Solar orbiter

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Design & layout of EUS for Solar Orbiter.

Summary.

- Requirements: Spatial, spectral, collecting power.
- Telescope options:
  - Front-end grating + 1-mirror telescope (Univ. Padova)
  - 2-mirror on-axis (strawman).
  - 2-mirror off-axis.
- Instrument layout.
- Spectrometer with holographic grating.
- Basic tolerances.

Requirements, optical

Imaging.

Spatial: 0.5arcsec pixel, FOV 34 arcmin.

Spectral: 580-630ang, in 34 arcmin

} Square detector ~ 4000 x 4000

Collecting power.

4.10^{12} photons/cm^2.sr per second (typical line)

λ ~ 600 ang

t ~ 1 second exposure

Requirements: Imaging

Spatial.

APS detector, min. size p~5μm for min. focal length FL

FL = p/(0.5arcsec) = 2.06 metres

Detector size 4000*5um= 20mm

Spectral.

$$\sin.\beta - \sin.\alpha = m\frac{\lambda}{d}$$

$\beta = 0$ - normal incidence at detector m=-1

1st-order differential with respect to λ :-

$$\Delta\beta \approx -\frac{\Delta\lambda}{d}$$

$$\frac{20\text{mm}}{R} \approx \frac{50\,Angst.}{(1/4800\text{ gr/mm})}$$

(1:1 imaging,

conservative grating technology)

R ~ 800mm

Collecting power

Parameter	Name	Value	Units	Comment
eta	detector efficiency	0.4		
tau	mirrors throughput	0.008		3 mirrors
g	grating efficiency	0.3		
B	photon radiance	4.00E+12	photons/cm^2.sr	
A	aperture area	113.097336	cm^2	12cm aperture
omega	pixel fov solid angle	5.8758E-12	steradian	0.5 arcsec pixel
t	exposure time	1	seconds	
Product		**2.55**	**photons**	

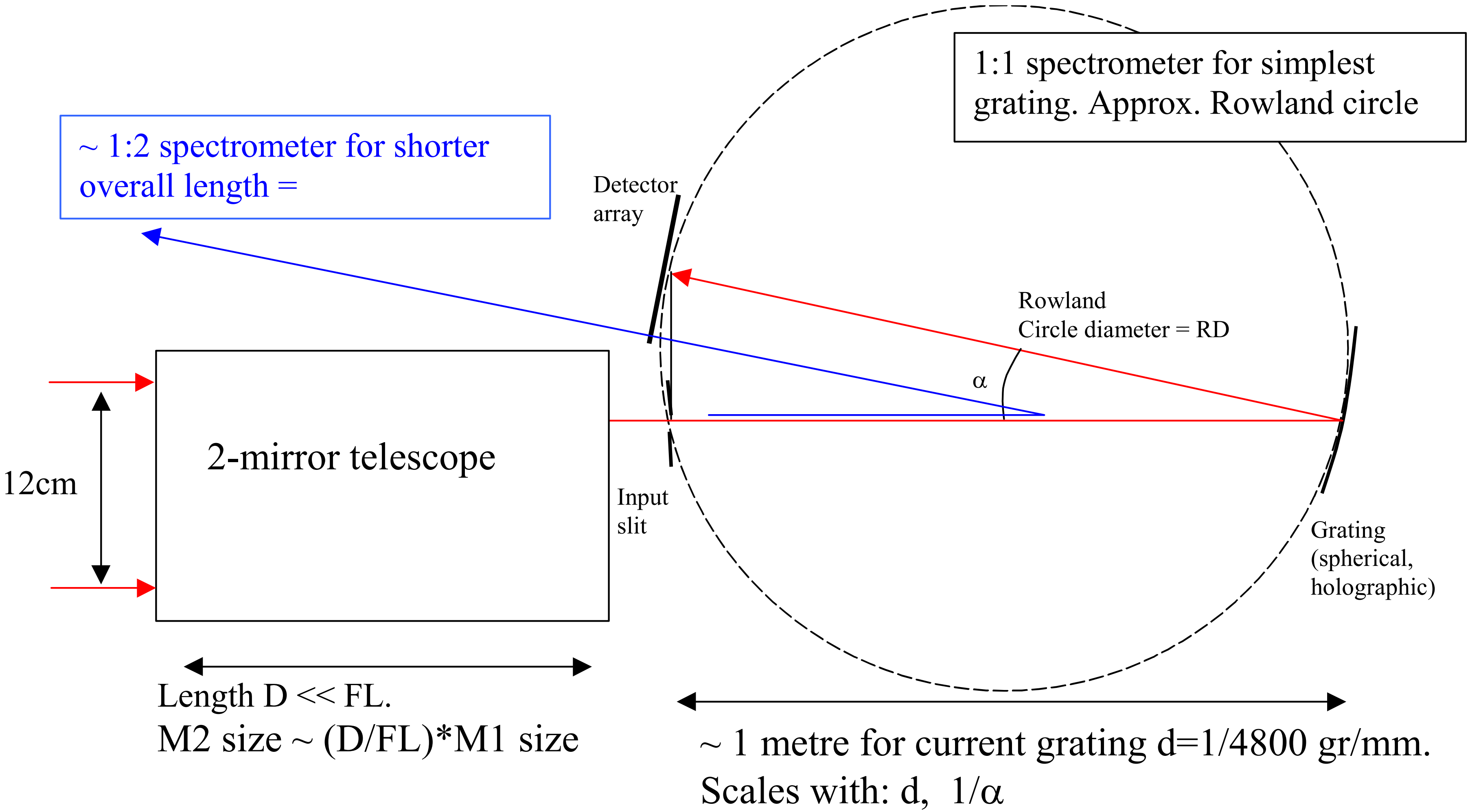
- 12cm aperture is reasonable limit given heat load problem

==> F-number = 2.06/0.12 ~ 17

Solar: 1371 watts/m^2*25*0.0113 = 390 watts.

- Have to limit to 3 reflections.

Instrument layout & trade-offs



Telescope options

1. Front-end GI grating + single mirror telescope + spectrometer.

- Previously proposed (Univ. Padova) to separate heat at front-end.
    - Light is pre-dispersed before spectrometer input slit.
- Relatively large size ~2m x 0.2m, tilted.
- Single mirror telescope (parabola), aberration control only at limited FOV
    - Spatial: Possibility to improve via grating design.
    - Spectral: No improvement possible after entrance slit.
        - Assume 1m focal length (requiring 1:2 spectrometer), have ~15μm spot size at slit at FOV edge.

Telescope option 2. Two-mirror on-axis (straw-man).

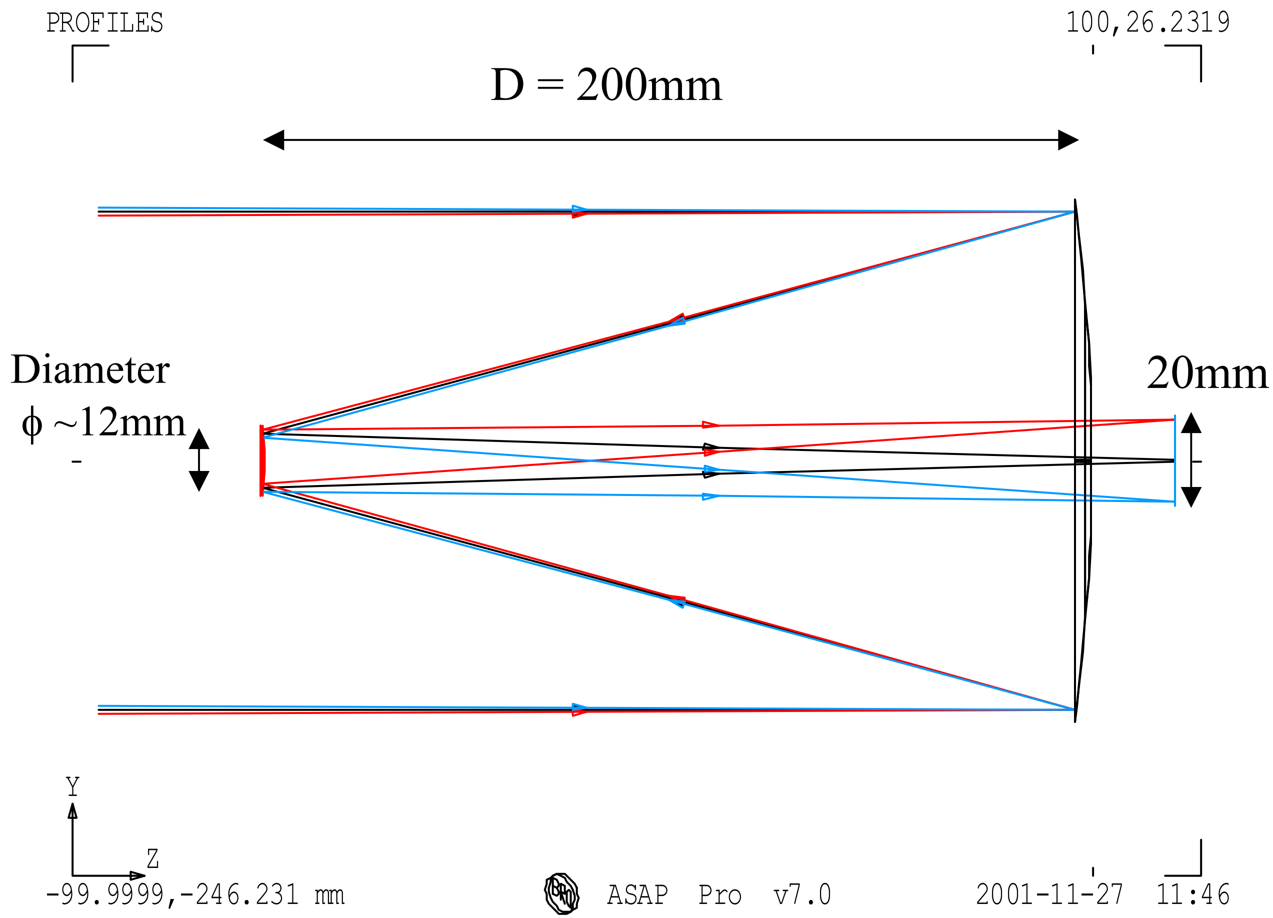
2. Good aberration control over required FOV.

- Image (slit) plane close to M1 to minimise length.
  - $\phi_{M2} \sim (D/FL).\ \phi_{M1}$
  - D ~ 200 to 400mm

    (D/FL) ~ 10 to 20 %

    $\phi_{M2} \sim$ 12 to 24 mm
  - Well-corrected, but

  Field curvature ~ 2mm



Telescope option 2. Two-mirror on-axis (straw-man).

Heat dissipation.

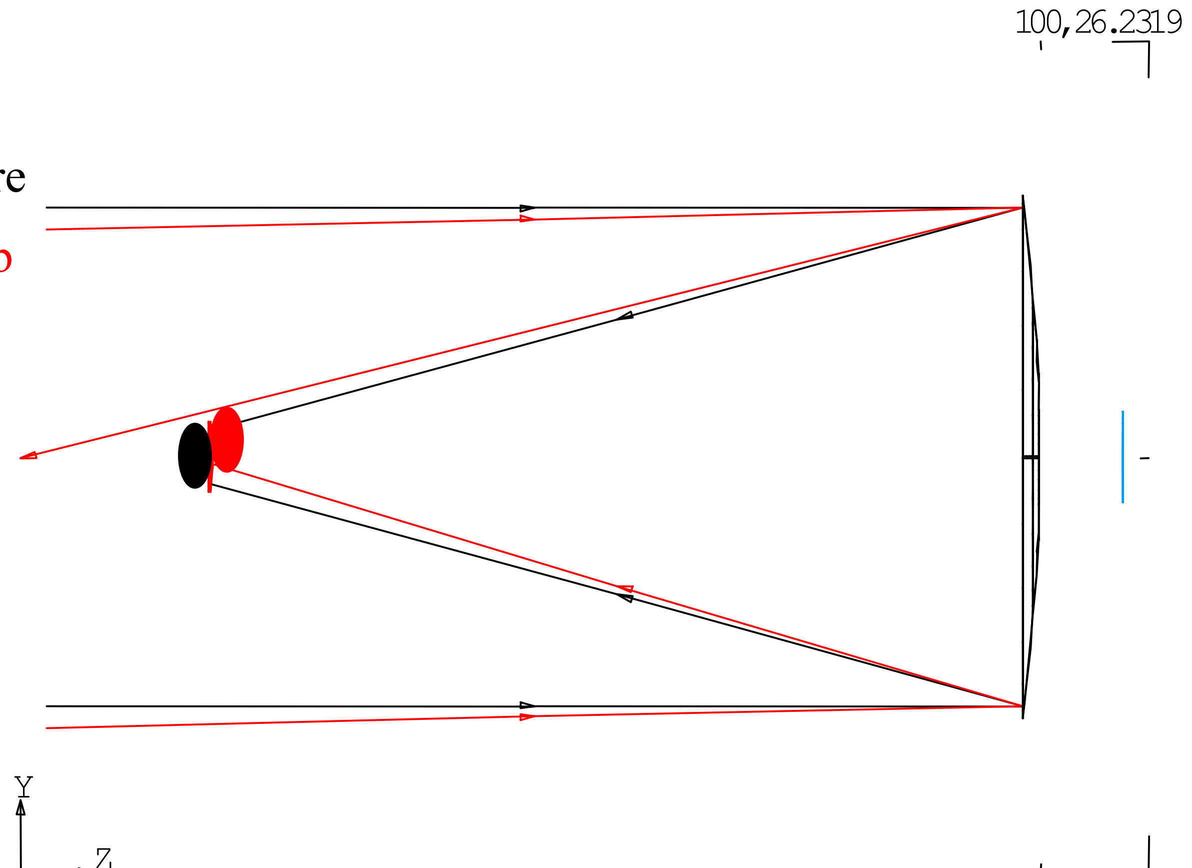
Load on M2 is high, due to :

Beam concentration.

Limited motion of beam on M2versus field angle :-

Sun centre

Sun limb



~ 80% of power from M1 hits M2

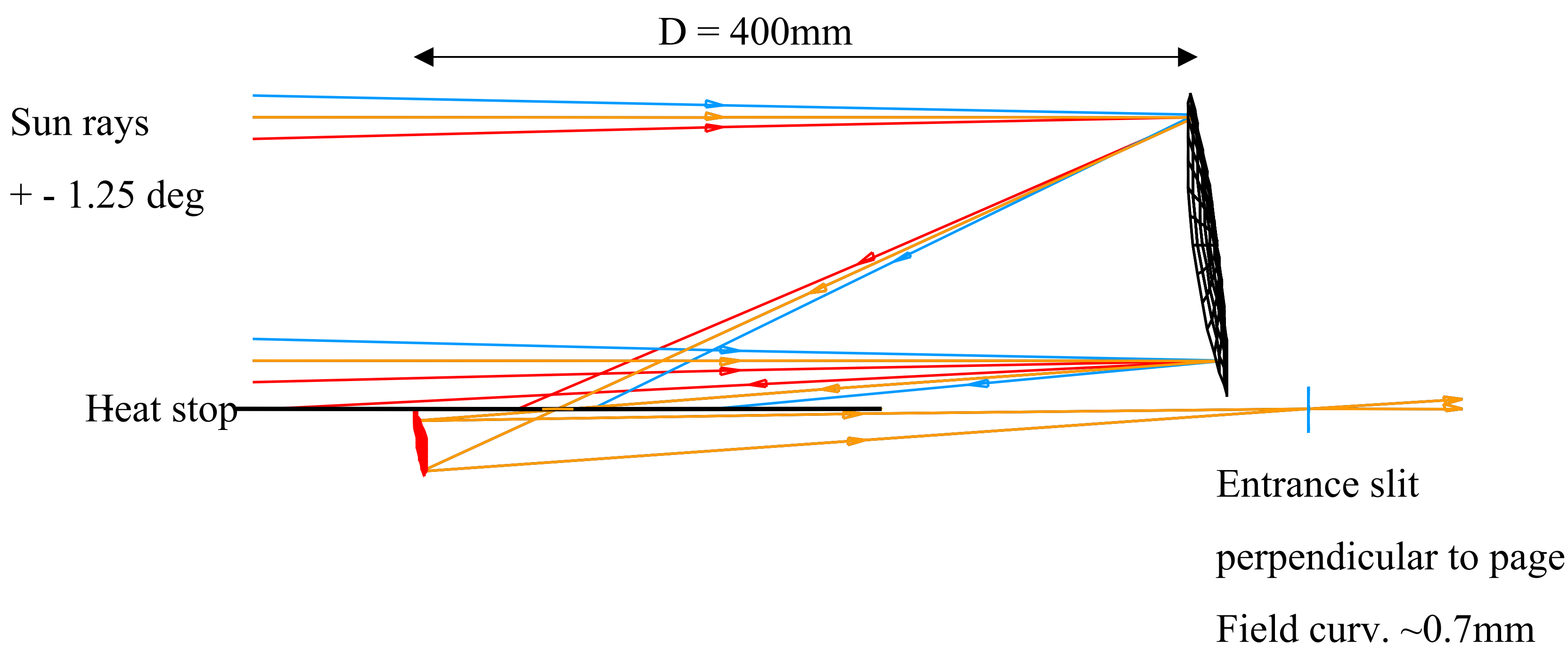
- M1 must be thermally absorbing
- Stringent opto-mechanical design
- large radiator panel needed

Solar orbiter

Telescope option 3. Two-mirror, off-axis.

PROFILES 307.017,115.962

Off-axis telescope & rays from full solar disc, blocked at heat stop



Y Z

-184.294,-553.362 mm ASAP Pro v7.0 2001-11-27 13:51

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Telescope option 3. Two-mirror off-axis.

- Solar image in M1, size ~ 2.5deg x 400mm = 17mm
- Heat stop aperture has to be curved & oversized due to aberrations.

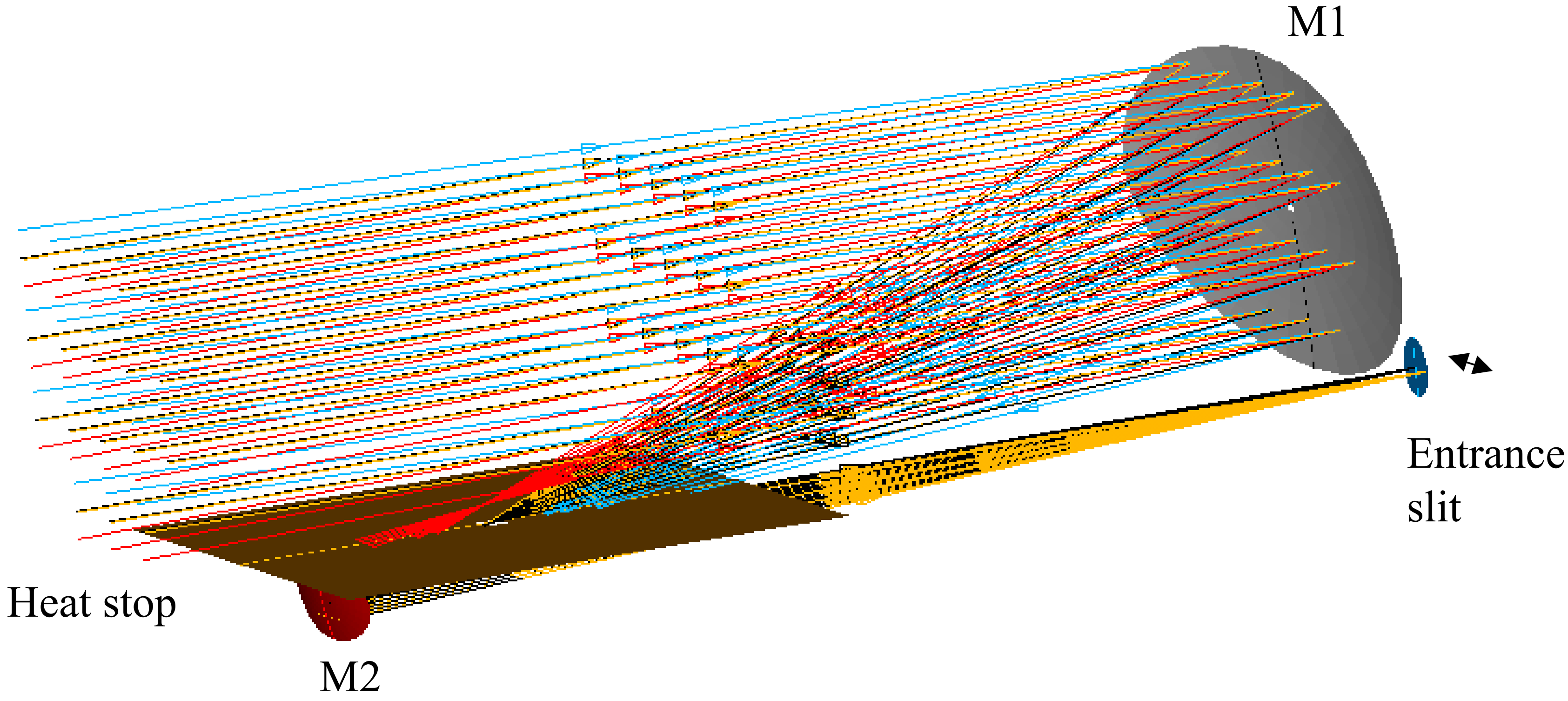
  select e.g. 34 x 10 arcmin = 2 % of solar power

  Reduced flux on M2.

  Reduced total load on spectrometer slit (same local flux)
- Design should allow M1 & stop to be heat-reflecting.

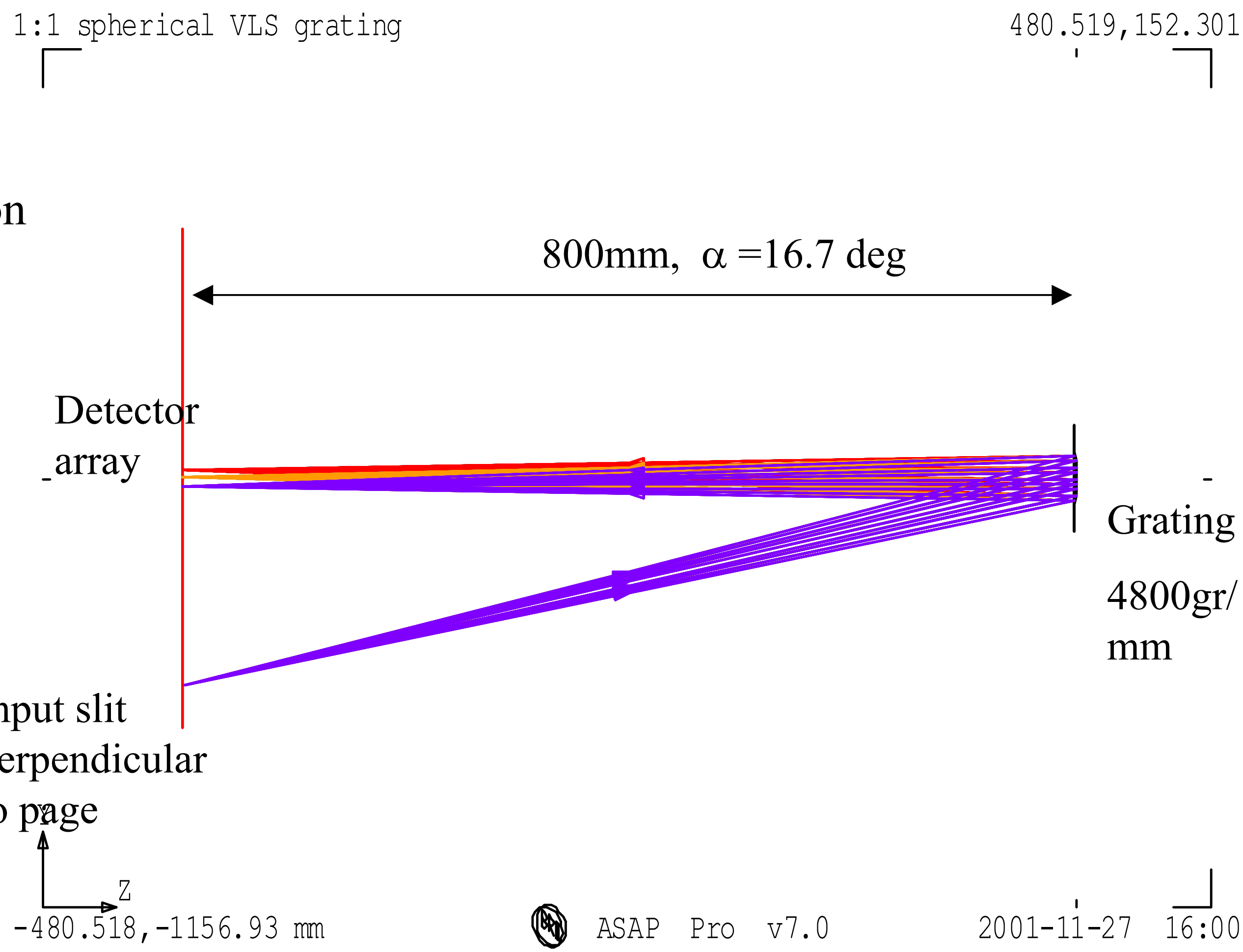
  Reduced total absorbed power & so relaxed the cooler & radiator requirements.

Telescope option 3. Two-mirror off-axis.



1:1 design, spherical variable-space holographic grating.

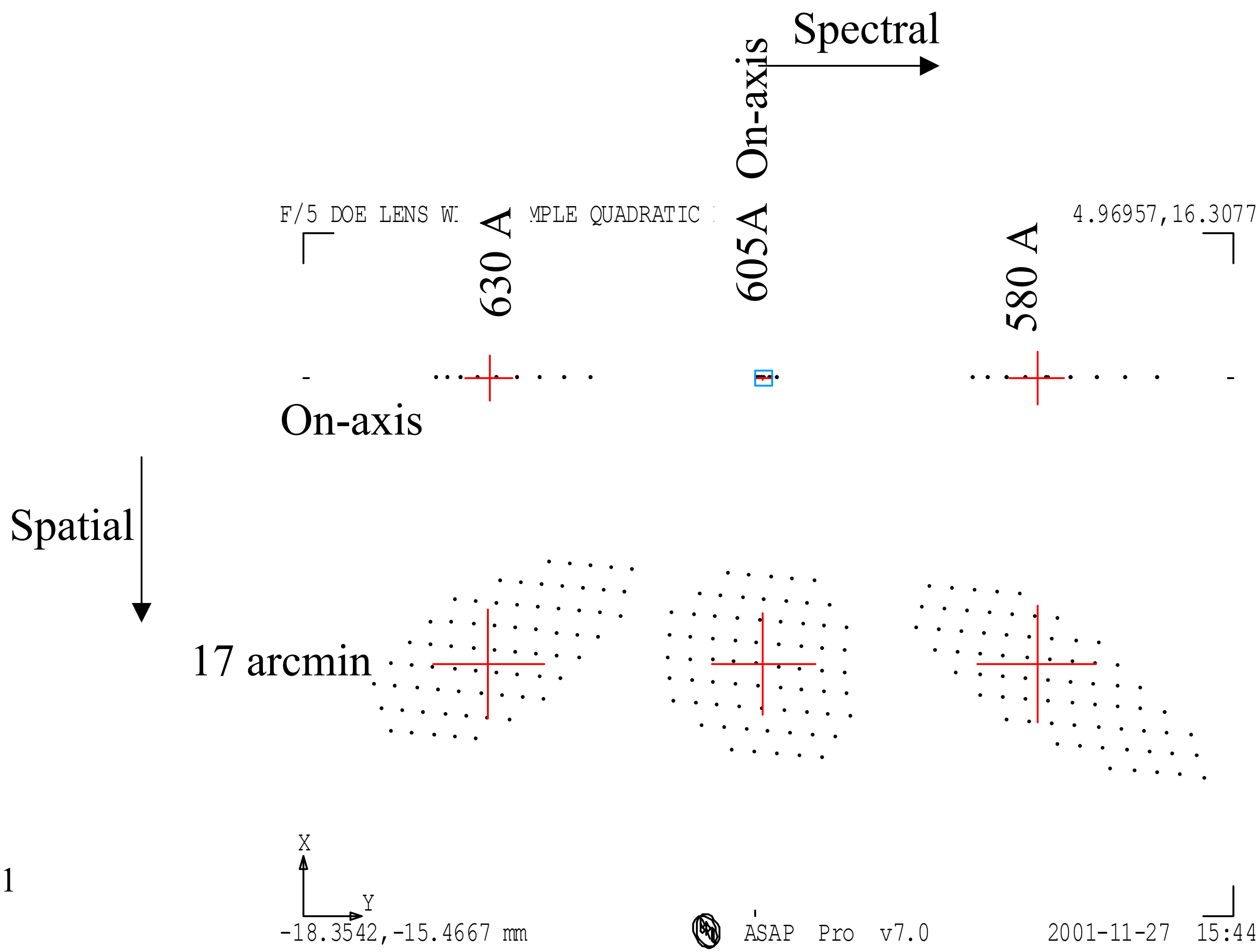
- Normal incidence on detector.
- Off-rowland for holographic form
- 580-630 Angst



1:1 design, spherical holographic grating.

Spot diagram cf. 10um square (shown in blue)

Hologram provides insufficient correction, need higher order grating function.



Tolerance sizes.

1. **absolute wavelength** calibration, i.e. No requirement for stability between ground & use. The spectrometer is self-calibrating in flight by being able to recognise known spectra.

2. **Pointing** is also calibrated in flight, e.g. by position of the solar limb.

(If these calibrations weren't so, optics would have to be stable to < 1 pixel, 0.5arcsec.)

3. **Telescope Focus**. If the focused spot were allowed to degrade by 2 um in diameter (~1/2 pixel) at the slit, the allowable two-mirror axial separation change would be ~3um, i.e. ~3um/200mm = 15 ppm relative. Active focus required ?

4. **Slit axial position** to telescope. 2um as above multiplied by F-no =17, giving ~34um.

4. **Spectrometer focus**. Grating axial (z) position relative to the telescope. For a 2um increase in spot size at the detector this motion is allowed to be ~50um. Similar motions are allowed in slit & detector position WRT the spectrometer.