# Integration and alignment of FLECHAS

Fibre Linked ECHelle Astronomical Spectrograph

# CAOS group

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# Purposes of our presentation

- Summary of our spectrographs
- FLECHAS specifications
- Optical design
- Integration and alignment of the instrument
- Spectra acquisition
- Brief data reduction

# Spectrographs:

- Ponchado (reflecting grating) 1994
- Fiasco (reflecting grating) 1997
- Loros (prisms) 2001
- Leches (échelle) 2002
- Besos (prism) 2003
- Ingratos (Grism) 2004
- Tragos (transmission grating) 2005
- Baches (échelle) 2005
- Dados (reflecting grating) 2006
- Pucheros (échelle) in preparation with UCC
- Flechas (échelle) 2009
- Next: Flechas++ (échelle)

# Spectrographs:

# FLECHAS requirements

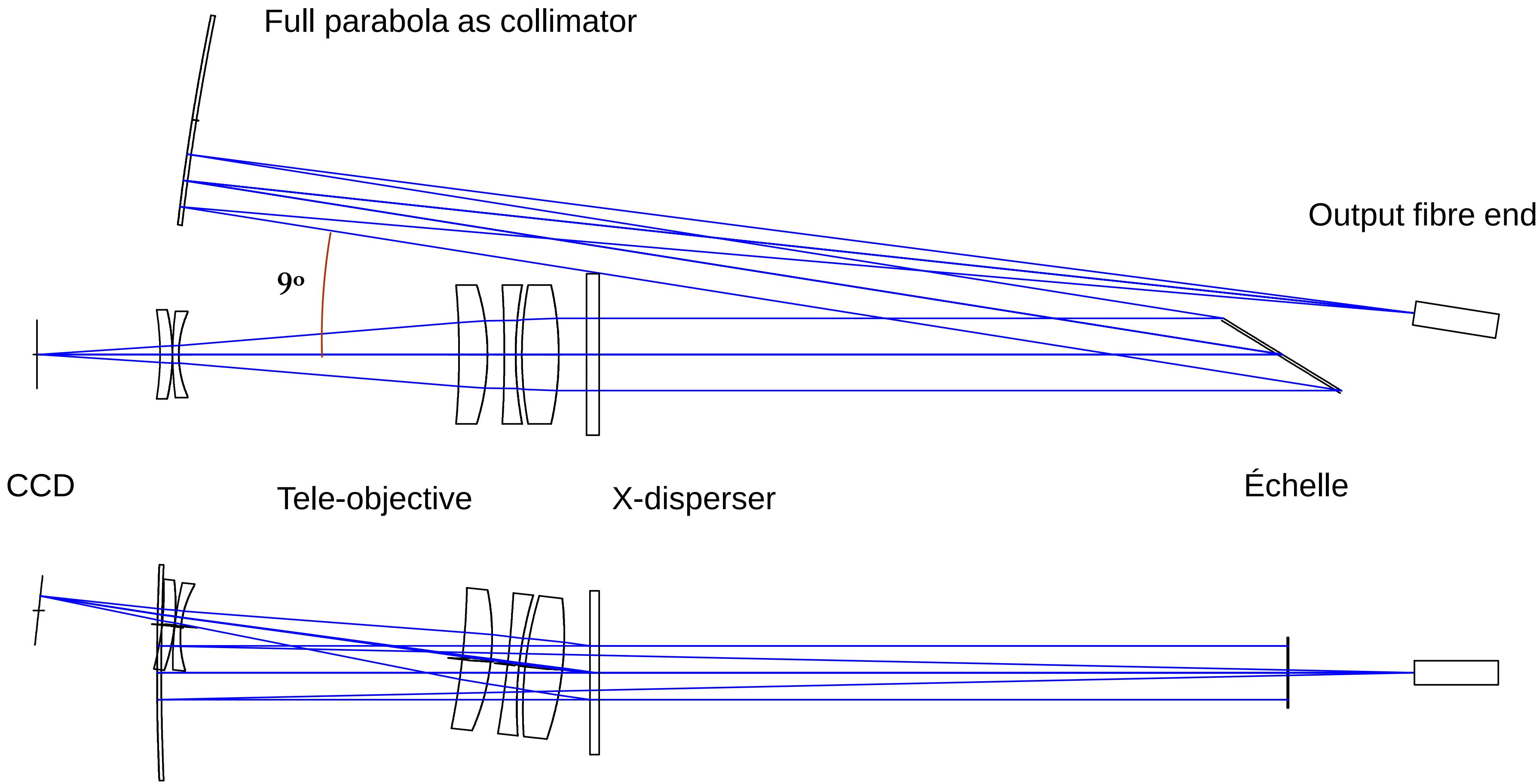
- Medium resolving power (R: 7000-11000)
- Wavelength range: 395 nm – 750 nm
- Mechanical stability (no flexures)
- Adapted to 1.2m telescope at F/10
- Off the shell optic and mechanic components
- No moving parts
- Simple and robust mechanical design
- Low maintenance

# Features

- What drives the design of the spectrograph? :

  Échelle size !!
- Fibre link to the telescope
  - Small fibre core
  - Fibre works at low F/# to reduce focal  ratio degradation
  - Mini and micro lenses to match telescope and spectrograph apertures
- Full parabolic mirror working as off-axis
- Transmission grating as X-disperser
- Photo-tele-objective to image the spectrum on CCD
- Large “unexpensive” CCD size.

# Optical design



# Optical design

To the question: why 9º between the collimator and objective beams?

This “grating” angle should be as small as possible in order to approach the Littrow configuration where the efficiency is the maximum. In the FLECHAS case, we found that 9º was the best compromise between the size of the camera objective and the optical table.

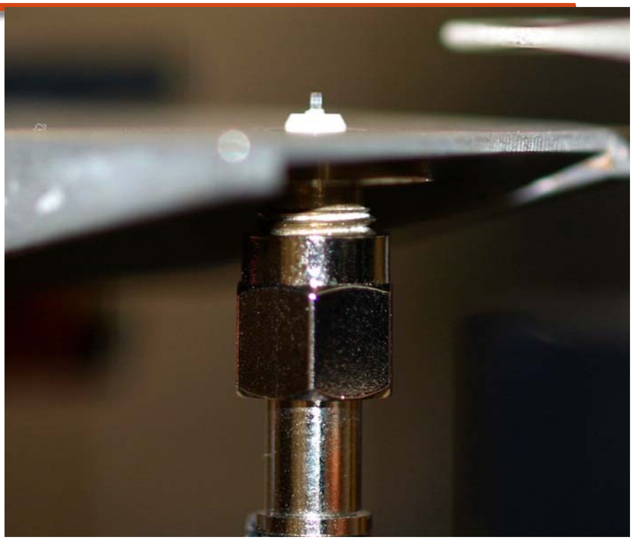
# Spectrograph

| | |
|---|---|
| • Parabola | f 444 mm, ø 75 mm, Edmund Optics |
| • Collimator beam | F/18 |
| • Pupil | 25 mm |
| • Échelle | 79 li/mm 63º 25  50  9, Thorlabs |
| • X-disperser | 200 li/mm 10º 58  58  10, Newport |
| • Objective | f 200   F/2.8, Canon |
| • CCD Atik 11000 | 4008  2672  9 µm (24  35) |

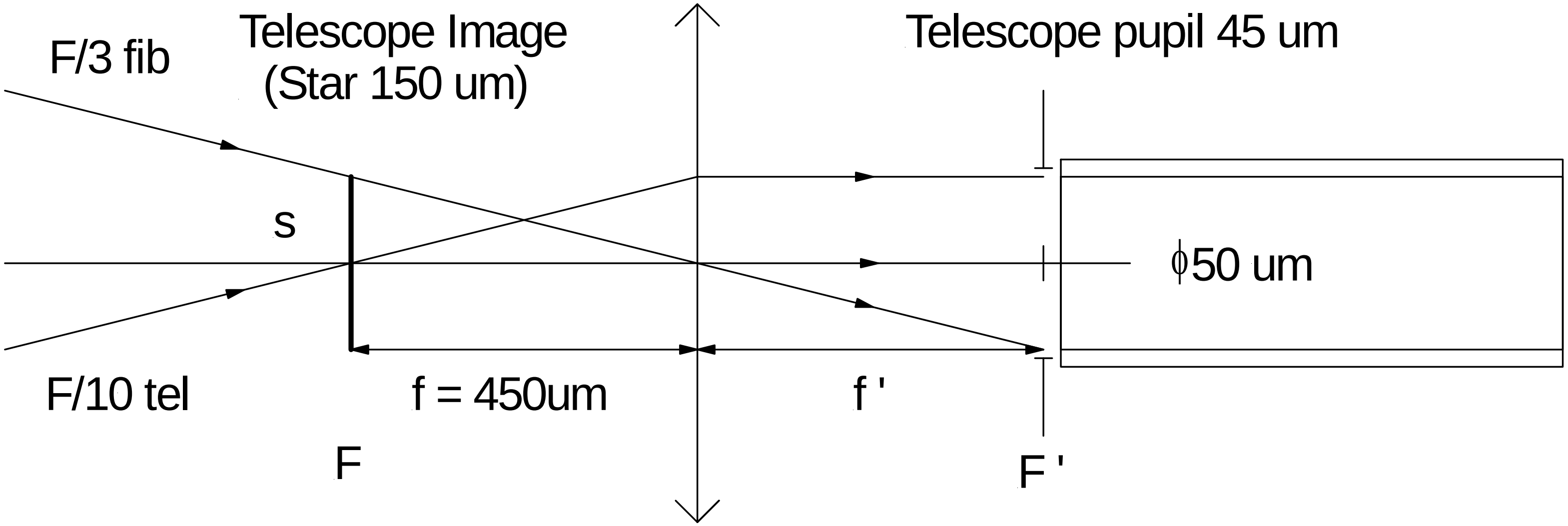
# Fibre link

- Telescope
  - 1.2 m at F/10
  - Plate scale: 58.2 µm/arcsec
  - Pinhole: 150 µm = 2.6 arcsec
- Fibre — 50 µm and 20 m long, Polymicro FBP
- Input lens — GRIN f = 450 µm, L = 1 mm, ø 0.5 mm, GrinTech
- Conversion beam — F/10 to F/3 in fibre
- Output lens — Doublet f = 5 mm, ø 3 mm, Linos
- "Slit" — ø 308 µm at F/18

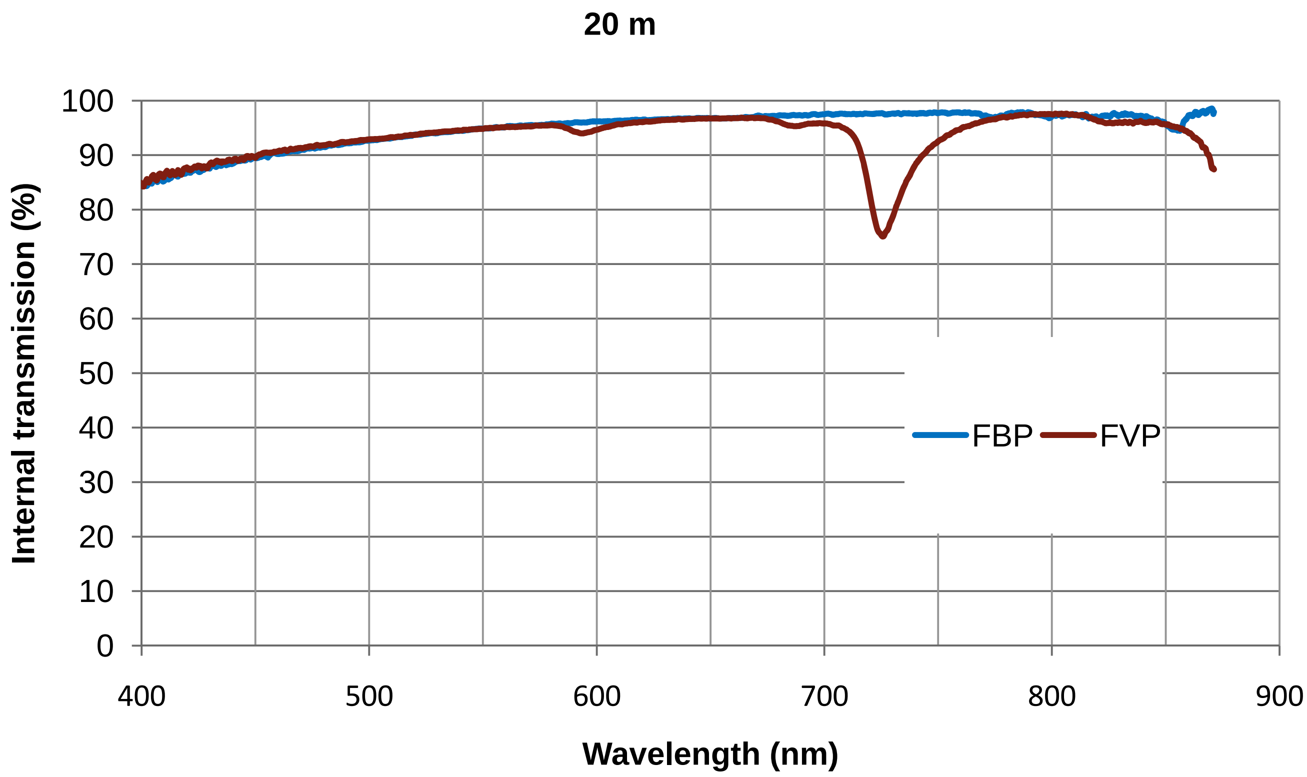
# Beam injection



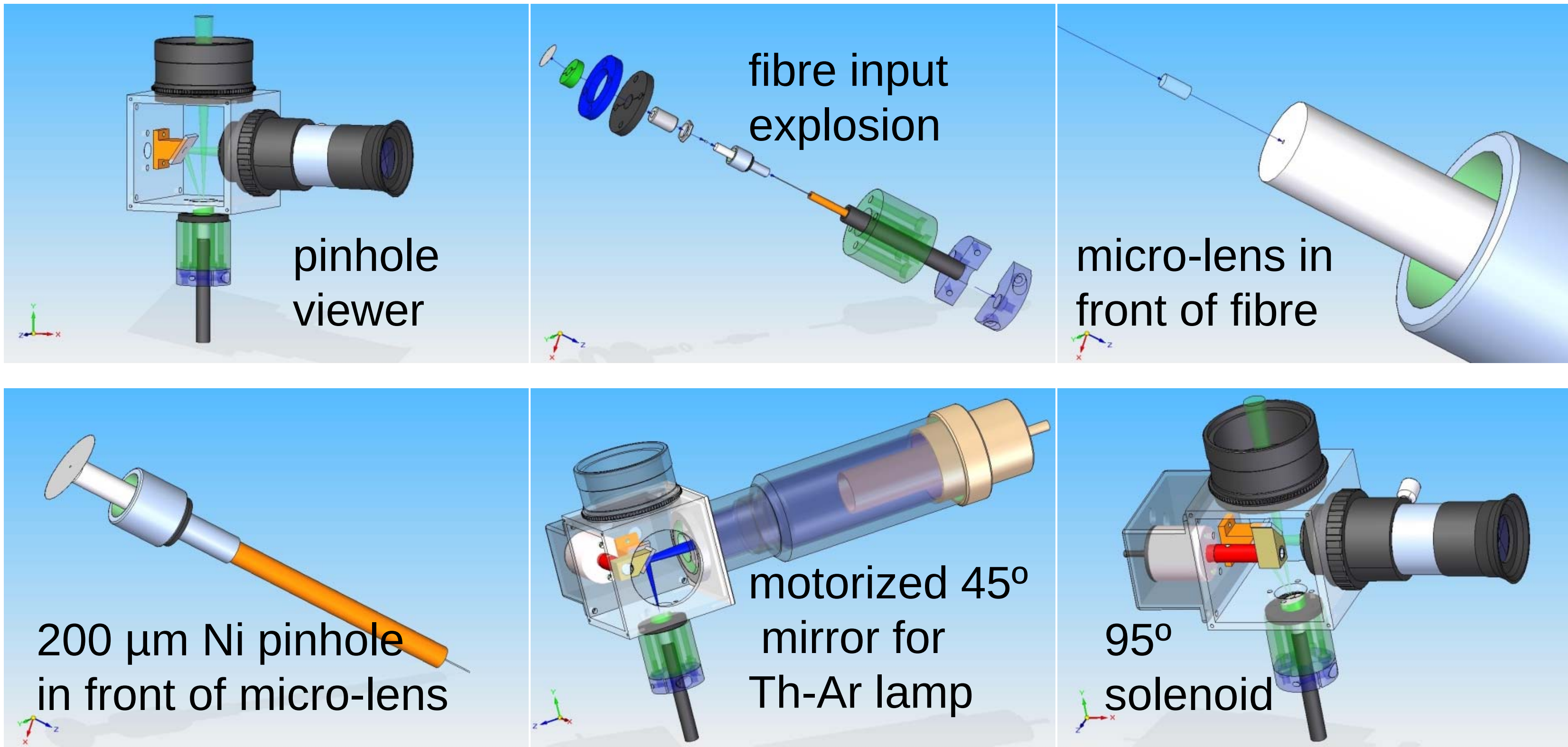
We have use the principle to project
the telescope pupil on the fibre input end



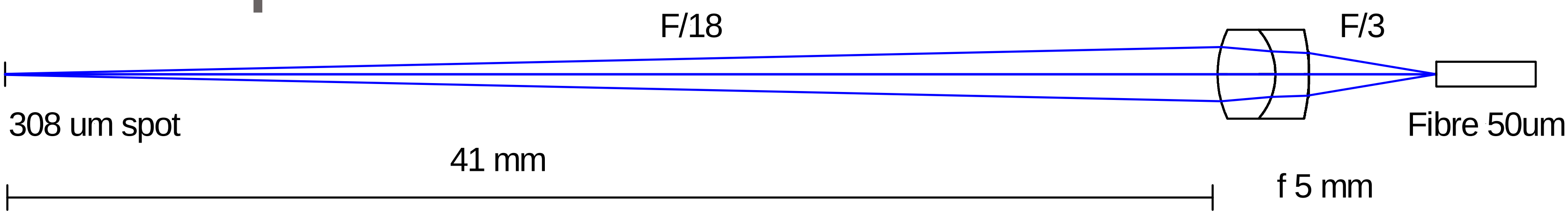
Fibre transmission (internal) in 20 m. FLECHAS uses the FBP type

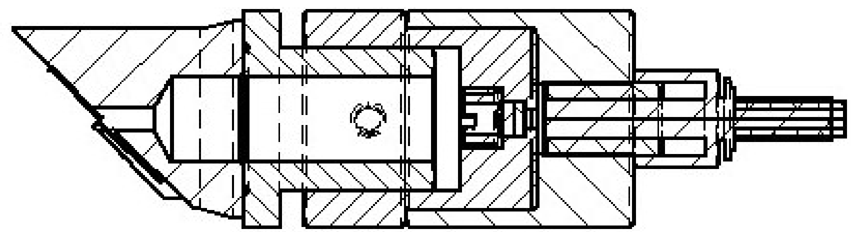


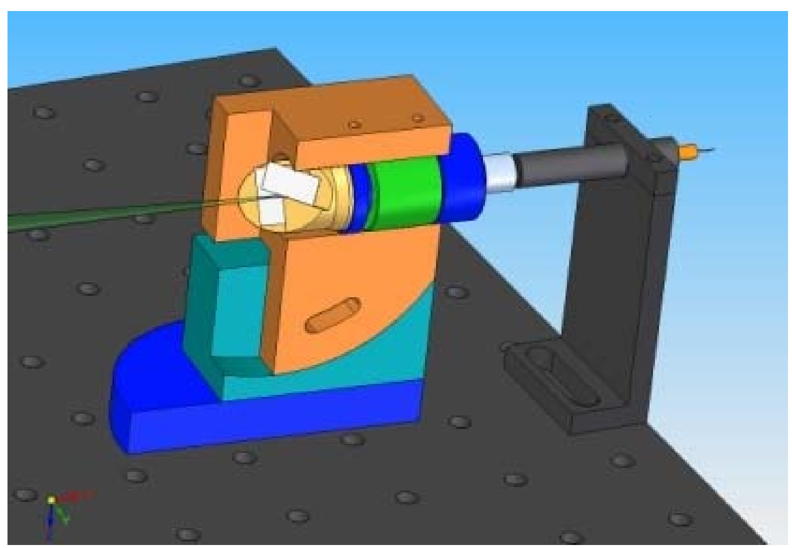
# Fibre Head


pinhole viewer
fibre input explosion
micro-lens in front of fibre
200 µm Ni pinhole in front of micro-lens
motorized 45º mirror for Th-Ar lamp
95º solenoid

# Output Beam





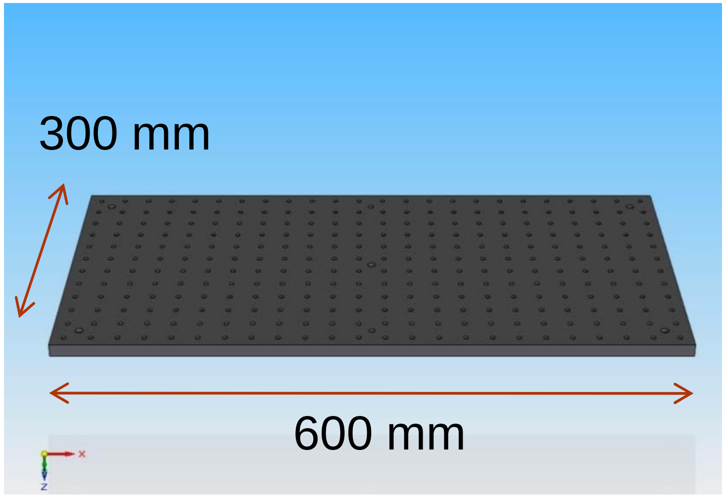
# This fibre link for a 30 cm Telescope

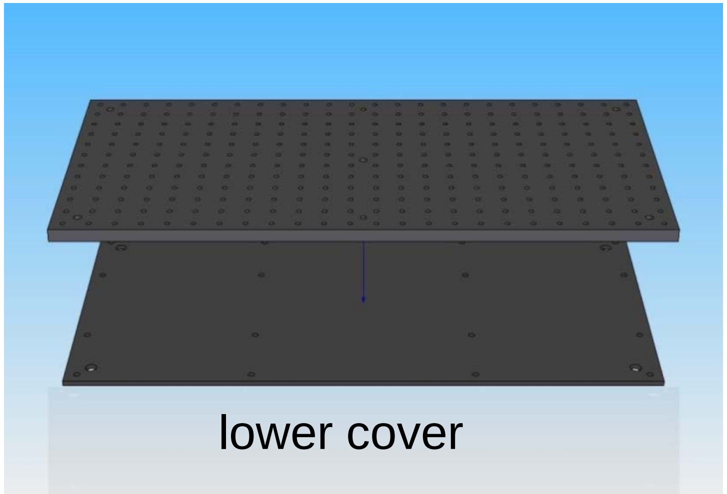
| | |
|---|---|
| • Best match | F/10 telescope |
| • Plate scale | 14.5 µm/arcsec |
| • Sky aperture | 10.3 arcsec ! (150 µm pinhole)<br>F/3 in fibre: good FRD |
| • 100 µm pinhole => | 6.9 arcsec, but the aperture into the fibre falls to F/4.5. The FRD is at the limit of acceptance |
| • Increasing resolution? | The output spot is 308 µm.<br>Need of an image slicer! |

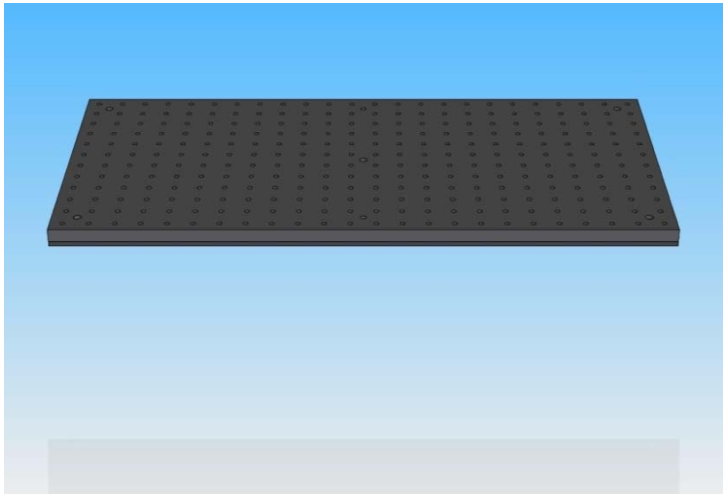
# Steps to integration and alignment

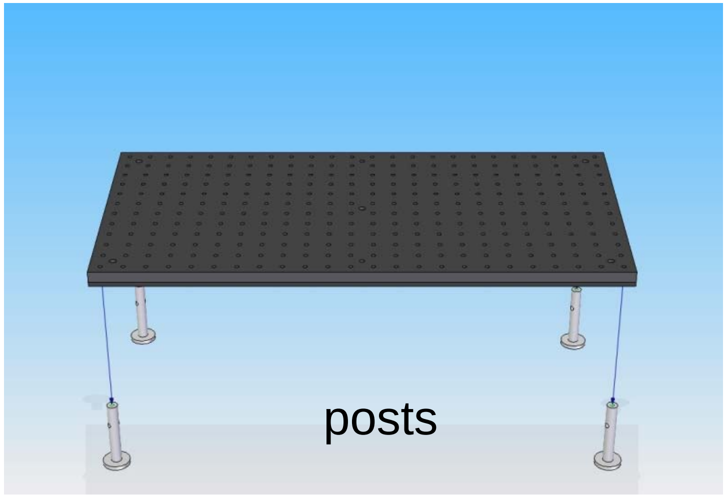
- Setup of the 9º angle between collimator and Échelle
- Setup of the fibre-parabola optical axis
- Alignment of parabola with respect to the optical axis
- Installation of auto-collimator mirror
- Finding the parabola focus
- Alignment of the output fibre end
- Alignment of the Échelle
- Alignment of the objective and camera
- Alignment of the cross-disperser
- Installation of the enclosure
- Example of spectra and calibration data reduction

# Set up of the optical table

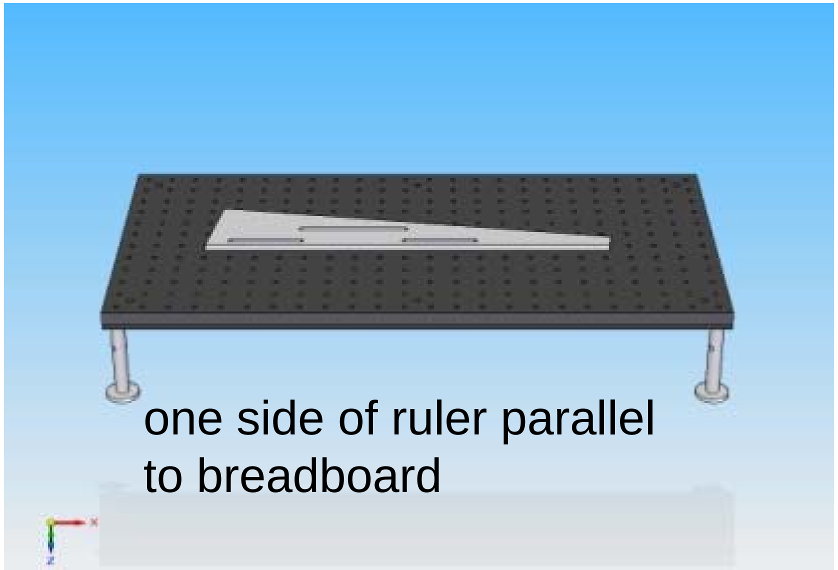


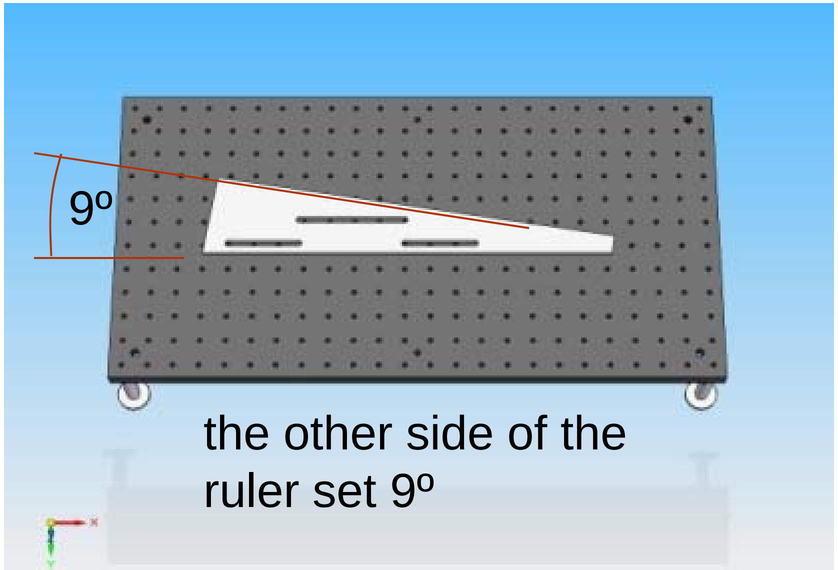



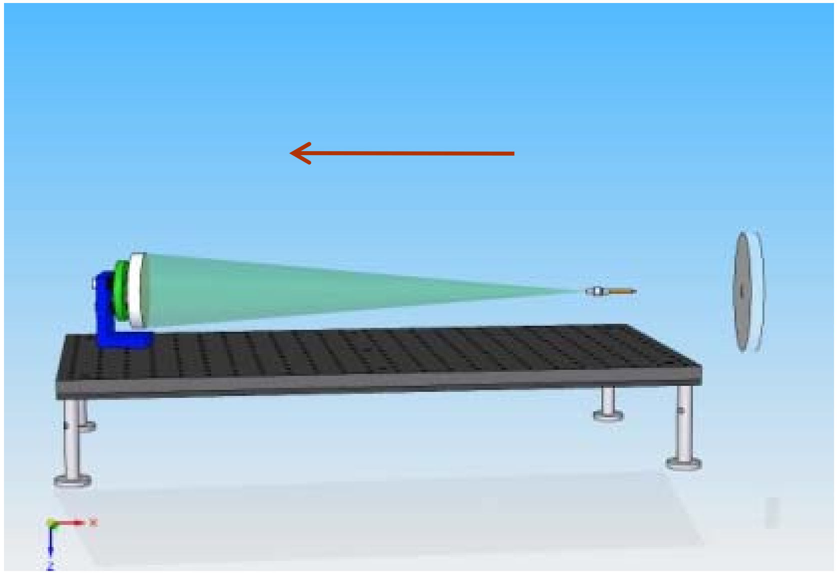


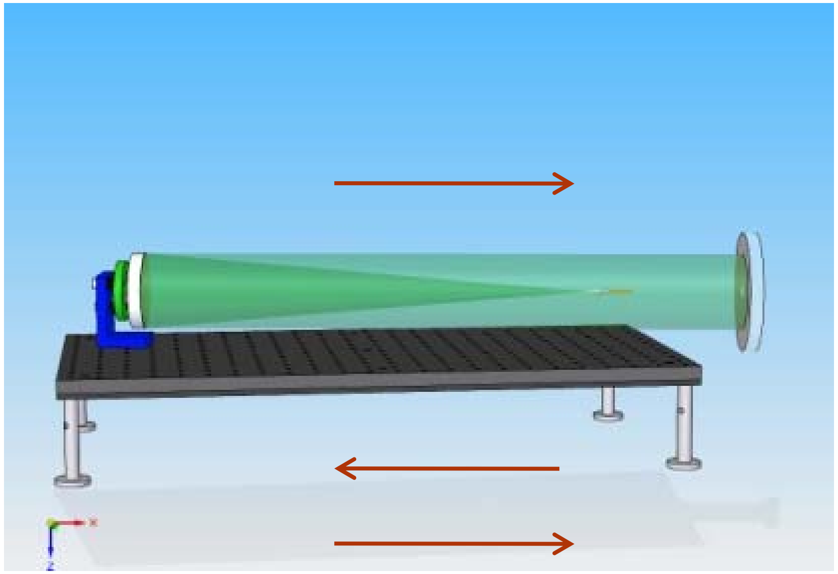
# Definition of the 9º angle between collimator and Échelle



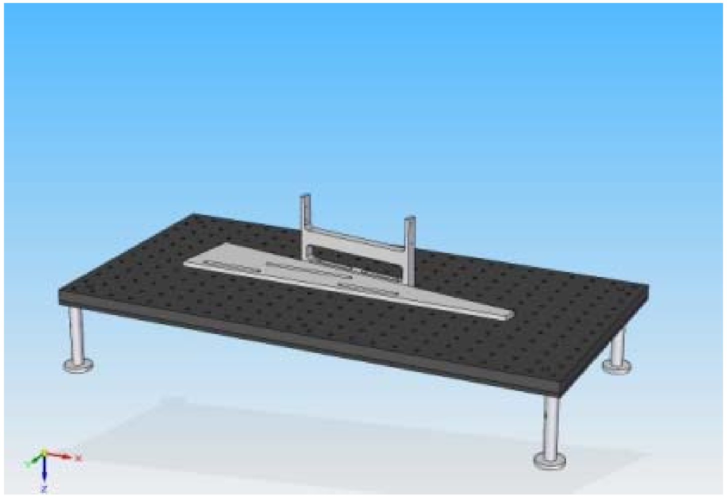



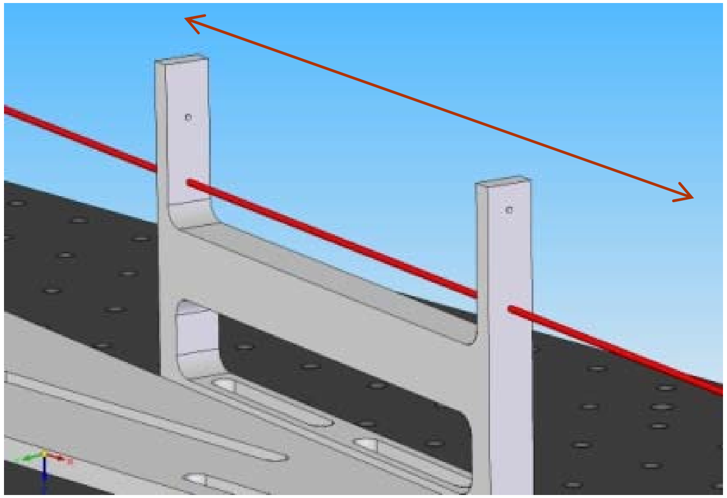
# Alignment of parabola by auto-collimation

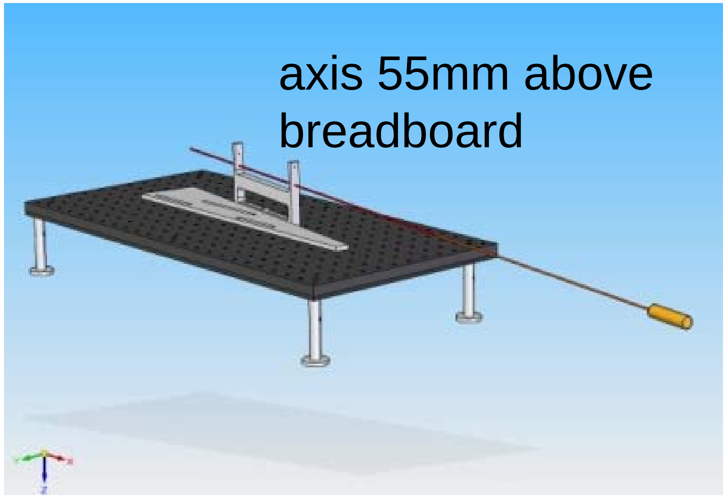


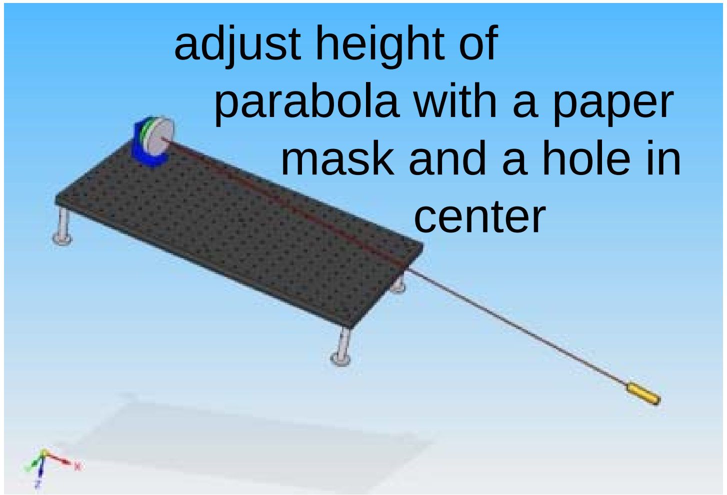


# Definition of the parabola optical axis with a laser

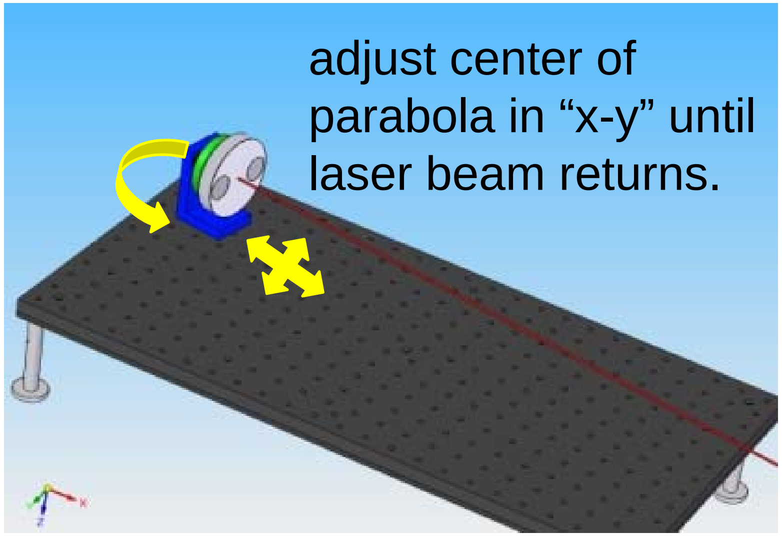


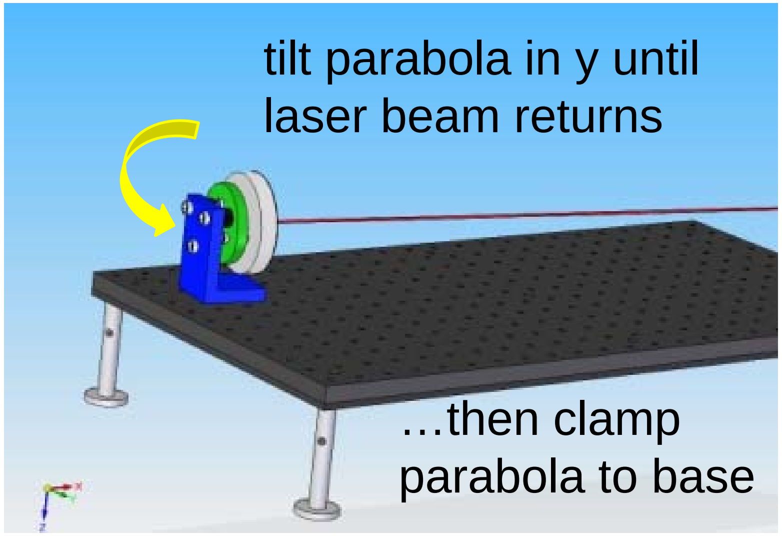




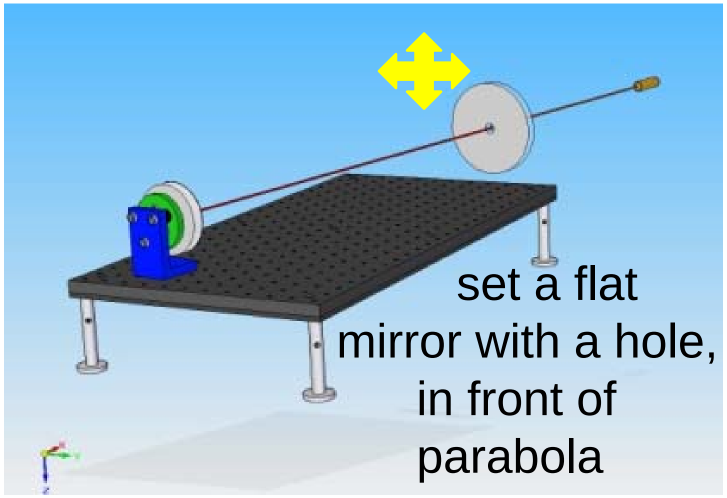



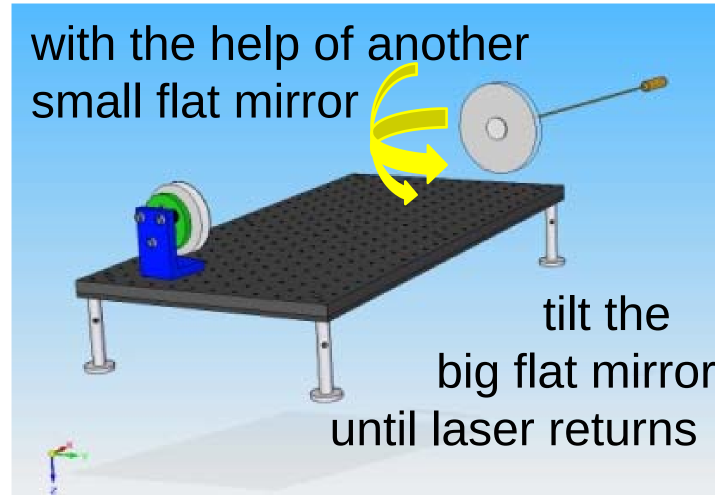
# Alignment of parabola

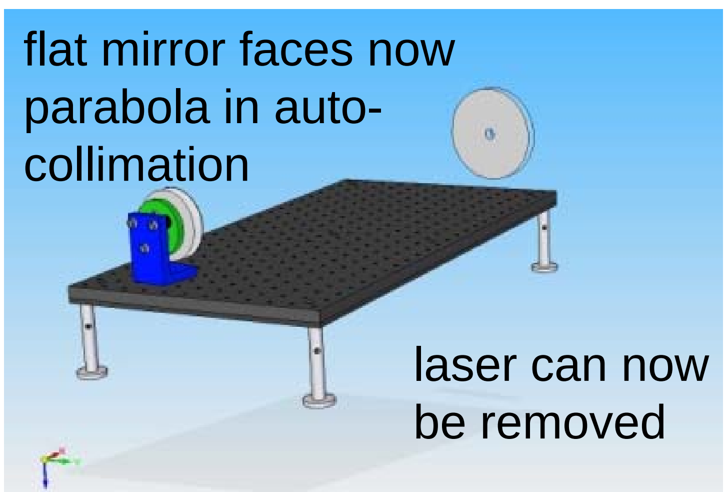


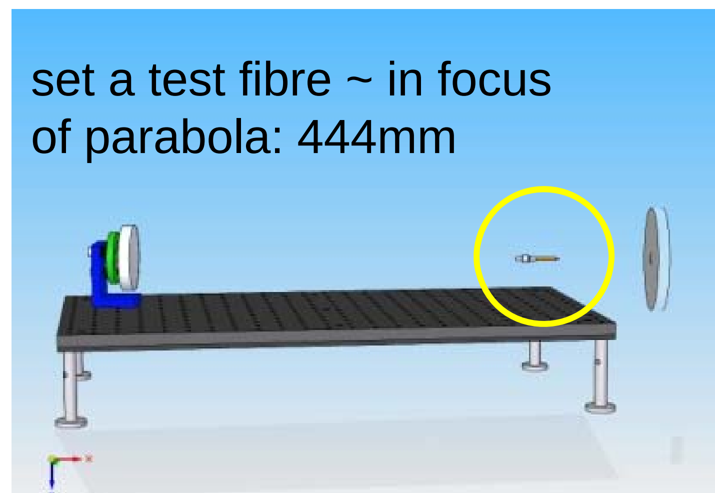



# Installation of auto-collimator mirror

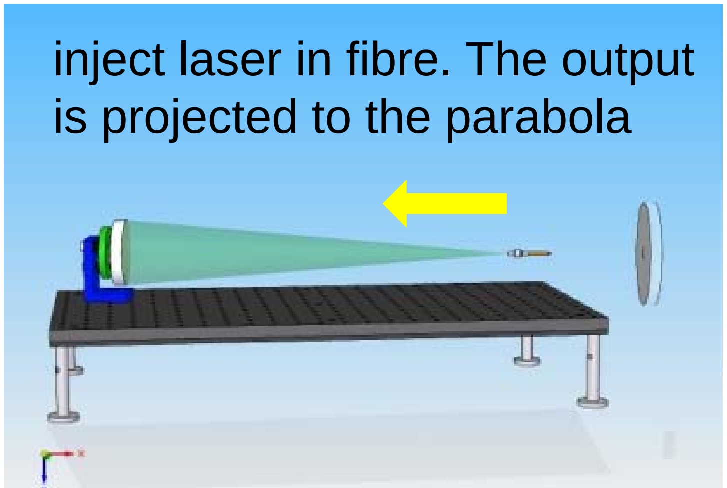


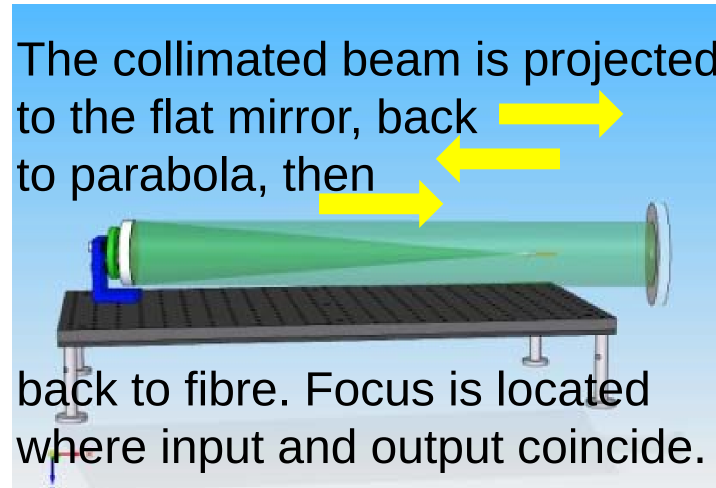



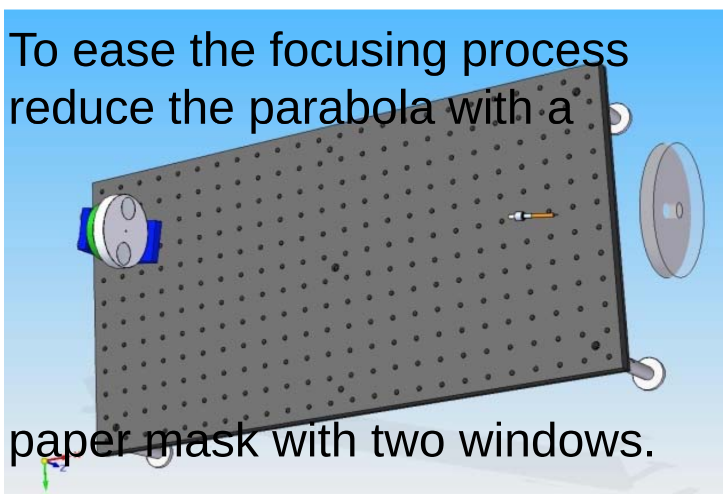



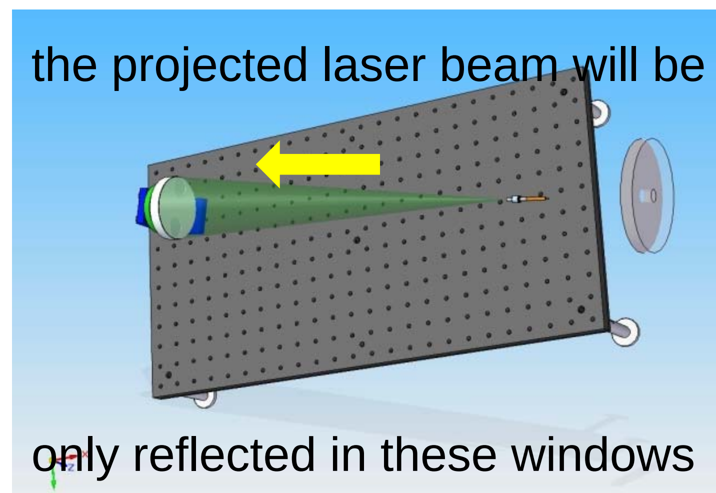



# Finding the parabola focus



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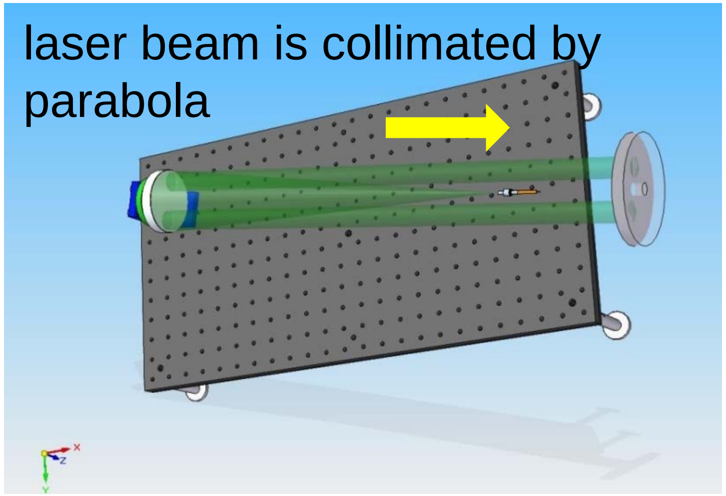
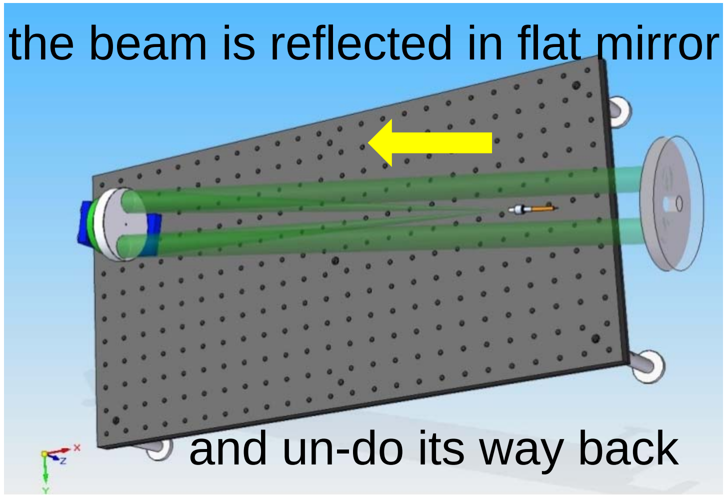
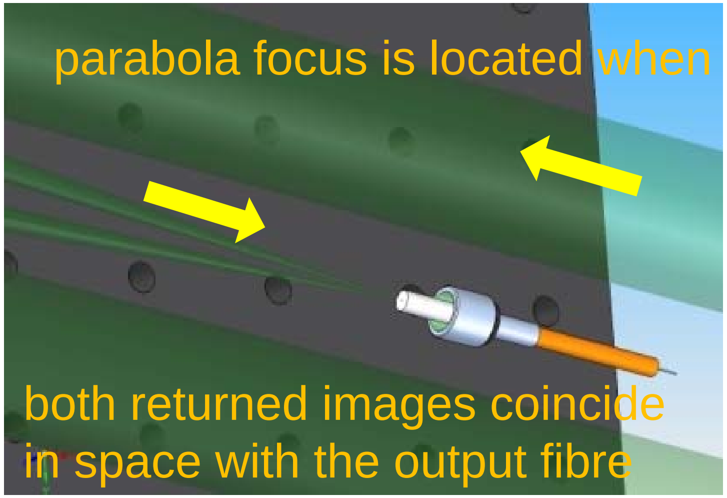
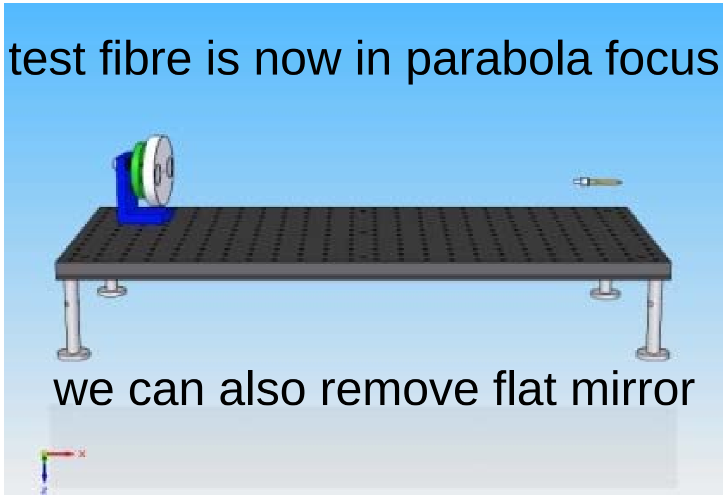
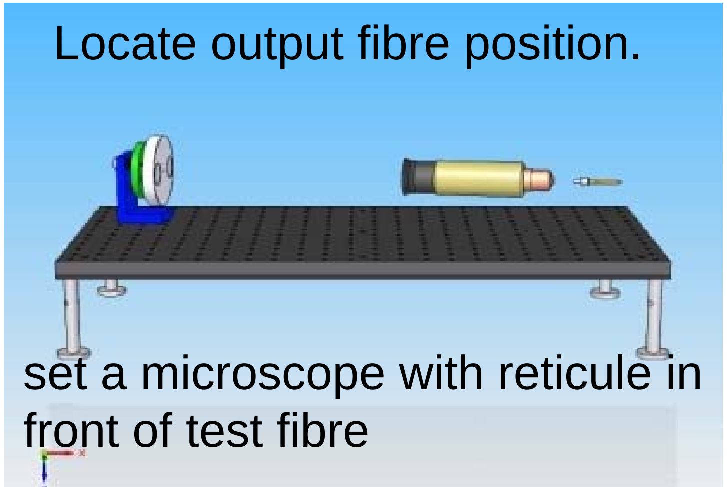


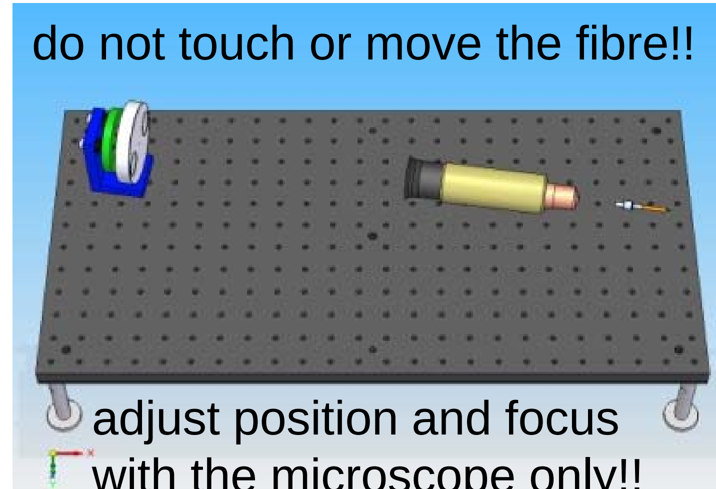



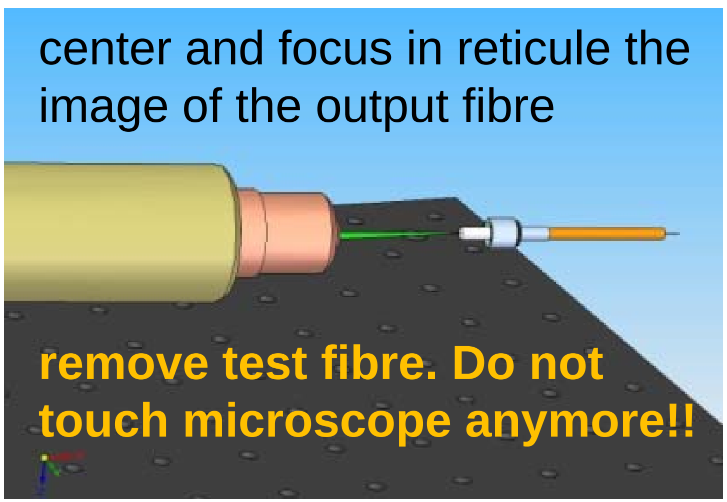



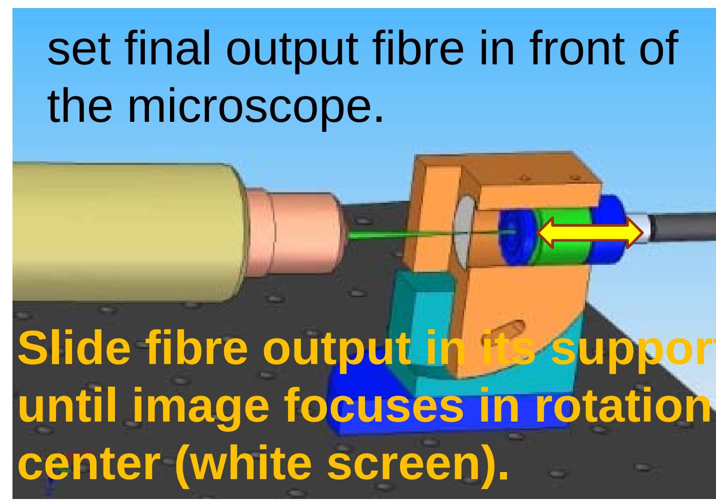



# Alignment of the output fibre end



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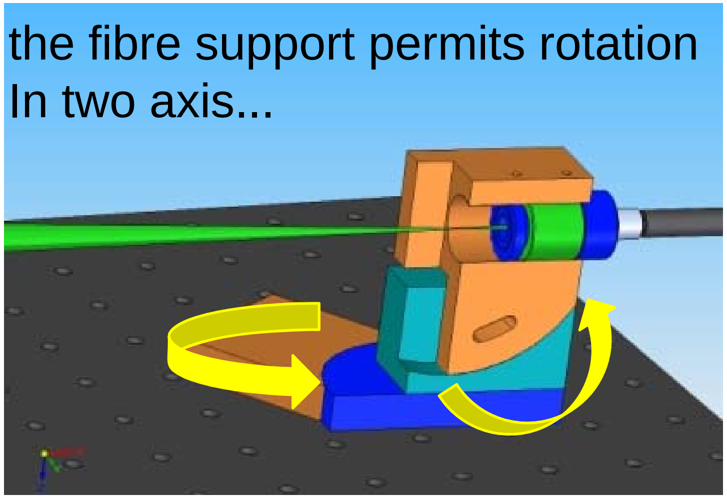
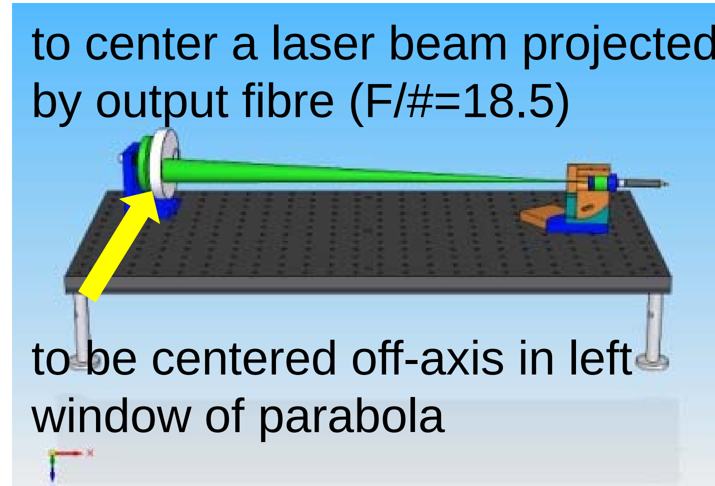
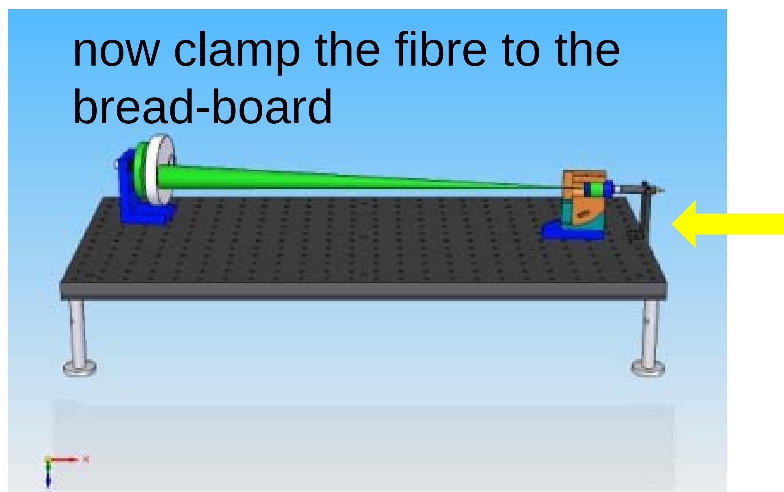
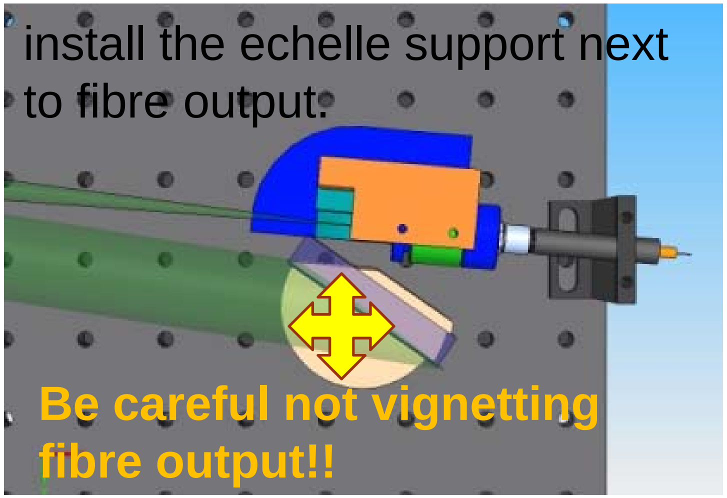
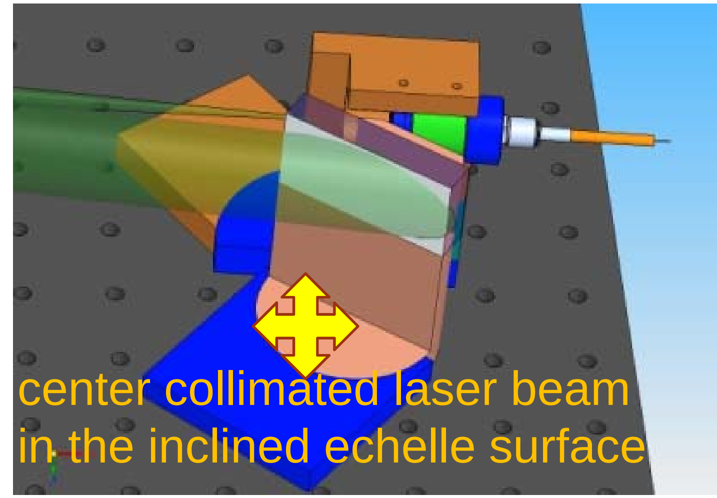


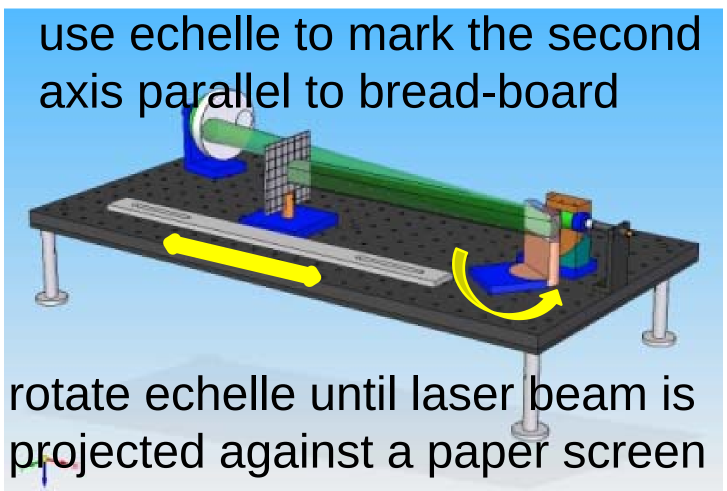



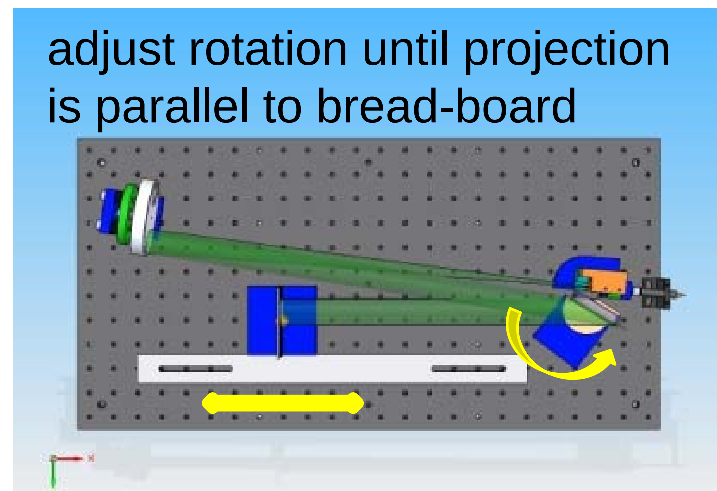



# Alignment of the Échelle

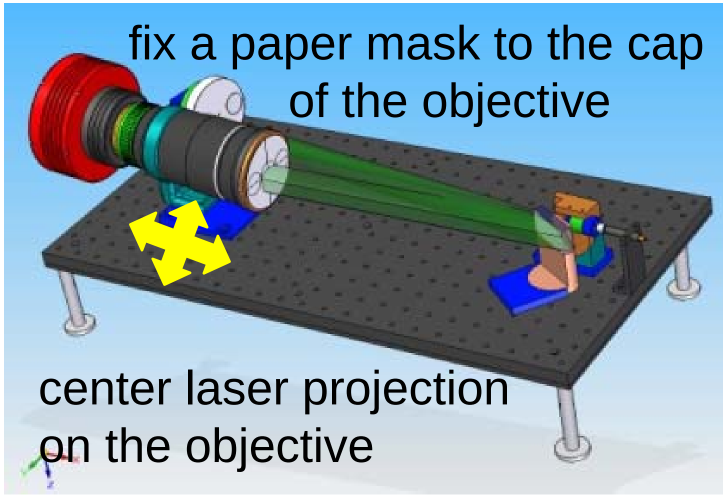


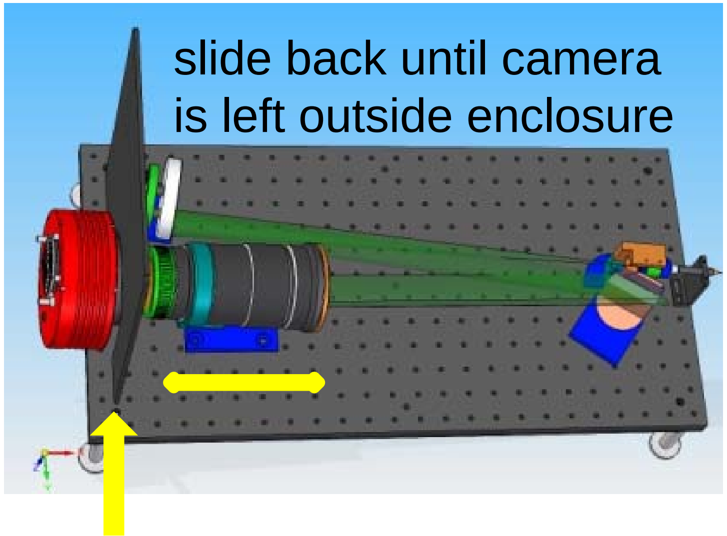



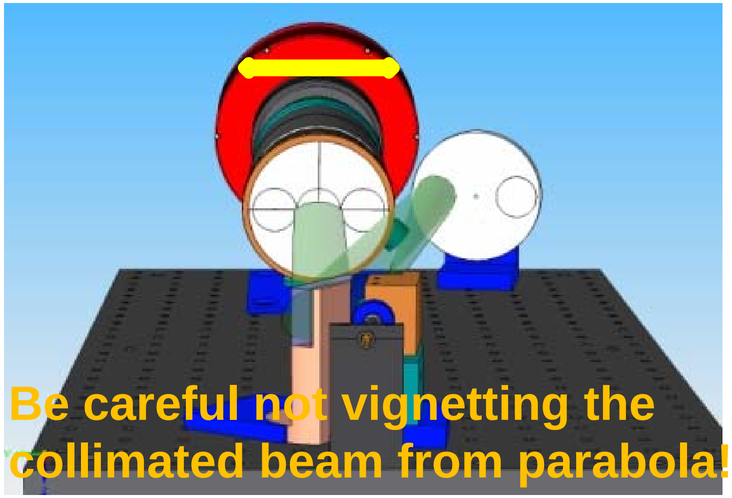



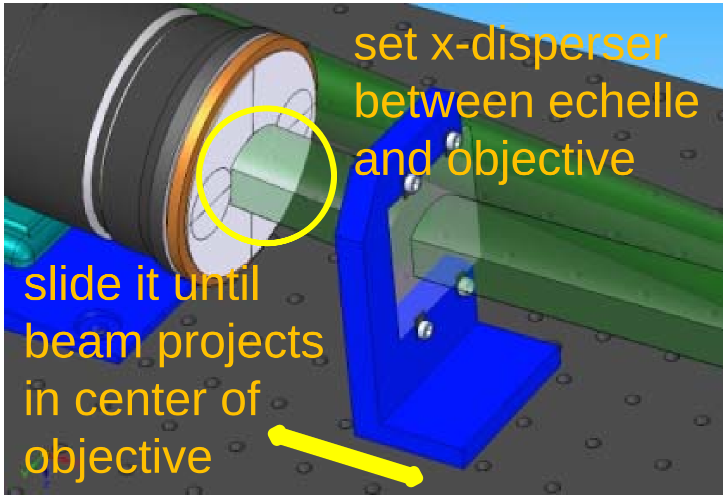
# Alignment of the objective and camera

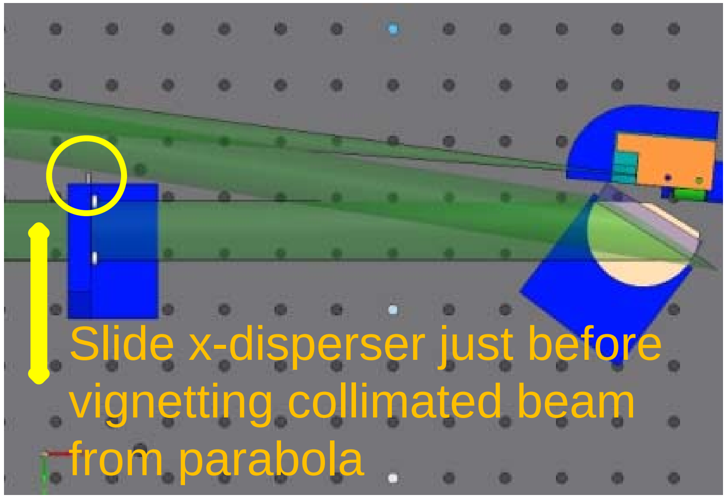


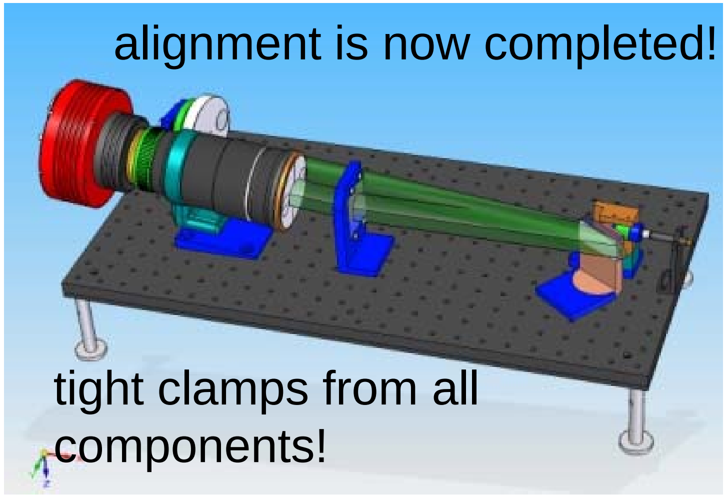



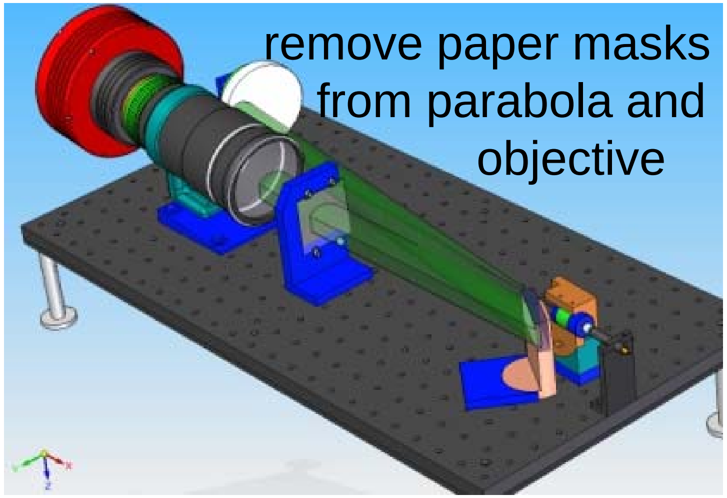



# Alignment of the cross-disperser

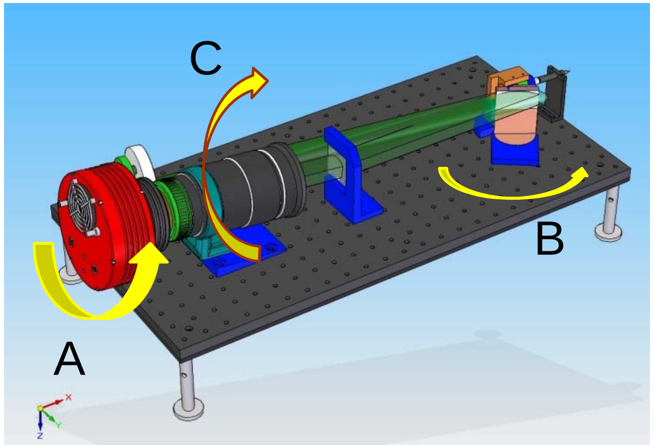


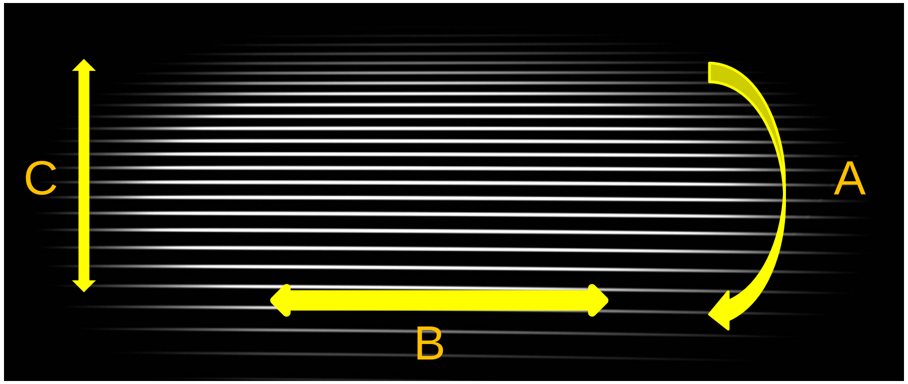



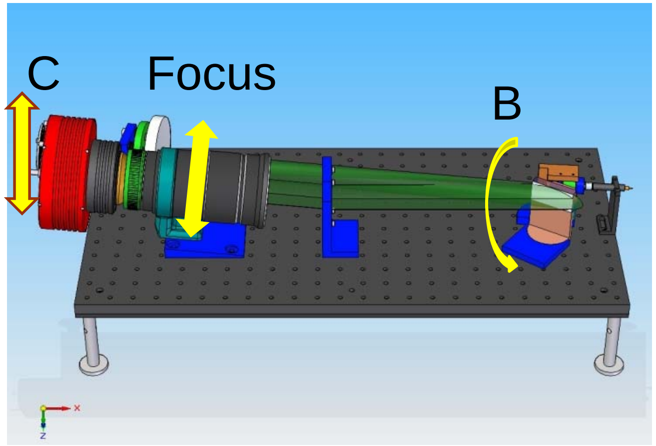



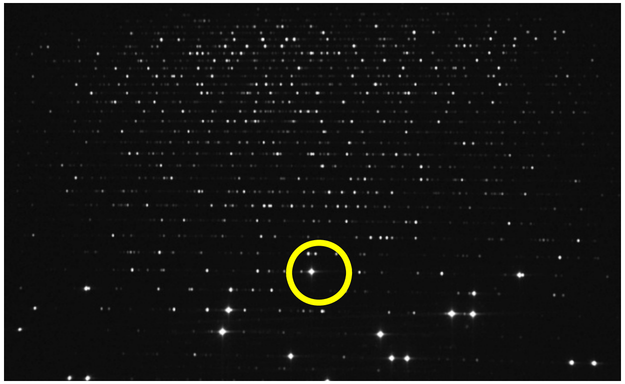
# Centring, rotation and focus of the spectrum



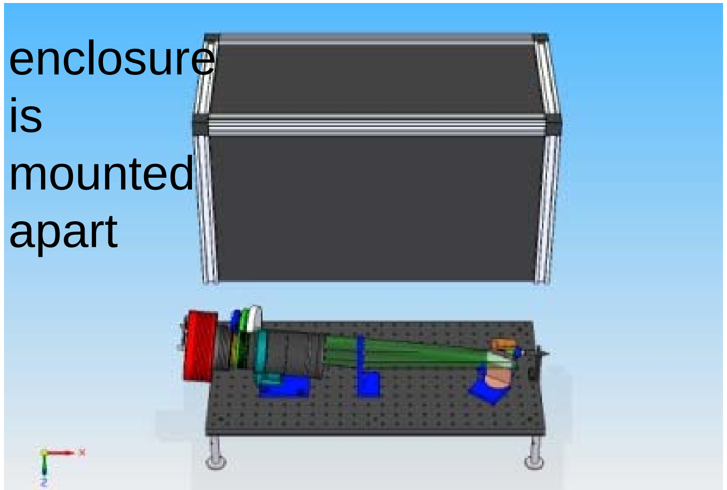



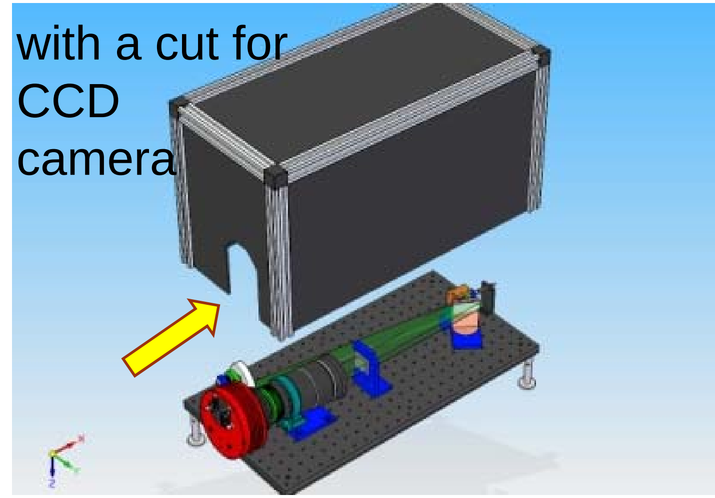

Focus

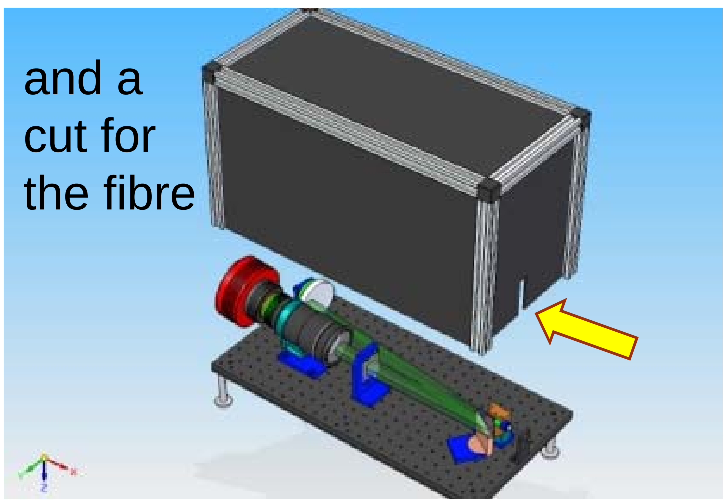


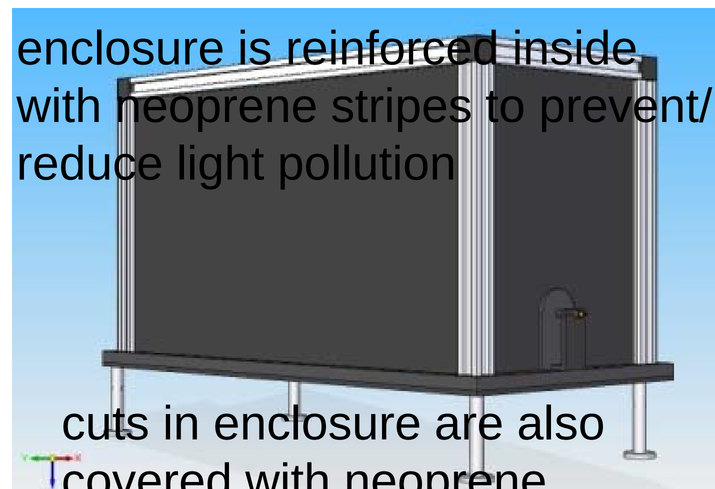



# Installation of the enclosure

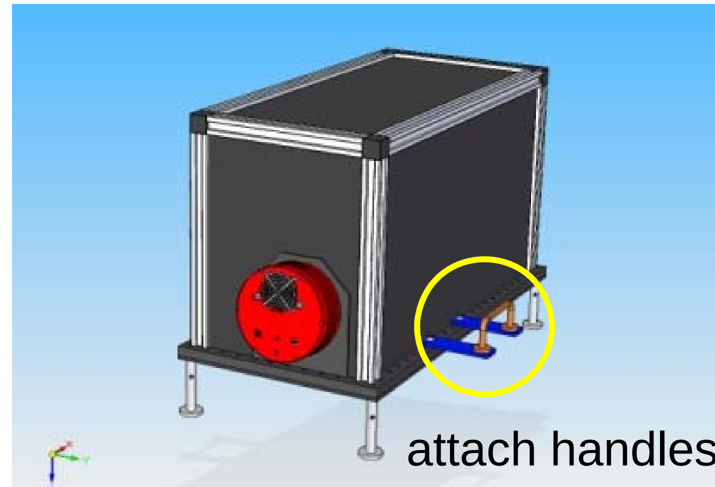


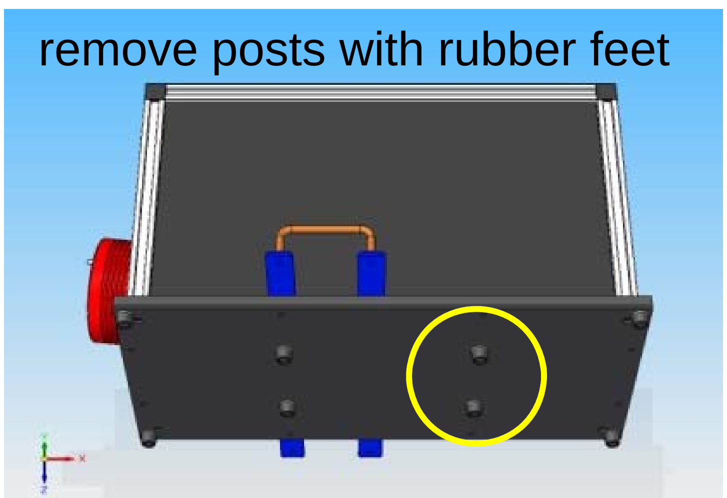



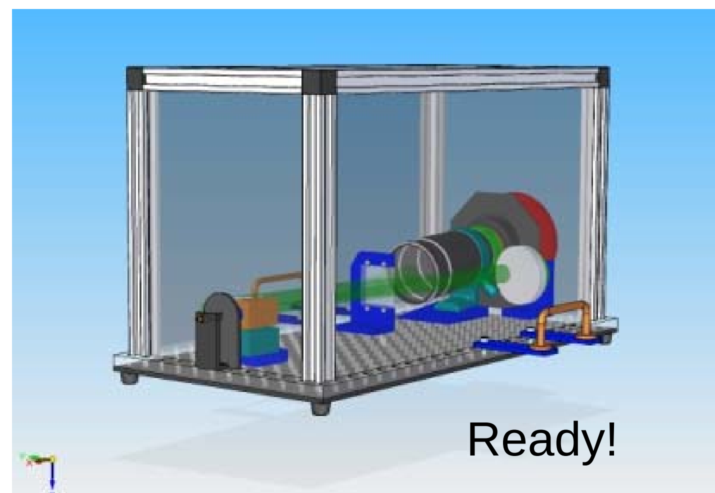



# Handles to take it away !

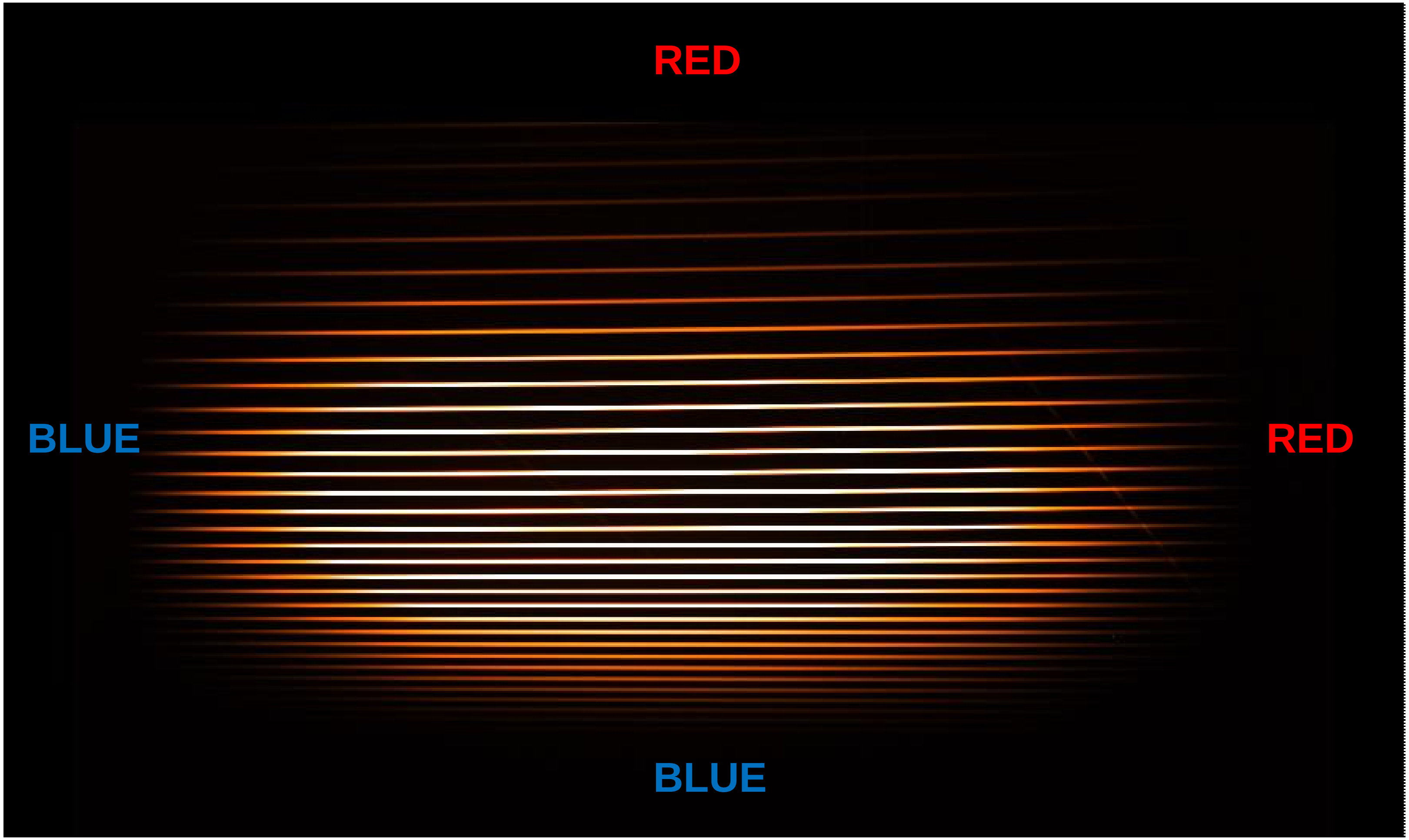



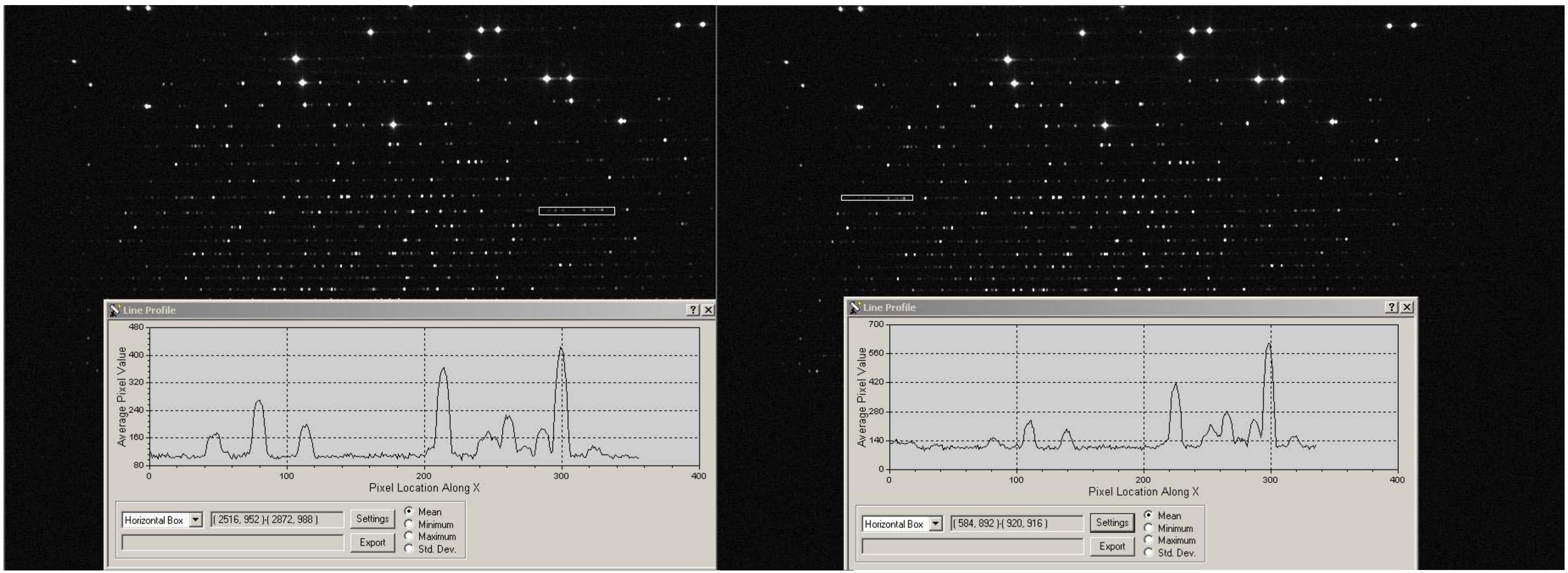
# Wavelength calibration

- With MIDAS (also available in Windows with Cygwin)
- Based in “SET CONTEXT/ECHELLE”
- Requires:
  - Spectrum of a halogen lamp for order identification
  - Spectrum of a thorium-argon lamp for line identification
  - An Atlas of a Thorium-Argon spectrum 400-900nm
- Provides:
  - Semi-automatic calibration: Two pair of lines are identified by hand, 1300 lines automatically
  - Resolving Power ($R=\lambda/\Delta\lambda$) calculated in 1000 lines
  - Order by order calibration and
  - it merges all orders in one continued spectrum

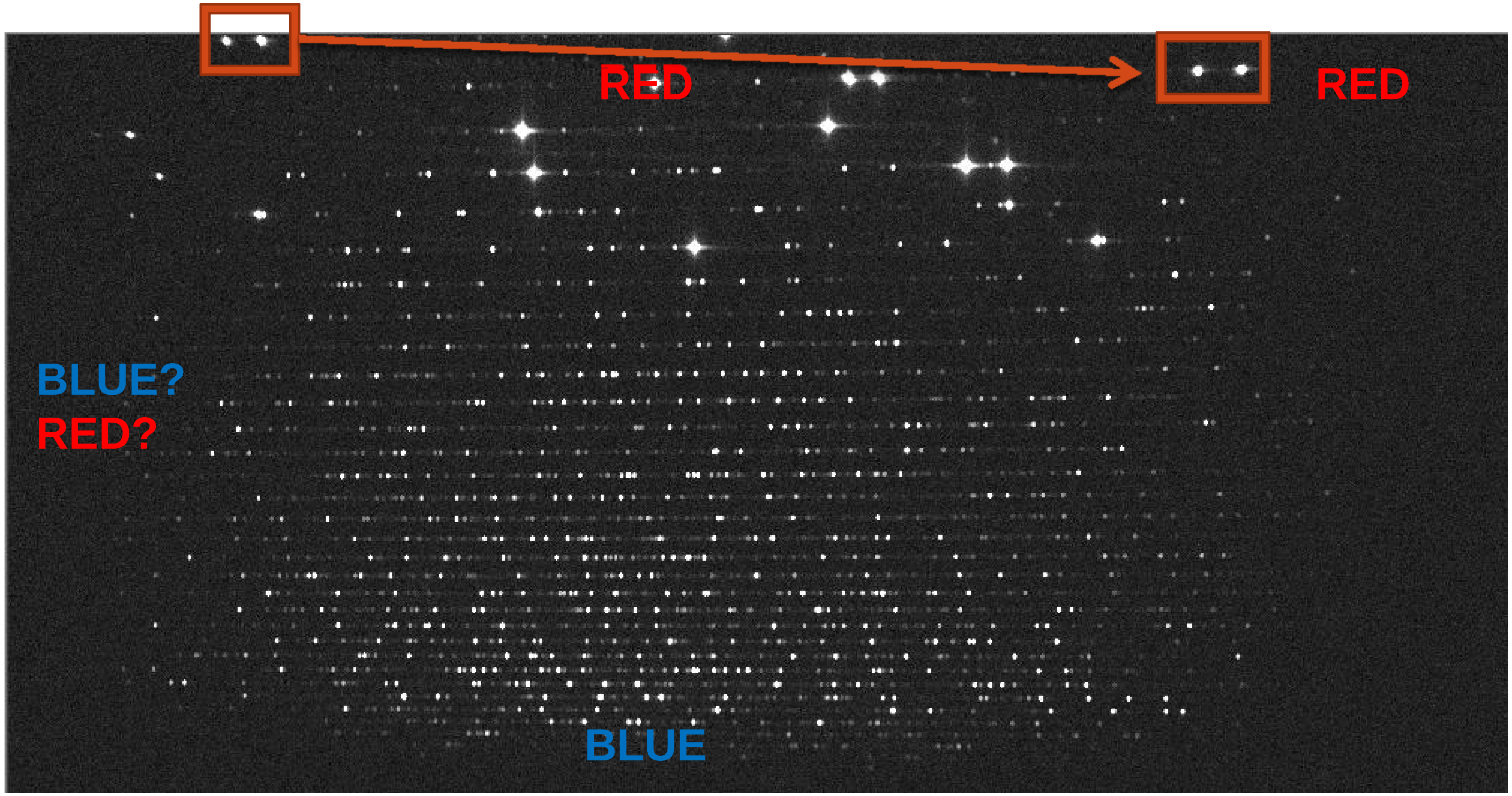
# Orientation



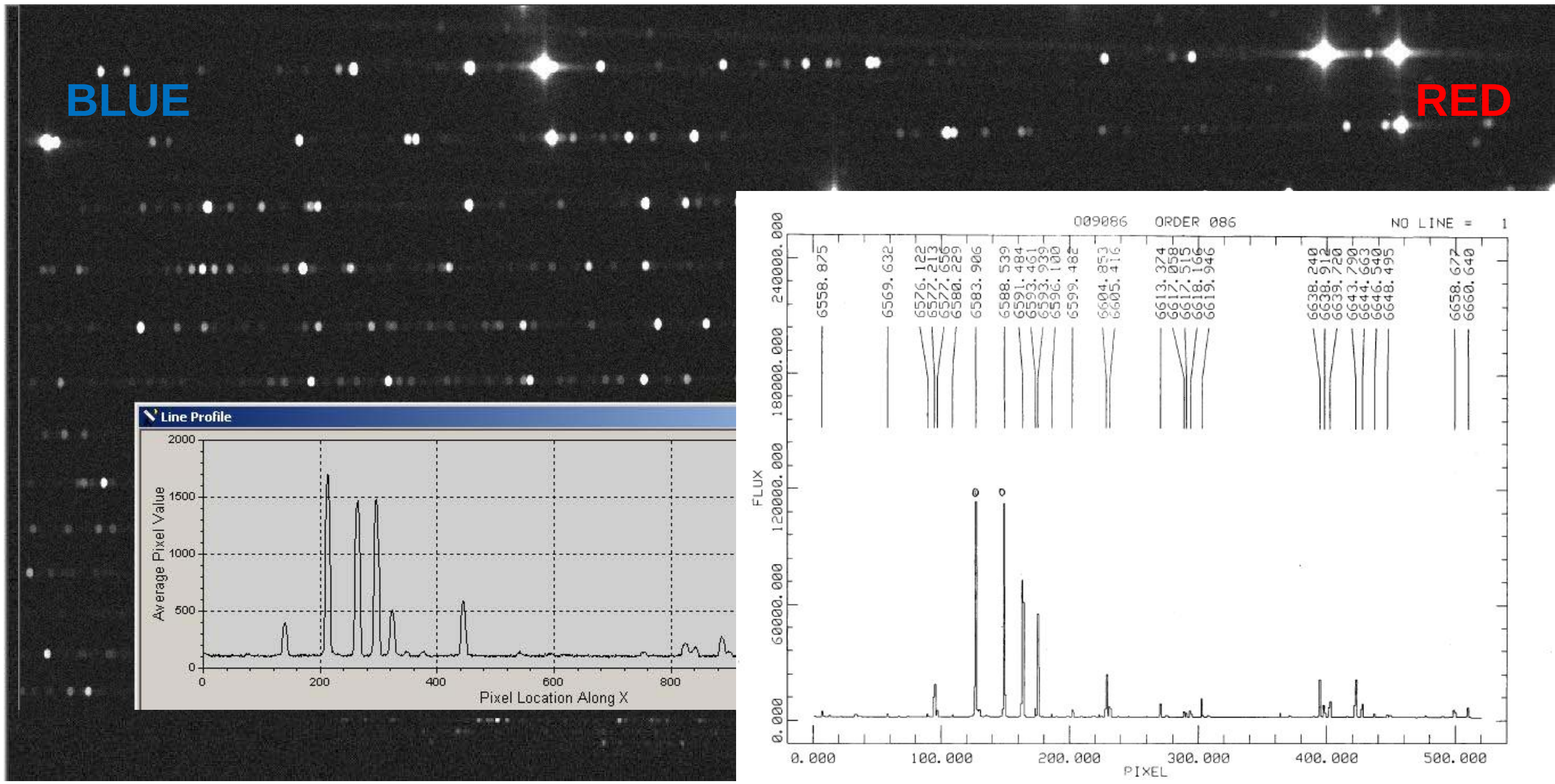
# Spectrum repetition



# Identifying orientation

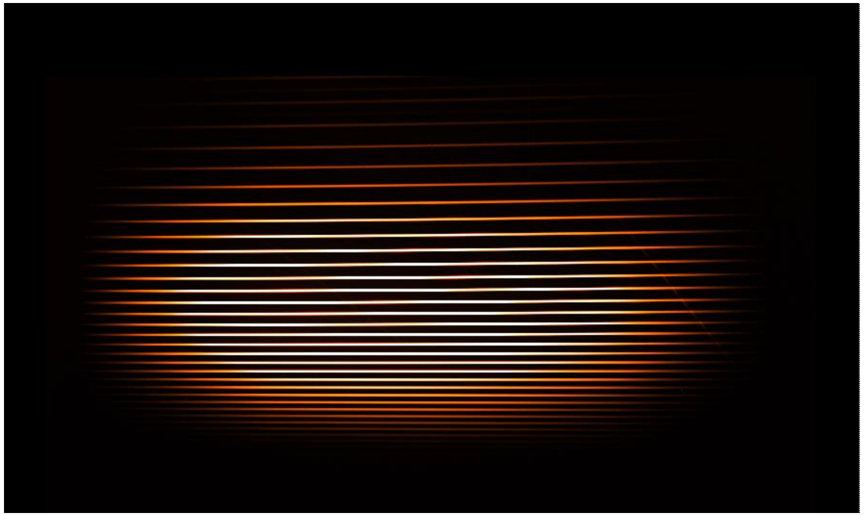


# Identifying orientation

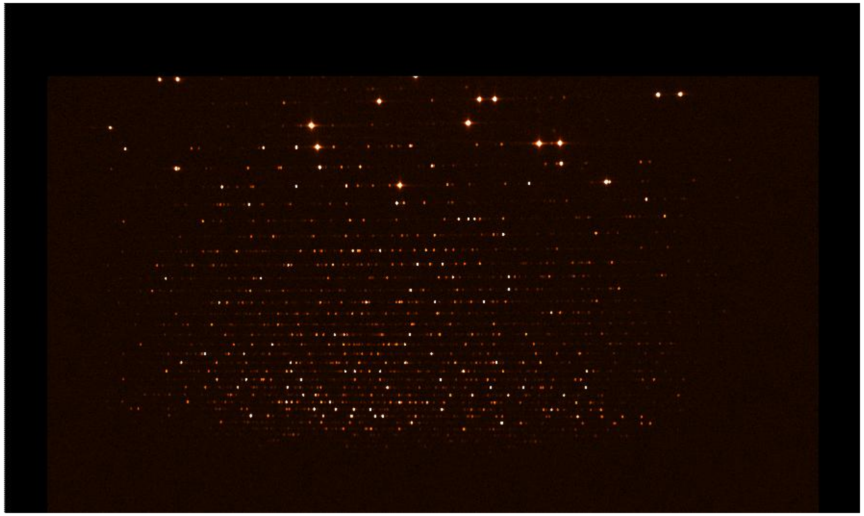


# Calibration data:

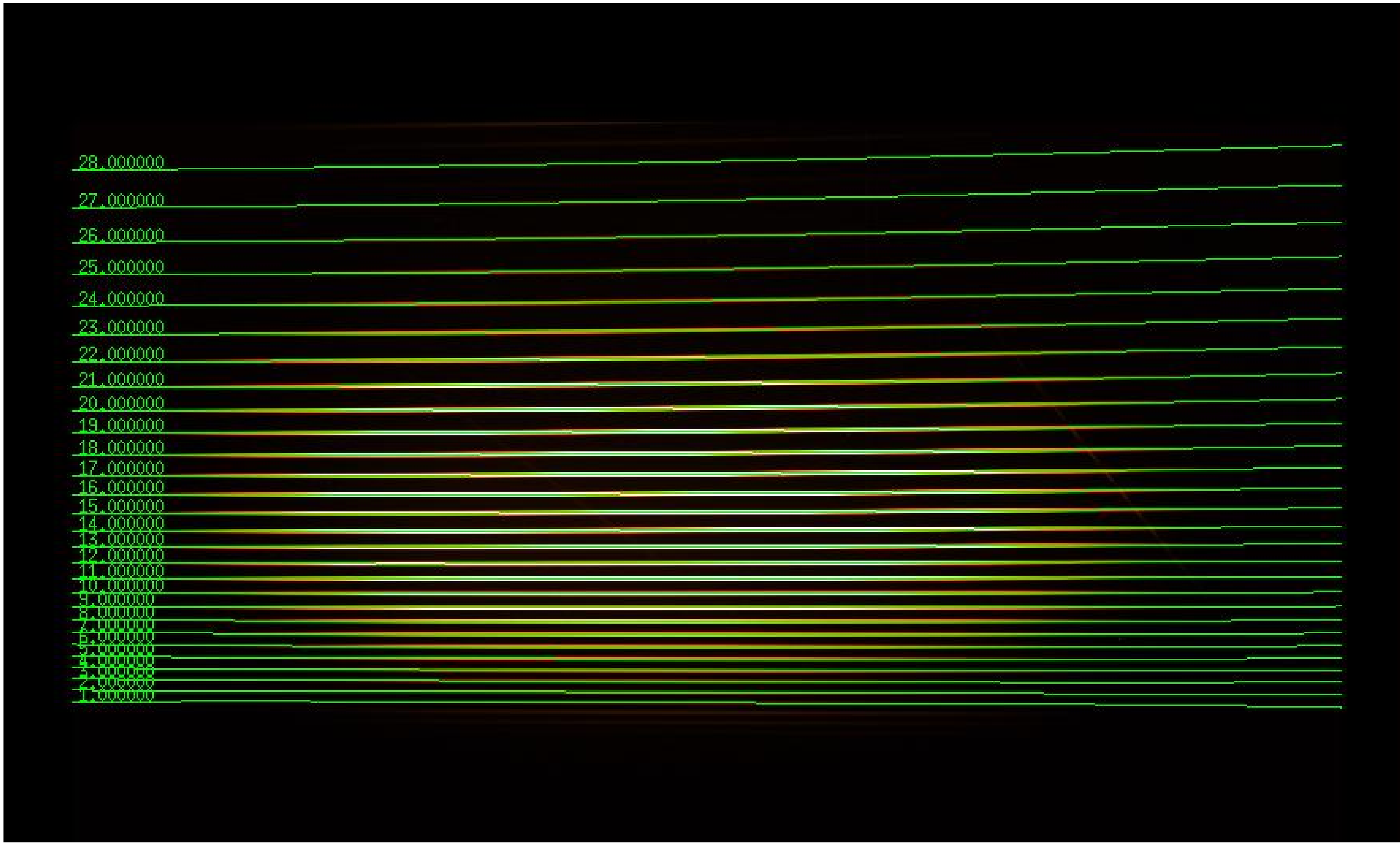
- Spectrum of an halogen lamp:



- Spectrum of a thorium-argon lamp:

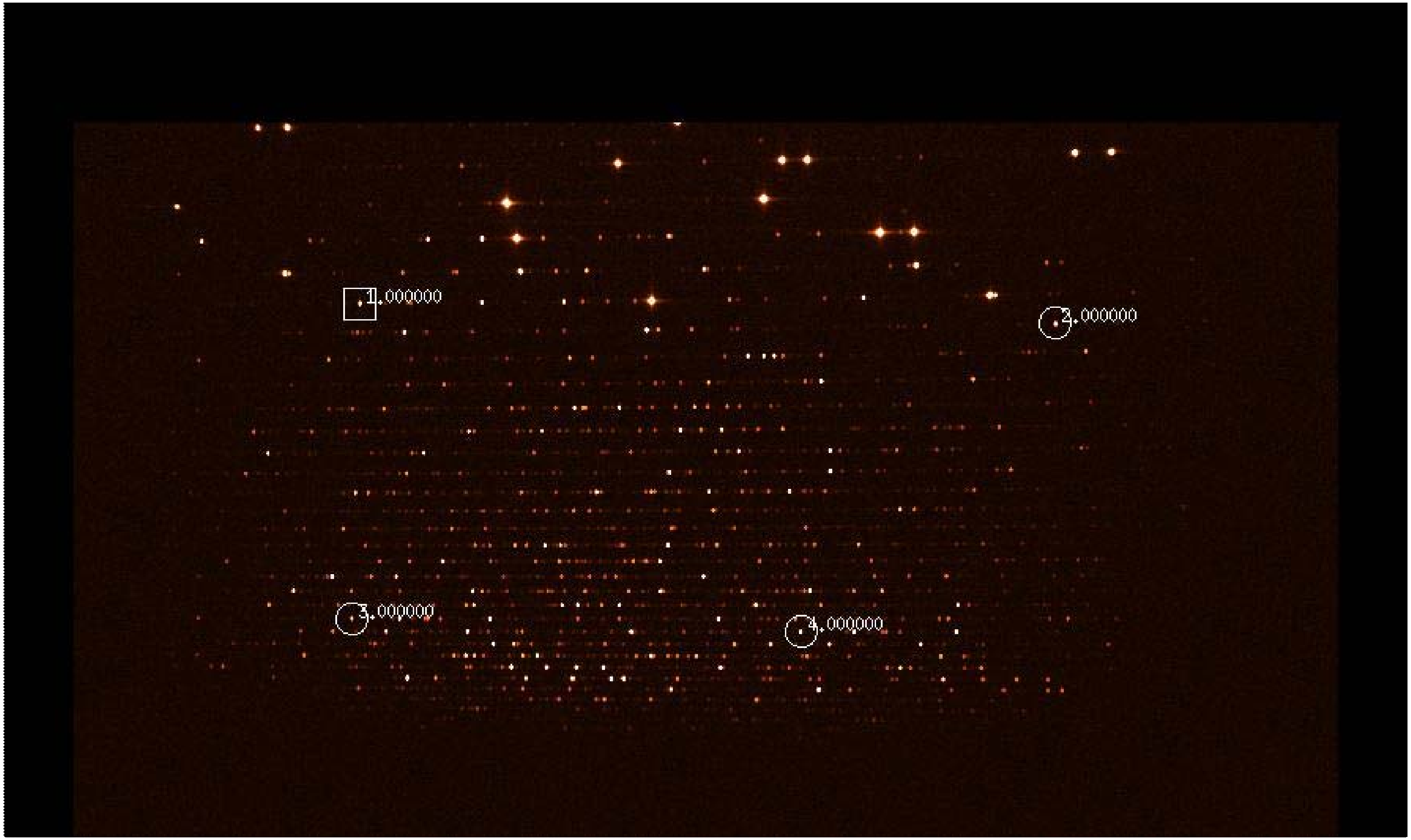


# Order identification



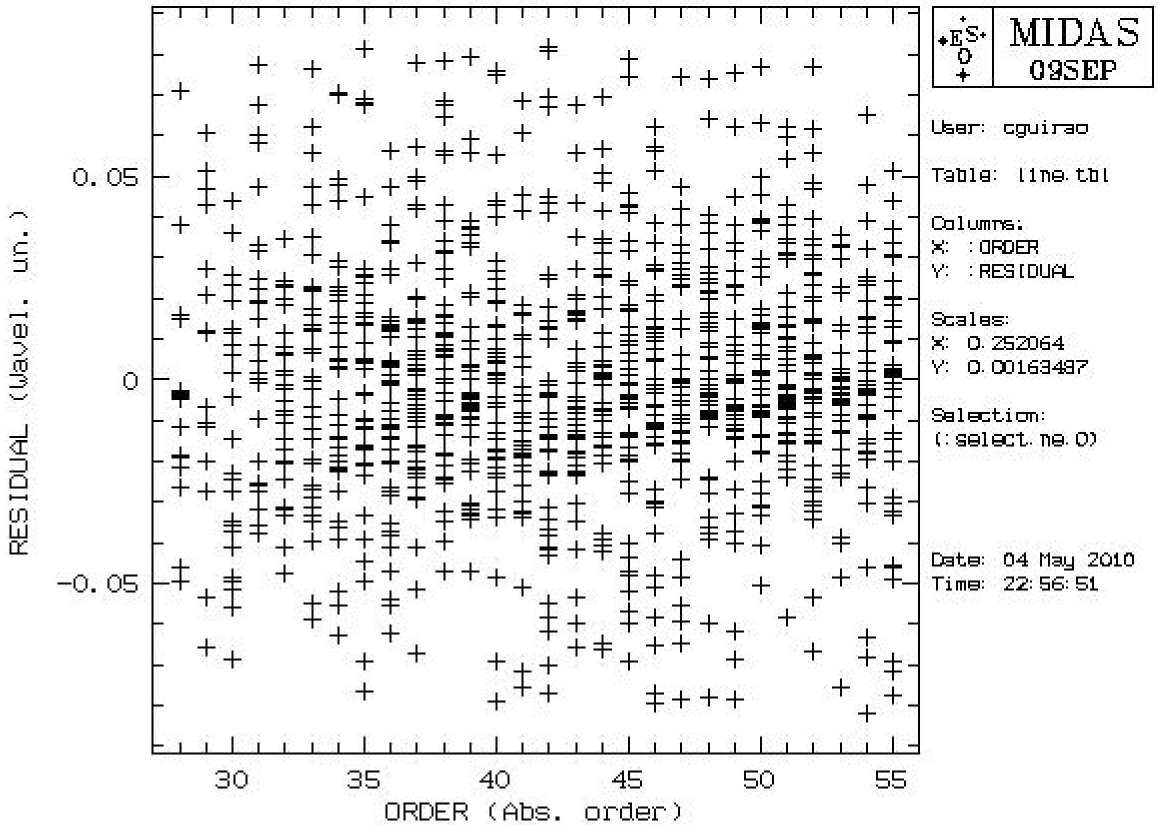
# Th-Ar. how many lines? ~2000!

# First, manual line identification:

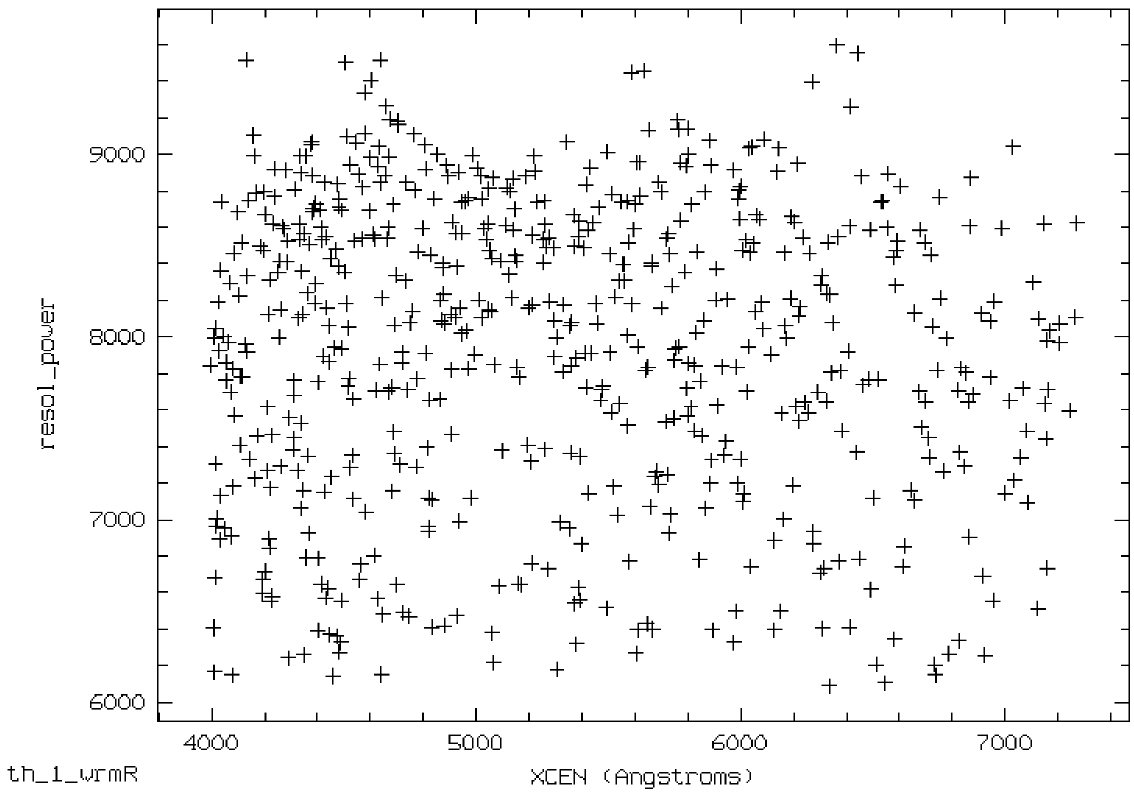


# Then, automatic line identification:

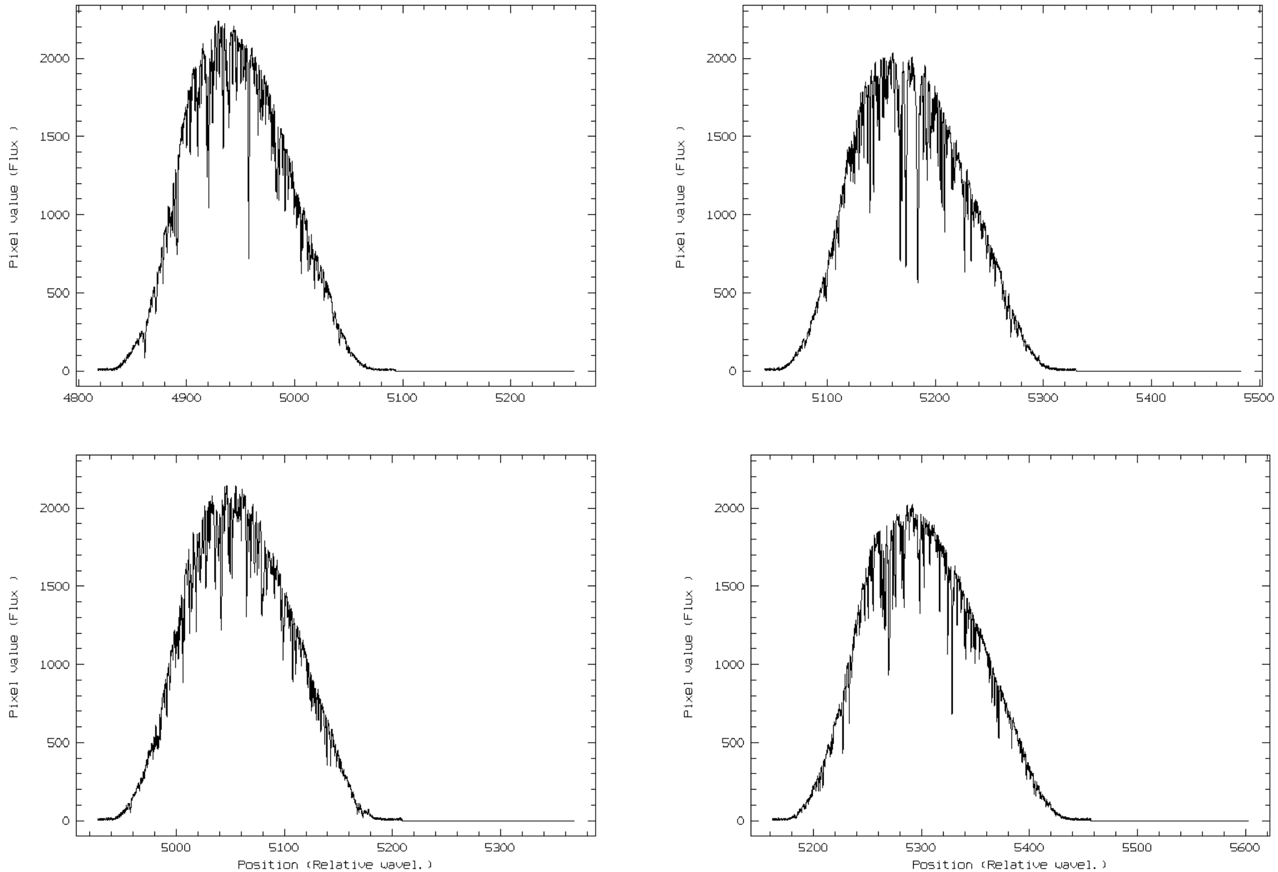
# Tolerance in the identification



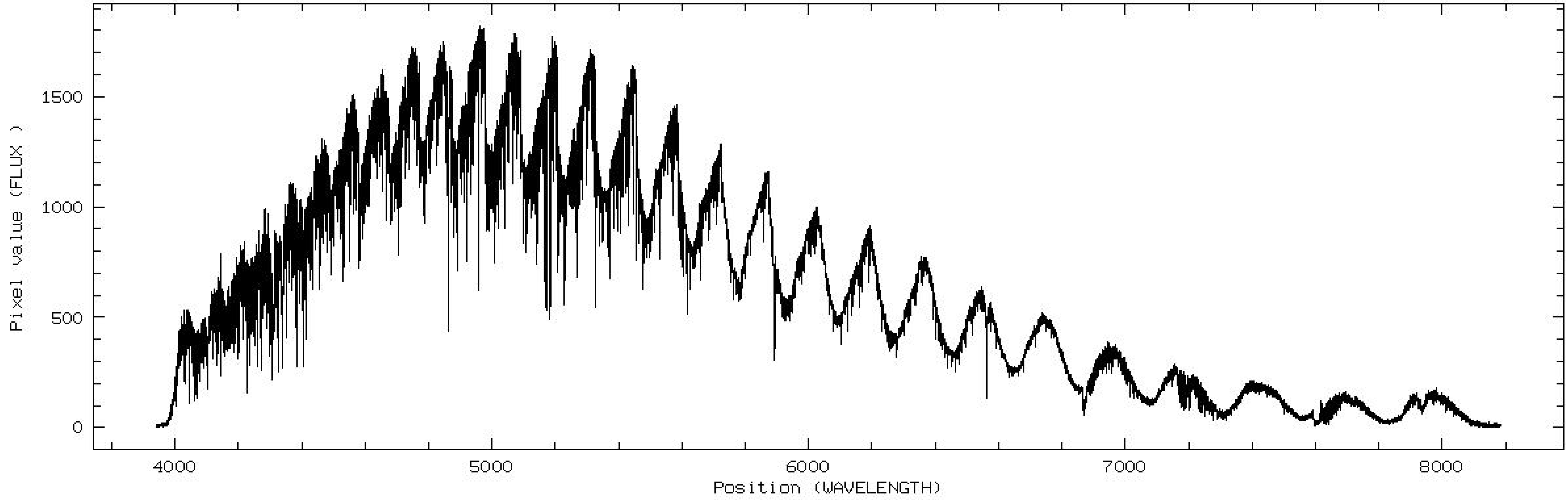
# Resolving Power (R=λ/Δλ)



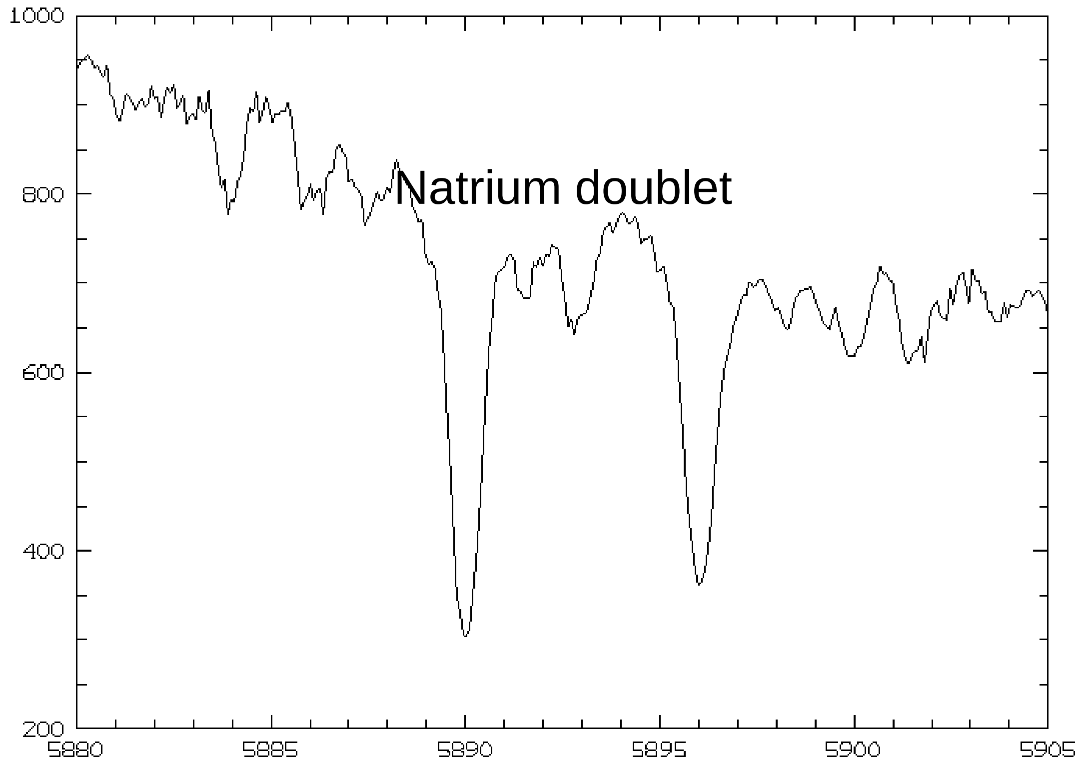
# Spectrum of the Sun order by order



# Merged spectrum of the Sun



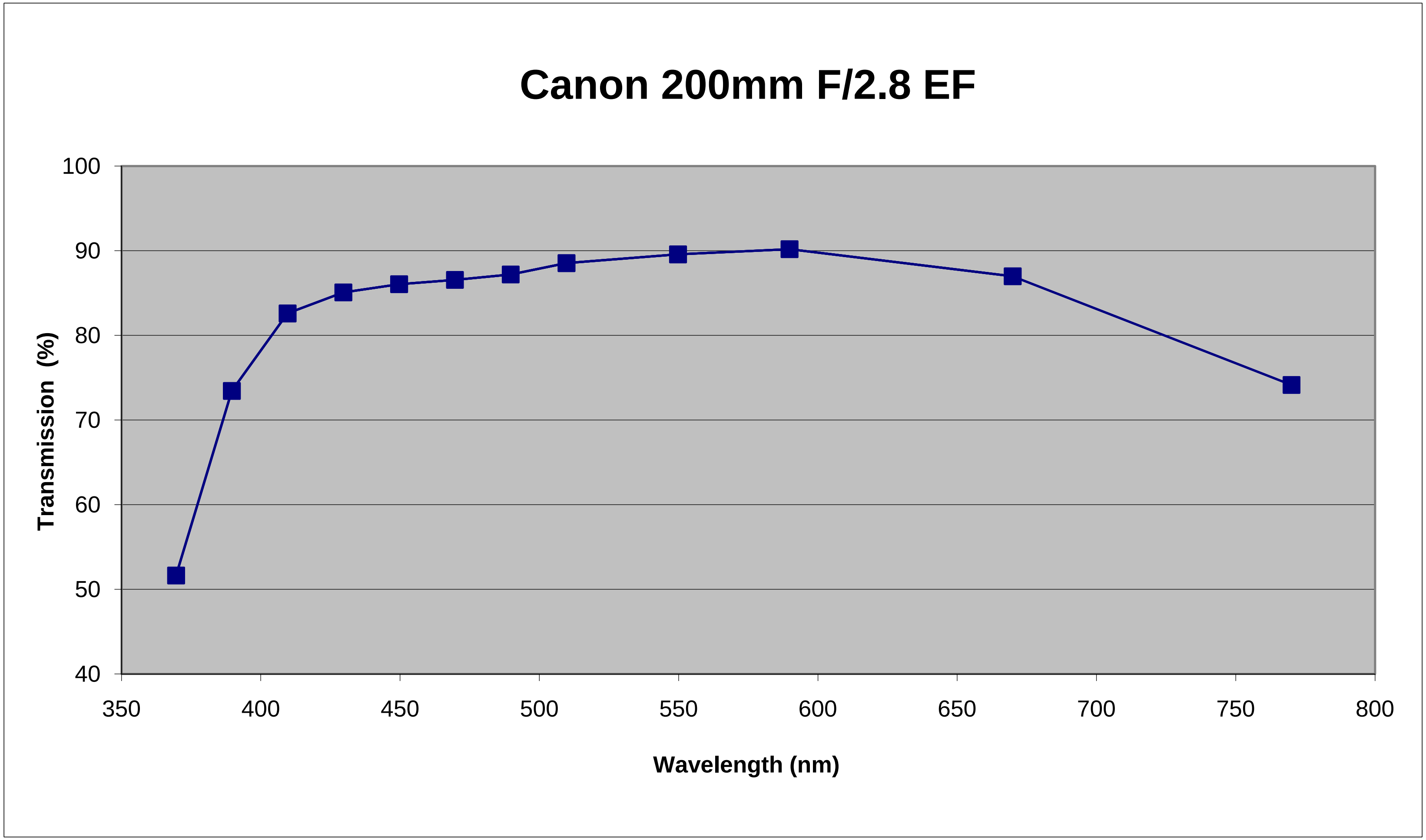
# Detailed spectrum of the Sun



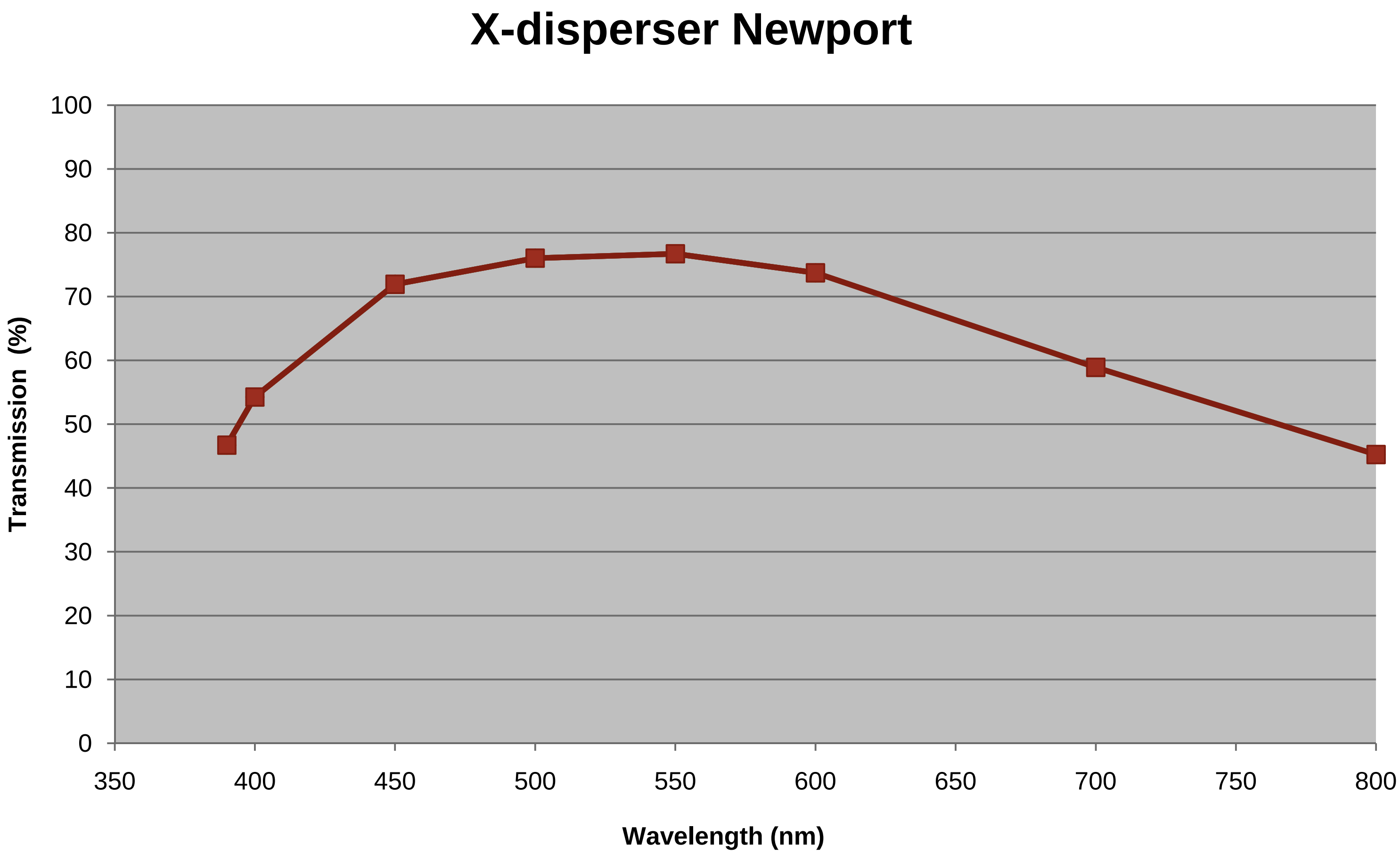
# Optical efficiency

| | |
|---|---|
| • Fibre link | 60 % |
| • Parabola | 90 % |
| • Échelle | 50 % (including vignetting) |
| • X-disperser | 78 % |
| • Canon objective | 90 % |
| | |
| Total | 19 % |

# Optical efficiency



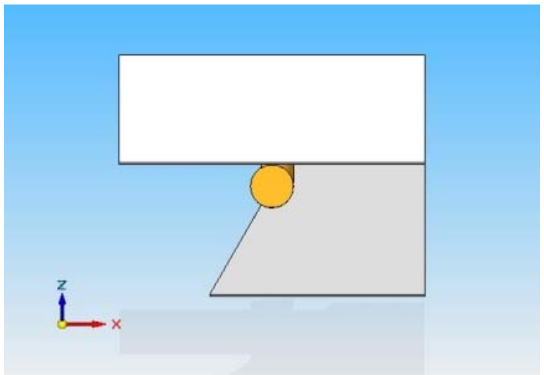
# Optical efficiency

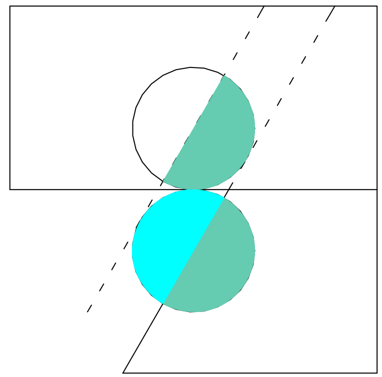
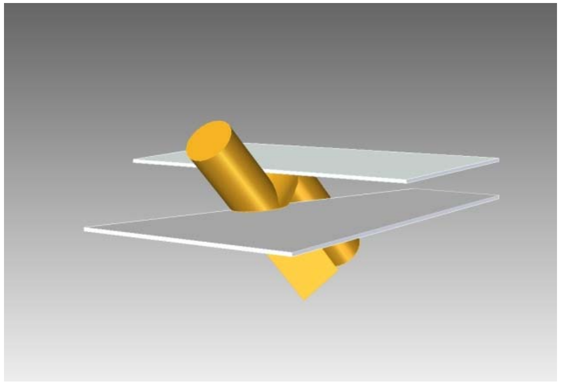
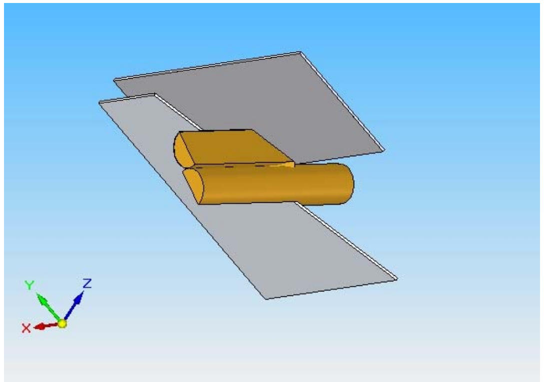


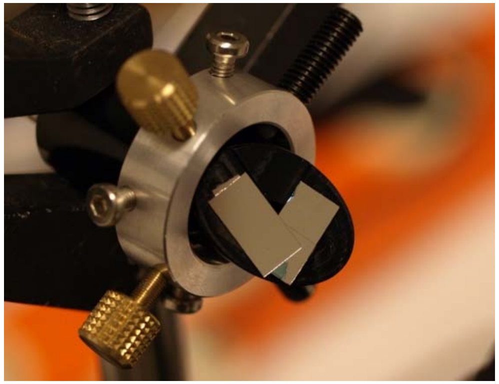
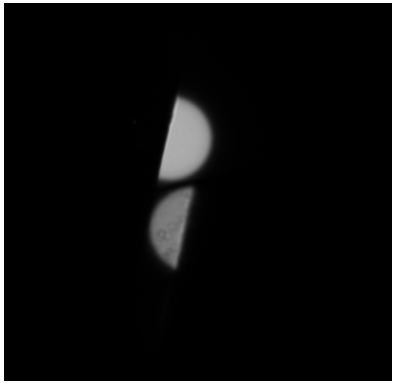
# Improvements

- Image slicer to increase resolution (x1.8)
- CCD camera with higher QE (QSI?)
- Mechanical improvements
  - Échelle support with tilt
  - Fibre support with height adjustment
  - Smaller and light tightness enclosure

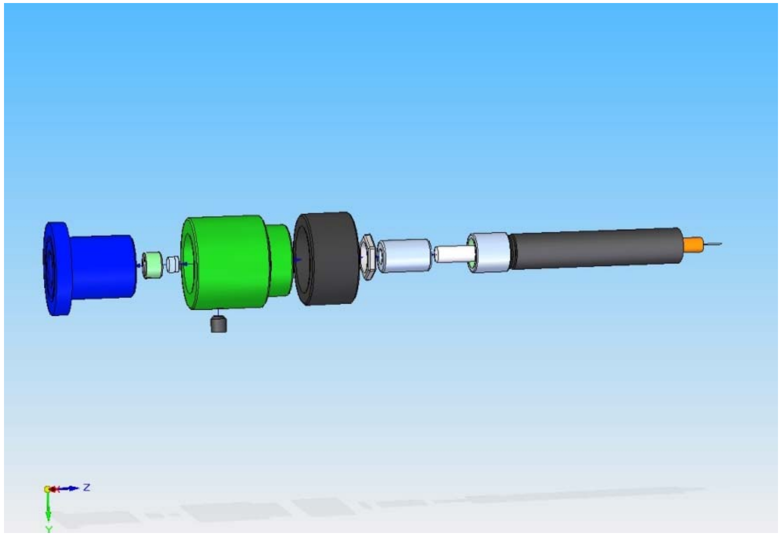
# Image slicer

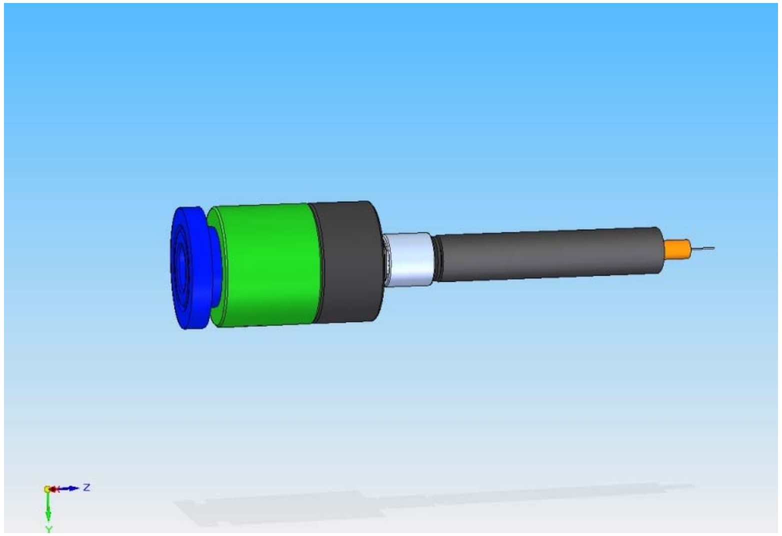


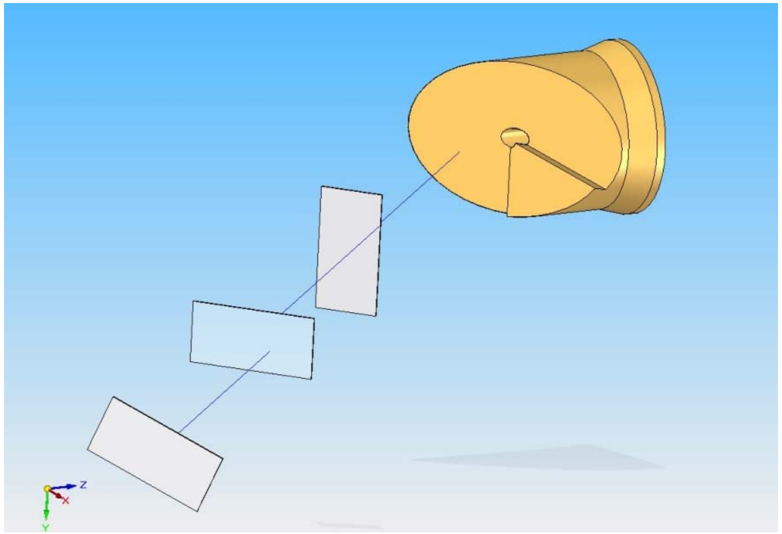




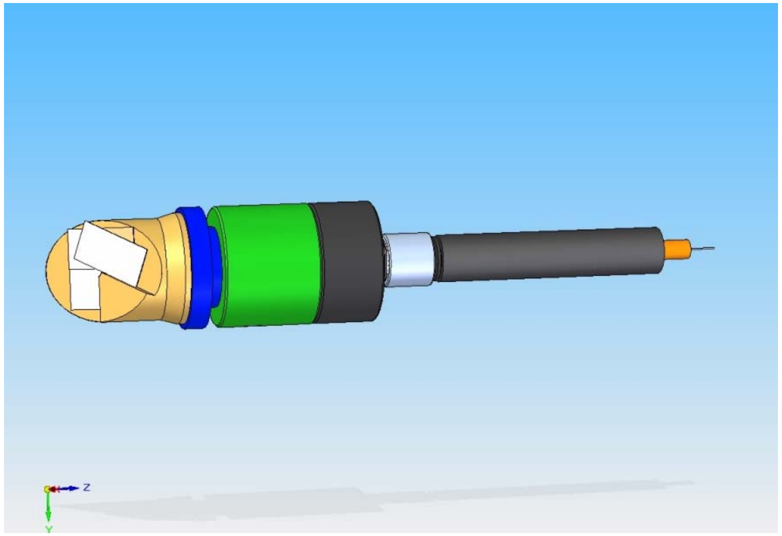



# Image slicer

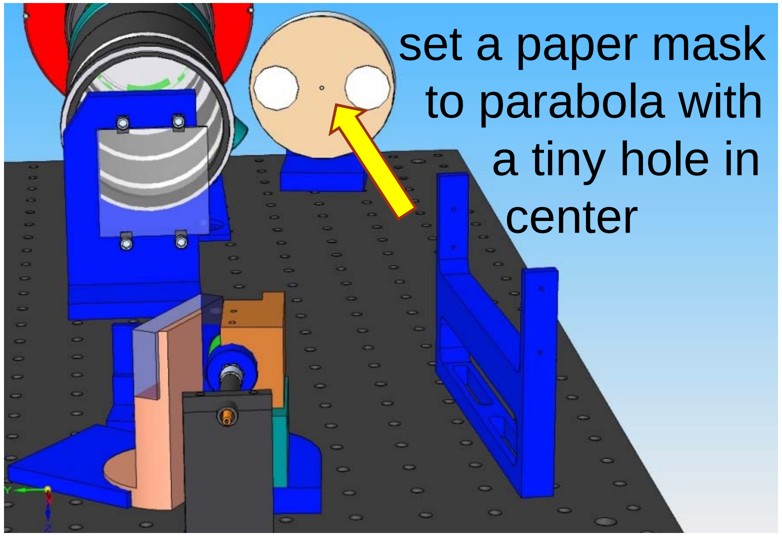


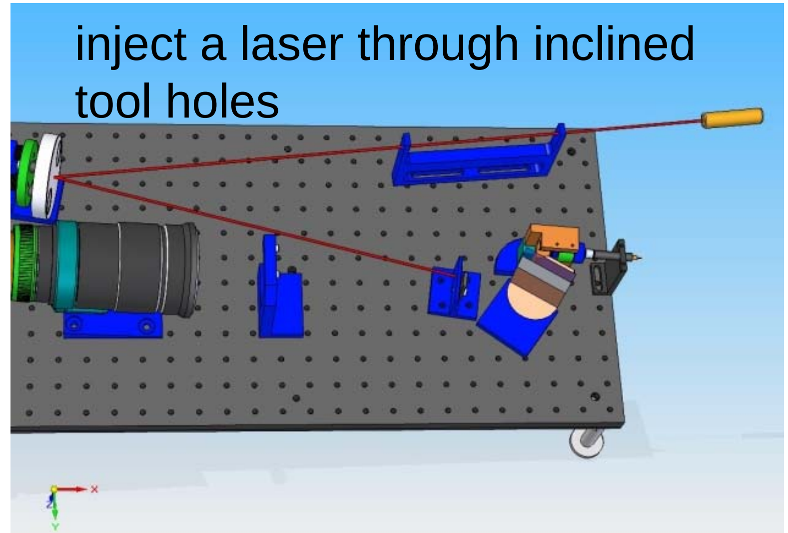


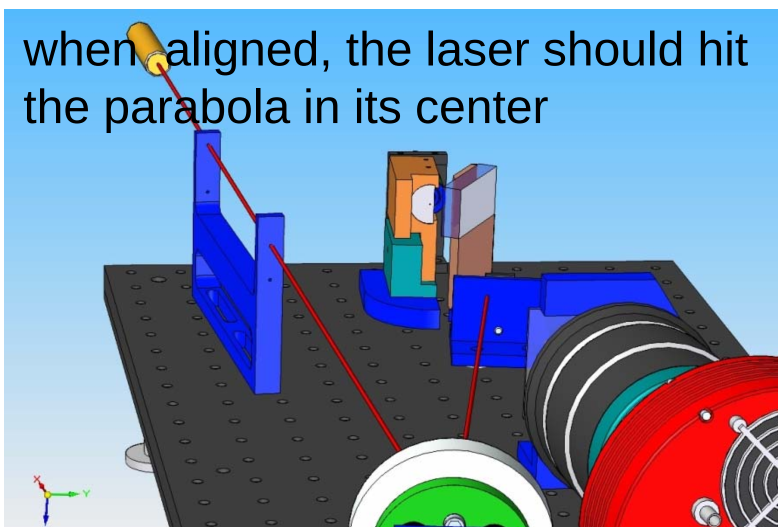


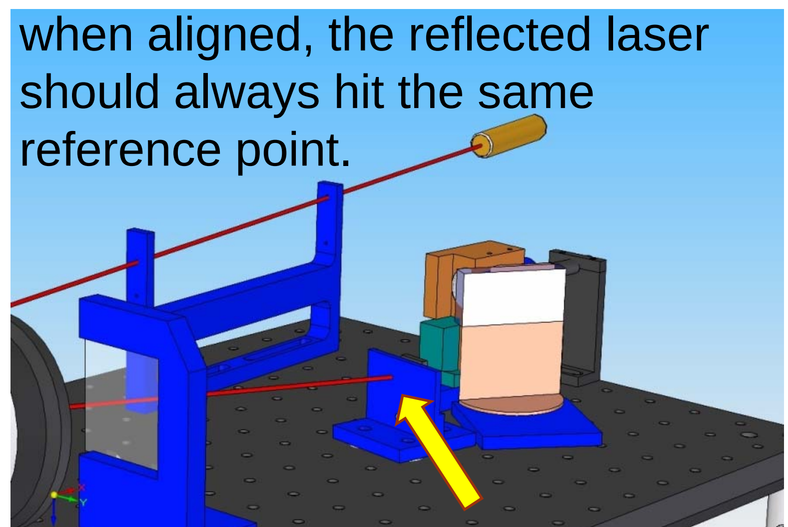


# Alignment verification after transport

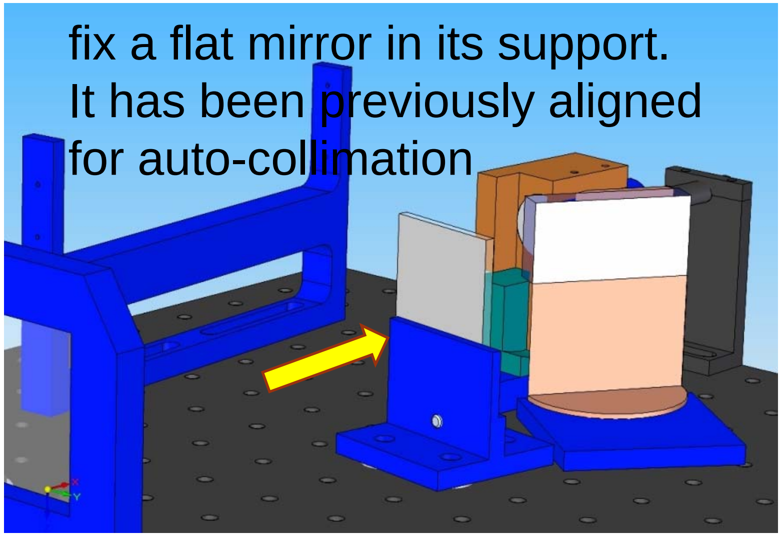


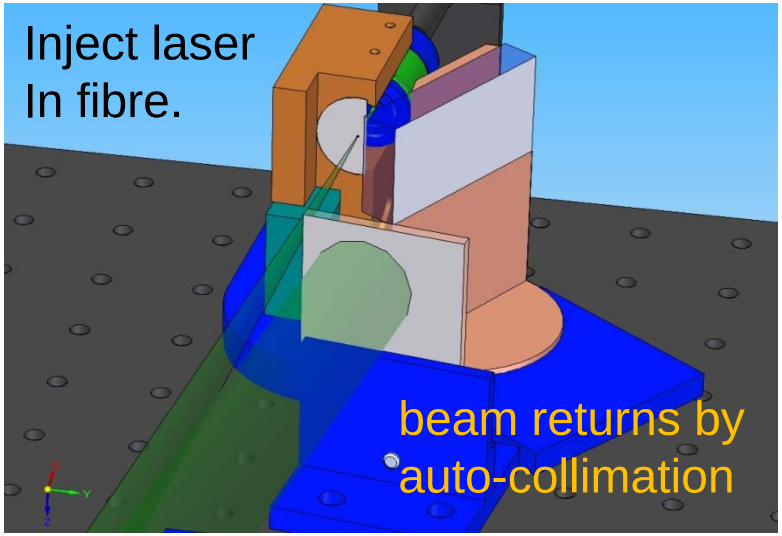



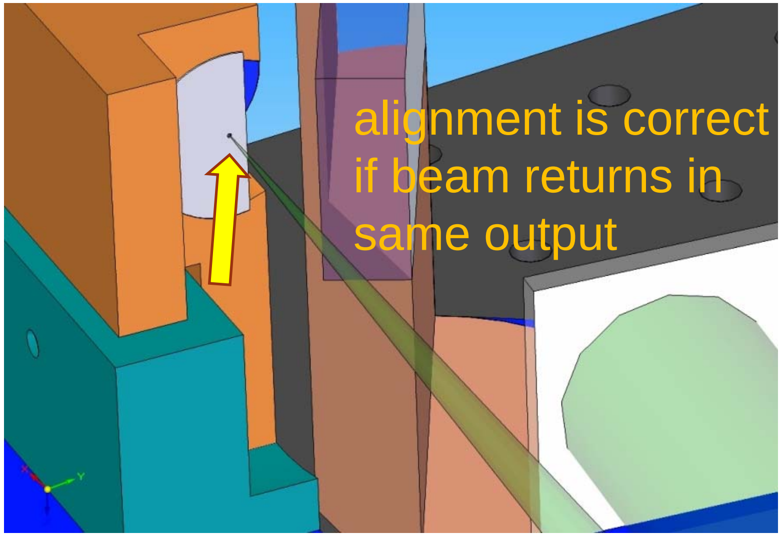



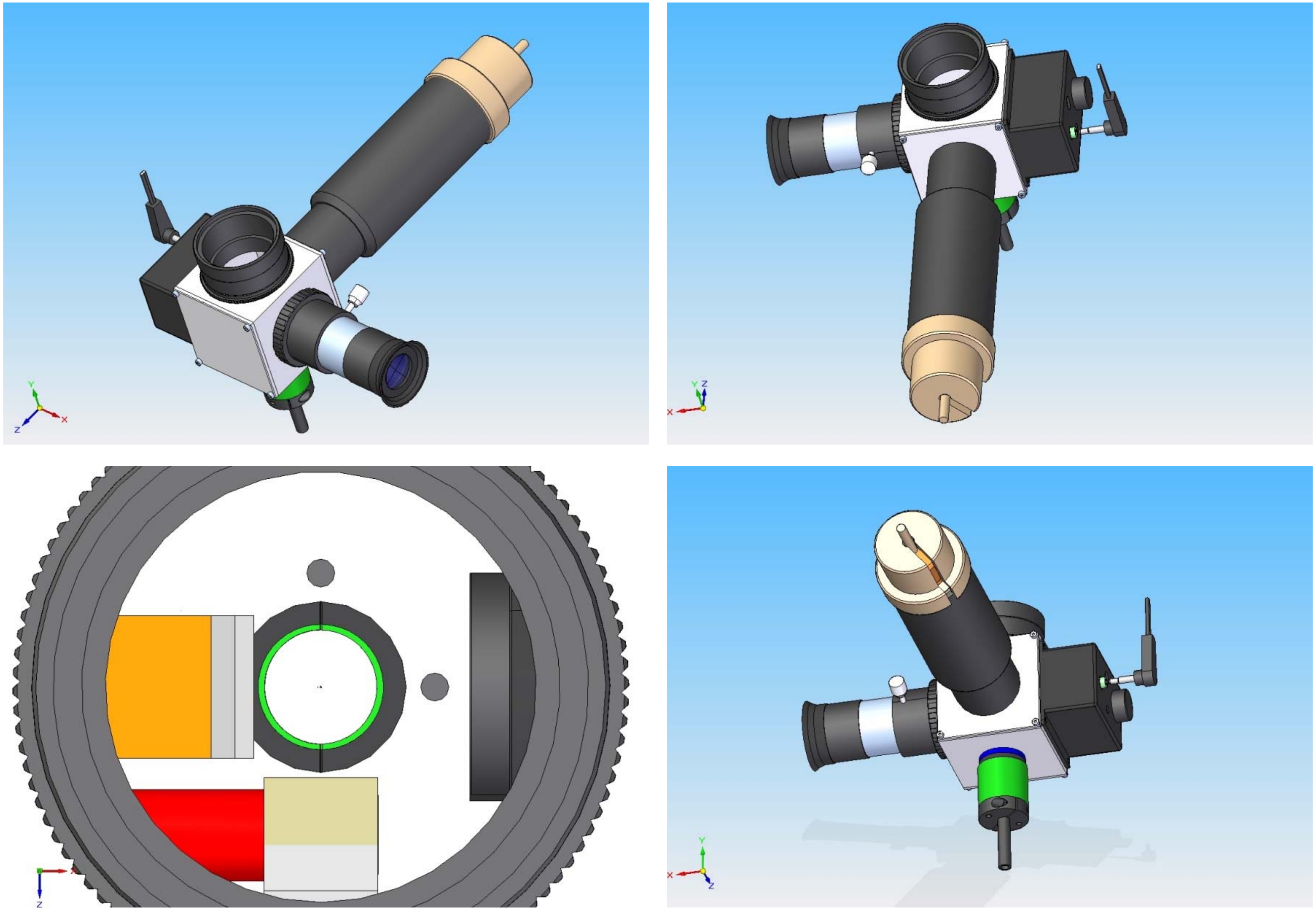
# Alignment verification after transport



# Mechanical parts



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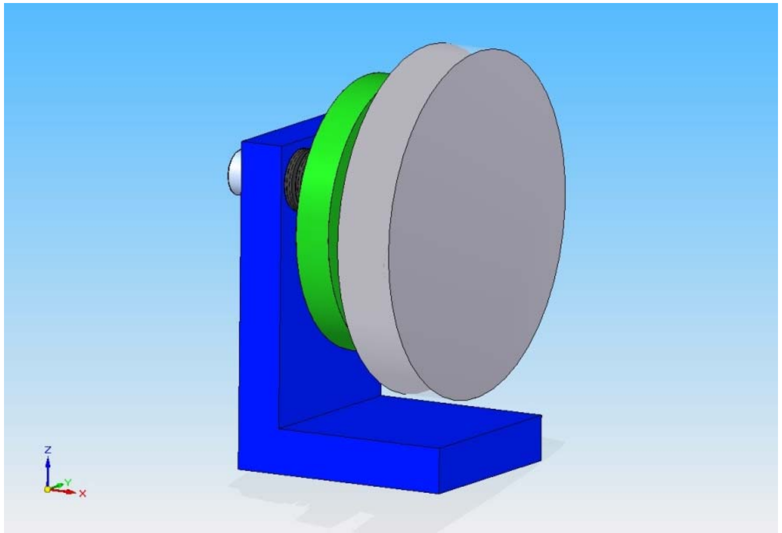
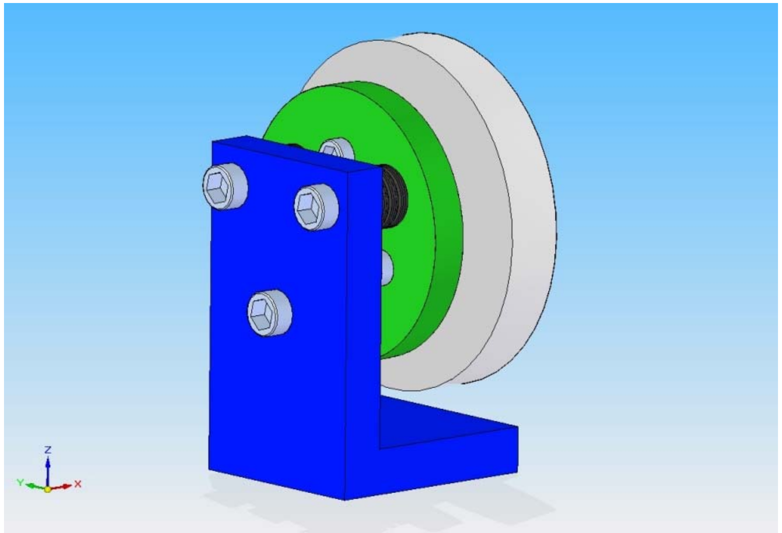
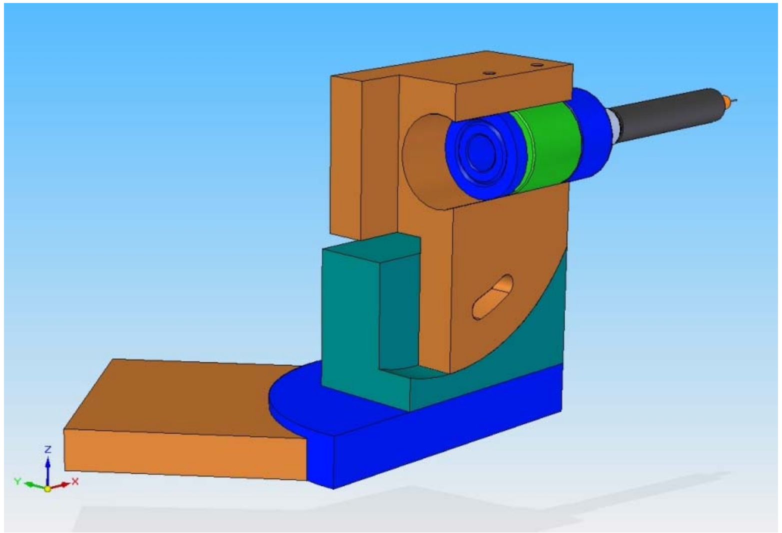
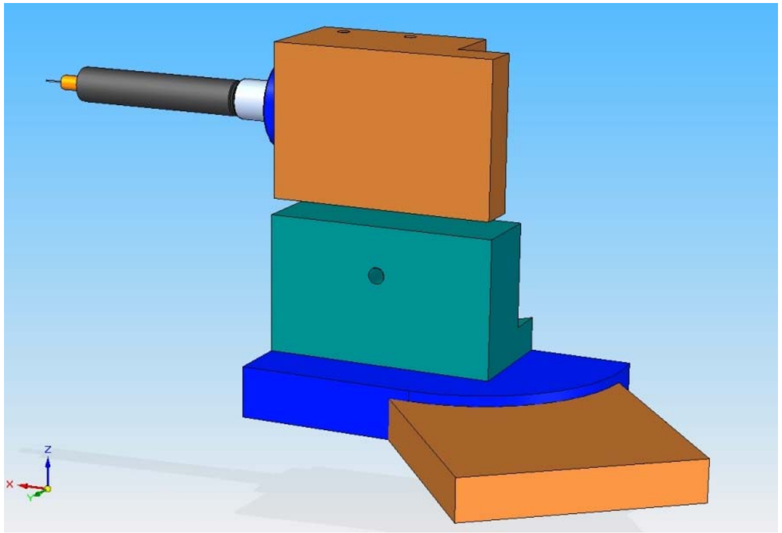
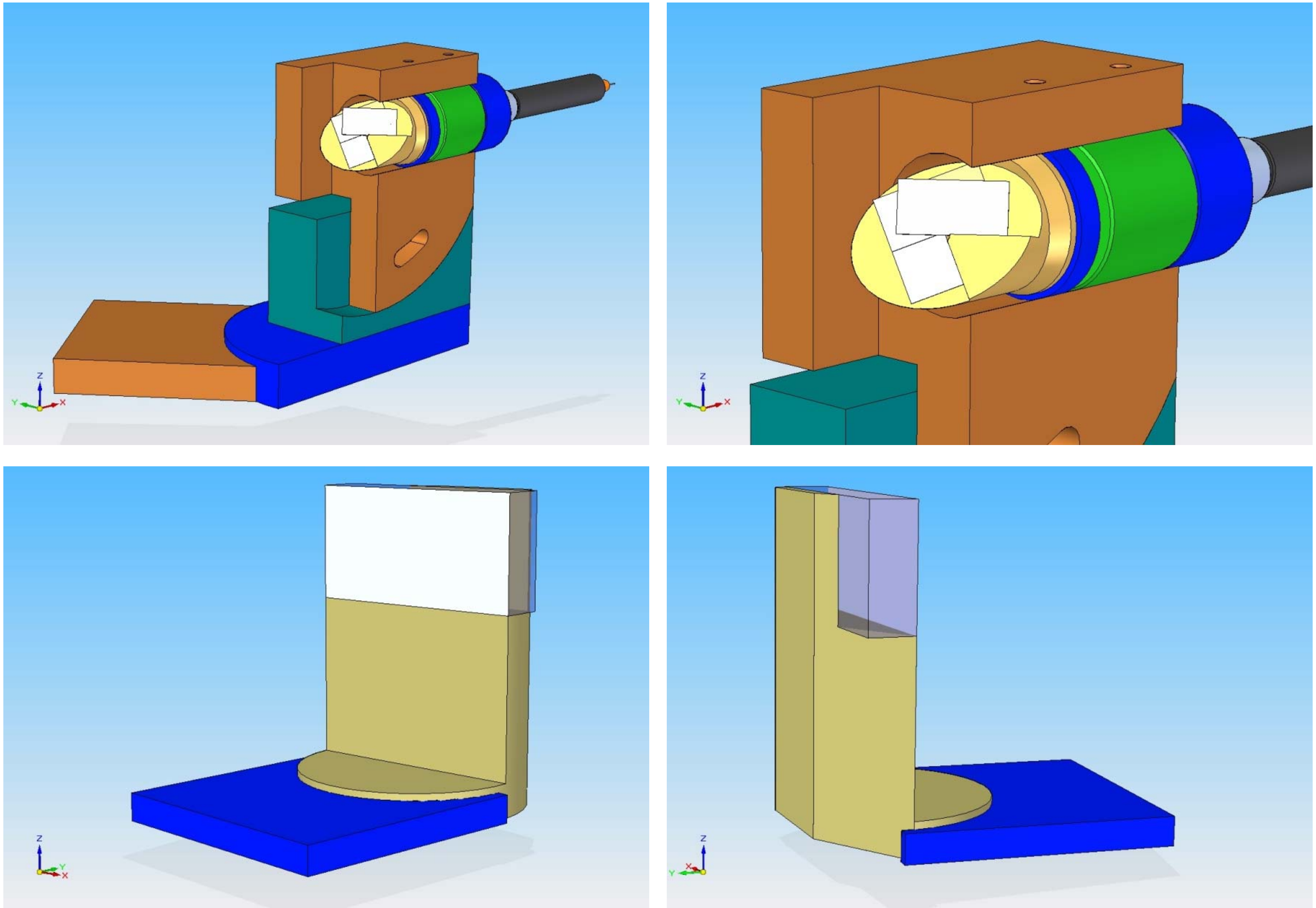




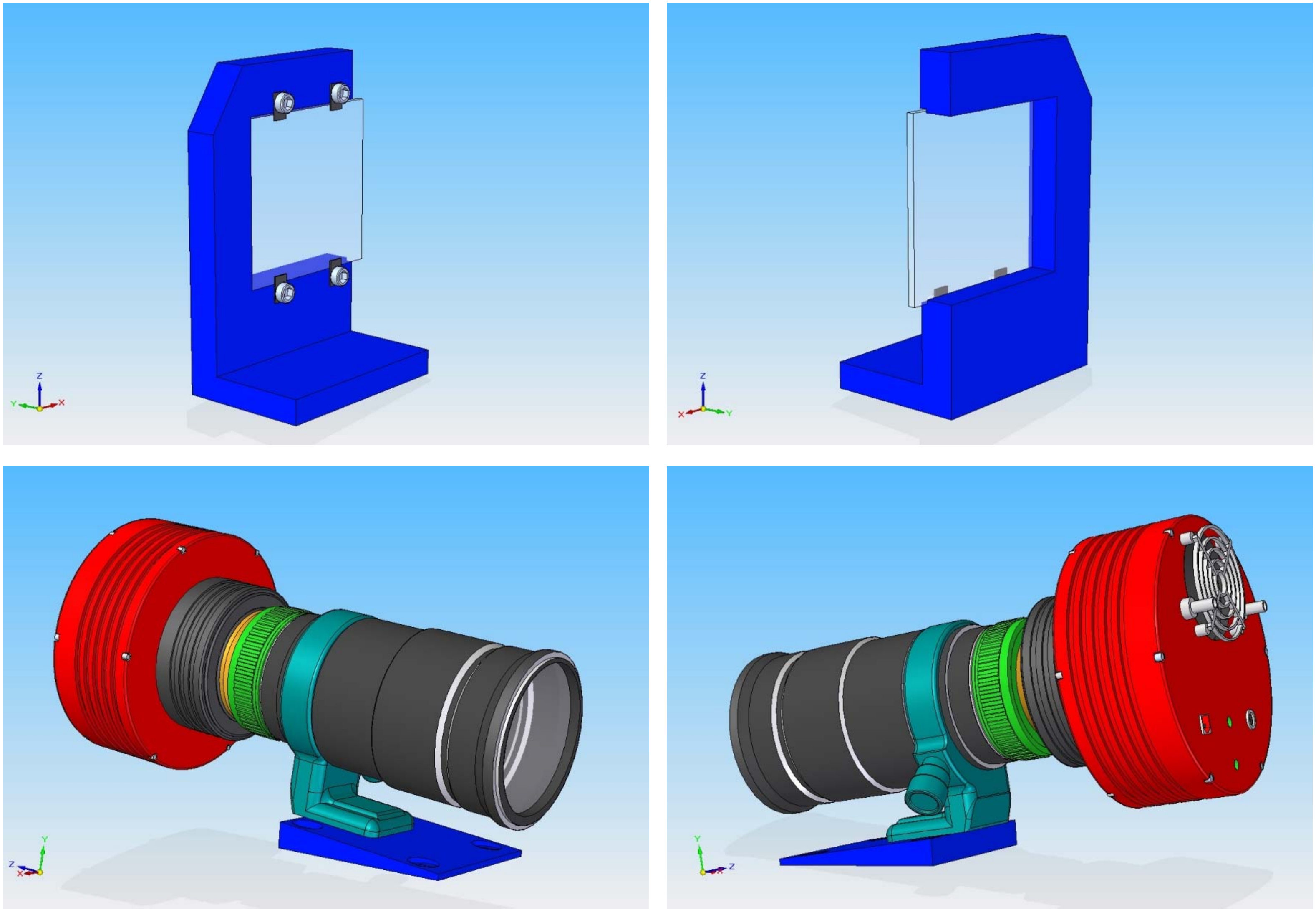




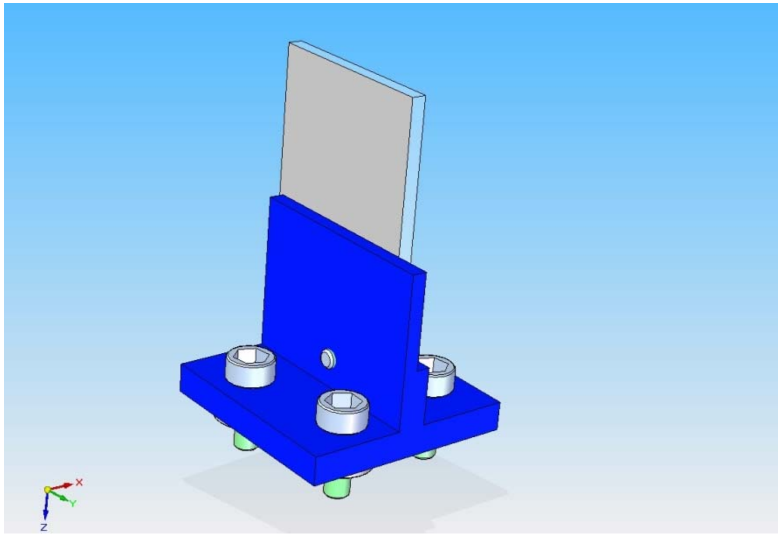
# Mechanical parts

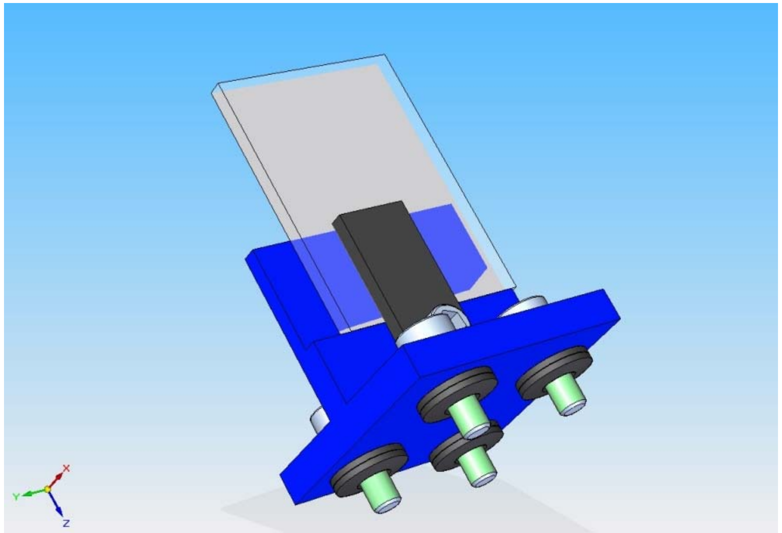


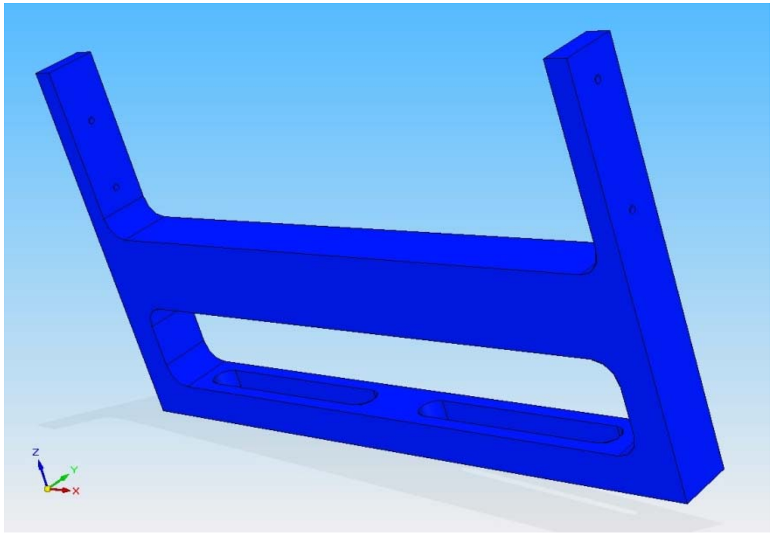
# Mechanical parts

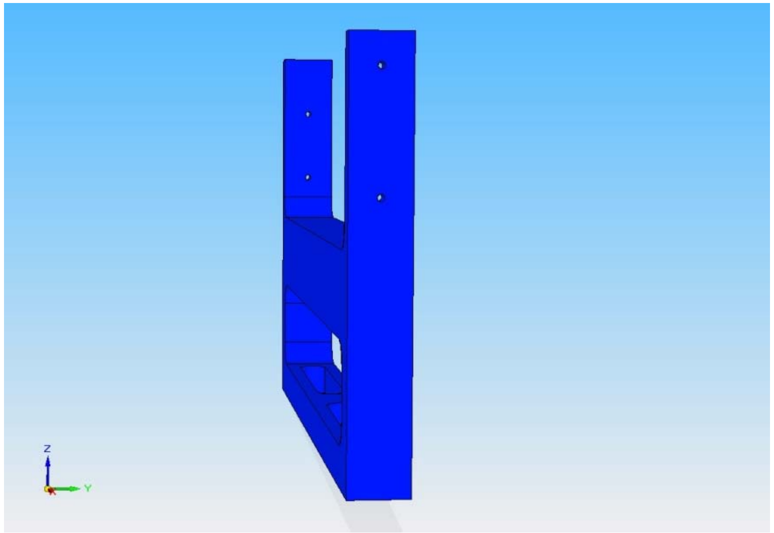


# Mechanical parts









- Thank you for your patience and attention !
- CAOS web page:

  spectroscopy.wordpress.com

- ASTELCO web page:

  http://www.astelco.com/