XUV spectroscopy for space (Solar-C EUVST) and laboratory applications

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Admission to third year - 13/09/2023

Summary

- Space application: Solar-C_EUVST
  - Slit Assembly coating analysis
  - Period abroad: Primary Mirror coating analysis

- Laboratory application: XUV bendable grating

Solar-C_EUVST

Extreme UltraViolet High-Throughput Spectroscopic Telescope

JAXA M-class mission

International participation

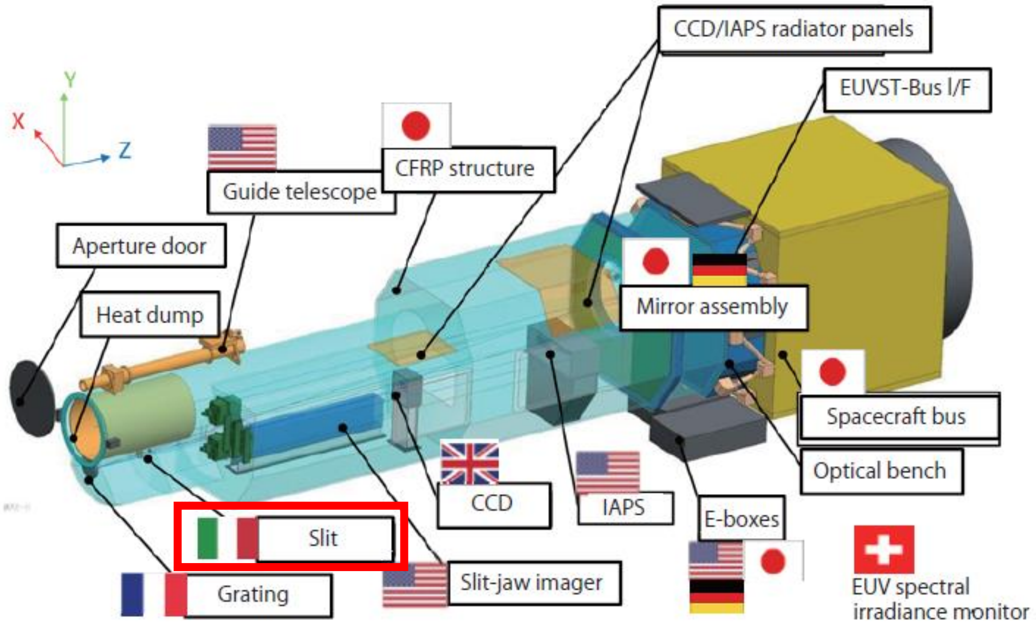
Purpose: to understand

- Formation of solar atmosphere and solar wind
- Instabilities of the solar atmosphere

The Italian contribution

INAF (Istituto Nazionale di Astrofisica) is responsible for the realization of the Slit Assembly

CNR-IFN will perform the calibration of the Slit Assembly



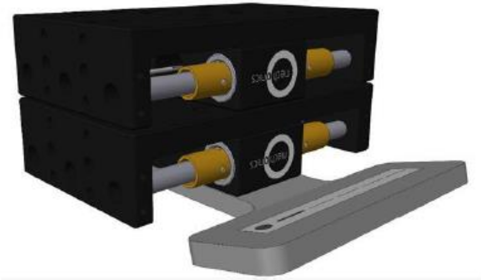
The Slit Assembly

Slit Assembly

Limit the light entering the imaging spectrograph

Reflect light onto the Slit-Jaw Imager

- 4 scientific slits
- 1 calibration slit
- 1 pinhole
- 1 circular aperture
- stop position



Positioner: two linear translators (piezo-actuator)

Redundancy and efficiency

Slit Assembly coating analysis

with Alain Jody Corso, Luca Poletto

Preliminary theoretical analysis of the Slit Assembly coating

High solar input on thin substrate → Coating to reduce heat absorption

Coating requirements:

- High reflectivity, especially in 280 nm band
- Not exceed 600 nm thickness

Coating	N7419	N7420	N7421	N7422	P3157	P3158
Solar absorbance α	0.254	0.322	0.396	0.175	0.560	0.603
Solar flux absorption by PM (W)	22.22	28.20	34.68	15.33	48.96	52.76
Reflected Solar flux (W)	65.27	59.29	52.82	72.16	38.53	34.73
Solar flux input on slit (W)	4.64	4.22	3.75	5.13	2.74	2.47

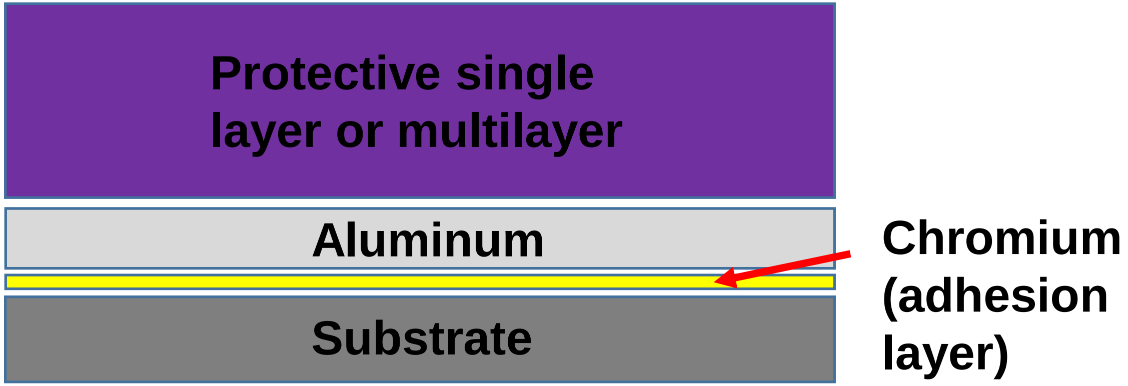
Slit Assembly coating analysis

Metal-based coating

Gold ✗
Silver ✗
Aluminum ✓

Needs protective layer → Protected Al coating

- Single-layer protected Al coating
- Multilayer protected Al coating



Single-layer protected Al coating

- Simple (single layer of SiO_2 or MgF_2)
- Not so efficient

Multilayer protected Al coating

- Complex (fully dielectric multilayer)
- Very efficient

Theoretical analysis of several coating structures:

- **SiO_2/Al and MgF_2/Al single layer**
- **$[MgF_2/SiO_2]$^3/Al; $[Al_2O_3/SiO_2]$^3/Al; $[TiO_2/SiO_2]$^3/Al and $SiO_2/[ZrO_2/SiO_2]$^3/Al multilayer**

Slit Assembly coating analysis

A genetic algorithm is prepared to optimize the thickness of each single layer
Another algorithm calculates the absorbed heat

N7422 Primary Mirror Coating		
Slit coating	Absorbed Heat (250-1700 nm)	Reflected Heat
Bare Al (reference)	0.357 W	4.213 W
Al + single layer [SiO_2 or MgF_2]	0.467 W	4.103 W
[Al_2O_3/SiO_2]/Al, 6 layers	0.386 W	4.184 W
[ZrO_2/SiO_2]/Al, 7 layers	0.363 W	4.207 W

Slit Assembly coating analysis

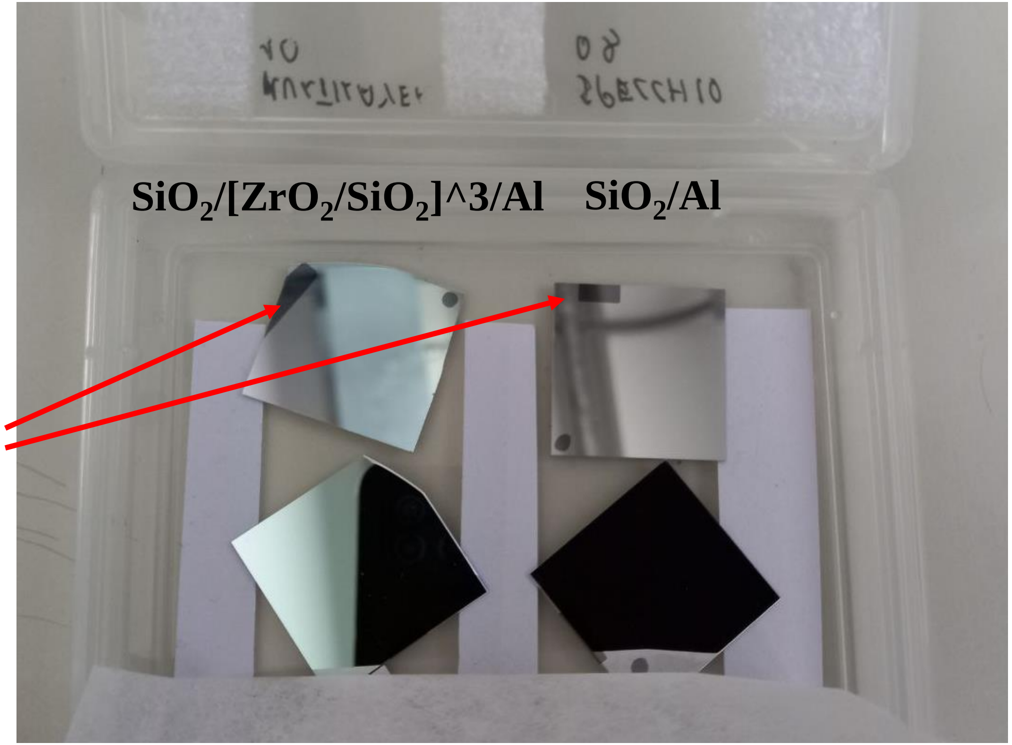
Label	Structure	Total thickness
$[ZrO_2/SiO_2]$ / Al, 7 layers	SiO2 (40 nm)	523 nm
	ZrO2 (74 nm)	
	SiO2 (82 nm)	
	ZrO2 (25 nm)	
	SiO2 (32 nm)	
	ZrO2 (90 nm)	
	SiO2 (80 nm)	
	Al (90 nm)	
	Cr (10 nm) – adhesion layer	

Label	Structure	Total thickness
SiO_2/Al, single layer	SiO2 (257 nm)	357 nm
	Al (90 nm)	
	Cr (10 nm) – adhesion layer	

Slit Assembly coating analysis

Measurements of the optical properties and thickness of the coating samples

Clamped area
Bare substrate used for thickness measurements

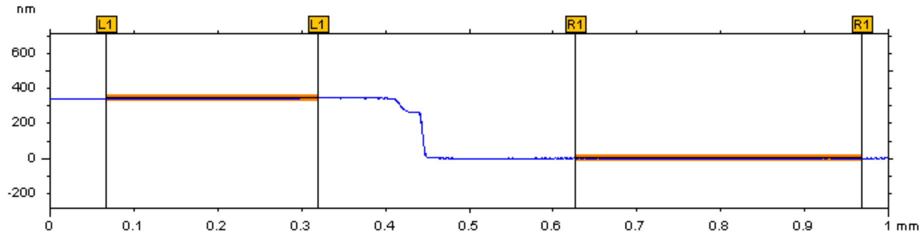


Measurements campaign:

- Profilometric analysis
- Reflectance analysis

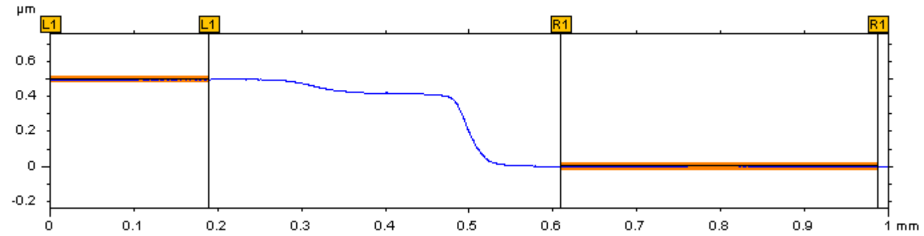
Reflectometer
Spectrophotometer
FTIR spectrometer

Slit Assembly coating analysis



	1
StpHt	-344 nm
TIR	348 nm
Avg	228 nm
Slope	-0.0351 °

SiO_2/Al



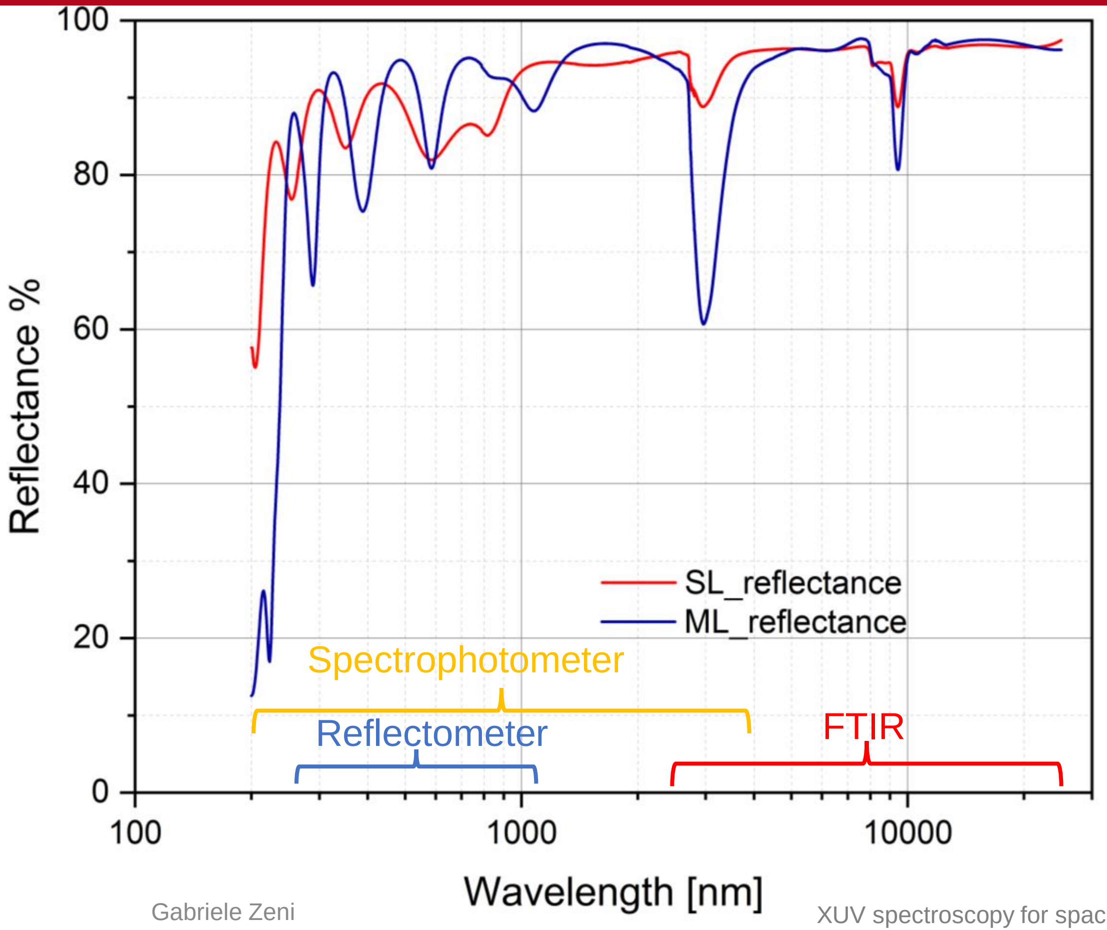
	1
StpHt	-0.497 µm
TIR	0.502 µm
Avg	0.384 µm
Slope	-0.047 °

$SiO_2/[ZrO_2/SiO_2]\wedge 3/Al$

	Theoretical thickness	Measured thickness	Error
Single layer	357 nm	344 nm	3.8%
Multilayer	523 nm	497 nm	5.2%

Small deposition error, compatible with the intrinsic precision of the deposition process

Slit Assembly coating analysis



Complete reflectance measurements, from the near UV (200 nm) to the mid IR (25 µm)

Three partially overlapped measured region:

- Reflectometer:
  300 – 1100 nm
- Spectrophotometer:
  200 – 3000 nm
- FTIR spectrometer:
  2500 – 25000 nm

Slit Assembly coating analysis

Absorbed heat, calculated using the measured sample reflectance
In the case of P3157, using also the reflectance measured by MPS

P3157 Primary Mirror Coating

Slit coating	Absorbed Heat (250-2500 nm)
SiO_2/Al	0.2659 W
$[ZrO_2/SiO_2]/Al$, 7 layers	0.2133 W

N7422 Primary Mirror Coating

Slit coating	Absorbed Heat (250-2500 nm)
SiO_2/Al	0.5290 W
$[ZrO_2/SiO_2]/Al$, 7 layers	0.4248 W

Slit Assembly coating analysis

The study has been shared with other EUVST teams and it has been presented at the ICSO 2022 conference

Zeni G. *et al.*, **Multilayer coating analysis for heat rejection on the Slit Assembly of Solar-C EUVST,** Proc. of SPIE Vol. 12777, Conference Paper, Jul 2023

Next steps:

- Ellypsometric analysis of $\mathbf{ZrO_2}$, since no data beyond 1700 nm is present in the literature
- Possible coating stress analysis

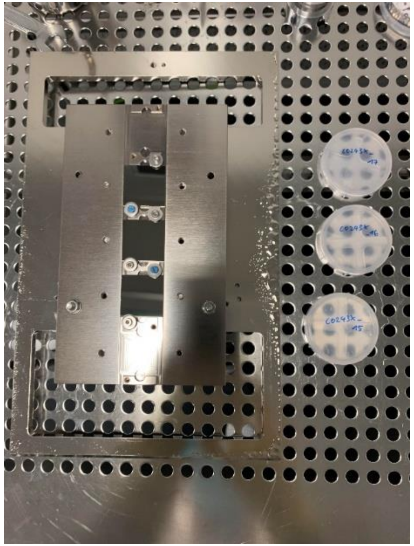
Primary Mirror Coating Analysis

with Udo Schuehle, Luca Teriaca

From January 2023 to June 2023: in Max Planck Institute for Solar System Research in Gottingen

Preliminary analysis of the reflectance stability of the PMA coating at variable temperatures

Temperature	Reflectance at 121.6 nm
22° C	37.7 %
60° C	37.8 %
100° C	37.9 %
100° C (after 18 hours)	37.8 %
120° C	38.5 %

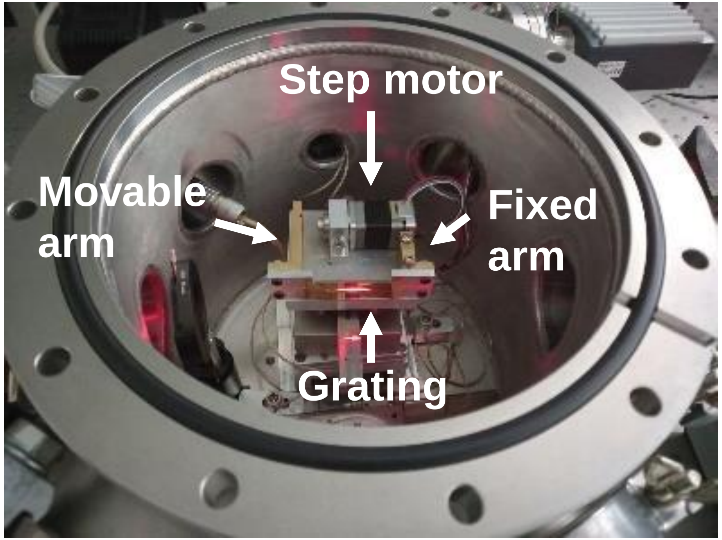


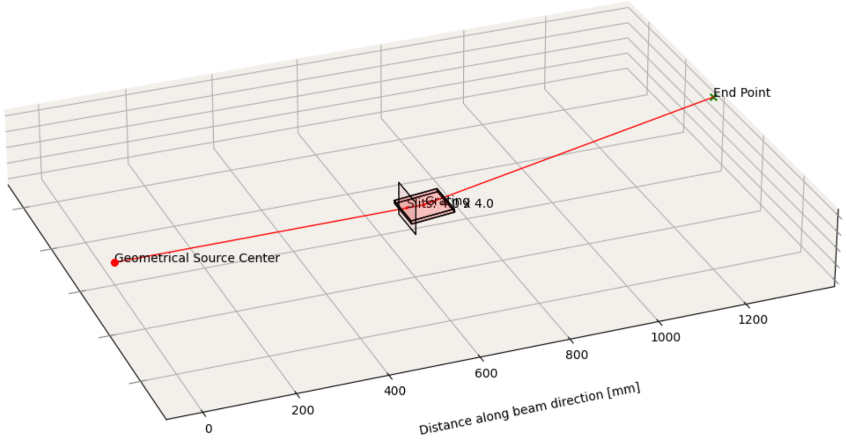
XUV deformable grating

with Fabio Frassetto, Luca Poletto

Focusing test of XUV deformable grating

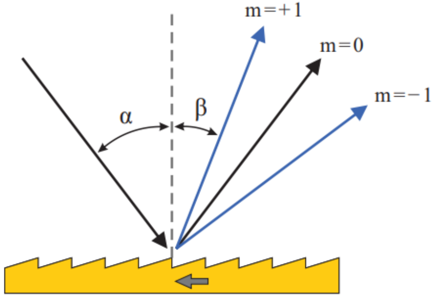
Deformable grating could be used in monochromator, reducing the amount of optical elements

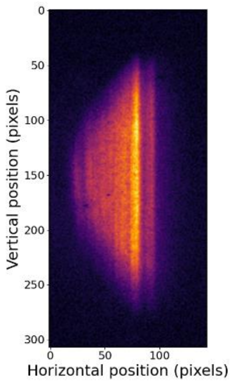




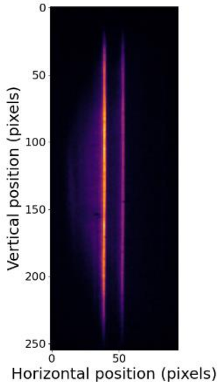
XUV deformable grating

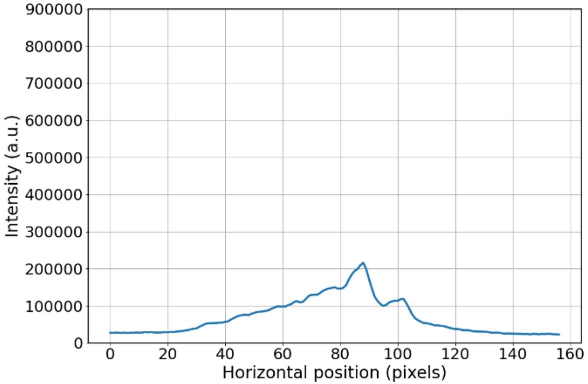
Test with He and Ne, three lines each, both with the blaze arrow of the grating toward the source and toward the camera

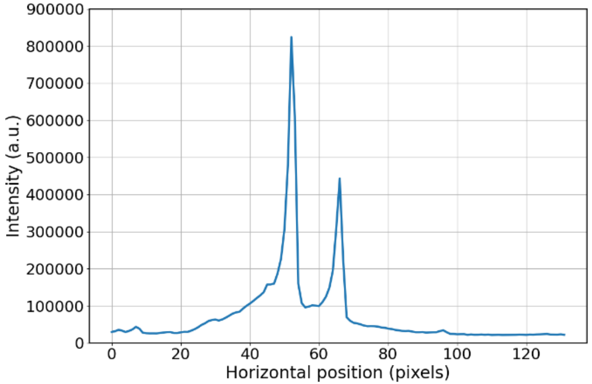




Ne 74.0 nm doublet





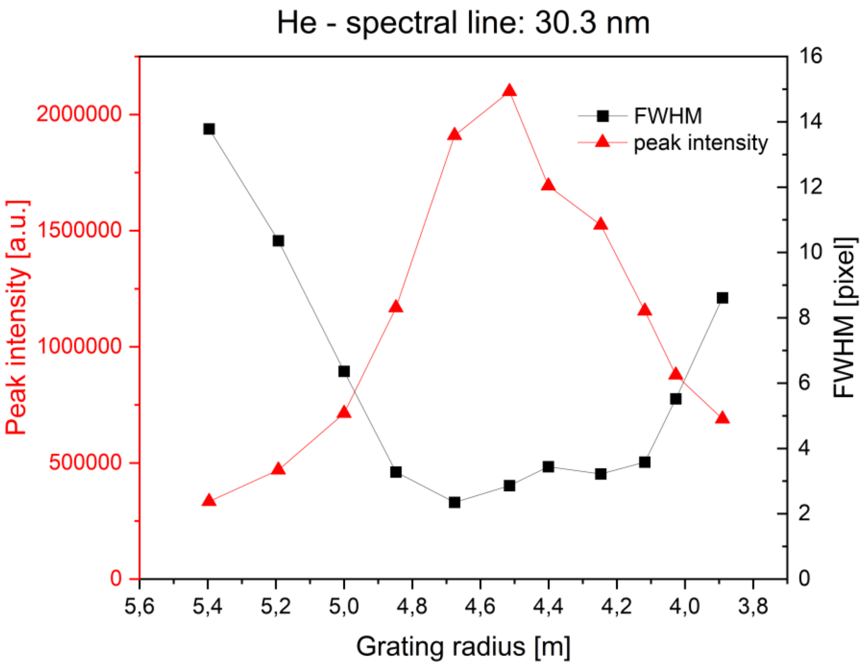


XUV deformable grating

Plot the FWHM and the peak intensity

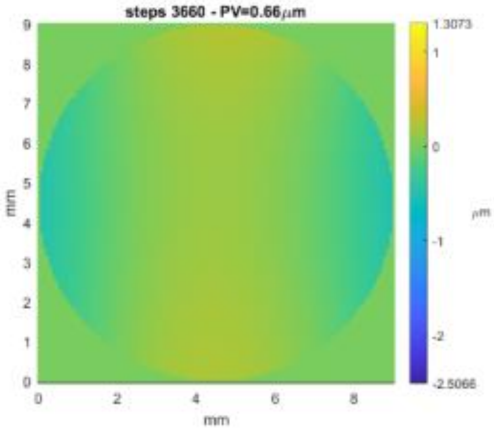
↓

Obtain the bending radius for the in-focus position

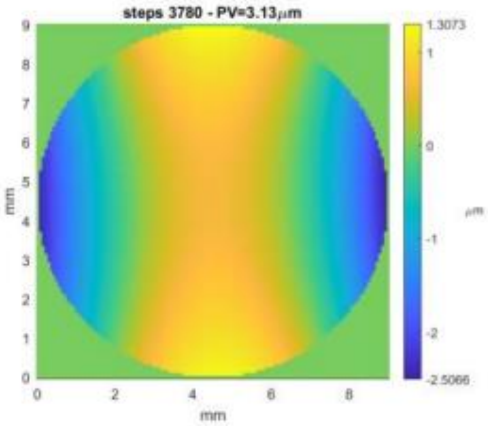


XUV deformable grating

Shack-Hartmann wavefront sensor (WFS) analysis → To analyze the shape of the deformation

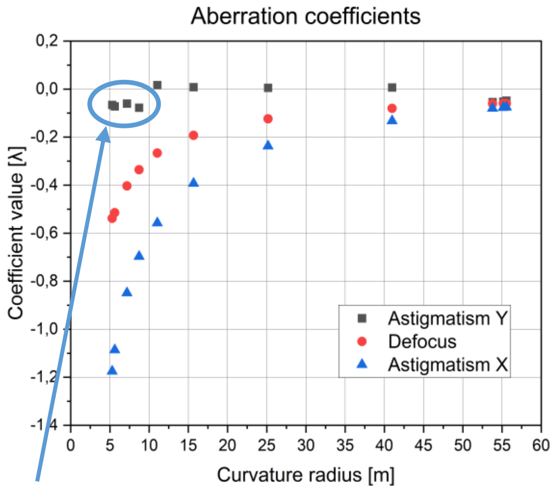


R = 50 m



R = 5 m

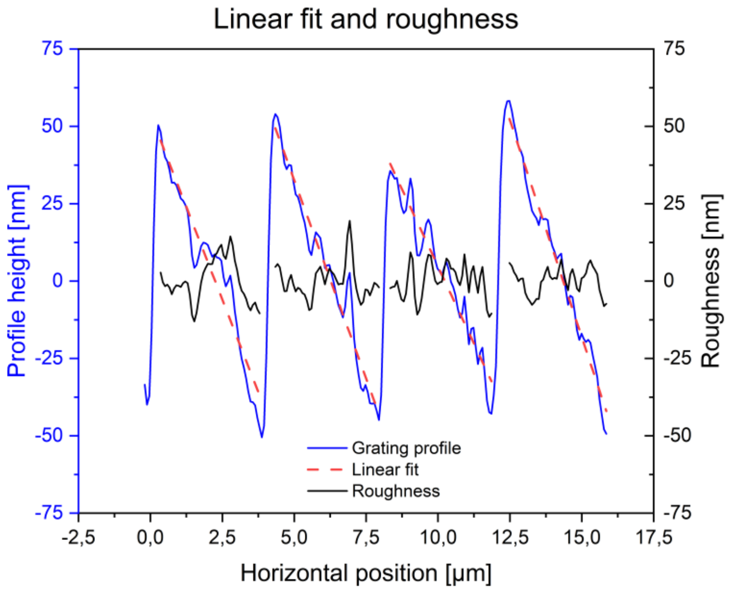
Almost pure cylindrical deformation

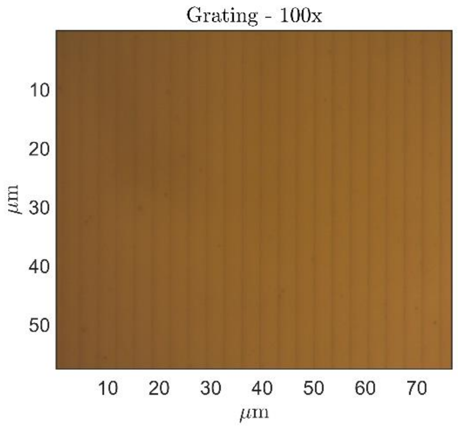


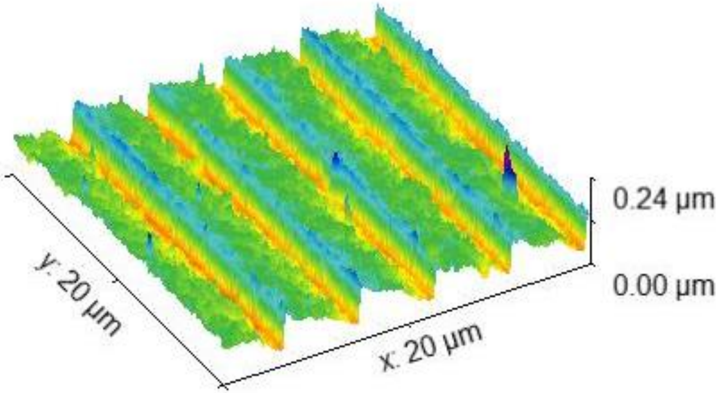
Very little residual sagittal astigmatism: unwanted torsional deformation

XUV deformable grating

Optical microscope surface analysis
AFM surface and roughness analysis







XUV deformable grating

Results:
- Fully working mounting frame
- Complete bending test of the deformable grating
- Complete analysis of the grating surface

The study has been presented at the SPIE Optics and Optoelectronics Conference in Prague, April 2023

Zeni G. *et al.*, **Bendable grating for monochromatization in the extreme-ultraviolet,** Proc. of SPIE Vol. 12581, Conference Paper, June 2023

Next steps:
- Possible development of a complete two stage bendable grating instrumentation

Thanks for the attention

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Activities for unexpected delays

- Collaboration in research activities at CNR-IFN lab, especially characterization of optical space elements operating in the UV and visible band
- Collaboration in the research activities about deformable grating and satellite instrumentation for the EUV observation
- Study of the reflectivity of mirror coatings in the UV band