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UNIVERSITÀ DEGLI STUDI DI PADOVA

Calibrazione ottica e metrologica dello spettrografo per la missione Solar-C EUVST

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Admission to second year - 05/09/2022

Solar-C_EUVST

Extreme UltraViolet High-Throughput Spectroscopic Telescope

JAXA M-class mission

International partecipation

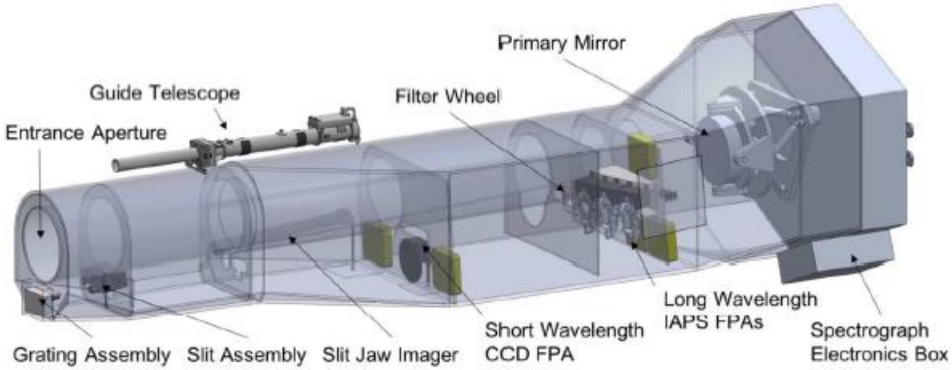
Purpose: to understand

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

The telescope

Primary instrumentations:

- EUV spectrometer
- Slit-Jaw imaging system



Observe all temperature regimes

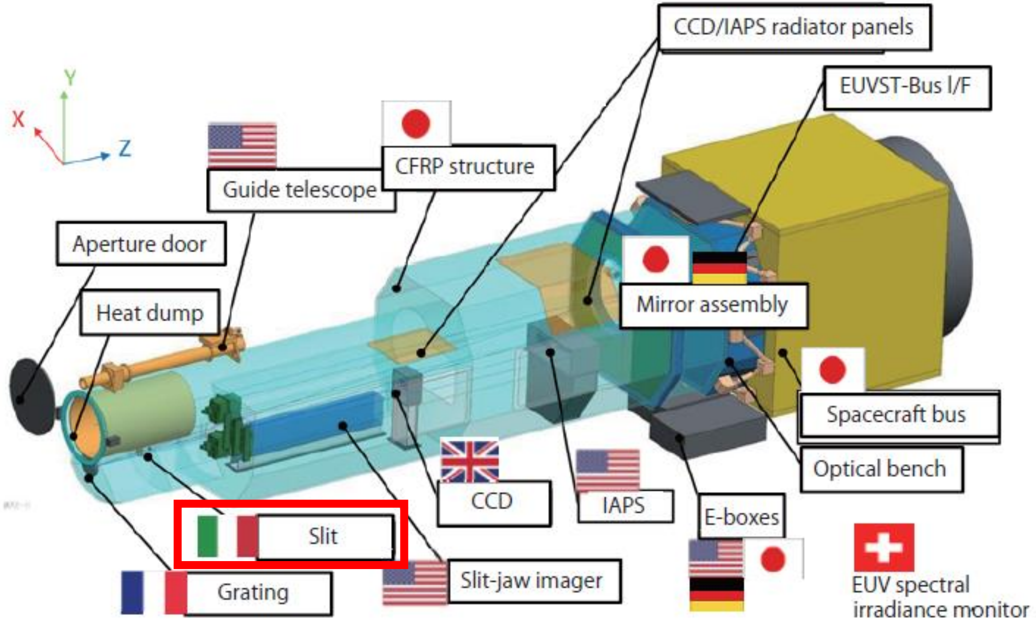
Track the evolution of the elemental structures of the atmosphere

Spectroscopic analysis of the dynamics of elementary process

The Italian contribution

INAF (Istituto Nazionale di Astrofisica) is responsible of 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

Research activities

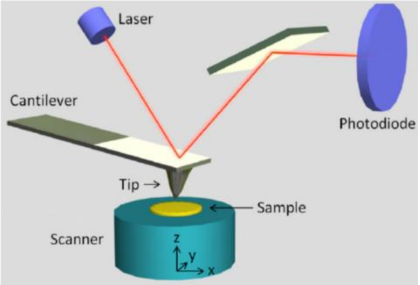
CNR-IFN has to optically and metrologically calibrate the Slit Assembly

- Preparation of the instrumentations needed to perform the measurements
- Metrological characterization of the slits and the substrate
- Morphological characterization of the slits and the substrate
- Reflectivity test of the substrate
- Calibration of the mechanism: repeatability, linearity, life test, hysteresis, characterization of the uncertainties

Research activities

Metrological characterization of the slits and the substrate

AFM (Atomic Force Microscope)



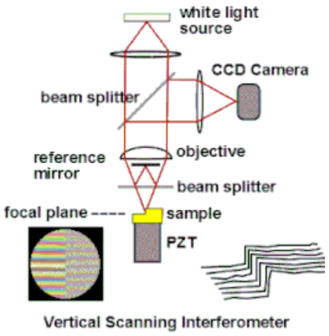
Analysis of microroughness

Optical microscope

Analysis of surface roughness
Shape of the slits

Research activities

Interferometer



Morphological characterization of the substrate

Analysis of substrate planarity and thermal deformation

Reflectivity test of the substrate

Reflectometer UV-vis → Reflectivity test in UV-vis band

FTIR → Reflectivity test in IR band

Research activities II

- Test of the instrumentation: sample test and broadband characterization of coatings (UV, vis, IR)

- Collaboration with the selected lab during the electron beam litography process: slits alignment, slits shape

- Collaboration with the selected industry during the realization/testing of the Slit Assembly: calibration of the mechanism (repeatability, linearity, life test, hysteresis, characterization of the uncertainties)

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 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

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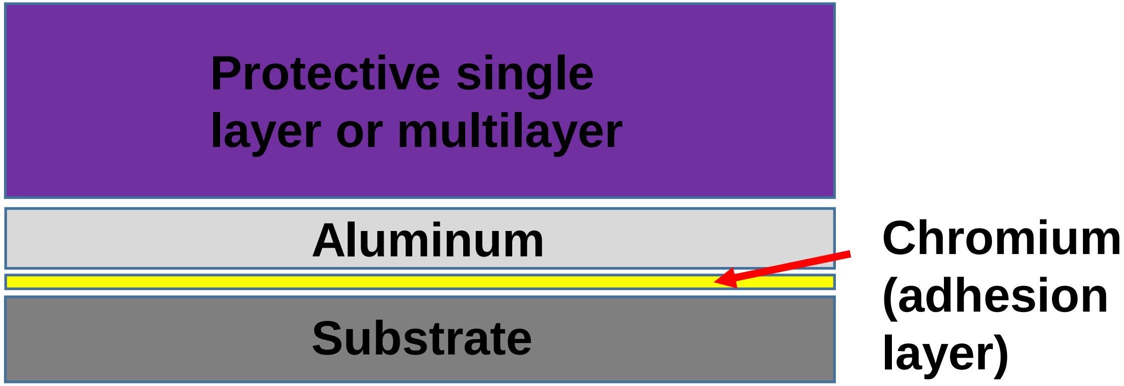
- Gold ✗
- Silver ✗
- Aluminum ✓

↓

Needs protective layer → Protected Al coating

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



Slit Assembly coating analysis

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**

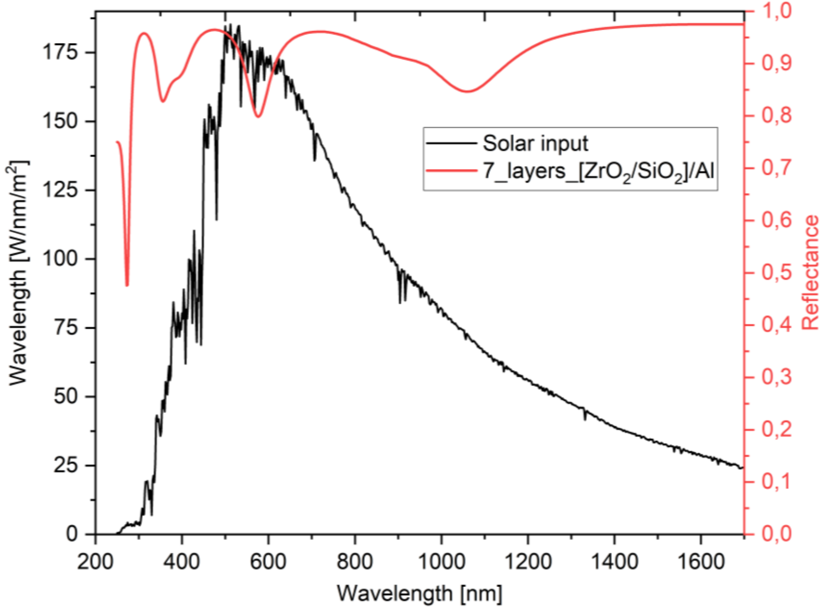
Slit Assembly coating analysis

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	



Slit Assembly coating analysis

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

Next steps:

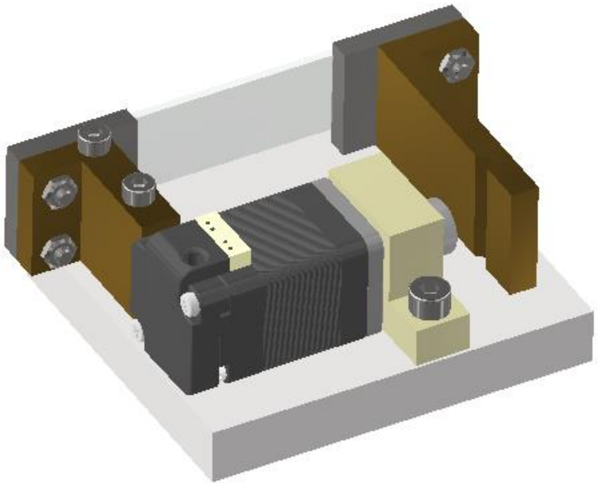
- Reflectivity test on coating samples
- Comparison between the real performance of the two multilayer **$[Al_2O_3/SiO_2]$^3/Al** and **$SiO_2/[ZrO_2/SiO_2]$^3/Al**

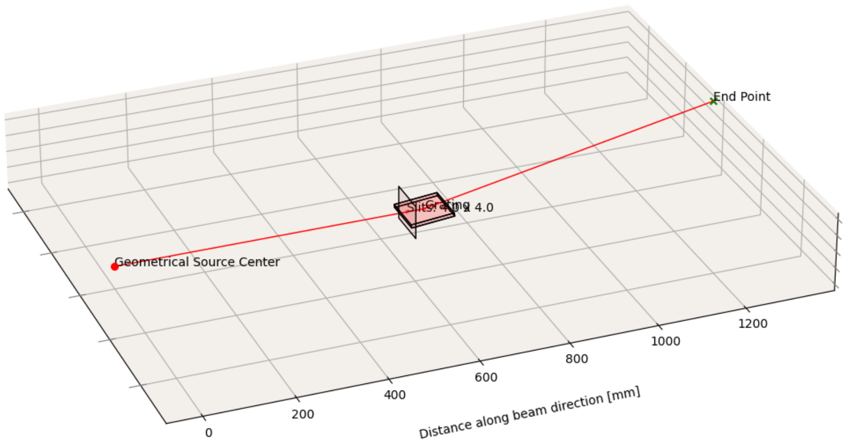
XUV deformable grating

with Fabio Frassetto, Luca Poletto

Focusing test of XUV deformable grating

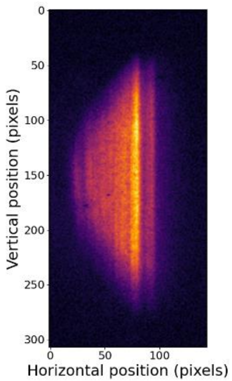
Deformable grating could be used in monochromator, reducing the amount of optical elements



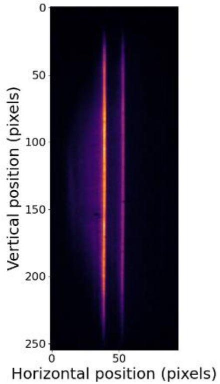


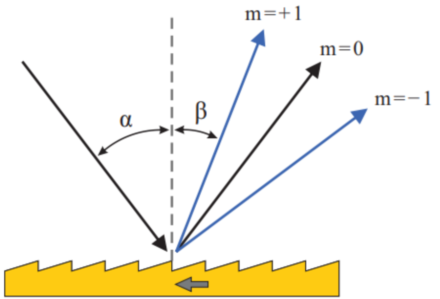
XUV deformable grating

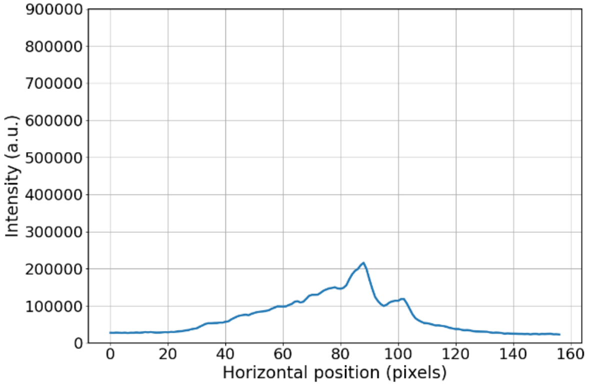
Test with He and Ne, three lines each, both with the blaze arrow of the grating toward the source and toward the camera

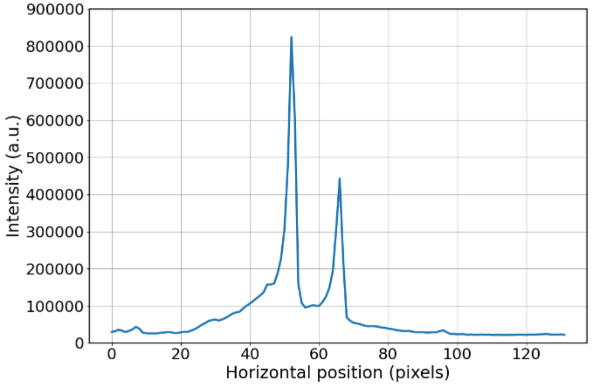


Ne 74.0 nm doublet









XUV deformable grating

Plot the peak width and the peak intensity

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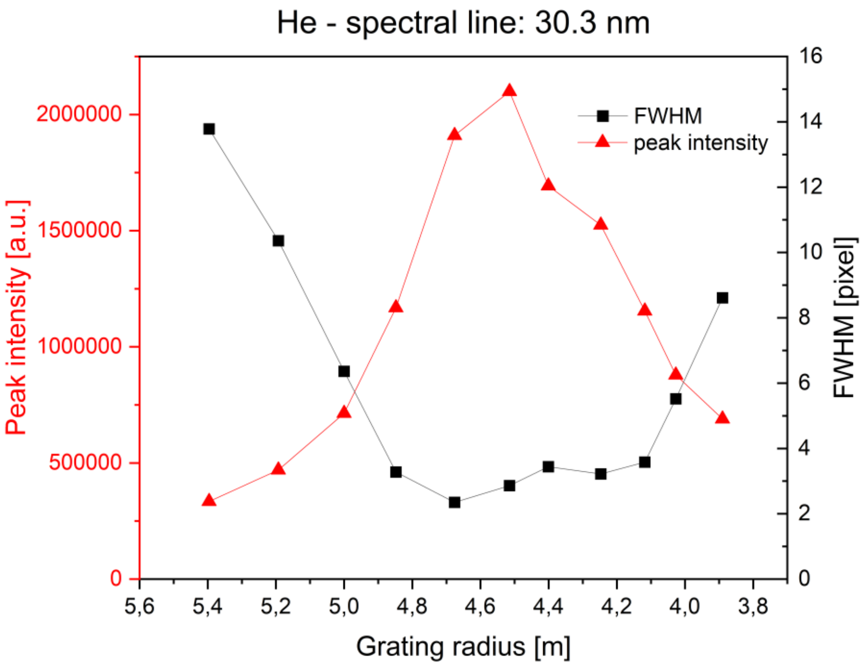
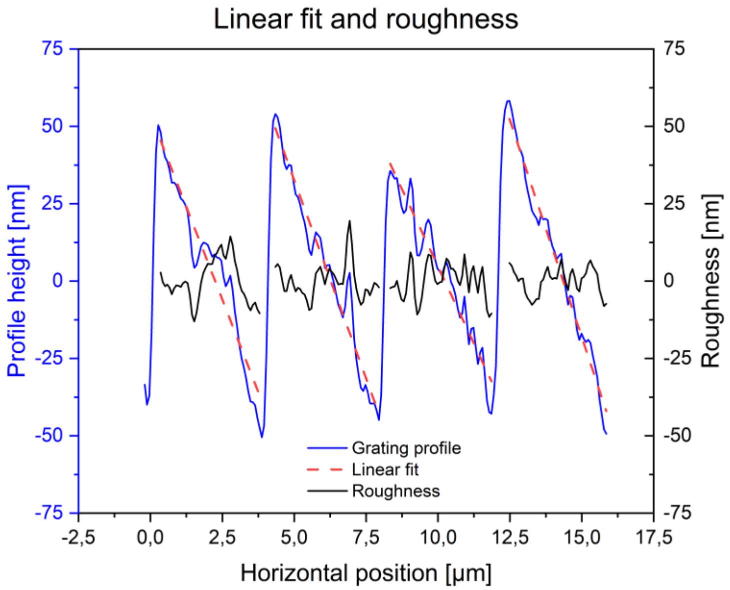
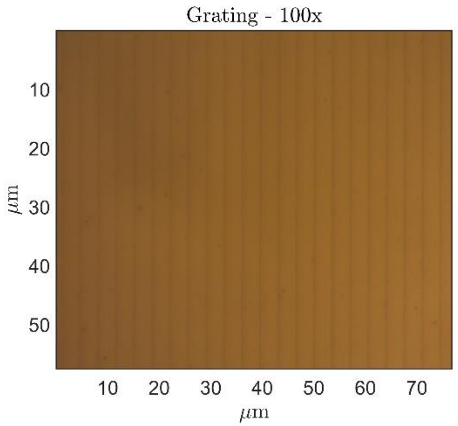
Obtain the bending radius for the in-focus position

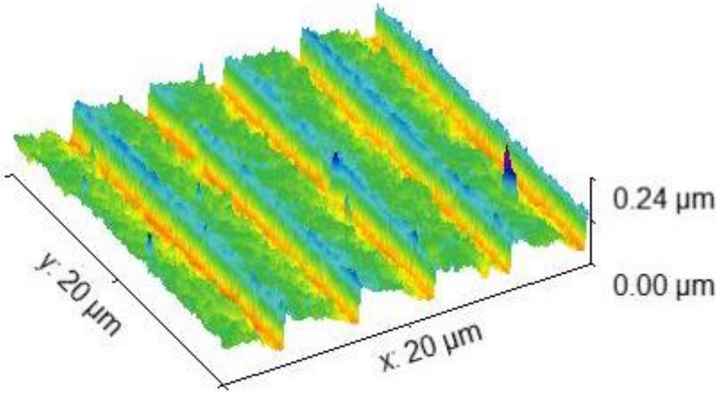


XUV deformable grating

Optical microscope surface analysis
AFM surface and roughness analysis







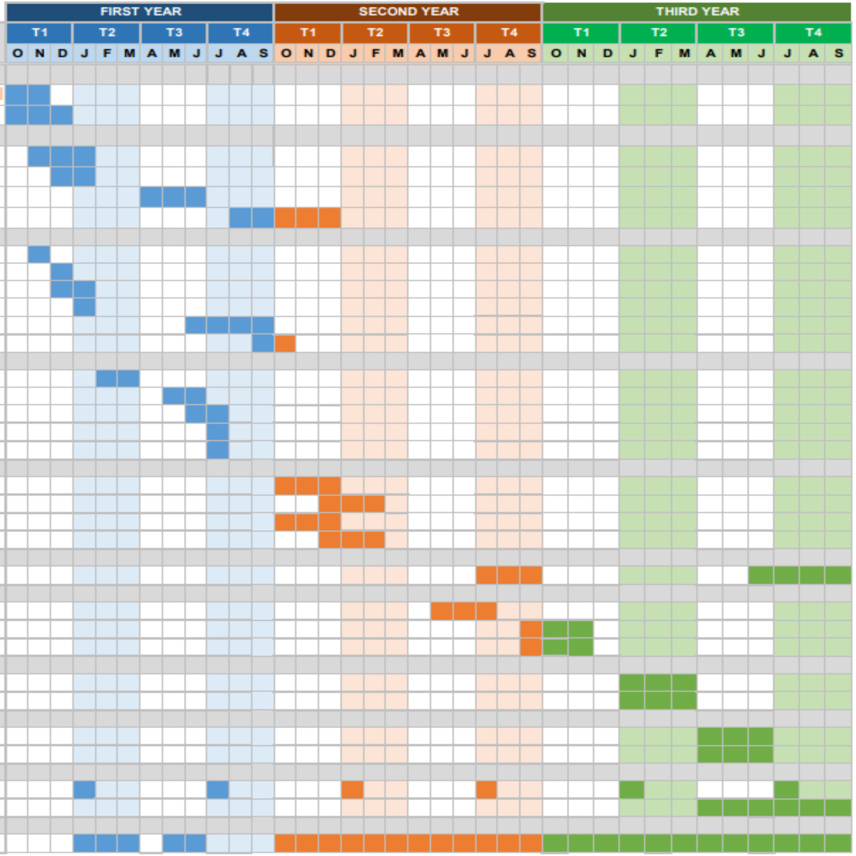
XUV deformable grating

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

Next steps:
- Paper and conference presentation
- Possible development of a complete two stage bendable grating instrumentation

Gantt-bar chart

WBS NUMBER	TASK TITLE	% OF TASK COMPLETE
1	**Solar-C_EUVST mission**	
1.1	Study of the EUVST instrumentation	70%
1.2	Bibliography research	
2	**Realization of the reflectometer**	
2.1	Preliminary design	5%
2.2	Mechanical design	0%
2.3	Realization	0%
2.4	Test campaign	0%
3	**Optical coating theoretical study**	
3.1	Preliminary study on the optical coating	0%
3.2	Realization of the genetic algorithm	0%
3.3	Test and simulation	0%
3.4	Report	0%
3.5	ICSO presentation and SPIE proceeding	0%
3.5	Sample test	0%
4	**XUV bendable grating**	
4.1	Mechanical design	0%
4.2	Test campaign	0%
4.3	Surface shape analysis	0%
4.3.1	AFM analysis	0%
4.3.2	Wavefront analysis	0%
5	**Preliminar analysis of other instrumentations**	
5.1	FTIR	0%
5.2	Contact profilometer	0%
5.3	Atomic force microscope	0%
5.4	Interferometer	0%
6	**Collaboration with CNR-IFN in Rome (or equivalent selected lab)**	
6.1	Characterization of the Slit realization (to be defined)	0%
7	**Characterization of the Slit substrate**	
7.1	Mechanical characterization	0%
7.2	Optical characterization	0%
7.3	Alignment characterization	0%
8	**Characterization of the positioning mechanism**	
8.1	Mechanical characterization	0%
8.2	Alignment characterization	0%
9	**Characterization of the whole Slit Assembly**	
9.1	Alignment characterization	0%
9.2	Repeatability test	0%
10	**PhD thesis development**	
10.1	Report	0%
10.2	PhD thesis writing	0%
11	**Educational activities**	
11.1	Educational activities	0%



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