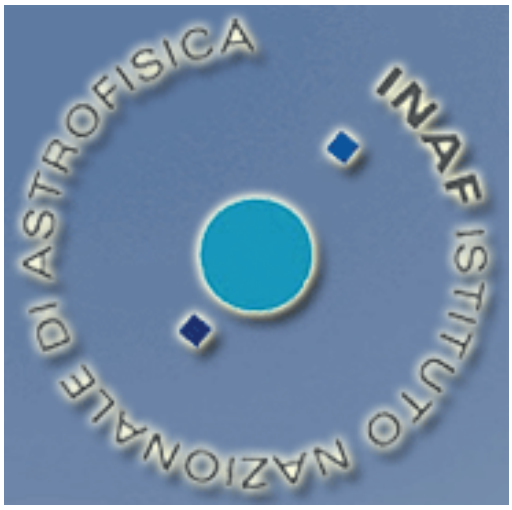
Spectra-COR:
Spectral Capability for the
Inverted-COR on Solar Orbiter



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0.0 Abstract

This document describes the possibility of including a EUV/UV spectroscopy path in the Solar Orbiter's METIS-COR with the inverted-occultation design. In this design a sector of the telescope primary mirror (M1) can be used to feed a multi-slit spectrometer where the grating replaces a sector of the secondary mirror (M2) corresponding to that of M1. The spherical varied line-spaced (SVLS) grating has 4800 lines/mm and it diffracts, at 2nd order, 30.4-nm radiation on the same detector used for the EUV/UV imaging. Alternatively, a 2400-lines/mm grating could disperse, at 1st order, 121.6-nm radiation on the same location on the focal plane. The multi-slit selects a number (e.g., 3) of angular field-of-views (FOV) from sun center (e.g., at 1.5°, 1.7° and 2°). This configuration for the spectroscopic path either utilizes some of the optical components of the imaging path (M1, EUV/UV detector) or replaces some of its parts (a sector of M2). Therefore, the inclusion of the spectroscopy path has a negligible impact on the instrument mass budget.

1.0 Optical concept of the UV spectroscopy path

Figure 1 shows a schematic layout of the inverted-occultation coronagraph with the spectroscopy path. The inverted-occultation coronagraph has been described by Fineschi (2009). The design for an optional EUV/UV spectroscopy path calls for a sector of the telescope primary mirror (M1) feeding a multi-slit spectrometer where the grating replaces a sector of the secondary mirror (M2) corresponding to that of M1. The spherical varied line-spaced (SVLS) grating has 4800 line/mm and it diffracts, at 2nd order, 30.4 nm radiation on the same detector used for the EUV/UV imaging.

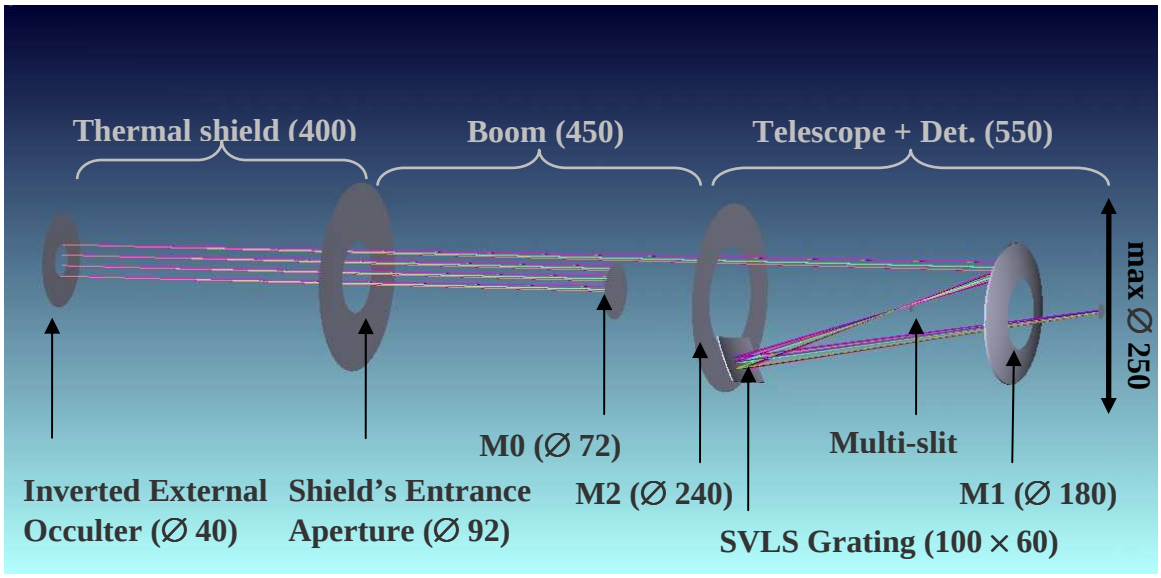

Figure 1 Conceptual layout of the inverted-occultation coronagraph with the insertion of a spherical variable line-space (SVLS) optimized for 4th order diffraction of HeII 30.4 nm. (Dimensions are in mm.)

1.1 Optical design of the EUV/UV spectrometer

Figure 2 shows the ray-traces of the optional EUV spectroscopy path that could be included in the inverted-occultation coronagraph. Figure 3 shows the preliminary configuration for the spectrometer with the grating's incidence and diffraction angles (e.g.,. Fineschi, 2004, 2005).

Focal Plane	Detector Format	$(125k)^2$ 25-μm
	Plate Scale	18 arcsec/25-μm
	Spectral Resolution (2-pix resolv. element)	12 pm
	Effective Focal Length (f/#)	300 mm (f/7.6)

Table 1 summarizes the optical specifications.

The spectrometer comprises a 4800-lines/mm spherical varied line-spaced (SVLS) grating that diffracts 30.4-nm radiation, at 2nd order, on the same detector used for the EUV/UV imaging. Alternatively, a 2400-lines/mm grating could disperse, at 1st order, 121.6-nm radiation on the same location on the focal plane. The multi-slit selects a number (e.g., 3) of angular field-of-views (FOV) from sun center (e.g., at 1.5°, 1.7° and 2°). This configuration for the spectroscopic path either utilizes some of the optical components of the imaging path (M1, EUV/UV detector) or replaces some of its parts (a sector of M2). Therefore, the inclusion of the spectroscopy path has a negligible impact on the instrument mass budget.

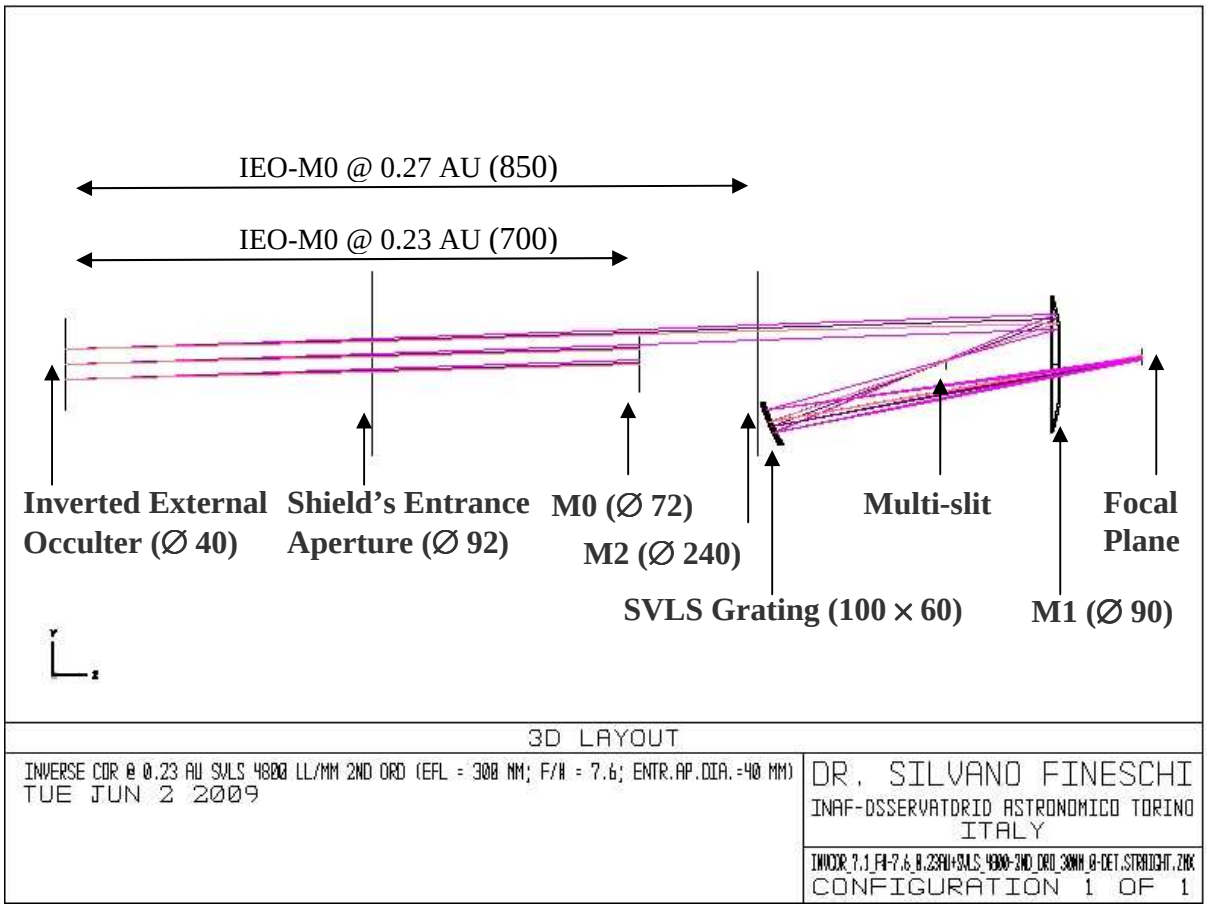

Figure 2 Ray-trace of the spectroscopic path in the inverted-occultation coronagraph. (Dimensions are in mm).

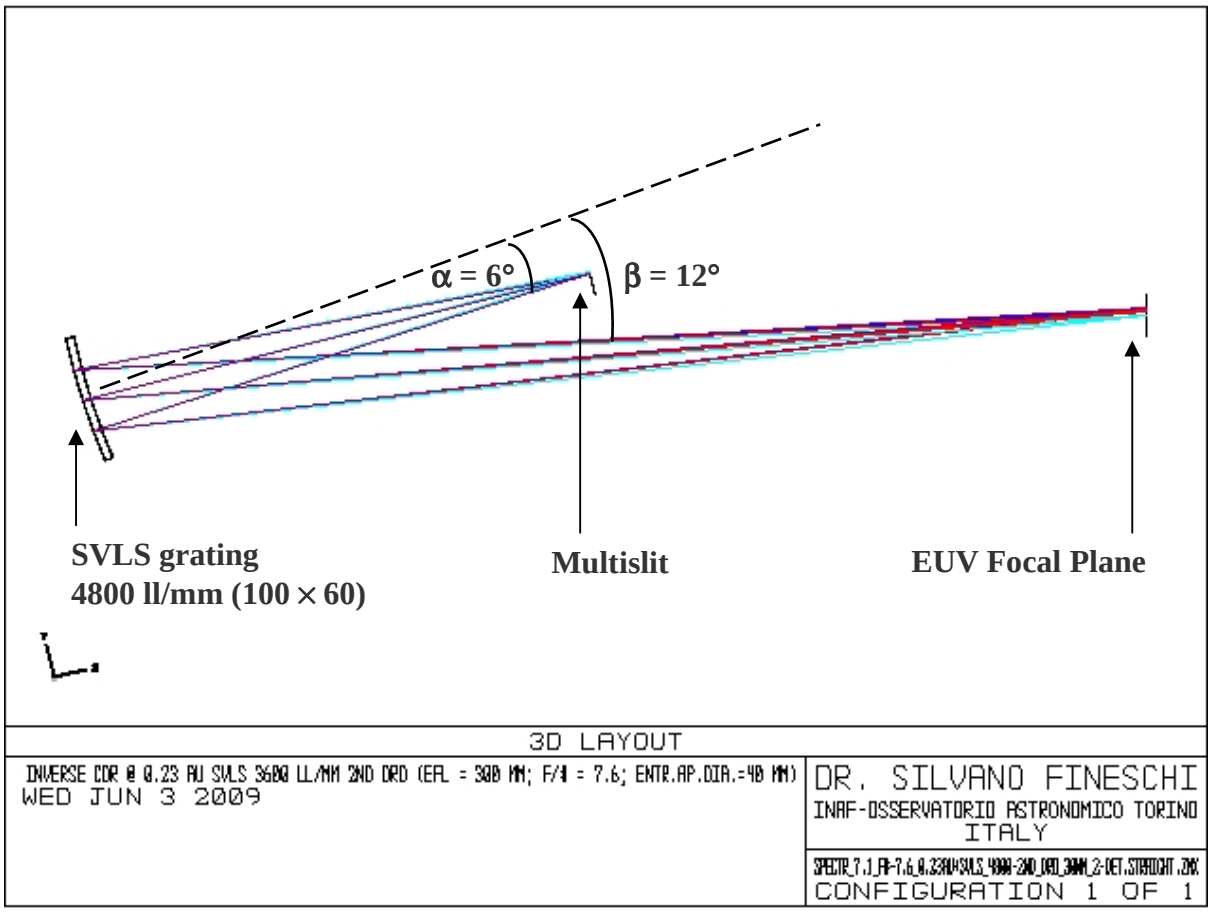

Figure 3 Ray-trace of the EUV spectroscopy path with incidence and diffraction angles for 2nd order 30.4 nm. (Dimensions are in mm)

Telescope Mirror	Dimensions of the spectroscopy sector		70 mm × 30 mm
	Radius of Curvature		300 mm
	Conic Constant		-0.70
	Off-axis		60 mm
Spectrometer	Entrance arm		245.4 mm
	Exit arm		499.6 mm
	Magnification		2
	Multislit	Slit # (FOV)	3 (1.5°, 1.7°, 2°)
		Width	25-μm
		Height (FOV)	2.5 mm (± 0.5°)
	Incidence angle (α)		6°
	Diffraction angle: 2nd order of 30.4 nm (β)		12°
Spherical Varied Line-Space (SVLS) Grating	Dimensions		100 mm × 60 mm
	Radius of Curvature	Sagittal	325.3 mm
		Transverse	325.3 mm
	Central Ruling Frequency		4800 l/mm
	Line Spacing Variation Factors (Harada, et al. 1995)	b_2	6.42 e-2
		b_3	-1.81 e-2
		b_4	2.96 e-3
Focal Plane	Detector Format		$(125k)^2$ 25-μm
	Plate Scale		18 arcsec/25-μm
	Spectral Resolution (2-pix resolv. element)		12 pm
	Effective Focal Length (f/#)		300 mm (f/7.6)

Table 1 Optical specifications of the EUV spectroscopy path.

1.2 Slits Field-of-view

Figure 4 shows an example of the multi-slit field-of-view with 3 slit apertures. The slits will rprovide EUV spectra in the FOVs along the direction tangential to the solar limb. Interpolation of the intensities between the multi-slits will recover some low-resolution EUV imaging along the solar radial direction. The FOV sector for EUV spectroscopy is about 35° out of the total 360° FOV. The remaining FOV is used for VL, UV and EUV imaging.

1.3 Spectral Coverage

The spectral range is defined by the band-pass of the grating's multilayer coating (≈ 4 nm). The equivalent spectral separation between the slits is 0.5-0.3 nm (Figure 5). This minimizes the overlap between the wings of the profiles in adjacent slits.

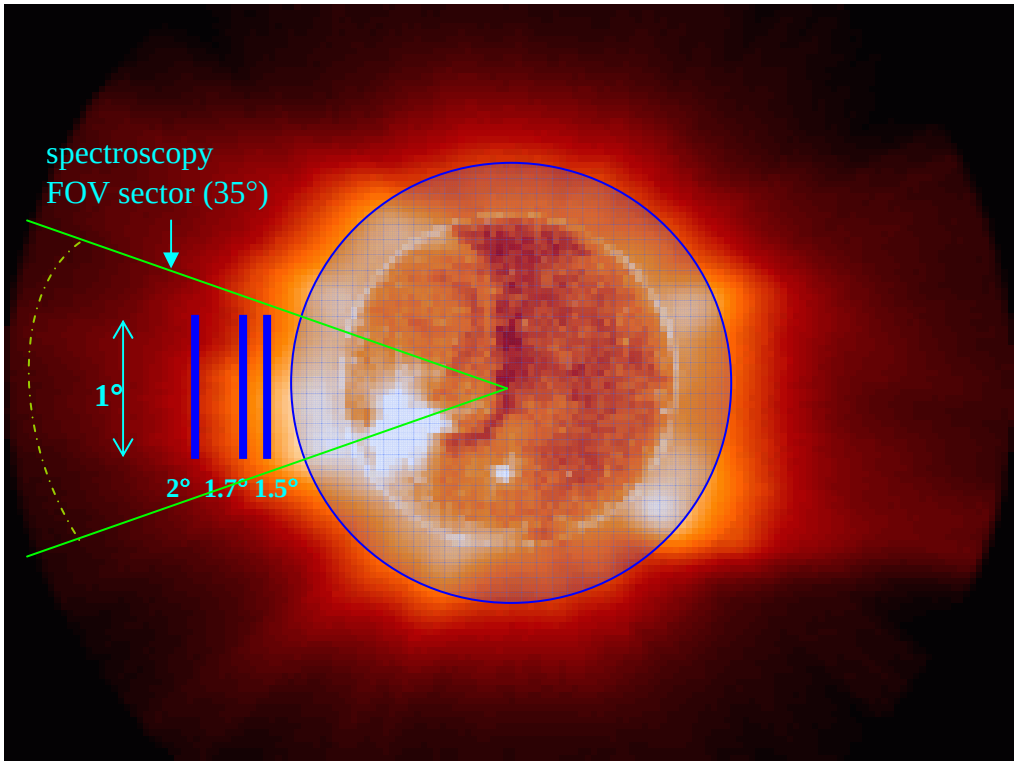

Figure 4 Example at 0.23 AU of multi-slits field-of-view for the EUV spectroscopy path. The FOV sector for EUV spectroscopy is about 35° out of the total 360° FOV. The remaining is used for VL, UV and EUV imaging

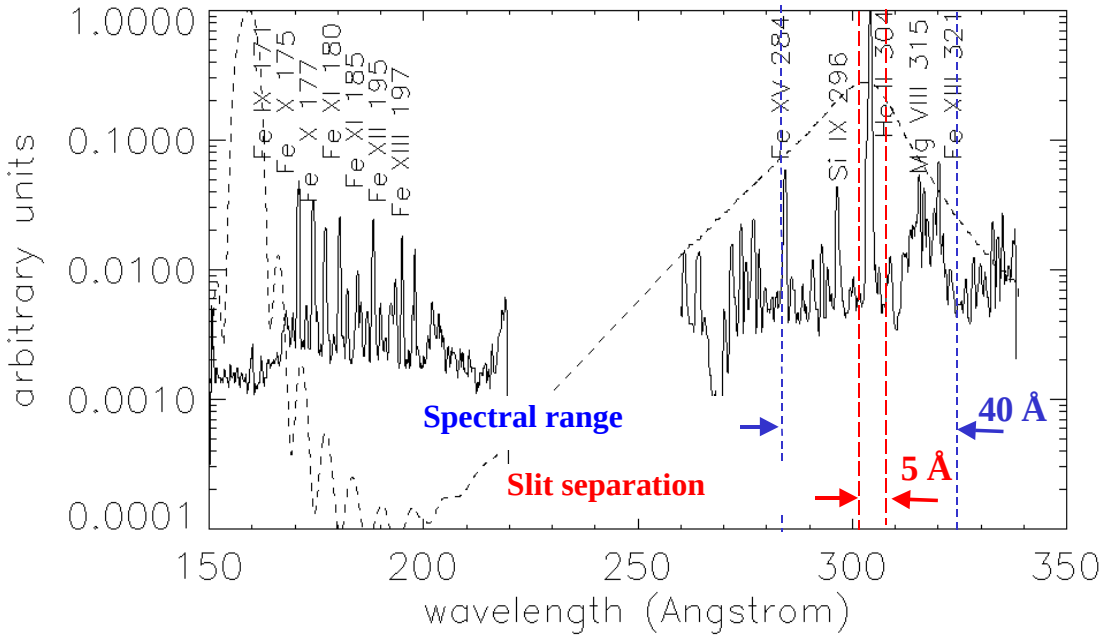

Figure 5 Chromospheric EUV spectrum illustrating the equivalent spectral separation between slits. The spectral range is defined by the band-pass of the grating's multilayer coating (dotted line).

1.4 Optical Performances

Figure 6 shows the optical performances (spot diagram and rms spot versus field-of-view) of the EUV spectrometer for the HeII, 30.38 nm, and the SiXI, 30.33 nm, lines. The optical performances in the spectral direction for those same lines are shown in Figure 7.

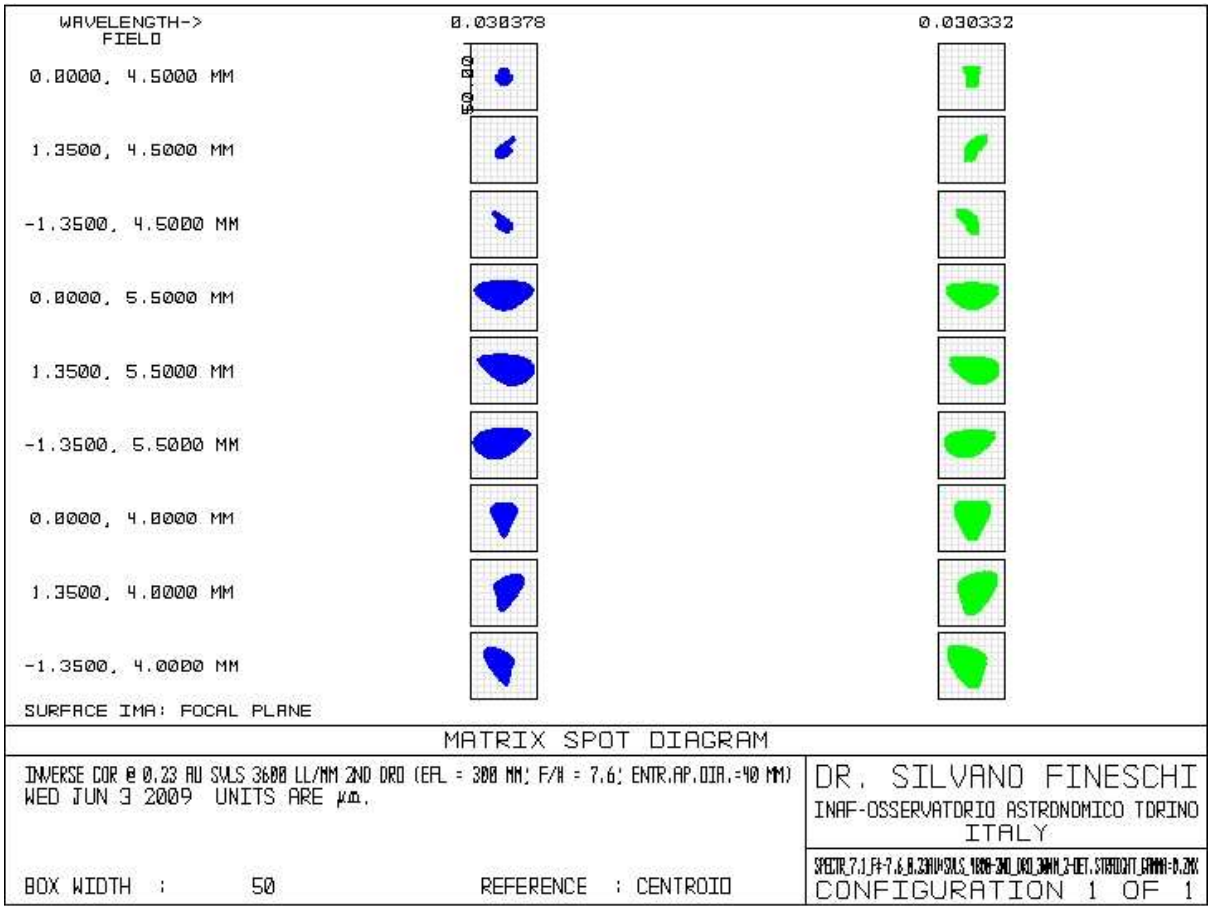

Figure 6 Spot diagram (rms) for the HeII, 30.38 nm, and the SiXI, 30.33 nm, lines. The box size is 50 µm, corresponding to the spectral resolution element.

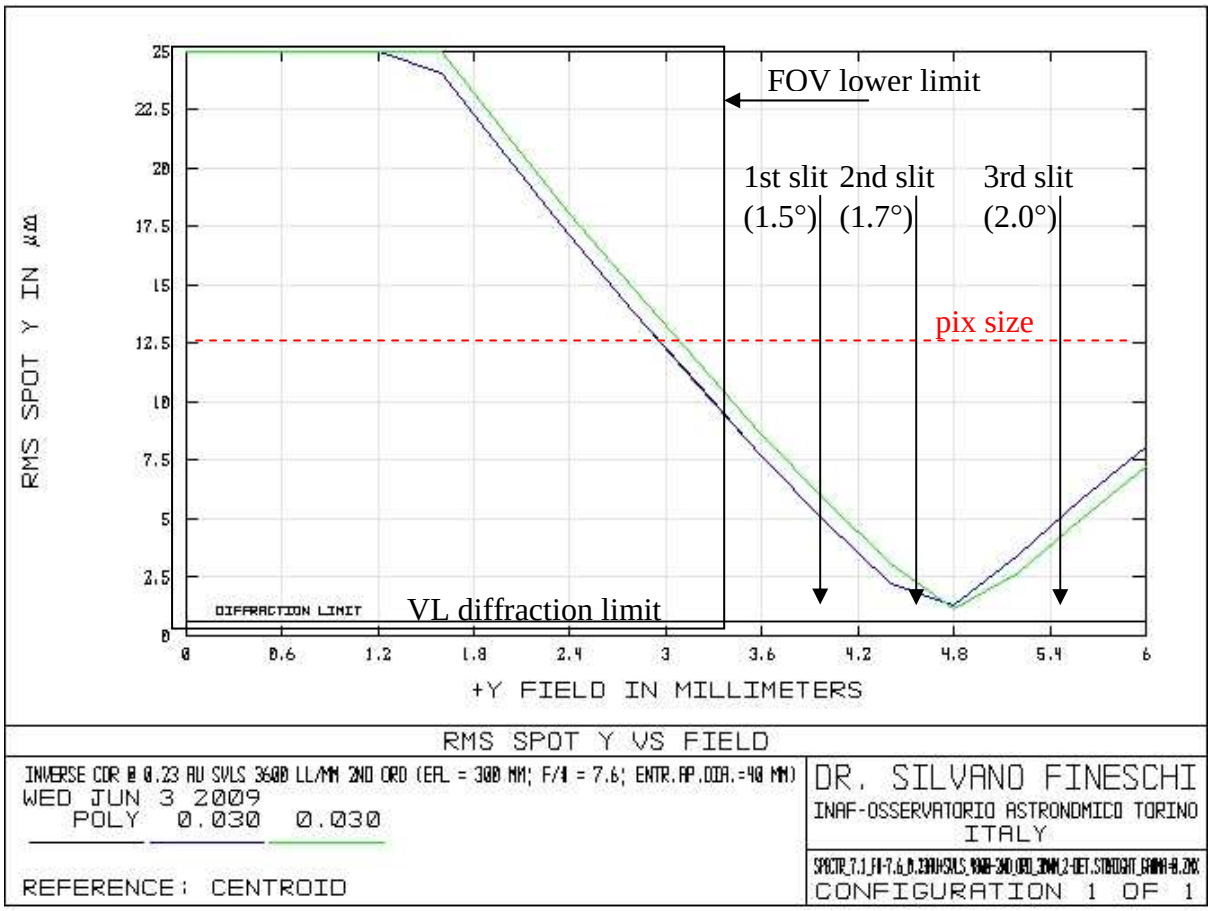

Figure 7 Spot size (rms) in the spectral direction for the HeII, 30.38 nm, (blue) and the SiXI, 30.33 nm, (green) lines. The arrows indicate the positions on the focal plane of the three slit images. (Pix size = 25 µm.)

2.0 References

Fineschi, S. et al. 2004, "Solar ultraviolet spectro-coronagraph with toroidal varied line-space (TVLS) grating", *Proc. SPIE* **5487**, 1165

Fineschi, S. et al. 2005, "Spectro-imaging of the extreme-UV solar corona", *Proc. SPIE* **5901**, 14

Fineschi, S., 2009, "Inverted-COR: Inverted-Occultation Coronagraph for Solar Orbiter", INAF-OATo Technical Report No. **119**

Harada, T. et al., 1995, "Design of high-resolution XUV imaging spectrometer using spherical varied line-space grating," *Proc. SPIE* **2517**, 107.

APPENDIX A

Abbreviation/ Acronym	DEFINITION
APS	Active pixel sensor
AU	Astronomical unit
EP	Entrance Pupil
EUV	Extreme ultraviolet
IAPS	Intensified Active pixel sensor
IEO	Inverted External Occulter
FOV	Field-of-view
LCVR	Liquid crystal variable polarimeter
ML	Multilayer
S/C	Spacecraft
SVLS	Spherical Varied Line-spaced
TBC	To be confirmed
TBD	To be determined
TVLS	Toroidal Varied Line-spaced
UV	Ultraviolet
VL	Visible-light