PARAS: PRL Advanced Radial-velocity All-sky Search

India's First dedicated Exo-palnet program

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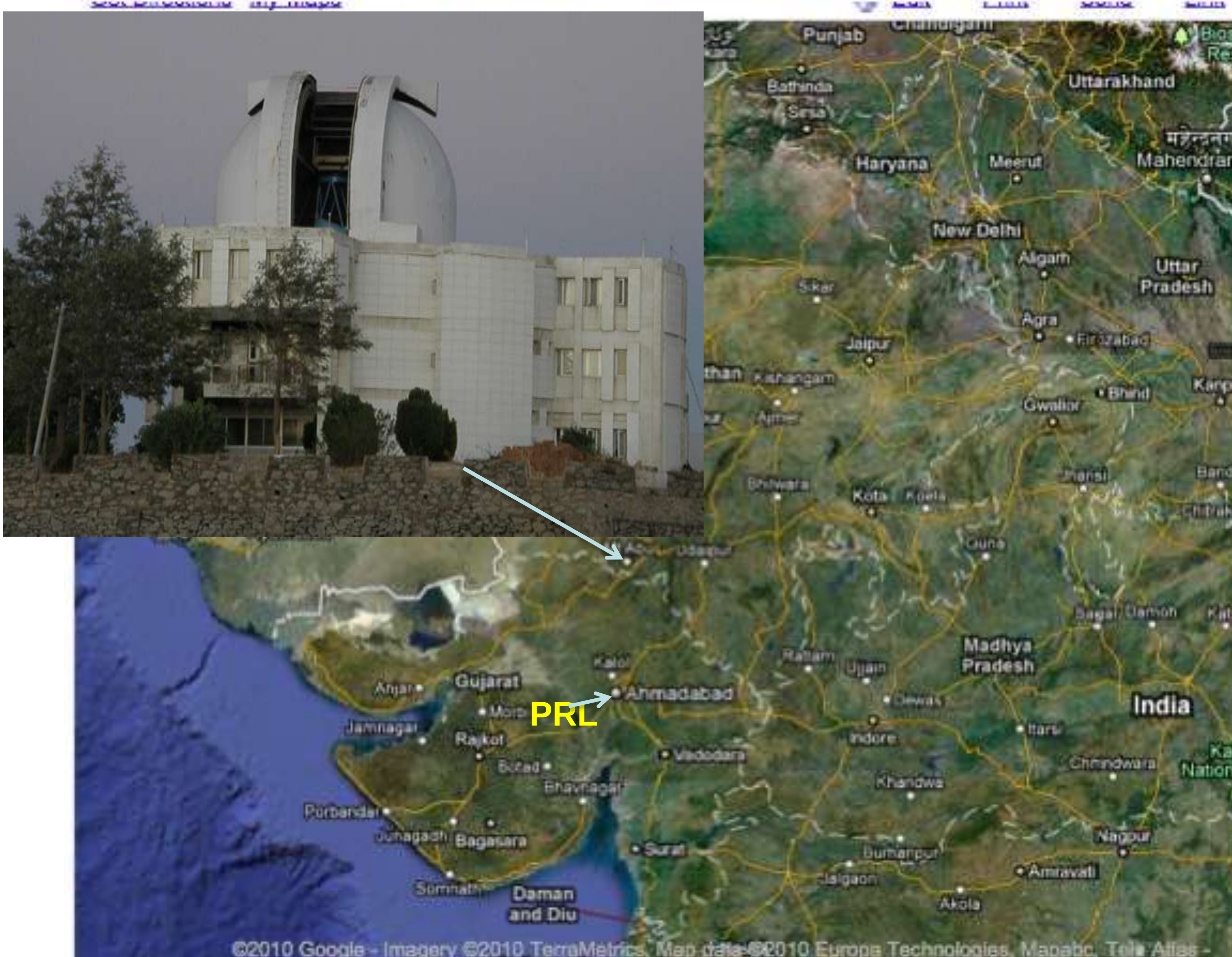

Punjab
Bathinda
Sirsa
Uttarakhand
Haryana
Meerut
Mahendranagar
New Delhi
Aligarh
Uttar Pradesh
Sikar
Agra
Firozabad
Jaipur
Ajmer
Gwalior
Bhind
Bhilwara
Kota
Jhansi
Guna
Udaipur
Ratlam
Ujjain
Madhya Pradesh
Gujarat
Ahmadabad
PRL
Anjar
Morbi
Jamnagar
Rajkot
Botad
Bhavnagar
Dewas
Indore
Itarsi
India
Vadodara
Chhindwara
Khandwa
Porbandar
Junagadh
Bagasara
Surat
Burhanpur
Nagpur
Amravati
Jalgaon
Somnath
Daman and Diu
Akola
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ABU 1.2m telescope

For PARAS we have about 80nights in a year (~10nights per month for 8 months)

Mt. Abu, Rajasthan, India., cloud free nights ~210, photometric ~150, median seeing ~1.1 to 1.2”, altitude ~1700meters, the highest peak in central and as well as western India, moderate light pollution ~ new moon V-band sky ~20.5mag/arcsec^2

Science Goals for PARAS

- The main science goals of the project are:

  Search for planets around a sample of 100s of Dwarf main-sequence G, K, M type stars within a volume of 100pc using the Simultaneous ThAr calibration technique; Ultimate goal <1m/s on bright targets, very Intensive monitoring- advantage of dedicated telescope

- Search for planets around G,K,M giants

- RV confirmations for transit searches

- Explore ultimate achievable precision on bright stars using an I2 cell in stabilized Fiber-fed spectrograph

Spectrograph Design Considerations

Resolution 60,000, should take in two fibers for doing simultaneous spectroscopy

Wavelength Coverage 3700A to 8800A; but main focus between 4000A to 6800A for Radial Velocity

Should be able to go to any 1 to 2m class telescope (up to 2.5m) in the Country (India)

Pupil diameter 100mm

Echelle R3.75, Blaze angle 75degrees, 31.6lines/mm (Master MR160)

White Pupil Configuration & A single large Prism as a Cross-Disperser

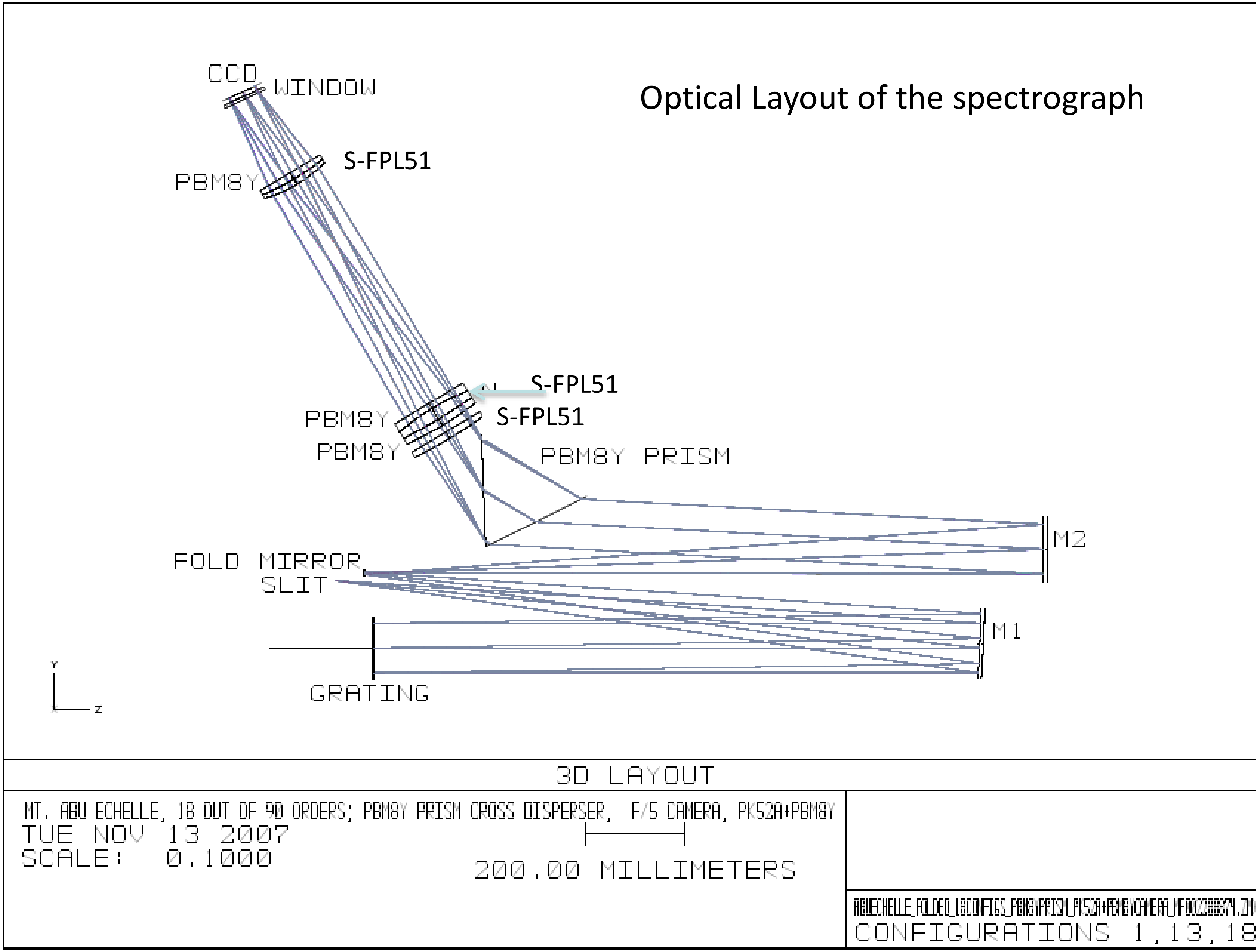
Spectrograph should be at least 30% efficient from the Slit position to the Detector

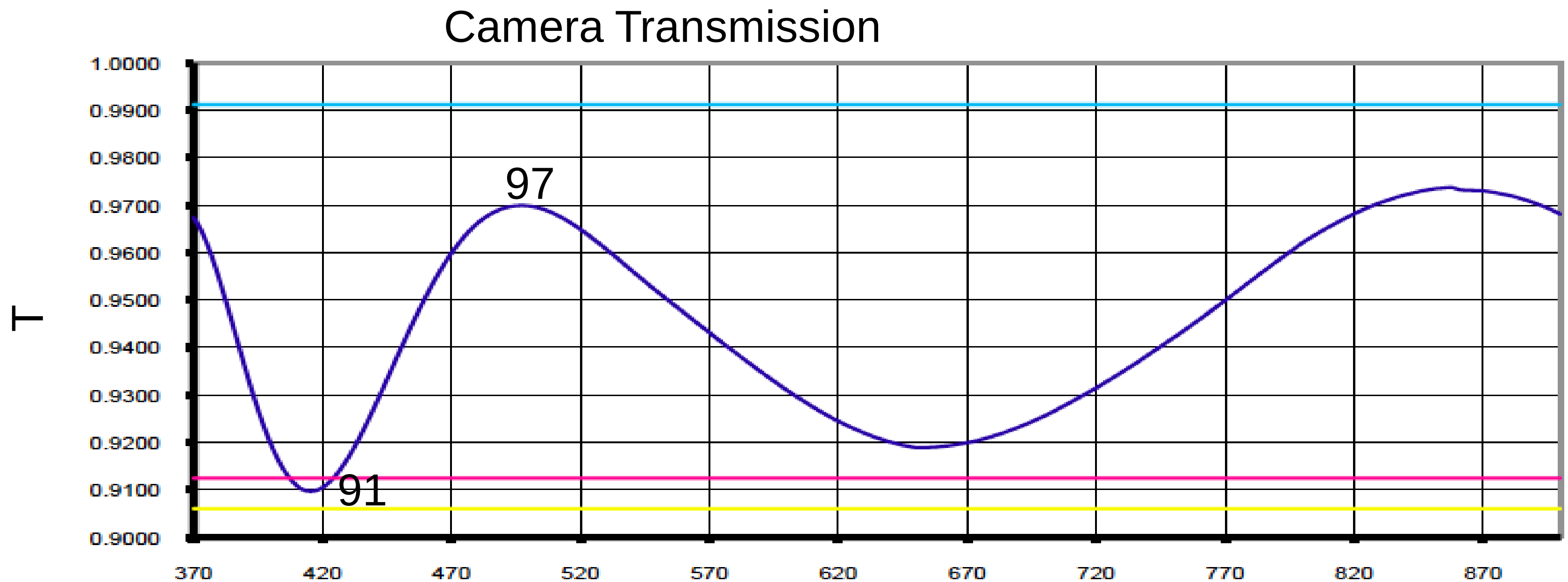
Spectrograph Design Considerations

After a year of toying with various design configurations within the White Pupil domain and Glass properties for maximum and uniform transmissions and as well as matching refractive indexes we found the following glasses to be very suitable for our spectrograph with more than 98% transmission between 3700A and 8500A:

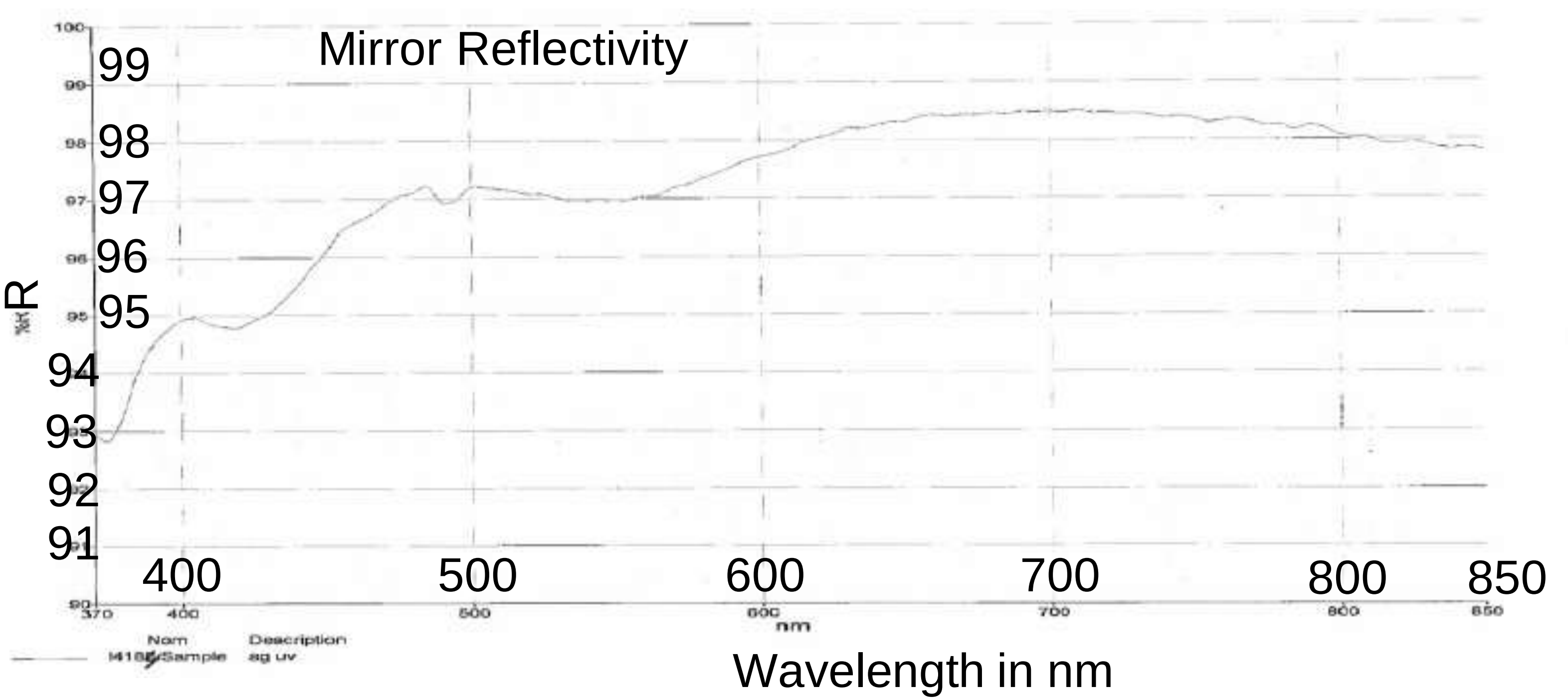
PBM8Y & SFPL51Y both from OHARA

Optical Layout of the spectrograph





Camera Transmission
T
1.0000
0.9900
0.9800
0.9700
0.9600
0.9500
0.9400
0.9300
0.9200
0.9100
0.9000
97
91
370
420
470
520
570
620
670
720
770
820
870



Mirror Reflectivity
%R
99
98
97
96
95
94
93
92
91
400
500
600
700
800
850
nm
Nom
Description
Sample
ag uv
Wavelength in nm

Prism Transmission Characteristics:

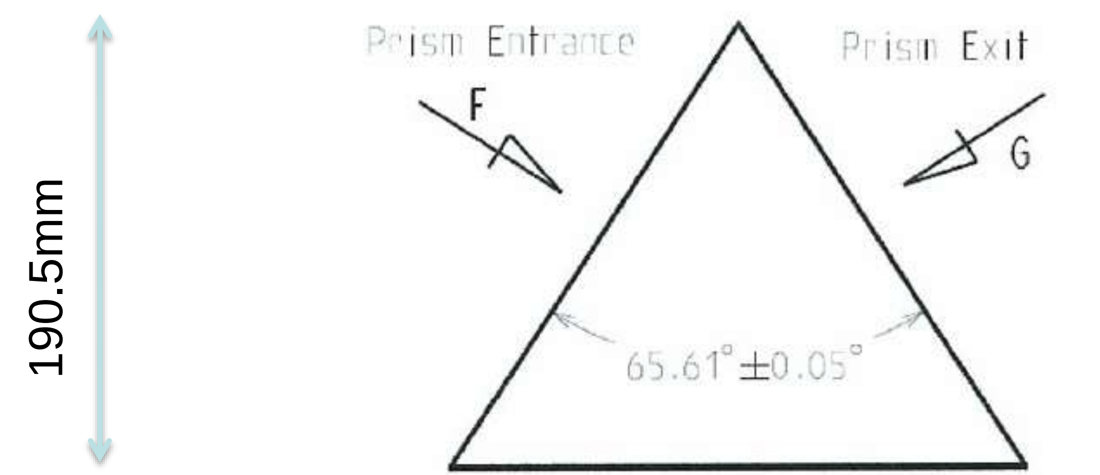
Efficacite/*efficiency:*

specifications/ *specifications:*

$T_{min} > 94\%$ $i = 60°$ $370nm < \lambda < 900nm.$ / Surface

$T_{moy} > 95\%$ $i = 60°$ $370nm < \lambda < 900nm.$ / Surface

Total Transmission thru the Thick Prism ~80%
Measured Transmitted wave-front error ~ 72nm



Installing the 4kx4k Grade 0
E2V CCD in the Dewar

Deep Depletion Astro-BB coating

Measured QE: 350nm → 57.2%
400nm → 92.4%
500nm → 96.5%
650nm → 87.9%
800nm → 84.0%
900nm → 52.0%

Mean dark signal at -120C
0.02 e/pixel/hour

Read Noise ~ 3.5e (150Kz readout speed)
Controller Gain ~ 1.7
Controller from Bob Leach
Dewar from IR labs, Cryo cooler from ARC,
<100nm vibration (amplitude) on the CCD

Spectrograph Design Considerations

CCD detector size : 61mm x 61mm with 15micron sq. pixel size
With an R3.75 Echelle and appropriate Prism Cross-Disperser at least 58mm cross-dispersion is required

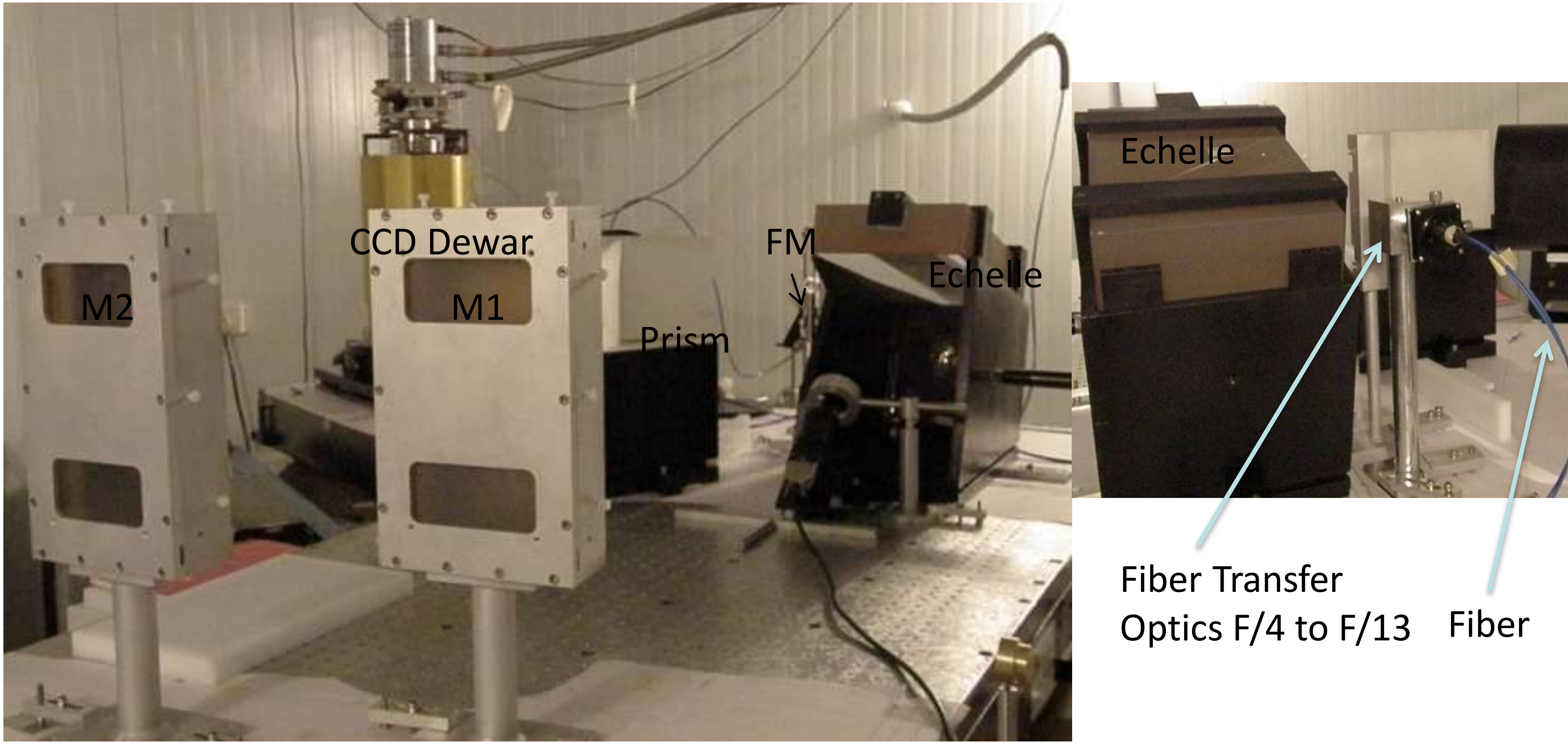
Two fiber spectra to be separated by ~17pixels and with sufficient inter order spacing up to 6800A (from 3700A) for RV measurements

High QE > 83% in the region of wavelength interest

Low read noise 2 to 4e (<4)

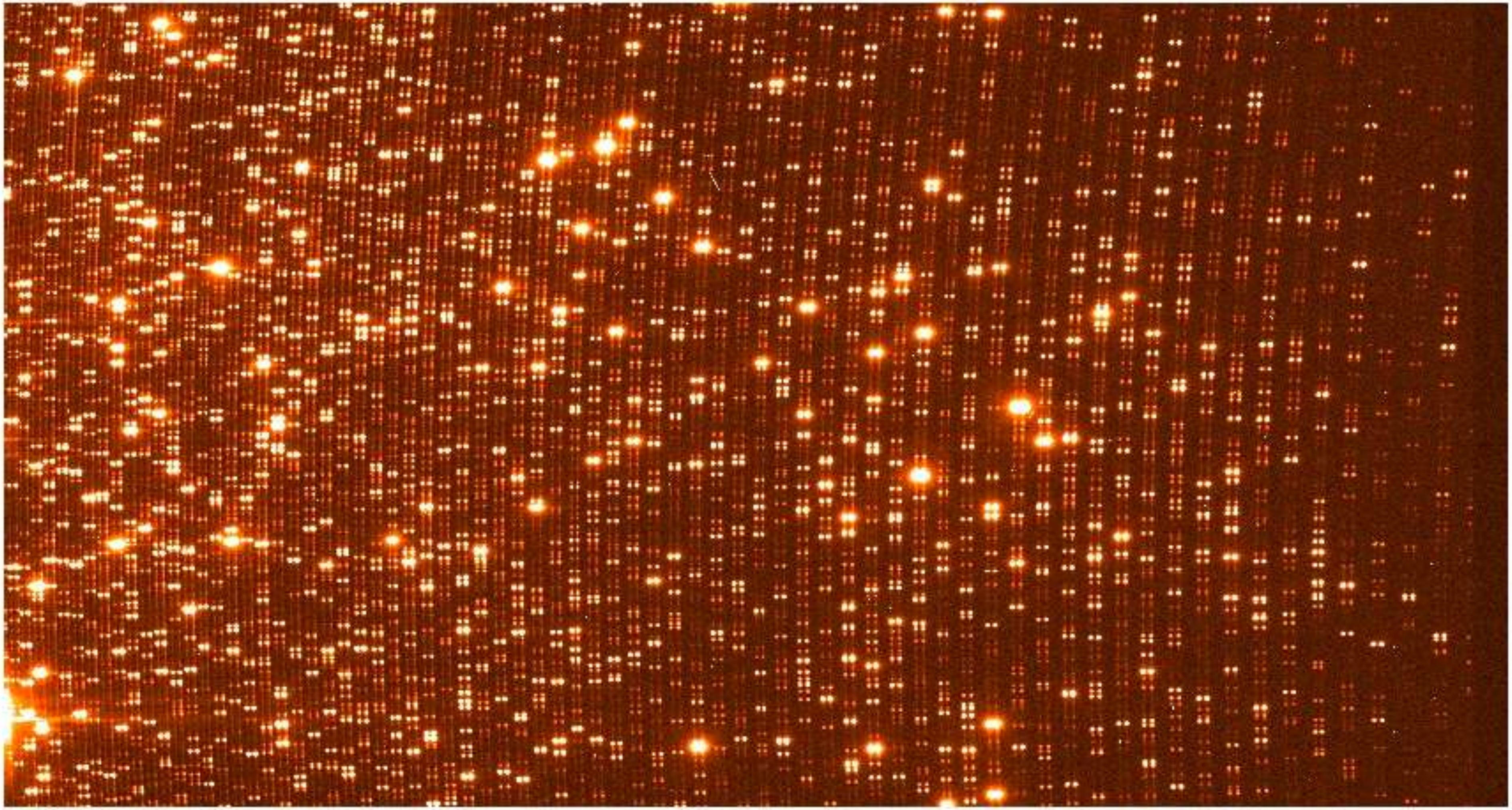
Low dark signal ~ 0.001e/sec/pixel

about 4 pixel sampling on detector per resolution for doing precision RV measurements

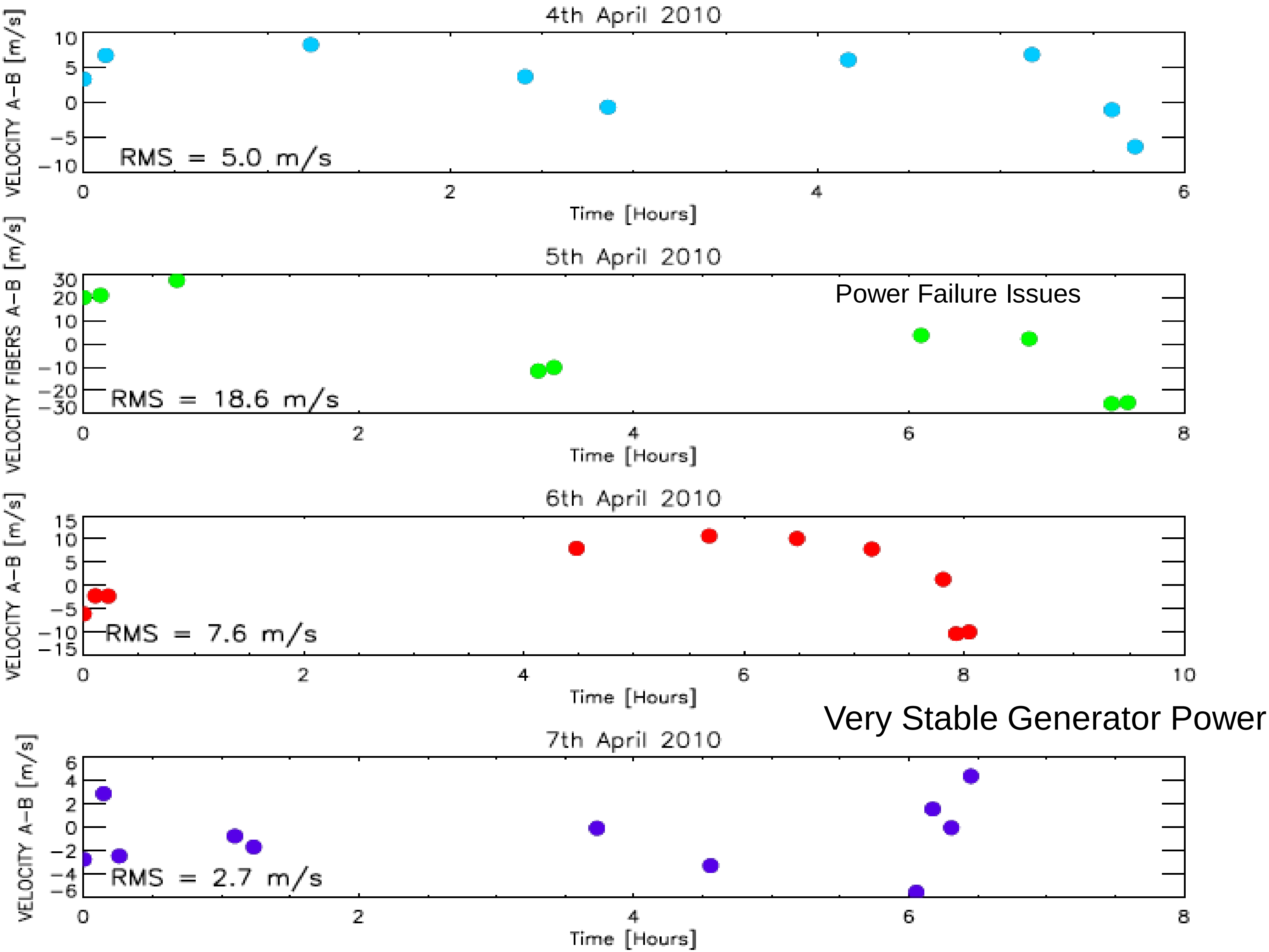


The PARAS spectrograph aligned on the optical bench kept on the Coude table. The Coude room is under temp. control environment of 0.035C at 25C.

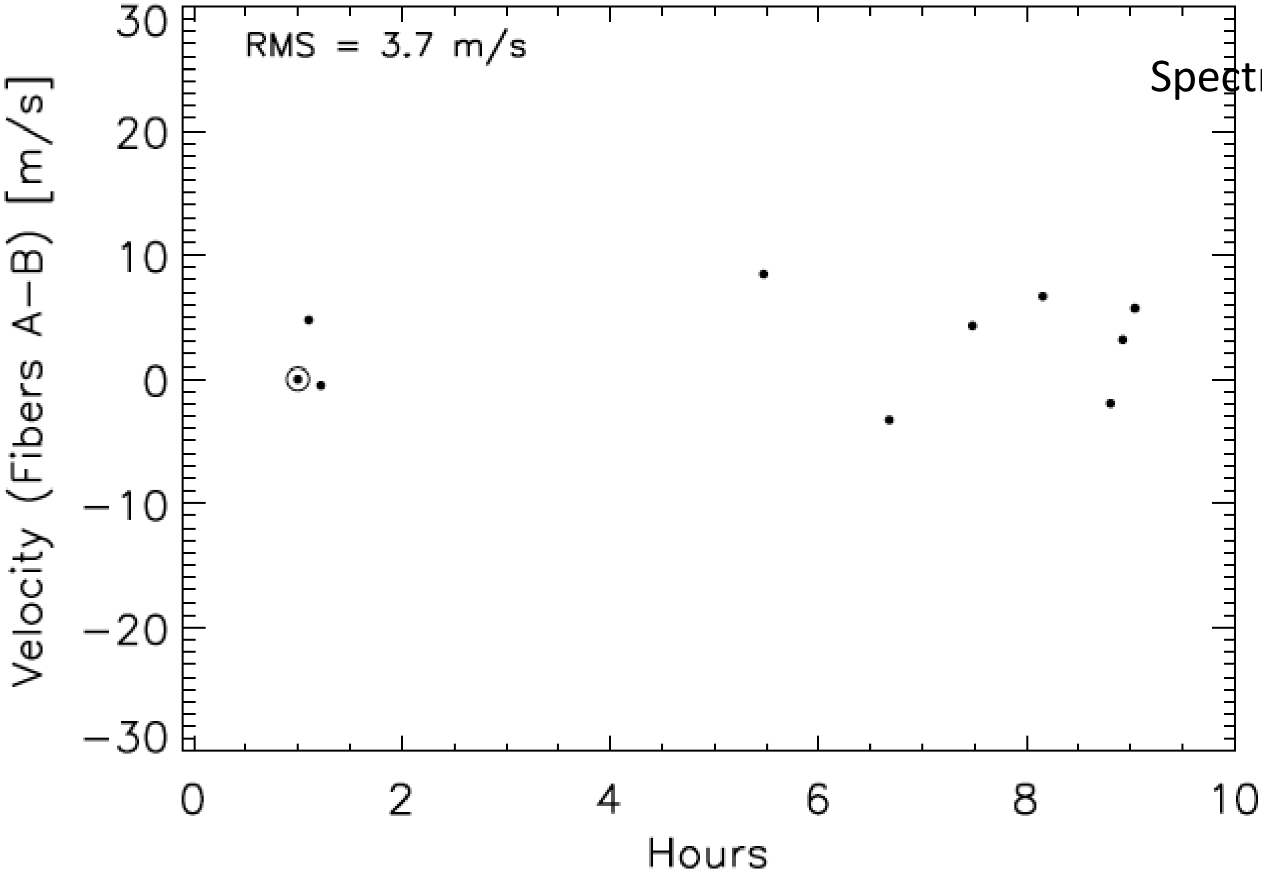
PARAS spectral format



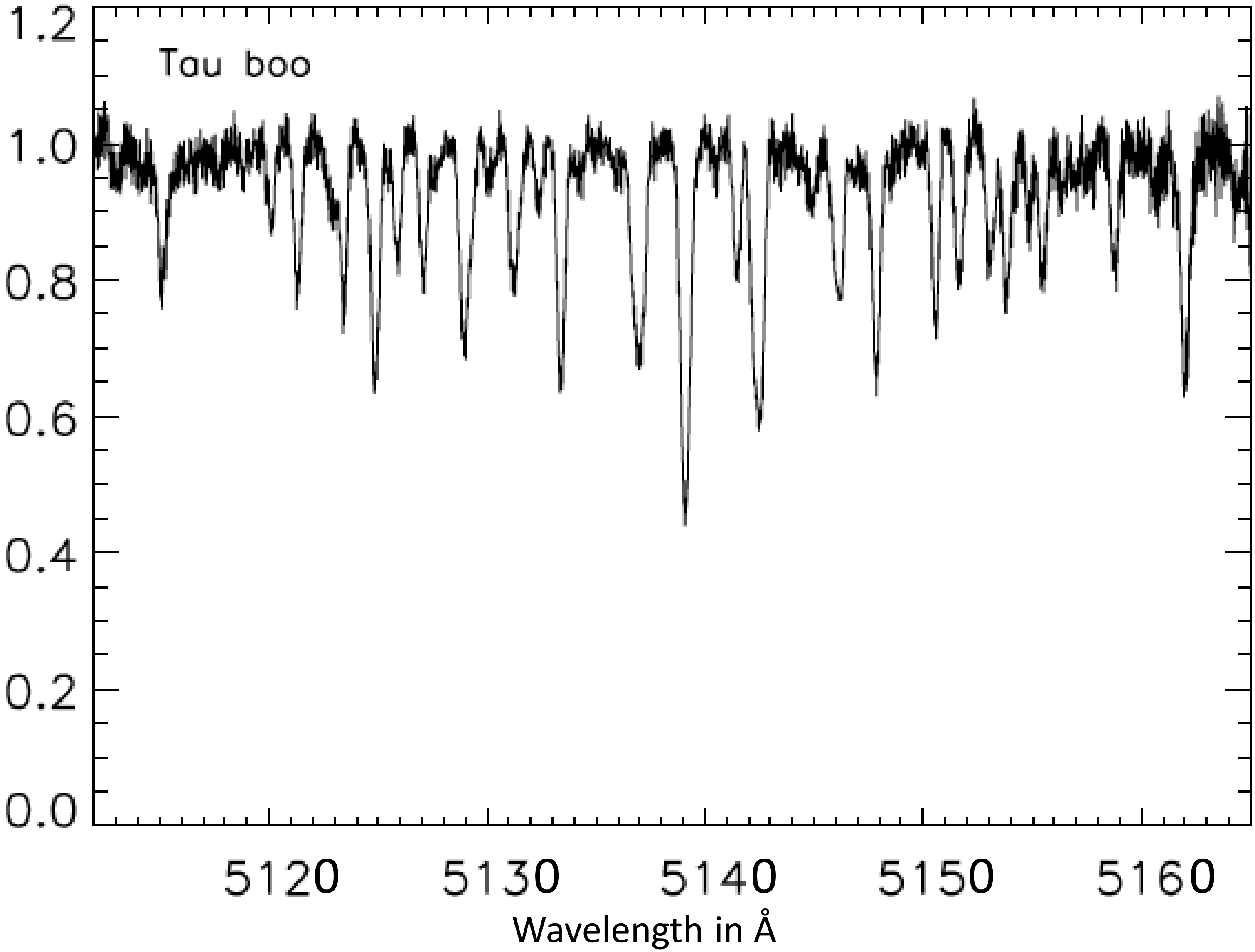
Scattering is minimal as Optics micro surface roughness are ~λ/100 on the Mirror surfaces


4th April 2010
VELOCITY A–B [m/s]
RMS = 5.0 m/s
Time [Hours]
5th April 2010
Power Failure Issues
VELOCITY FIBERS A–B [m/s]
RMS = 18.6 m/s
Time [Hours]
6th April 2010
VELOCITY A–B [m/s]
RMS = 7.6 m/s
Time [Hours]
Very Stable Generator Power
7th April 2010
VELOCITY A–B [m/s]
RMS = 2.7 m/s
Time [Hours]

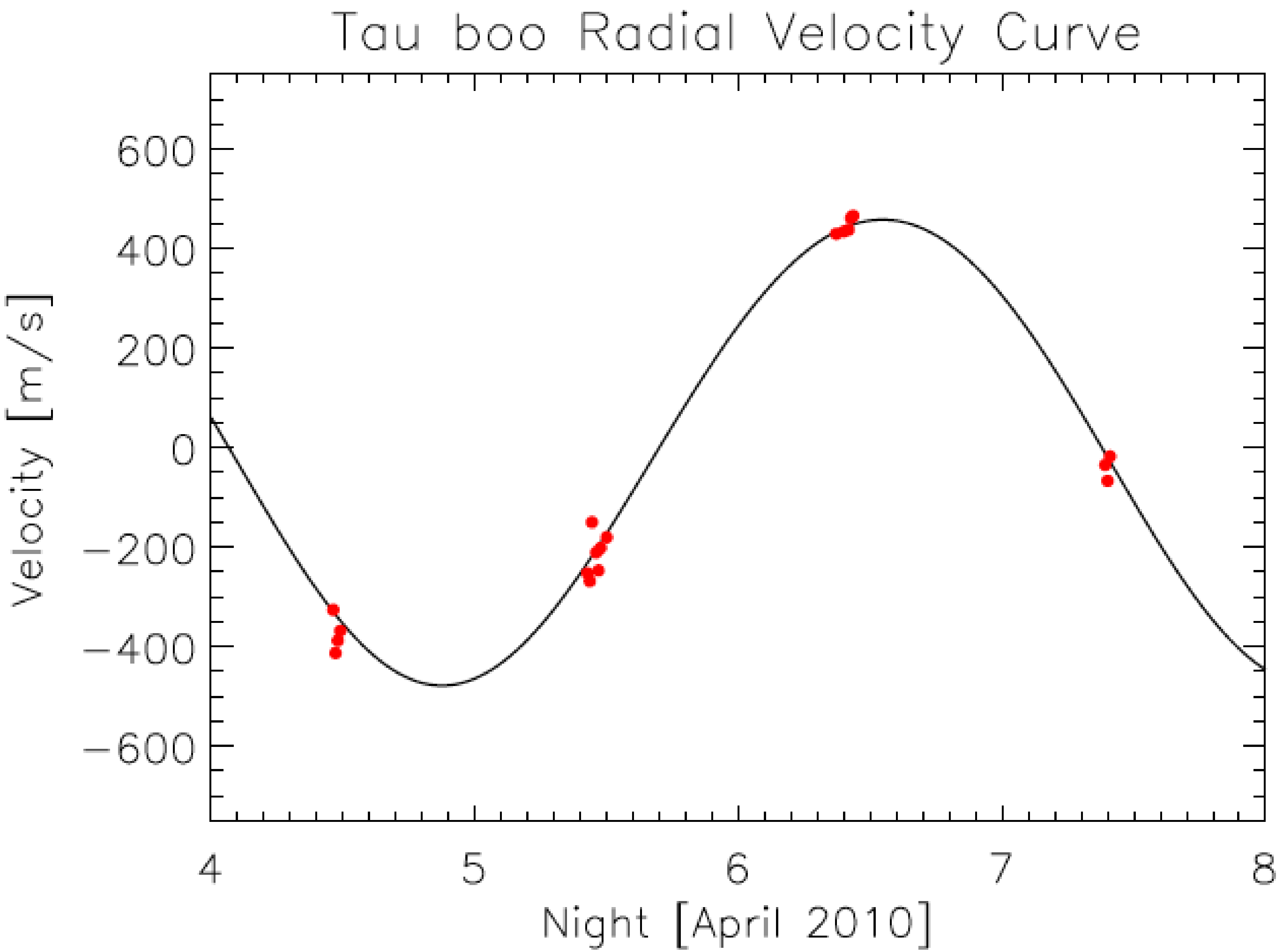
Spectrograph Stability



We had issues with the Optical bench flexing by amount of a pixel in ~36 hours due to mechanical issues, which are now corrected with the Vacuum Chambers



Tau boo
1.2
1.0
0.8
0.6
0.4
0.2
0.0
5120
5130
5140
5150
5160
Wavelength in Å



Tau boo Radial Velocity Curve
Velocity [m/s]
600
400
200
0
−200
−400
−600
4
5
6
7
8
Night [April 2010]

Spectrograph Efficiency : From the slit position to the Detector ~ 30%

Expected total efficiency:

Telescope + Fiber coupling (with FRD) ~ 10%

Telescope + Fiber coupling + Double Scrambler ~ 7%

Issues with the telescope:

1) Tracking issues, present error up to 2.5” with guiding
2) Beam splitter issues

We have designed a new focal reducer which should be installed by Nov 2010 along with the Tip/tilt unit

Beam Splitter being changed to a Pellicle

Optical Scramblers for removing illumination variations due to telescope tracking errors. Such variations can produce RV errors up to 5-10m/s on star.

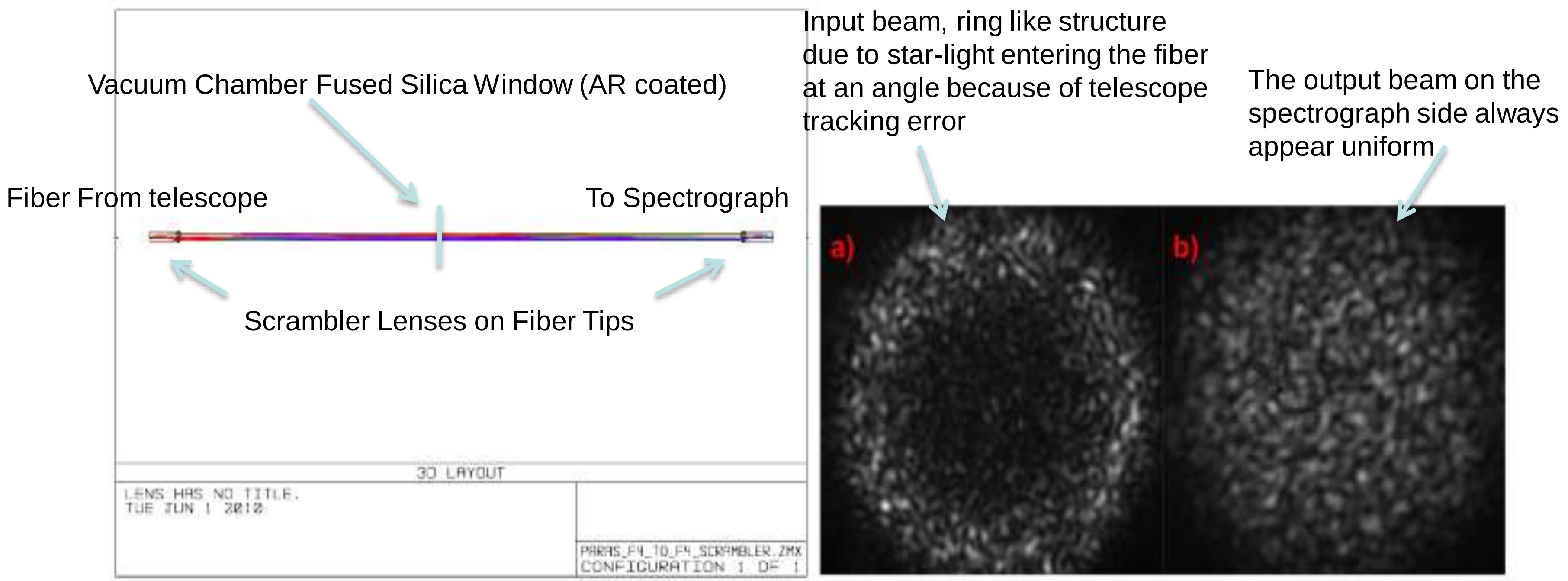
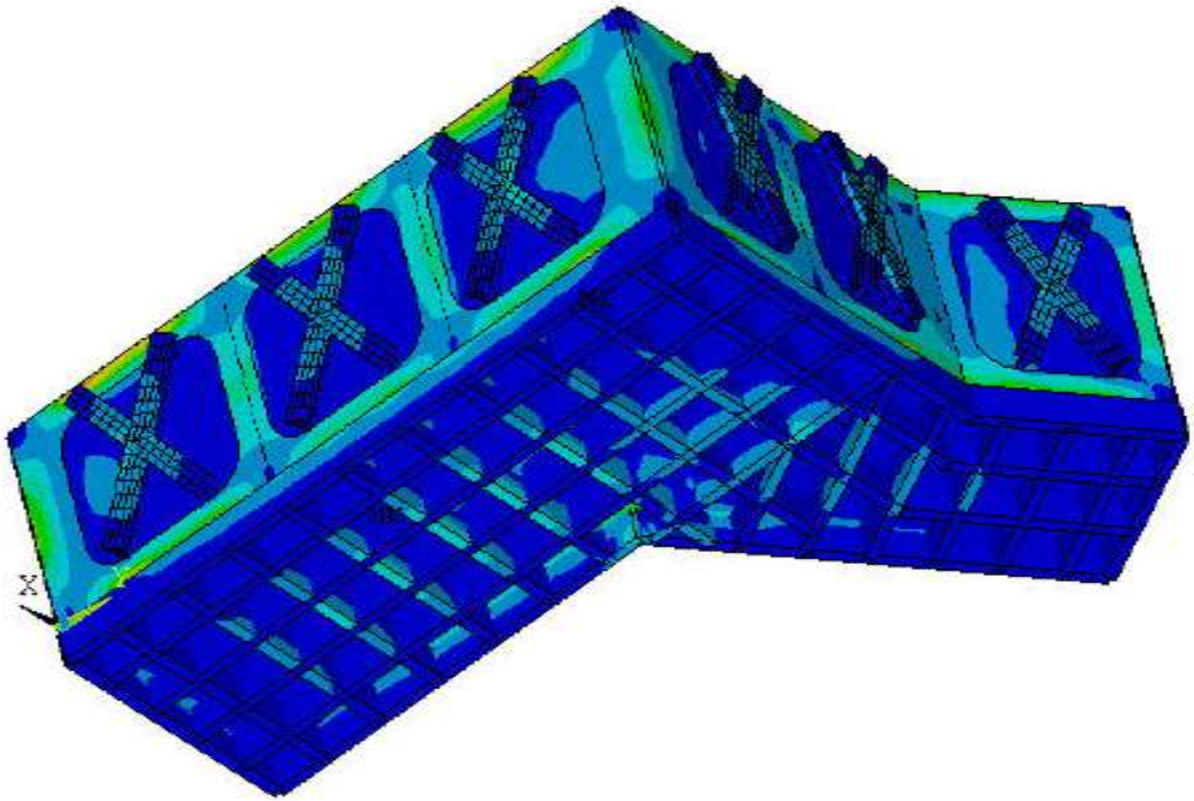


Figure 9. Scrambler Optics ray diagram. BMV Opticals based on our design manufactured the Scrambler Doublets. Right: the effect of scrambling, even though the input beam appears to be in circular ring like structure, the output beam will always appear uniform.

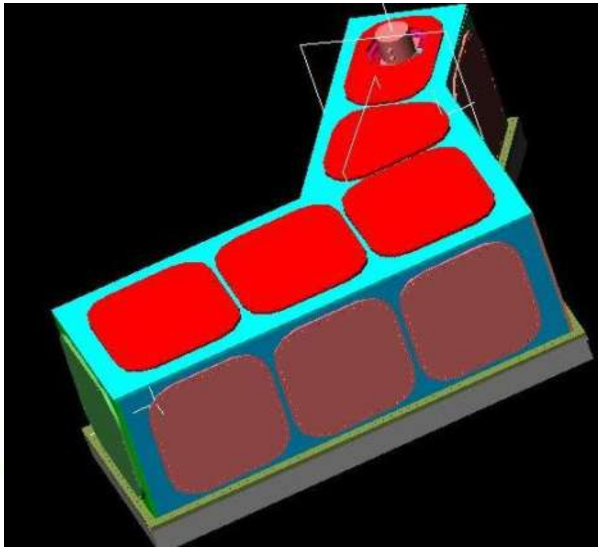
From left fiber to right fiber the light is scrambled: light coming out at equal angles enter radially on the second fiber and vise versa thus effectively scrambling the light (Hunter & Ramsey 1992)

The Vacuum Chamber Design

Finite Element Analysis of the Vacuum Chamber done using Ansys by Aditya High Vacuum



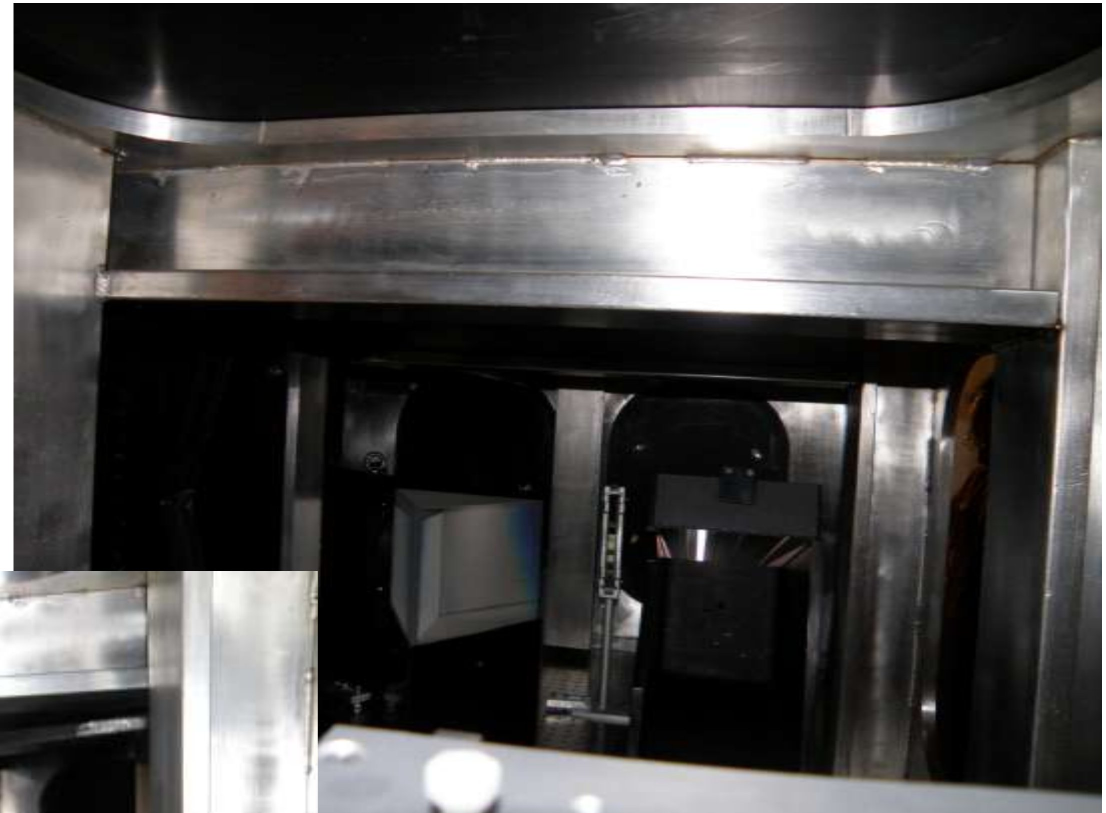
Schematic of the Vacuum Chamber



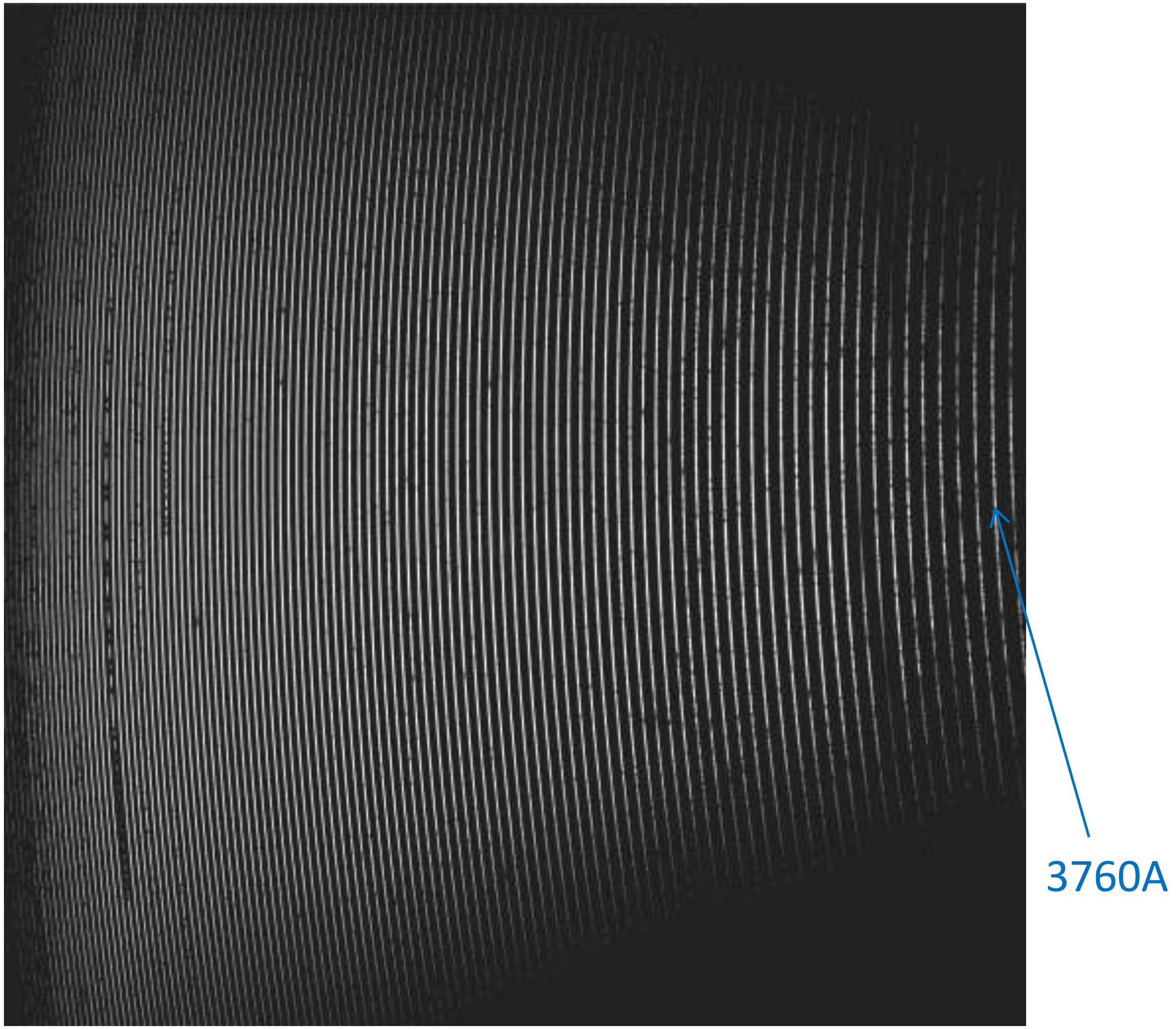
Bottom View: Showing the deformations in the base plate

Low Vacuum ~ 0.01mbar
With LN2 trap in the outer chamber, pumping will be required once in 4 days, to keep the pressure between 0.01mbar and 0.04mbar,
Need to pour LN2 every 12 hours

Without the LN2 trap,
We can maintain the pressure at 0.2mbar to 0.4mbar for 36hours



Optics being installed inside the Vacuum chamber



In Summary

- Resolution ~ 60000, wavelength ~3760A, m=162 to ~8600A, m=71 (m=order)
- In a temp. control environment, 25 +/- 0.035C

- And……

- Will be installed in a low-Vacuum Chamber in September 2010, @0.01mbar
- We plan to achieve ~3m/s RV precision on targets of 9 to 10th mag in the next one year and **attempt to work down to 1m/s on on the sky on bright targets** with continuing improvements in instrumentation and analysis.

Telescopes in India where PARAS can go in the future provided we get 10nights/month:

A new 1.4m telescope in the Himalayas which is just installed at a reasonable good site at 8500feet,

At the same place a new 3.6m telescope is scheduled to come up in 2013

Finally, PRL will have its own 2.5m telescope at Mt. Abu in 2016