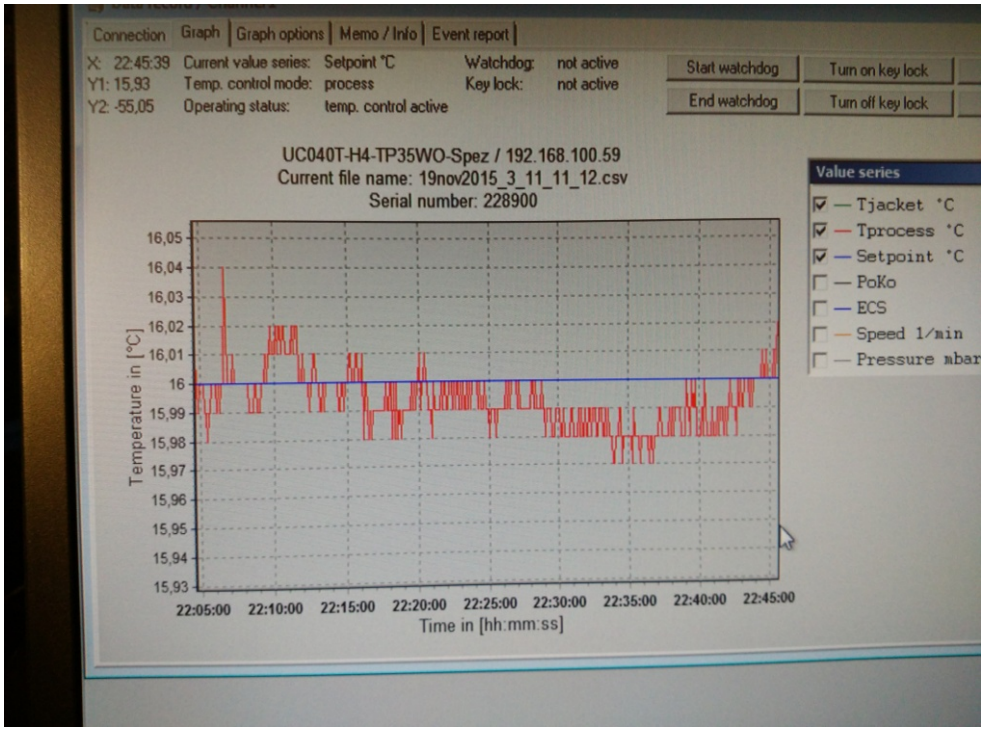

Chiller, AHU & Thermal Control Elements


Heating/Cooling Coils

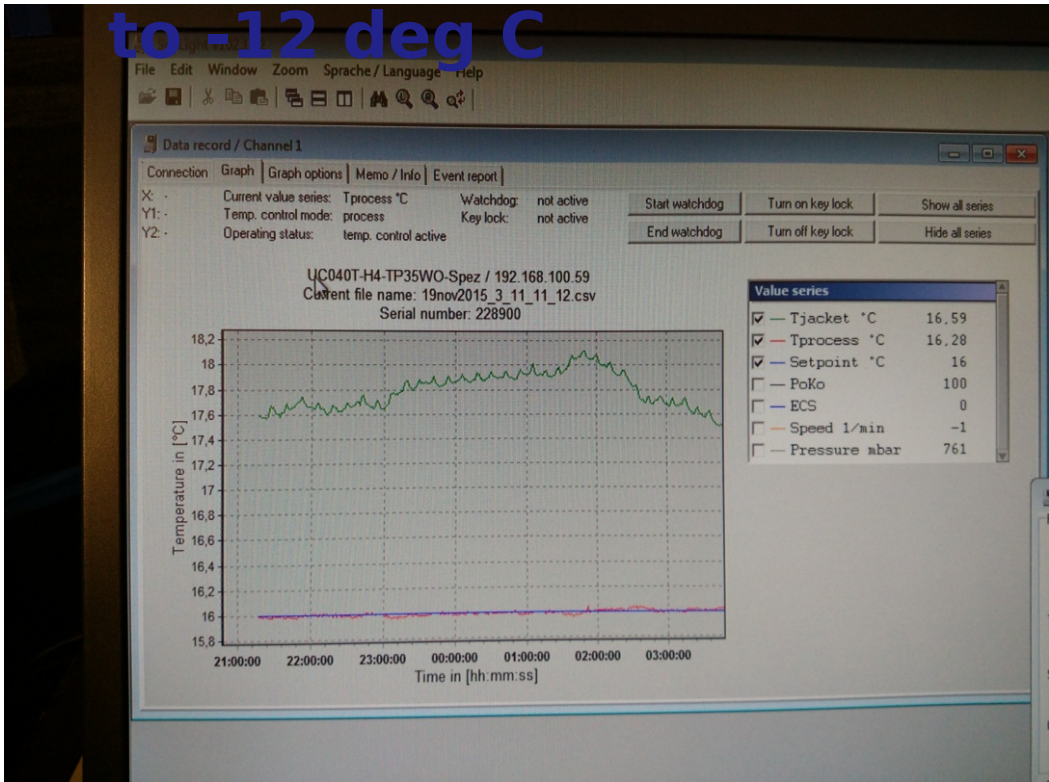

HMI with real time display
For Any Issues Please Call
09448092022
16.02
17.75
16.00



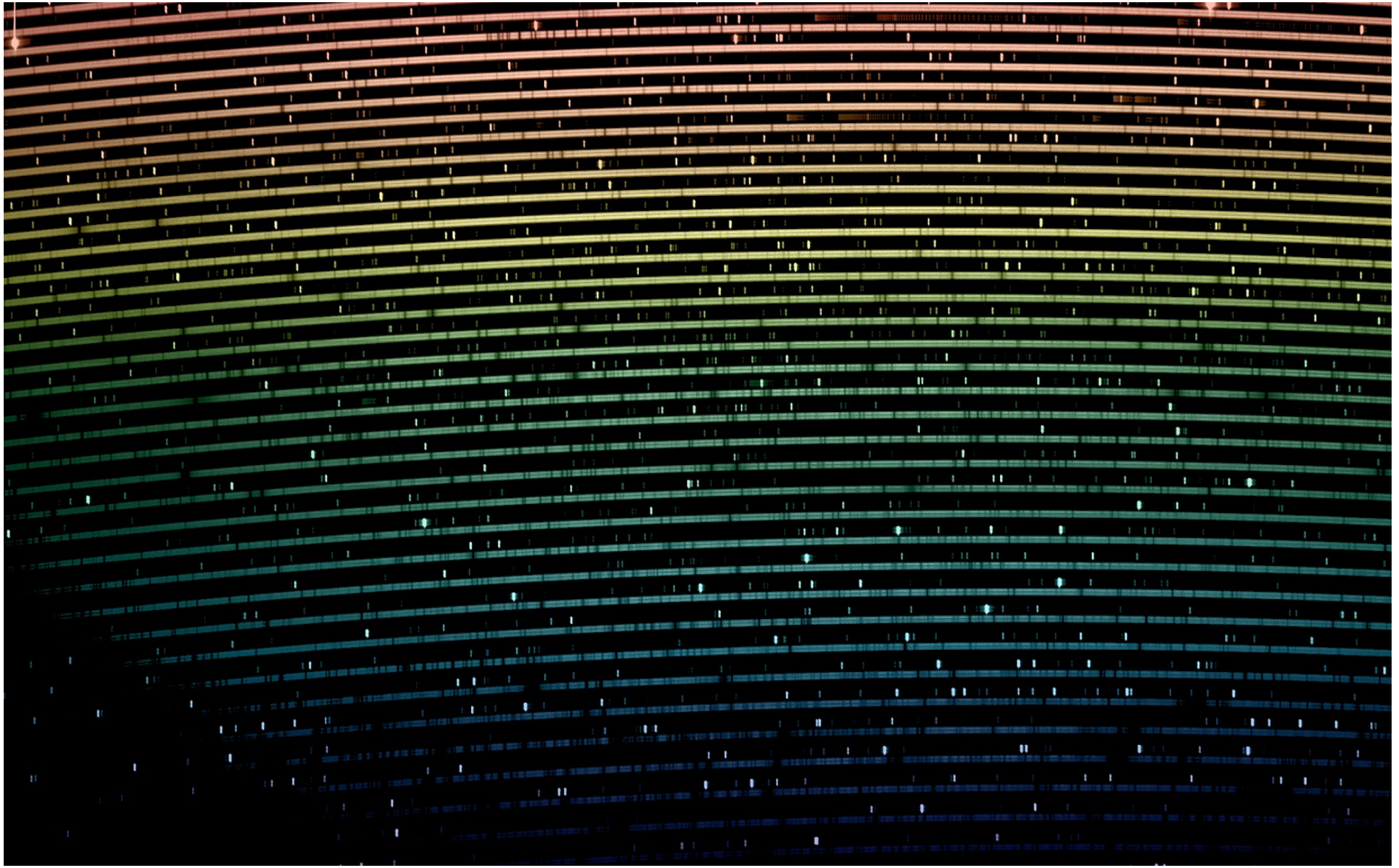
Thermal Stability



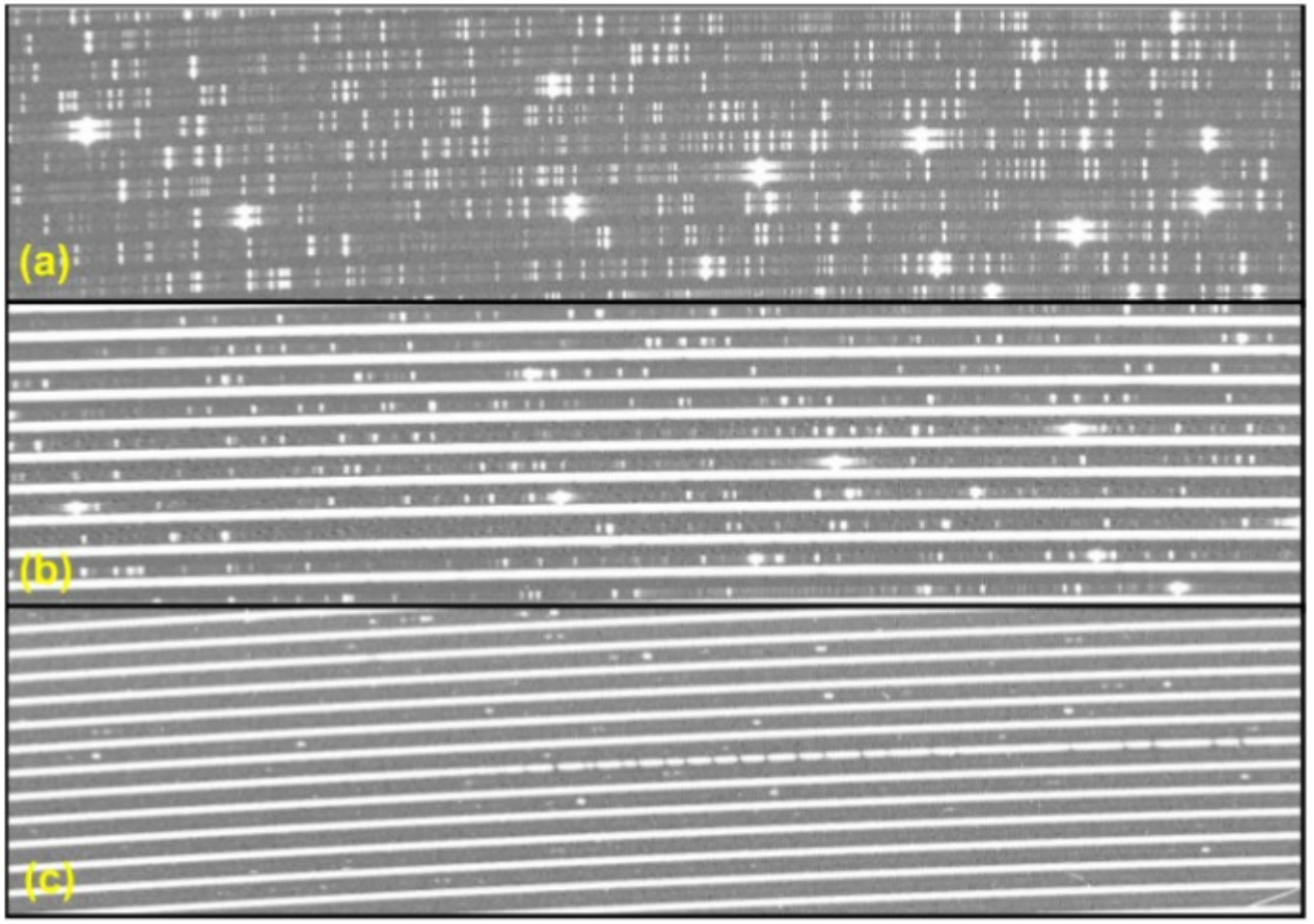
Temperature stability obtained is +/- 0.05 deg C against the requirement of 0.5 deg C on the set point(+16 deg C) when the ambient temperature was varying between -8 to -12 deg C



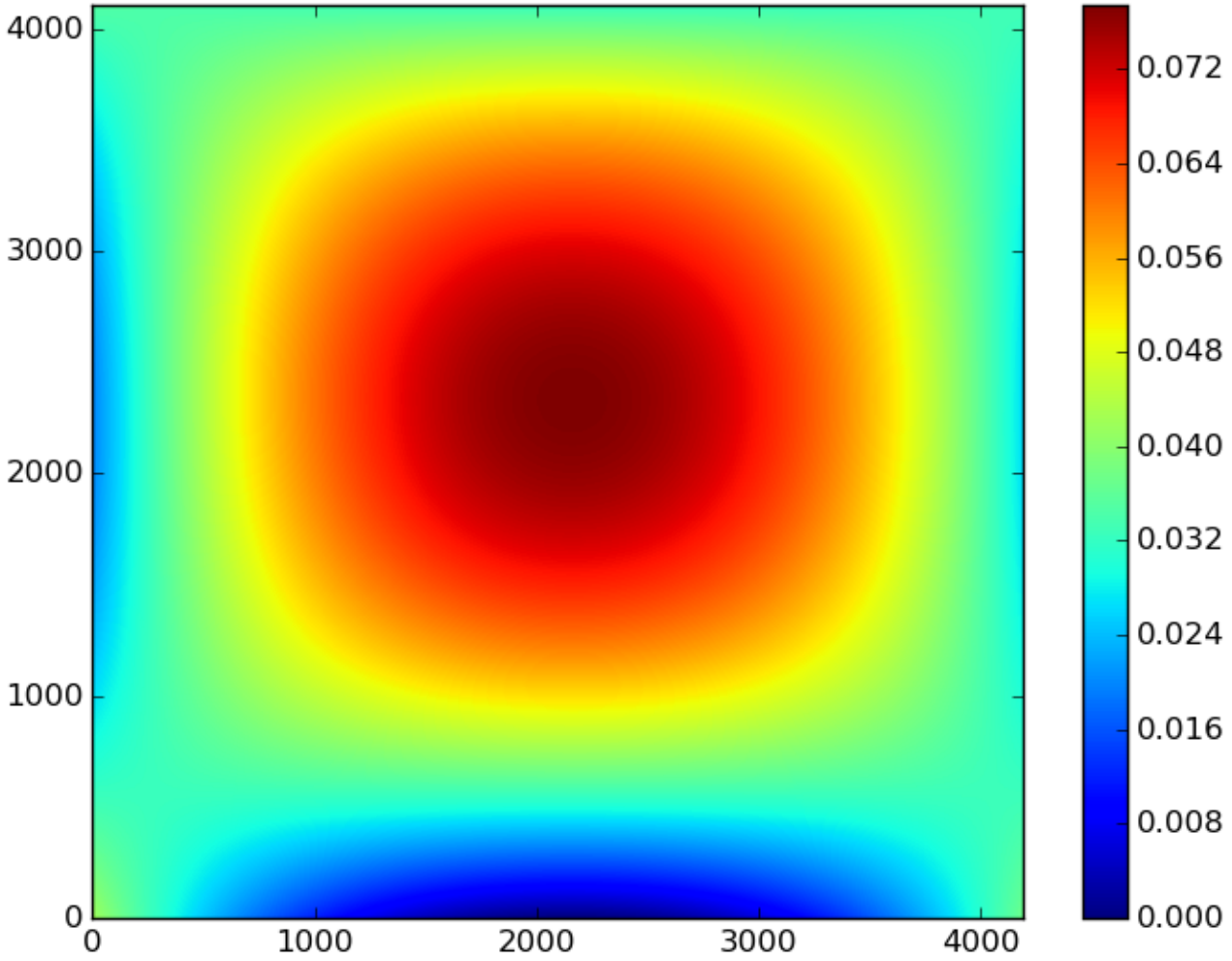
Spectral format at the detector



HESP observing modes



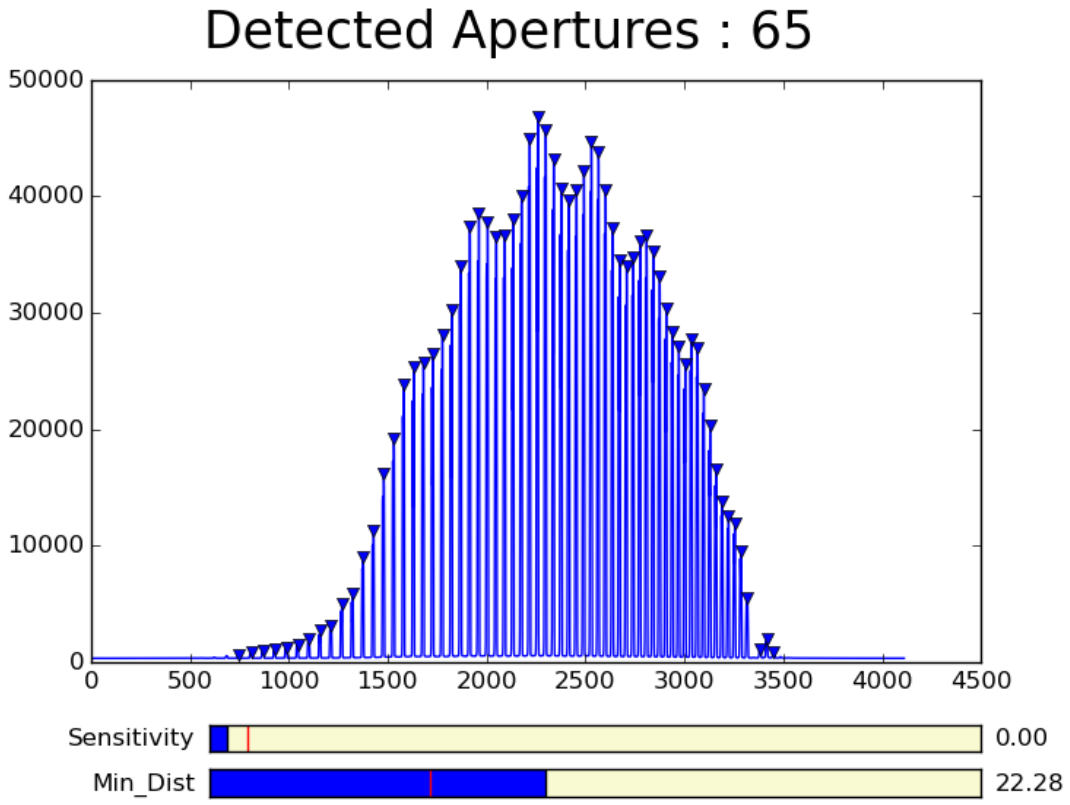
Scattered light in HESP

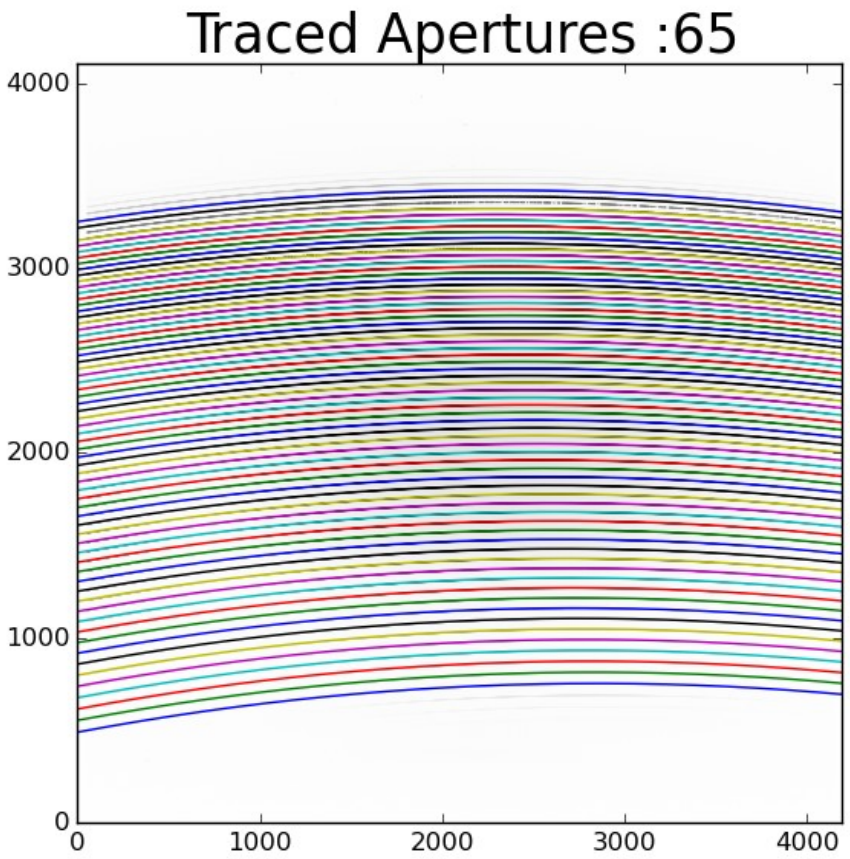


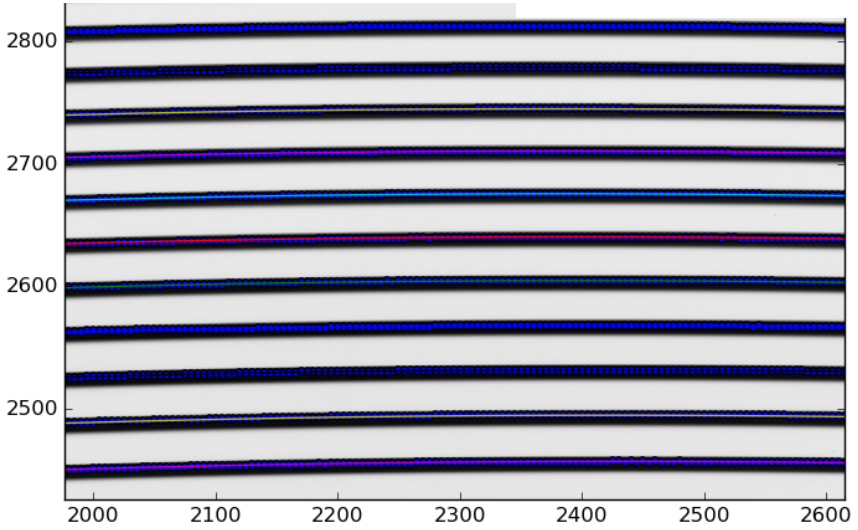
HESP data pipeline

hesp_createlist	Creates the [files.list] file which contains classification and information of each file
hesp_preproc	Creates [Master BIAS file] and does Overscan correction, Bias subtraction and optional Cosmic ray removal
hesp_trace	Traces the different orders from a (Star/Flat) file.
hesp_extract	Extracts the different orders from the Data files and creates an intermediate ec.fits file
hesp_calibrate	Uses a master calibration and identifies the orders and shifts to calibrate the data.
hesp_view	The front end for viewing the calibrated data. The tracing can be verified in this window the same time.

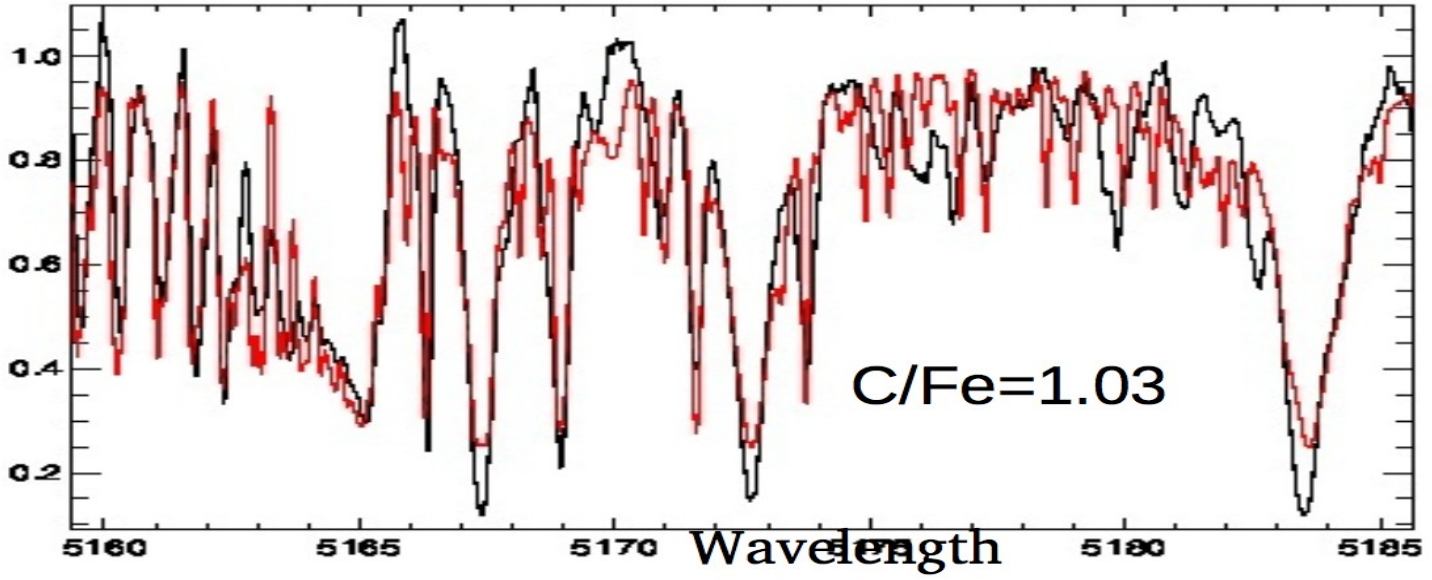
Tracing Interface

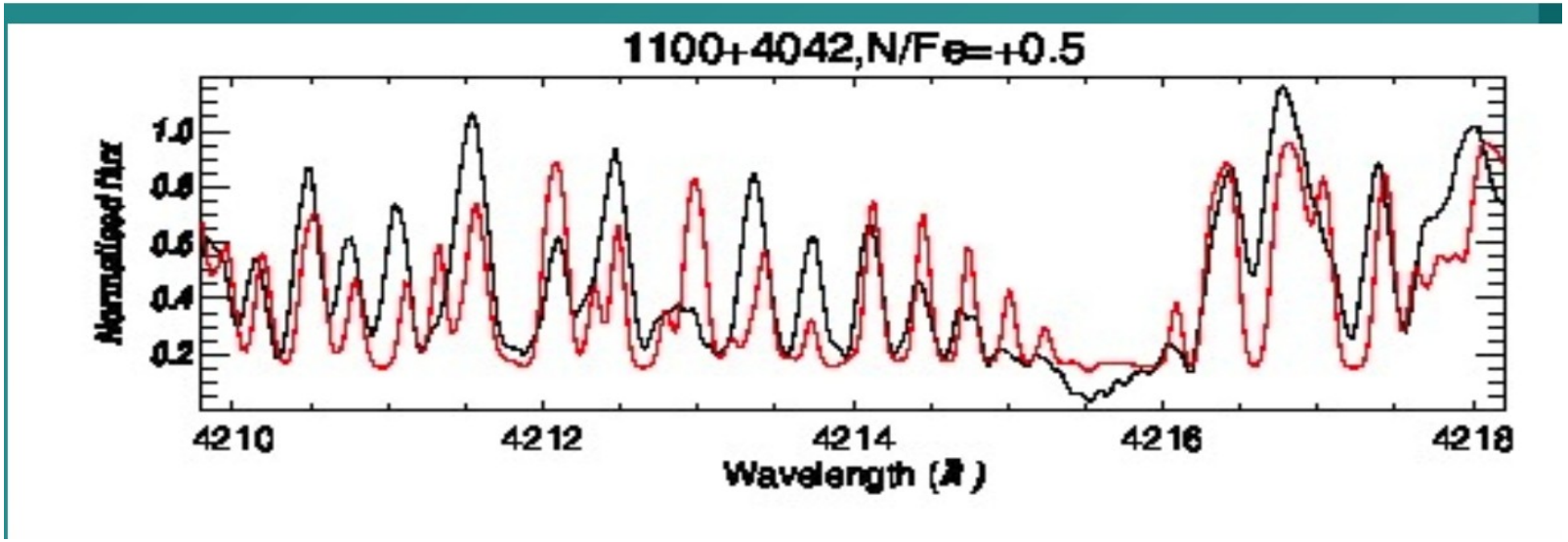




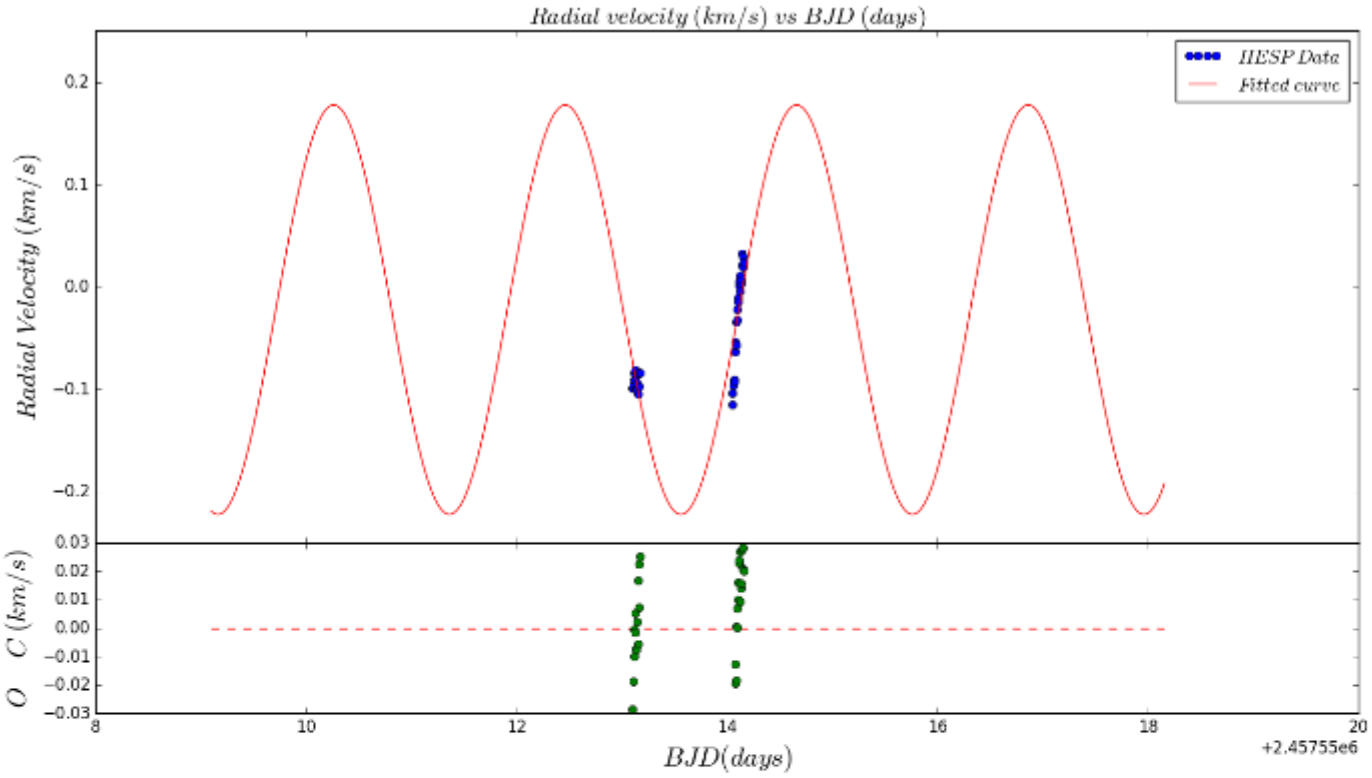


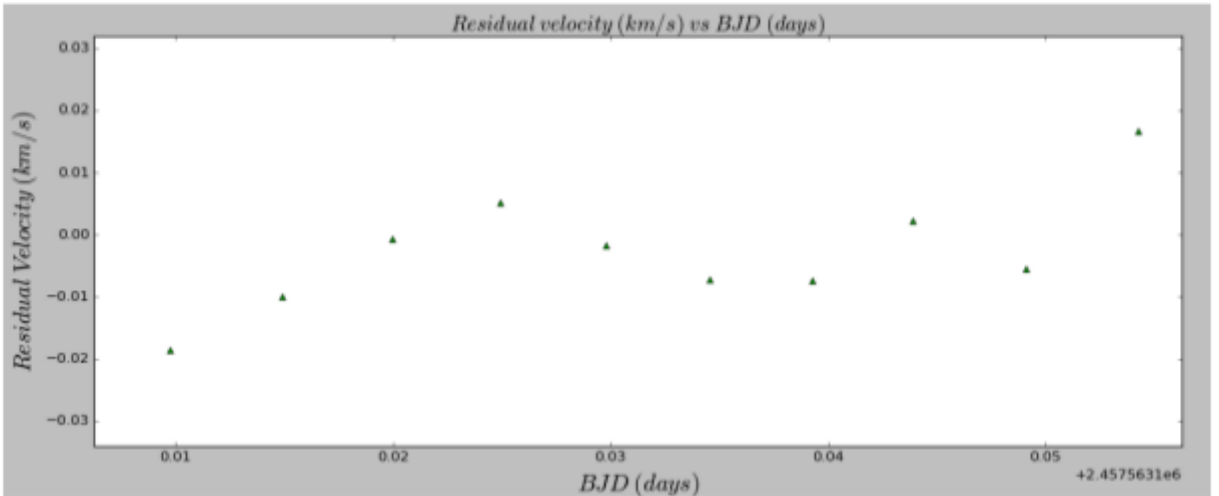
CEMP star using HESP





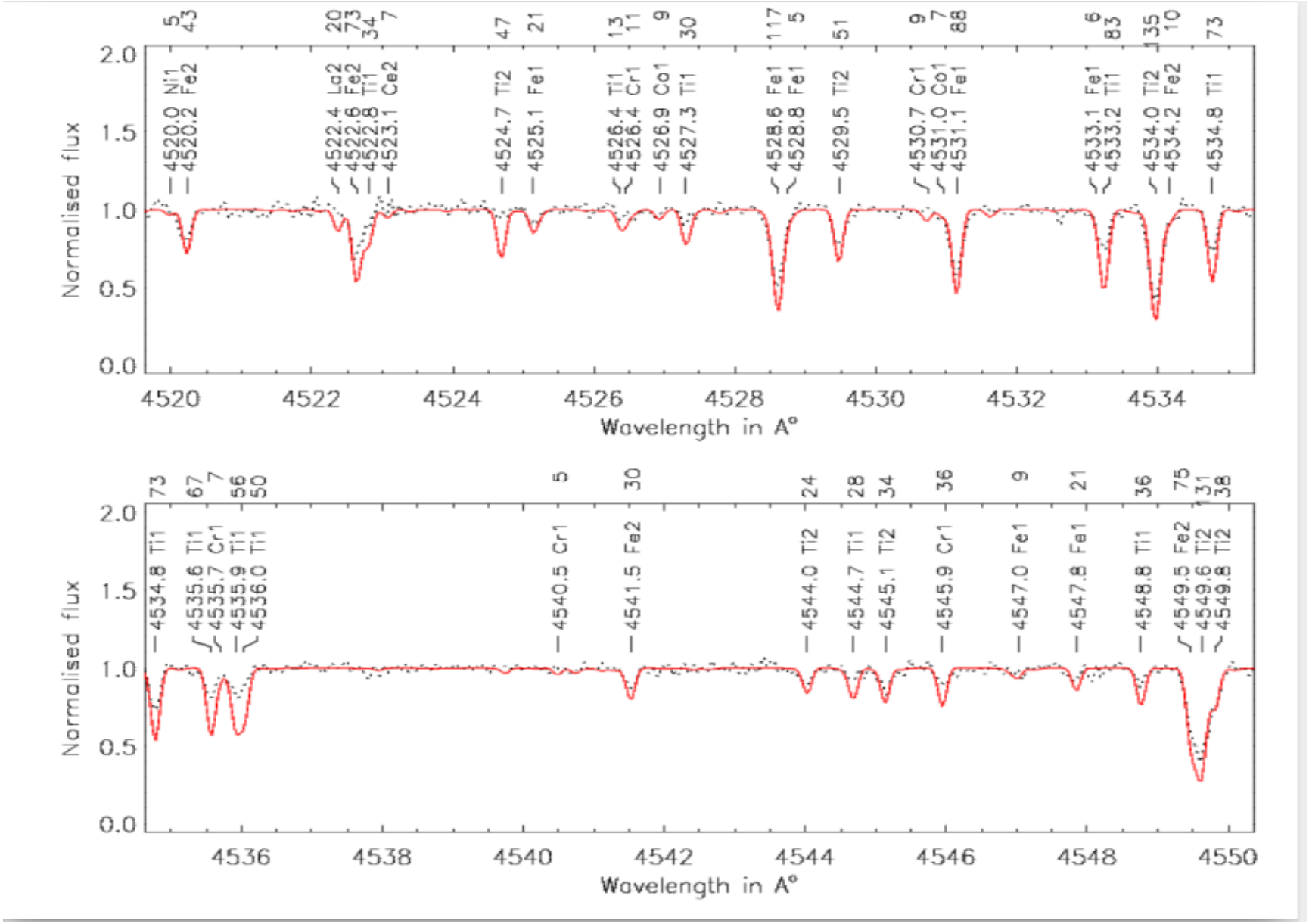
EXOplanet observations with HESP





Rossitter effect

New EMP stars with HESP



Binarity among EMP stars