Possible German Contribution to the UV Spectropolarimeter of LUVOIR

- expertise
- heritage
- Interests of MPS

Udo Schühle

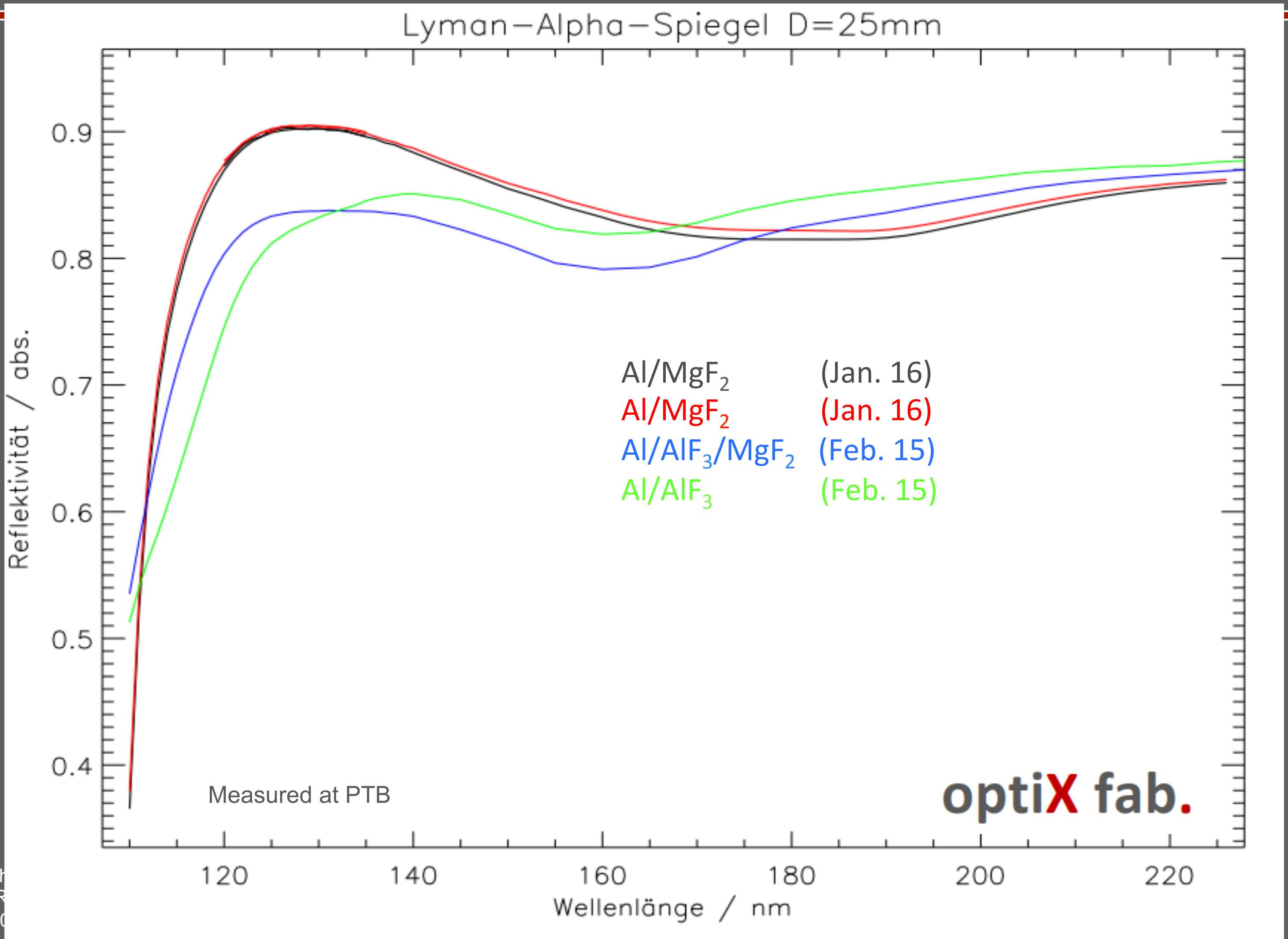
Max Planck Institute for Solar System Research

Possible contribution to the UV Spectropolarimeter by Max Planck Institute for Solar System Research:

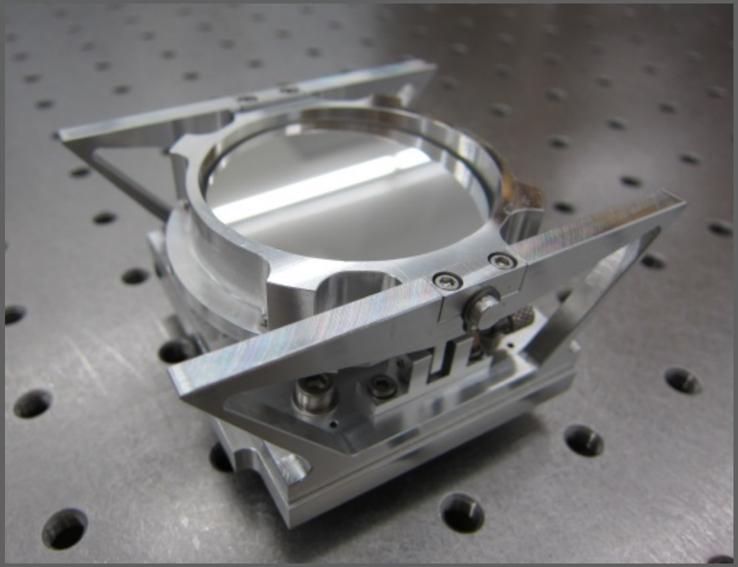
- VUV mirrors and coatings
- MCP detectors down to 90 nm
- Cameras (incl. electronics)
- Mechanisms

Udo Schühle
LUVOIR WS
11.-12. 01. 2017

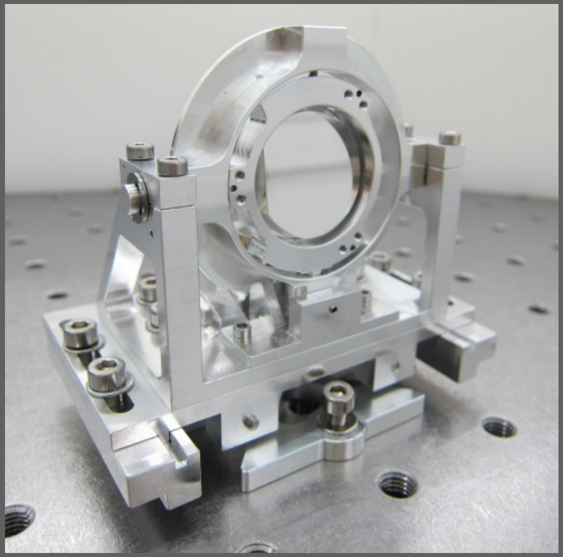
Mirror coatings with protected Aluminium optimized for Lyman-α



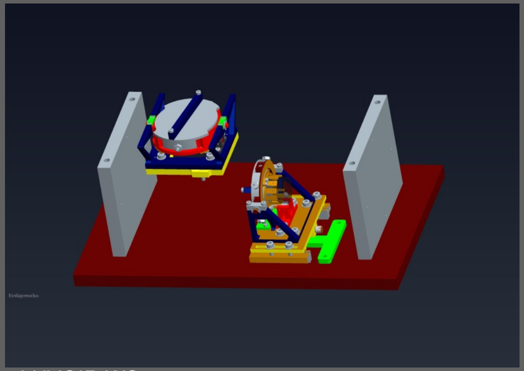
Lyman-α Mirrors for Solar Orbiter EUI

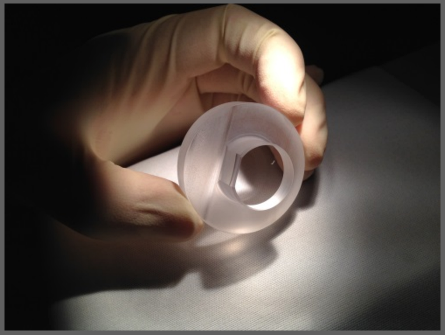


M1



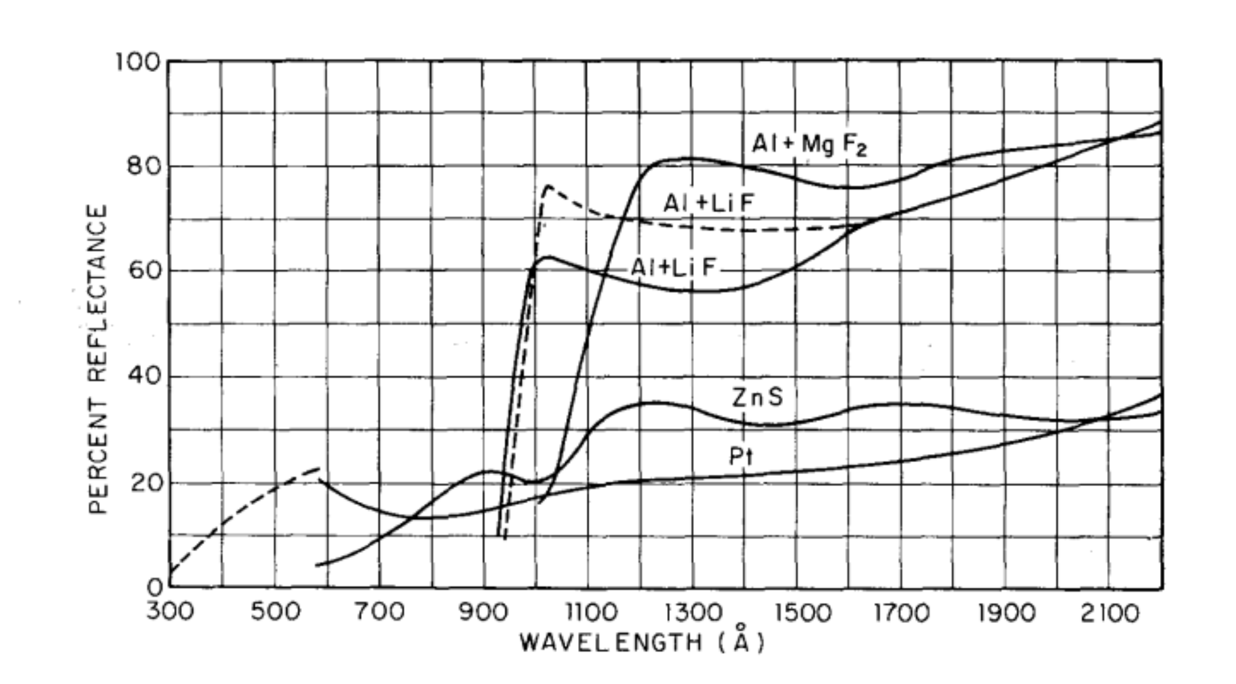
M2





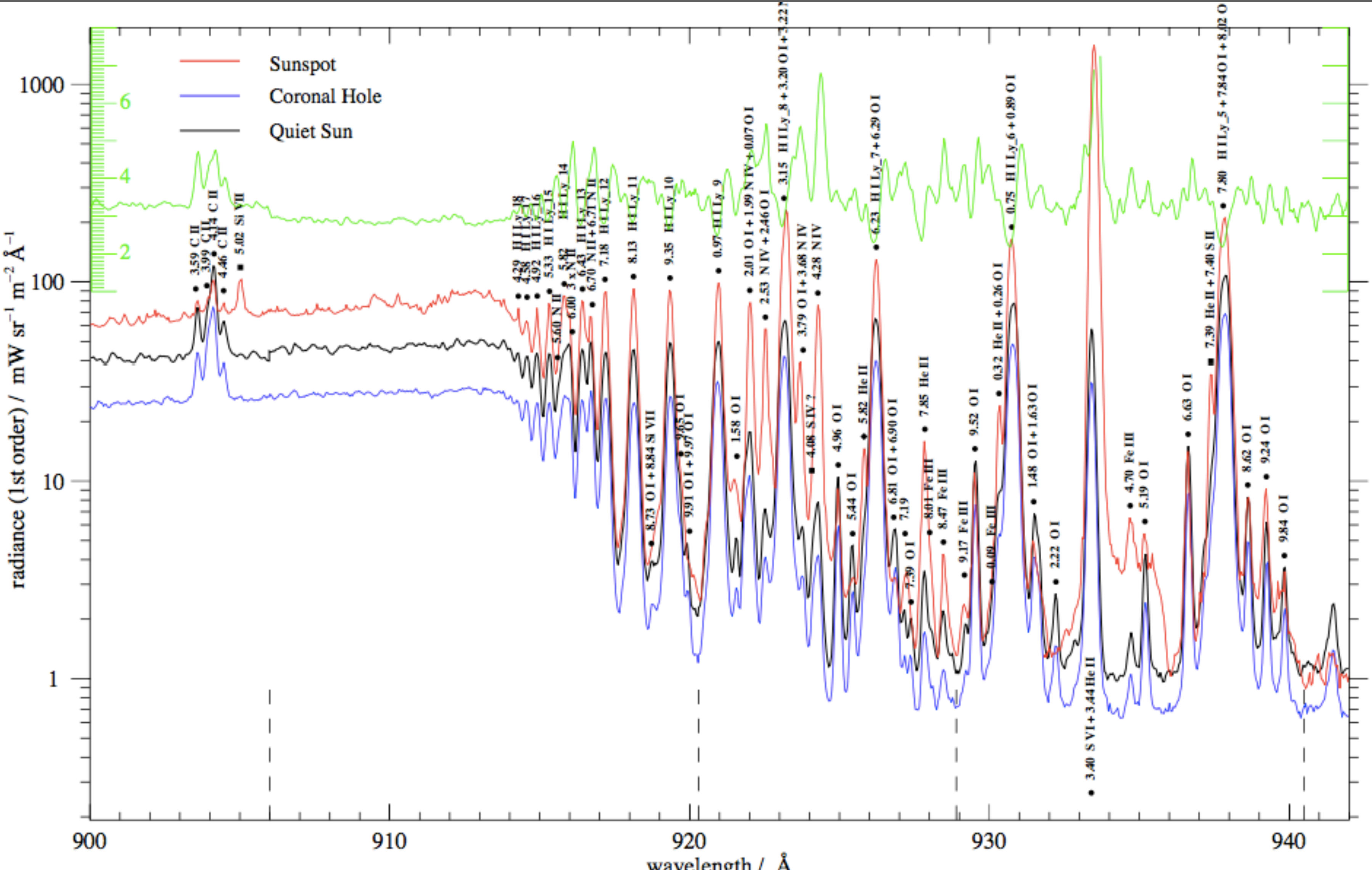
Uncoated substrate

Mirror coatings with protected Aluminium



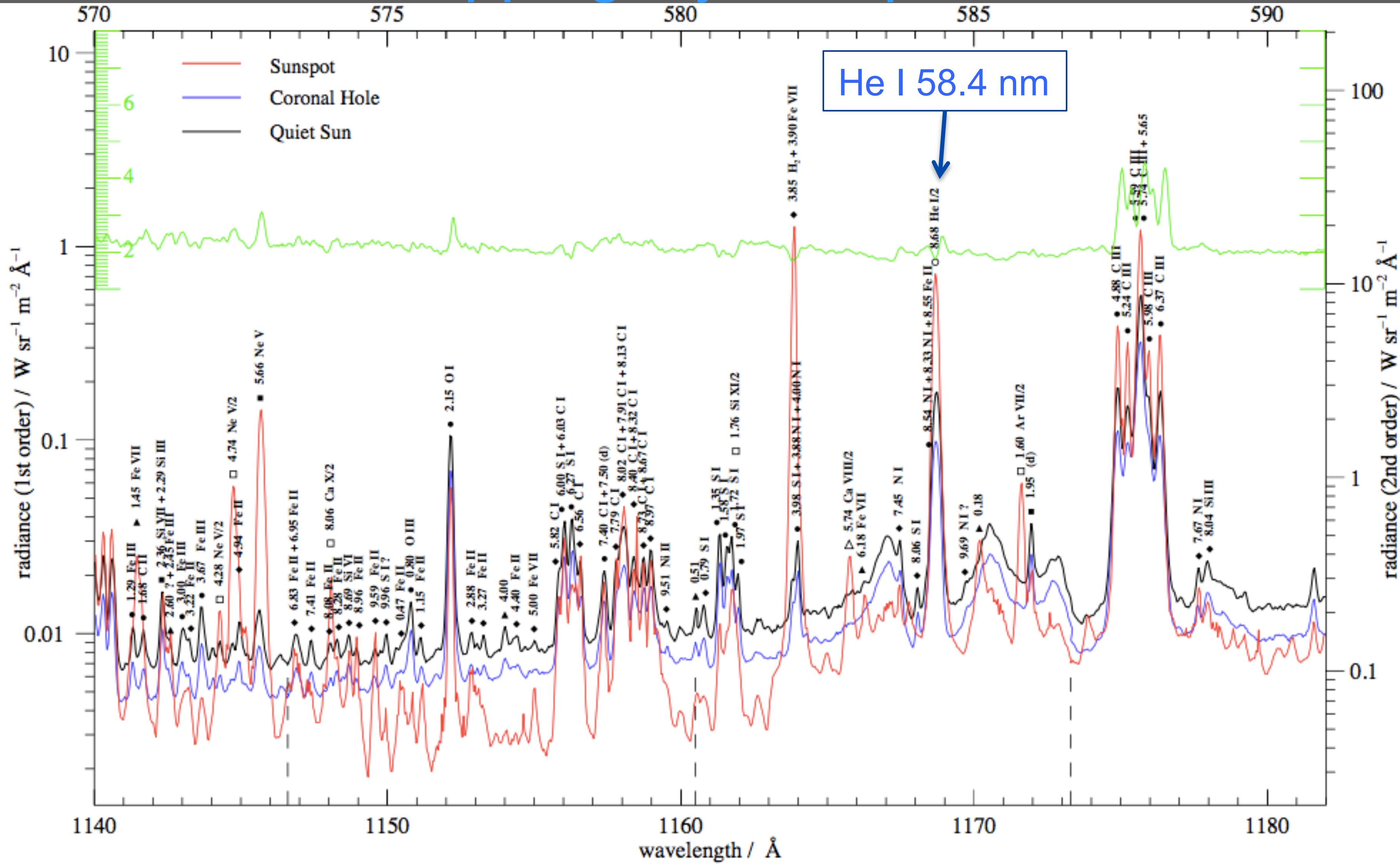
Our coatings with Al/AlF_3/LiF/MgF_2 were not stable under environmental test conditions.

Lines below 110 nm: coatings with SiC or B_4C capping layer required

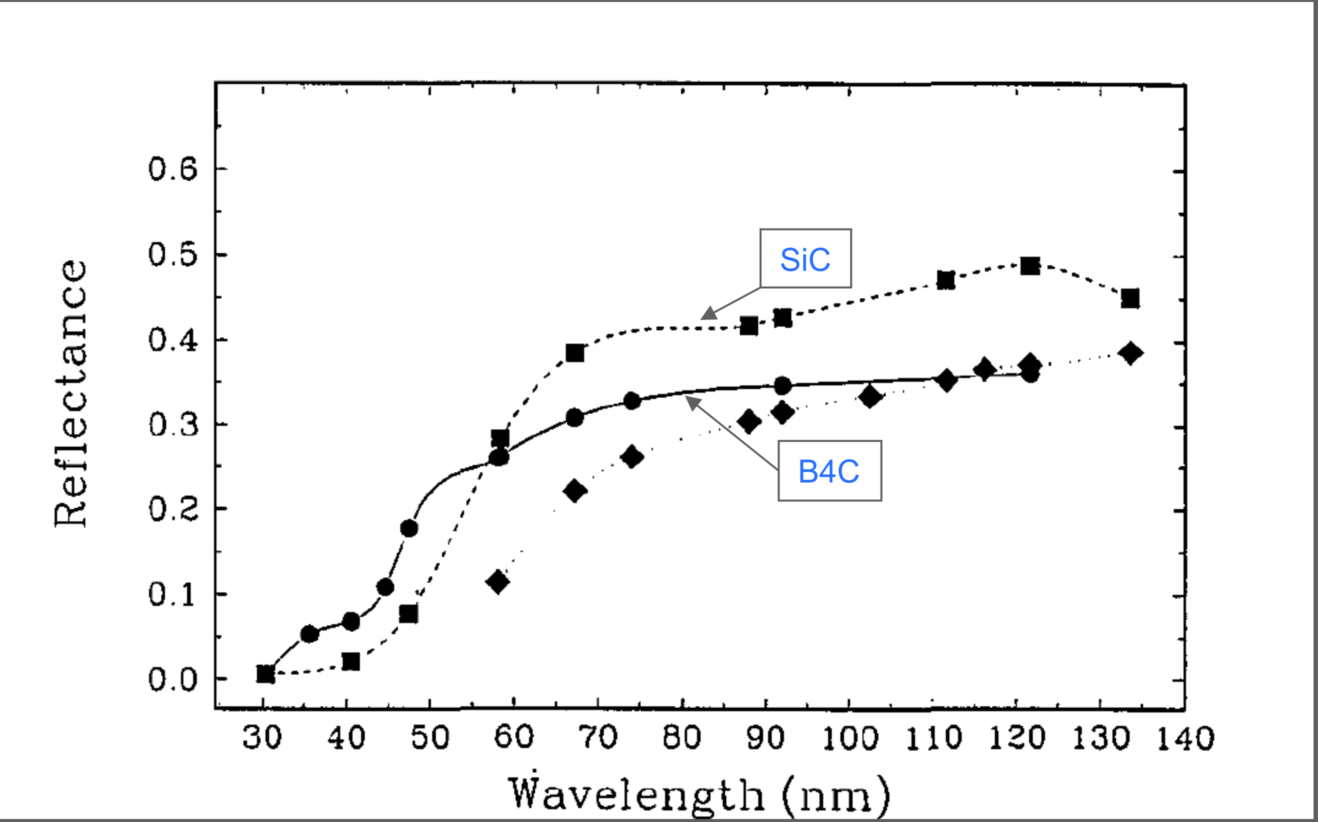


Lines below 110 nm: as short as 58.4 nm - coating with B_4C capping layer required

MAX-PLANCK-GESELLSCHAFT

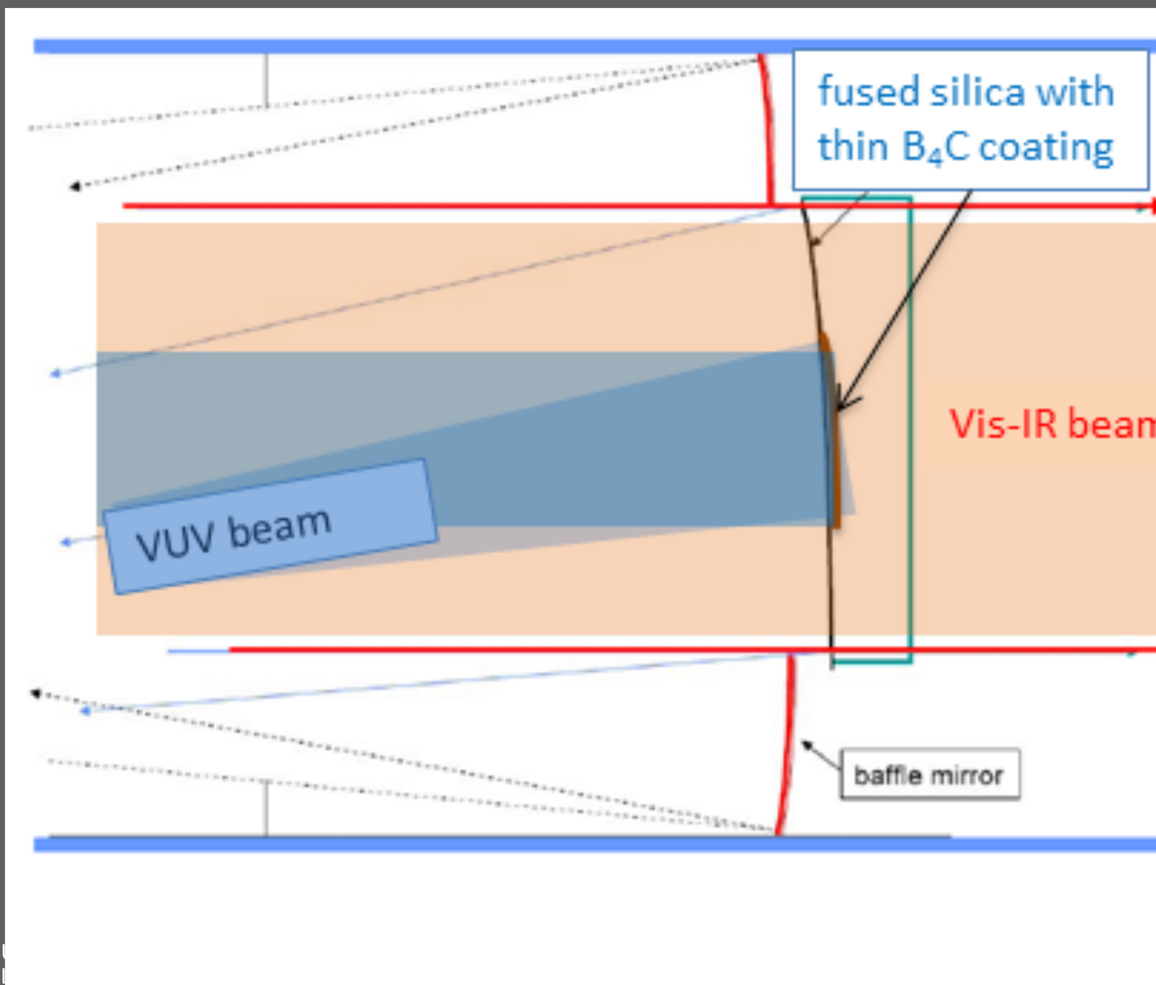


Below 110 nm: coatings with aluminium + SiC or B_4C capping layer



normal incidence reflectance coatings of silicon carbide and boron carbide for mirrors and gratings above 45 nm

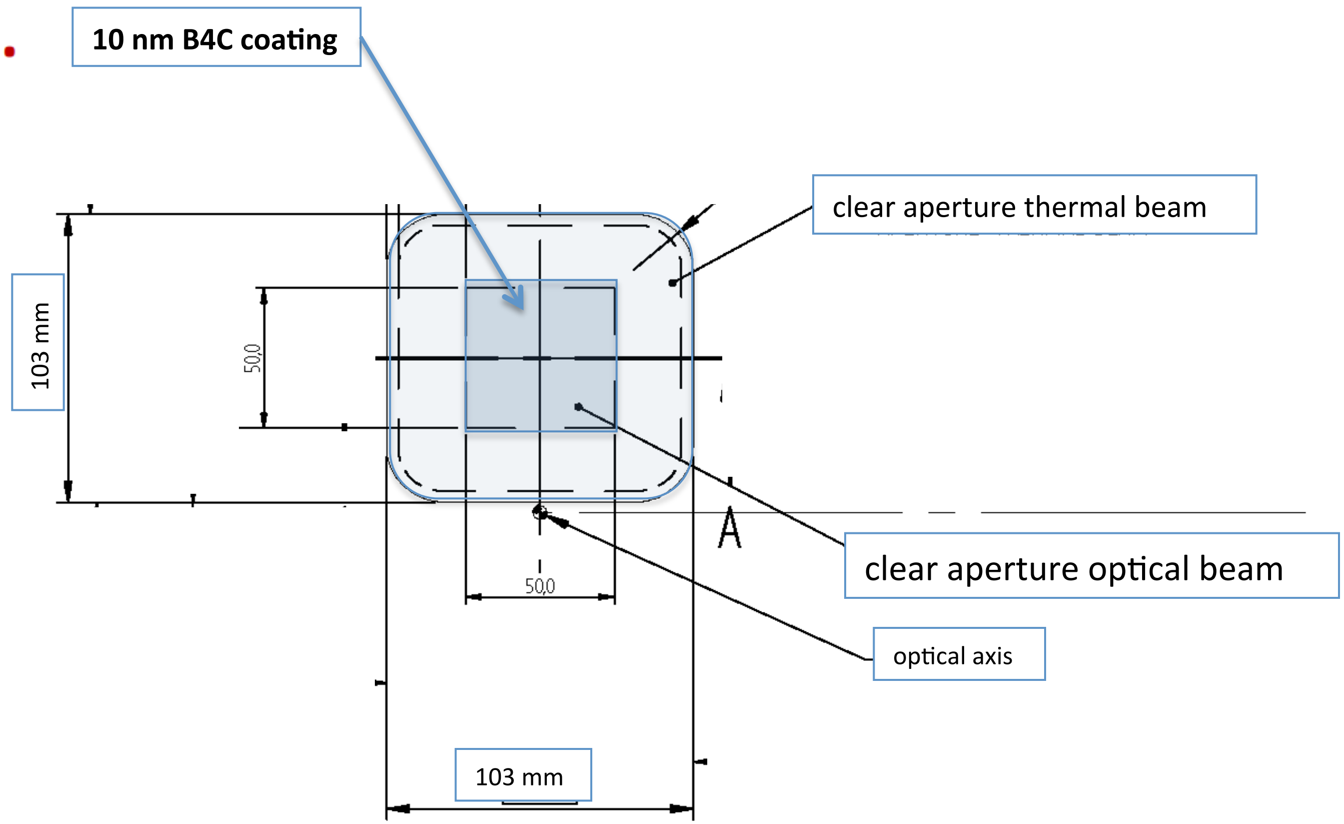
Primary mirror for SPICE (Solar Orbiter)



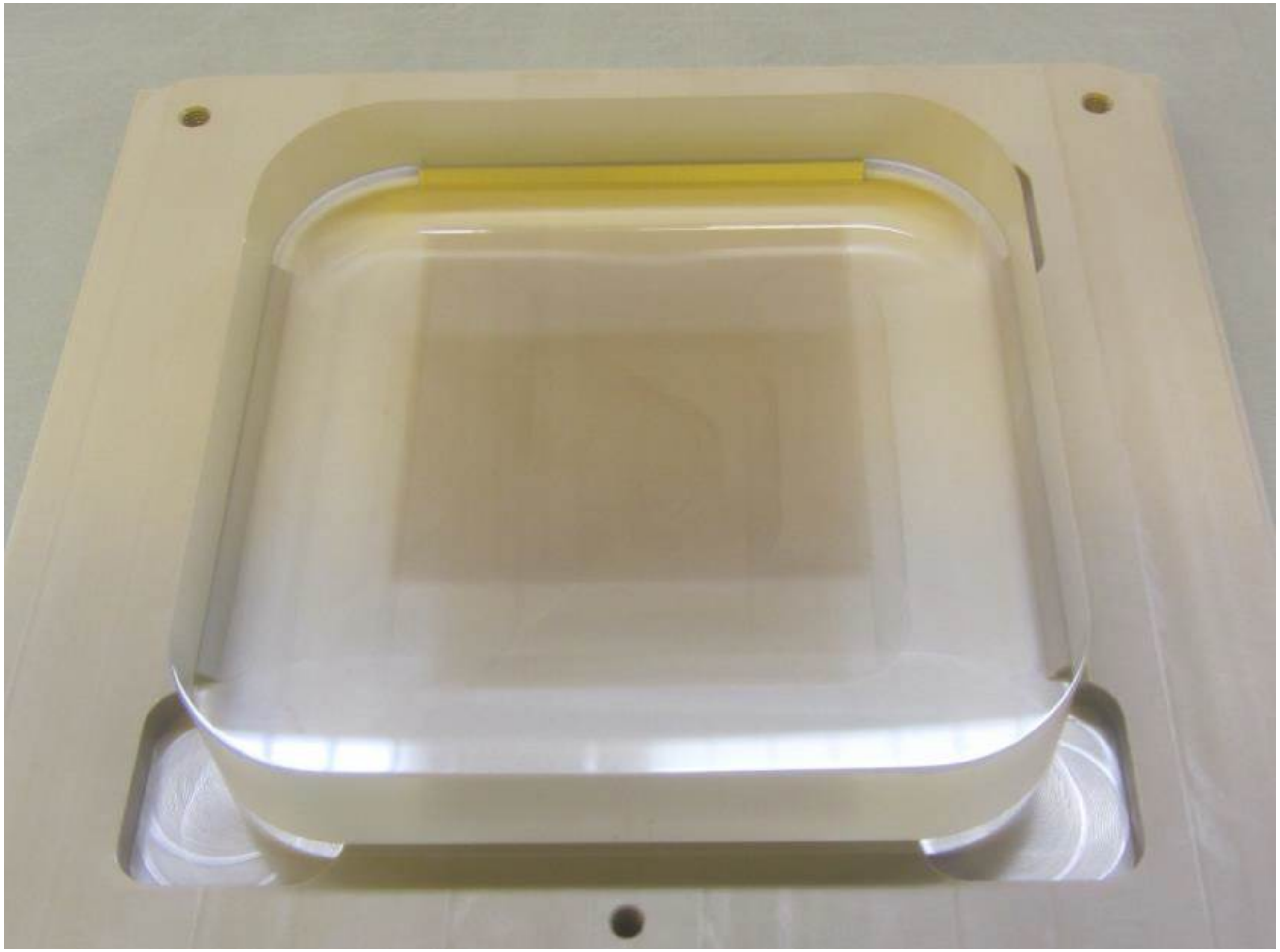
Dichroic mirror for VUV reflectance and VIS-IR transmission

Semi-transparent coating with boron carbide

optiX fab.

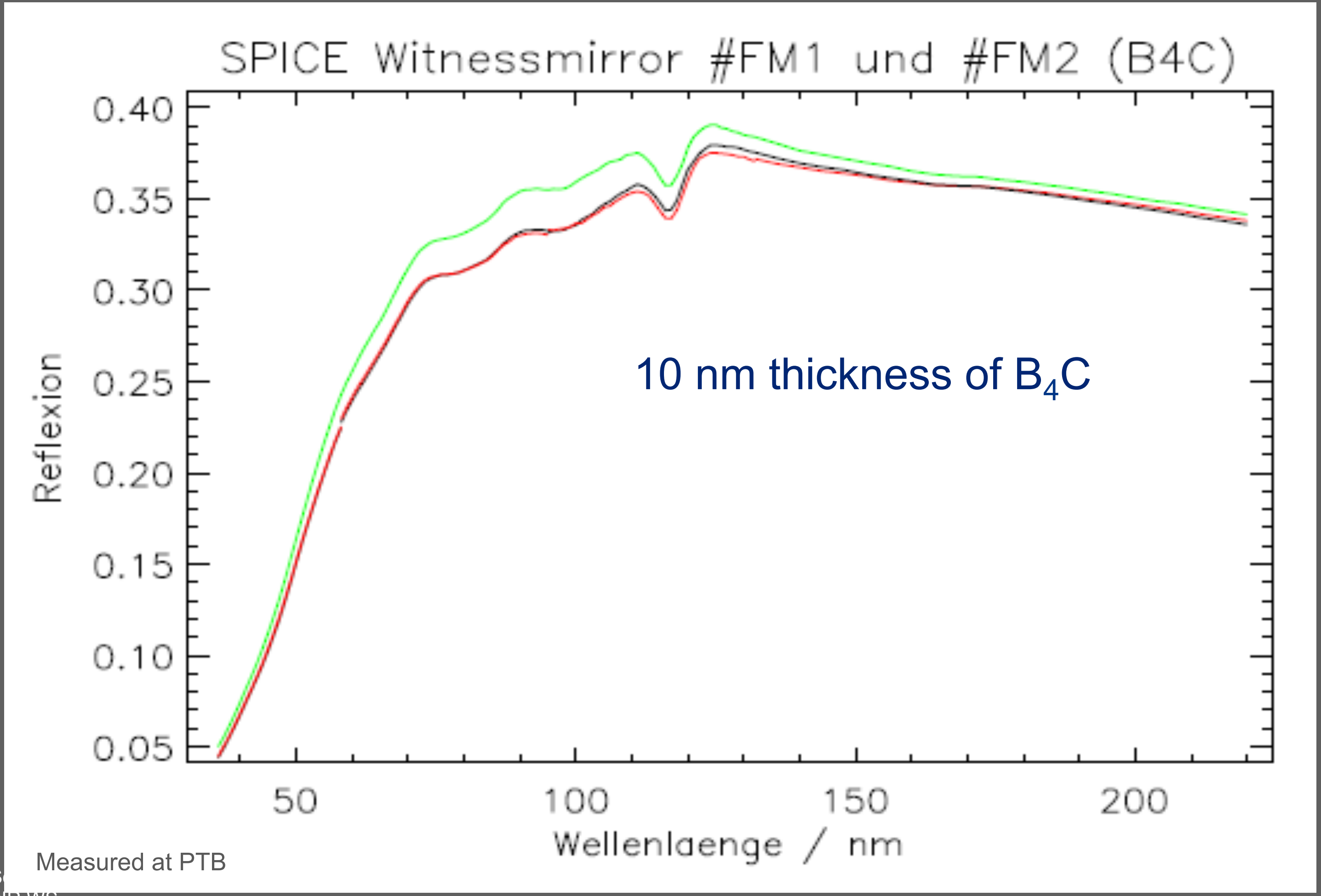


SPICE Primary Mirror design

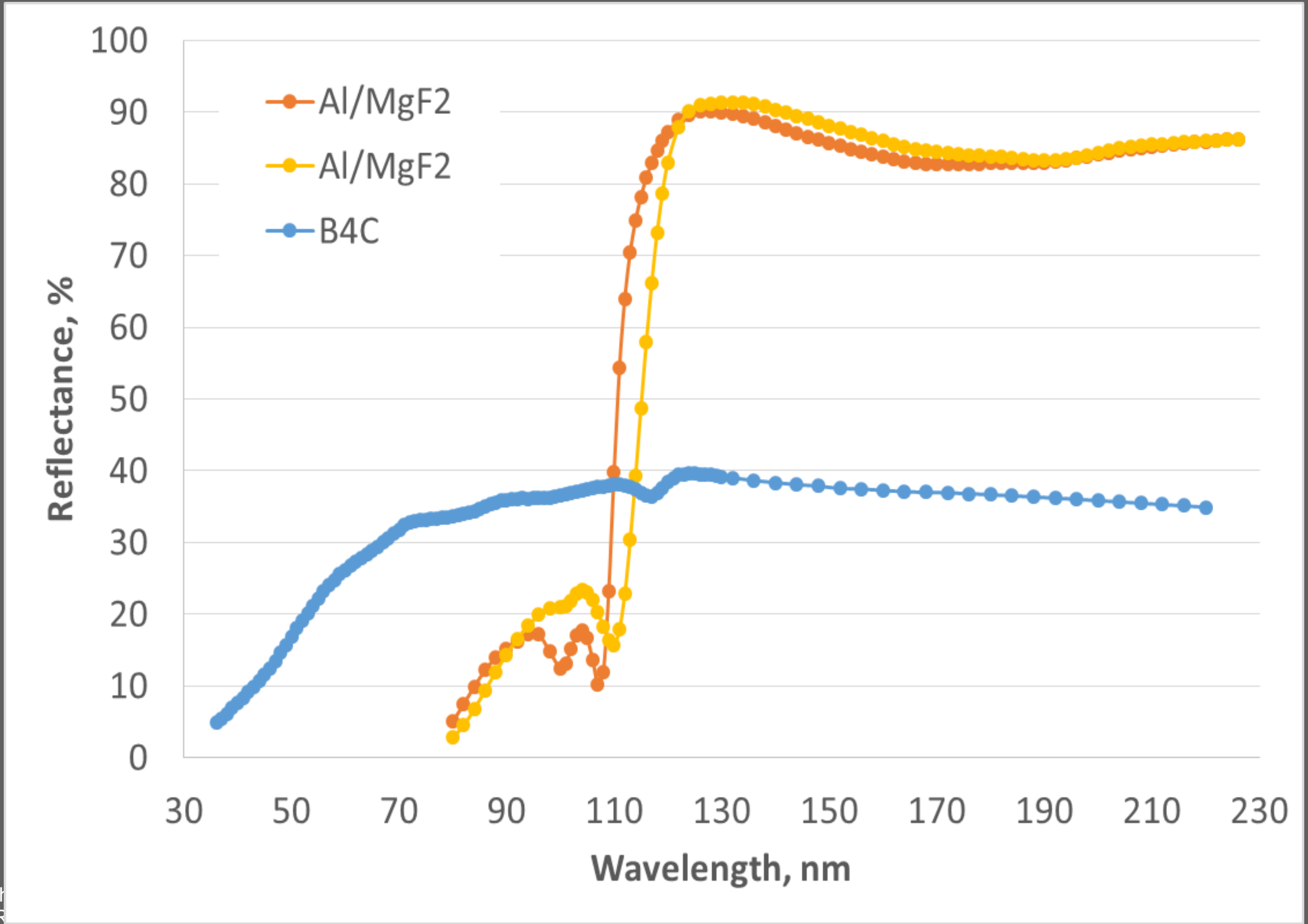


optiX fab.

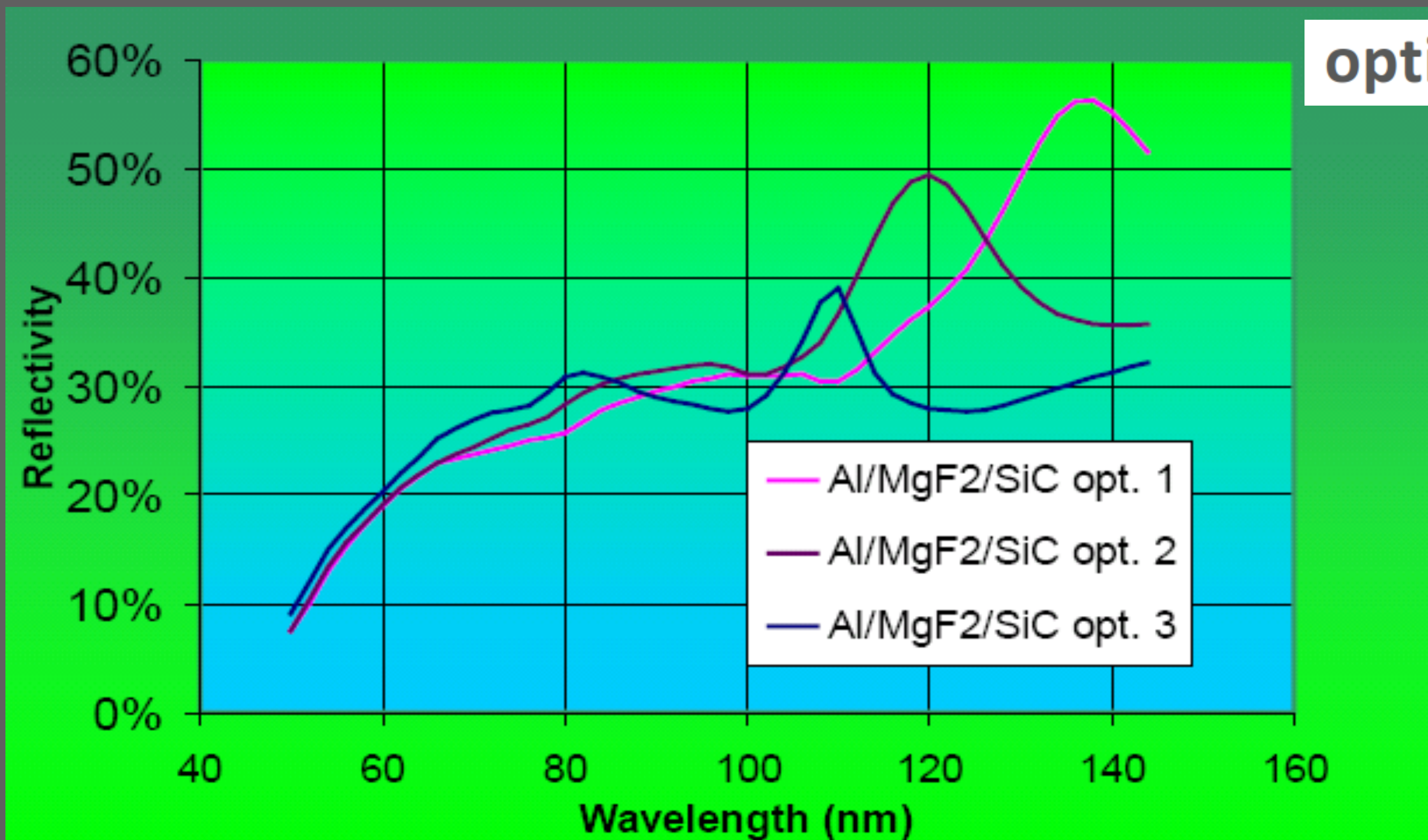
VUV reflectance of thin B_4C coating



Mirrors for 40 ... 230 nm



combination of Al/MgF_2 with SiC capping layer



optiX fab.

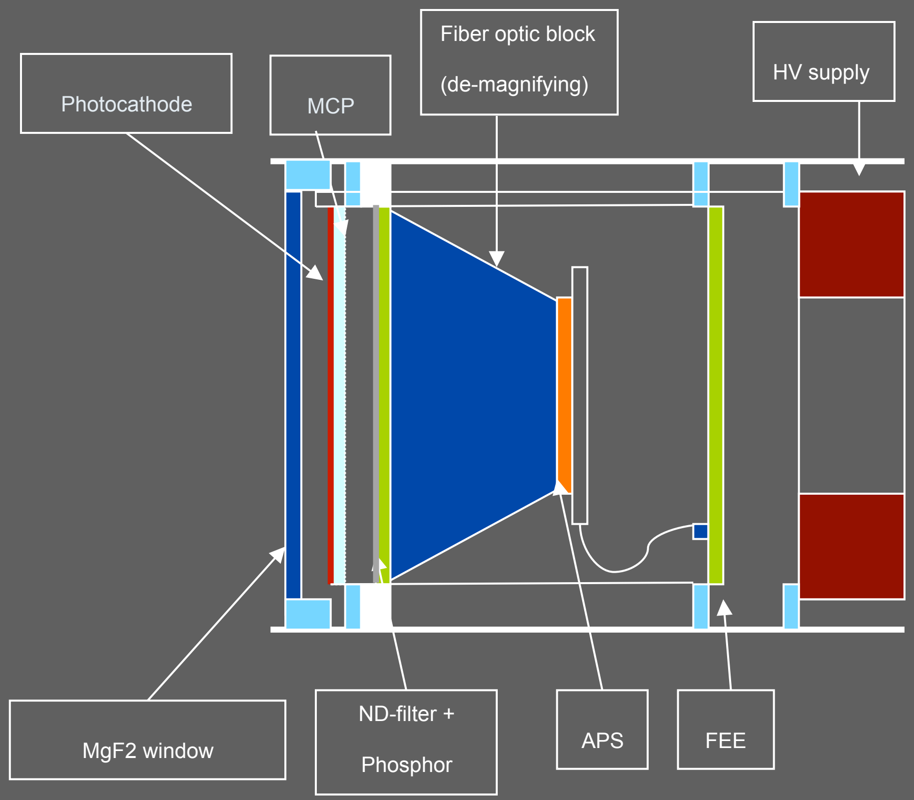
➔ Going below 110 nm comes at a high cost, needs strong scientific justification

Possible contribution to a UV Spectropolarimeter by Max Planck Institute for Solar System Research:

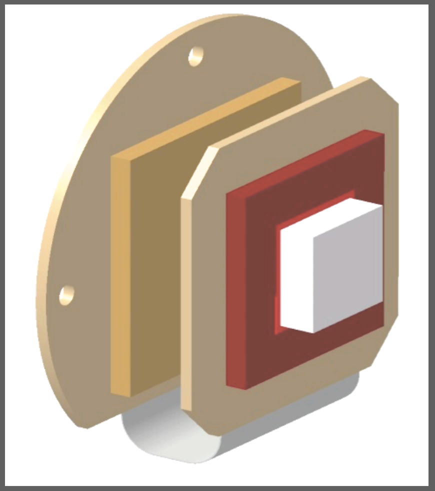
- VUV mirrors and coatings
- MCP detectors down to 90 nm
- Cameras (incl. electronics)
- Mechanisms

VUV MCP Detectors

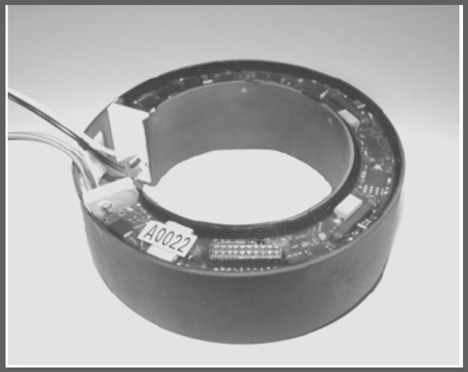
Solar-blind intensified APS detector



APS sensor array on PCB

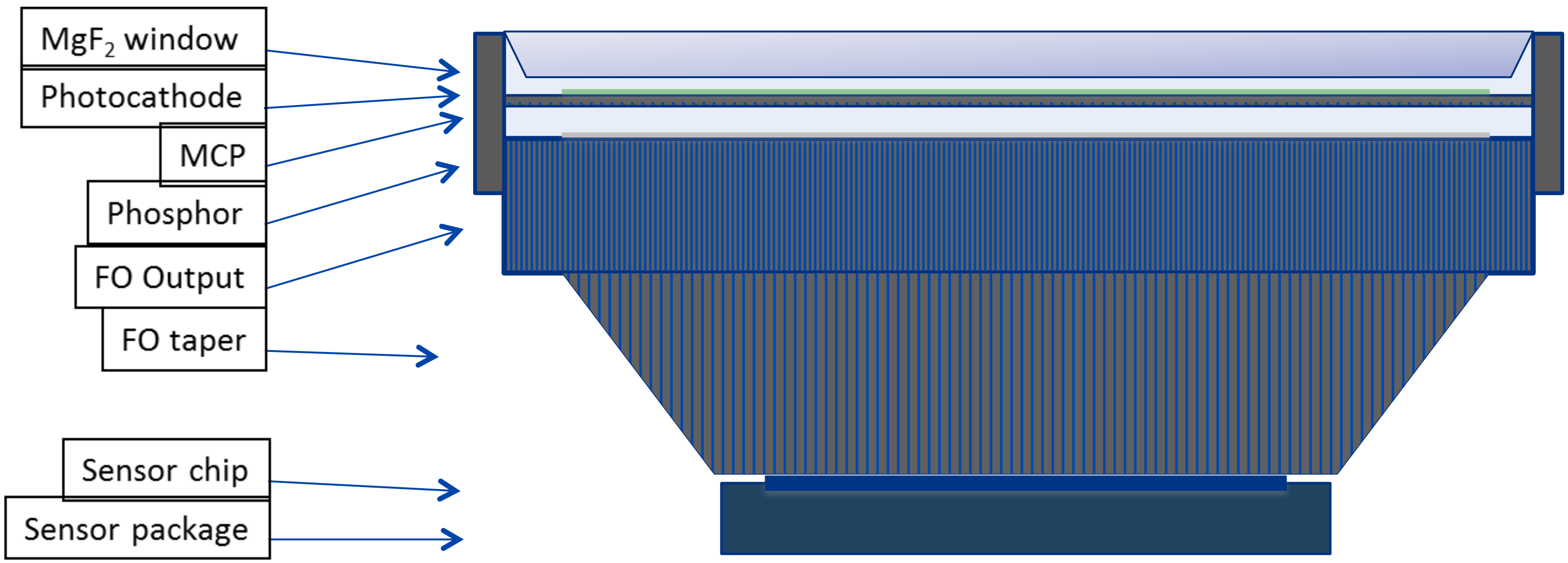


HV power supply

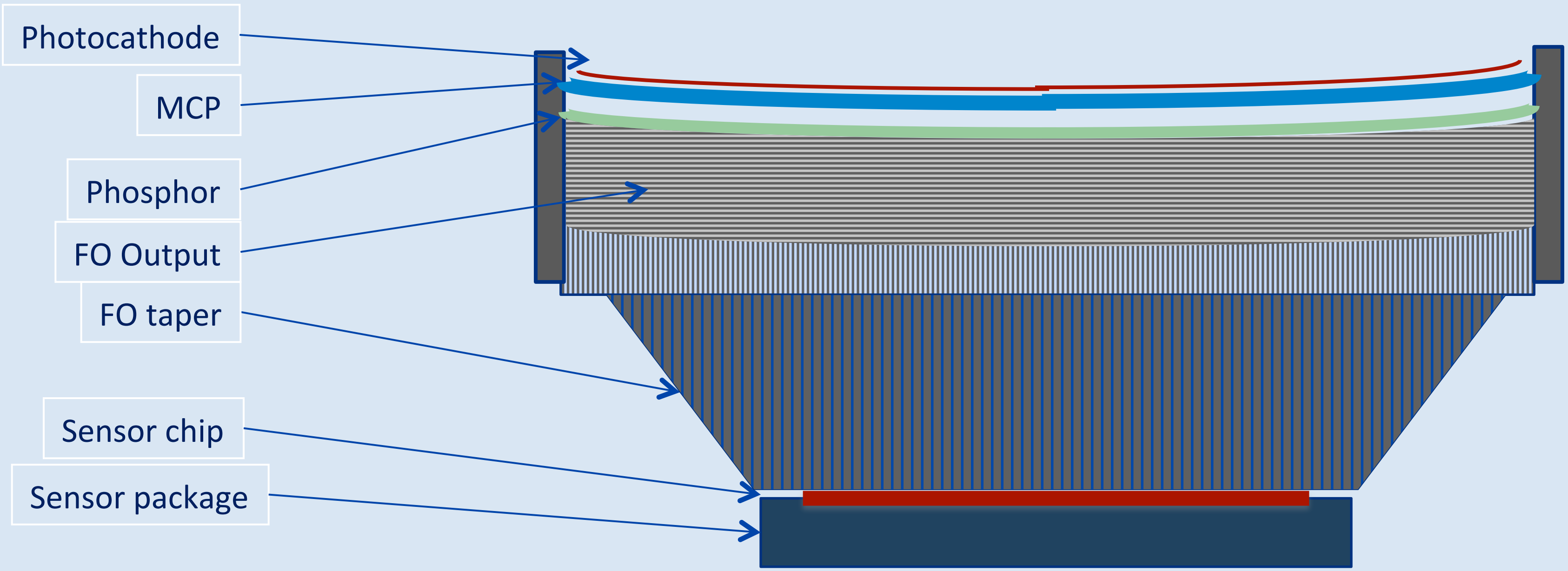


Udo Schühle
LUVOIR WS
11.-12. 01. 2017

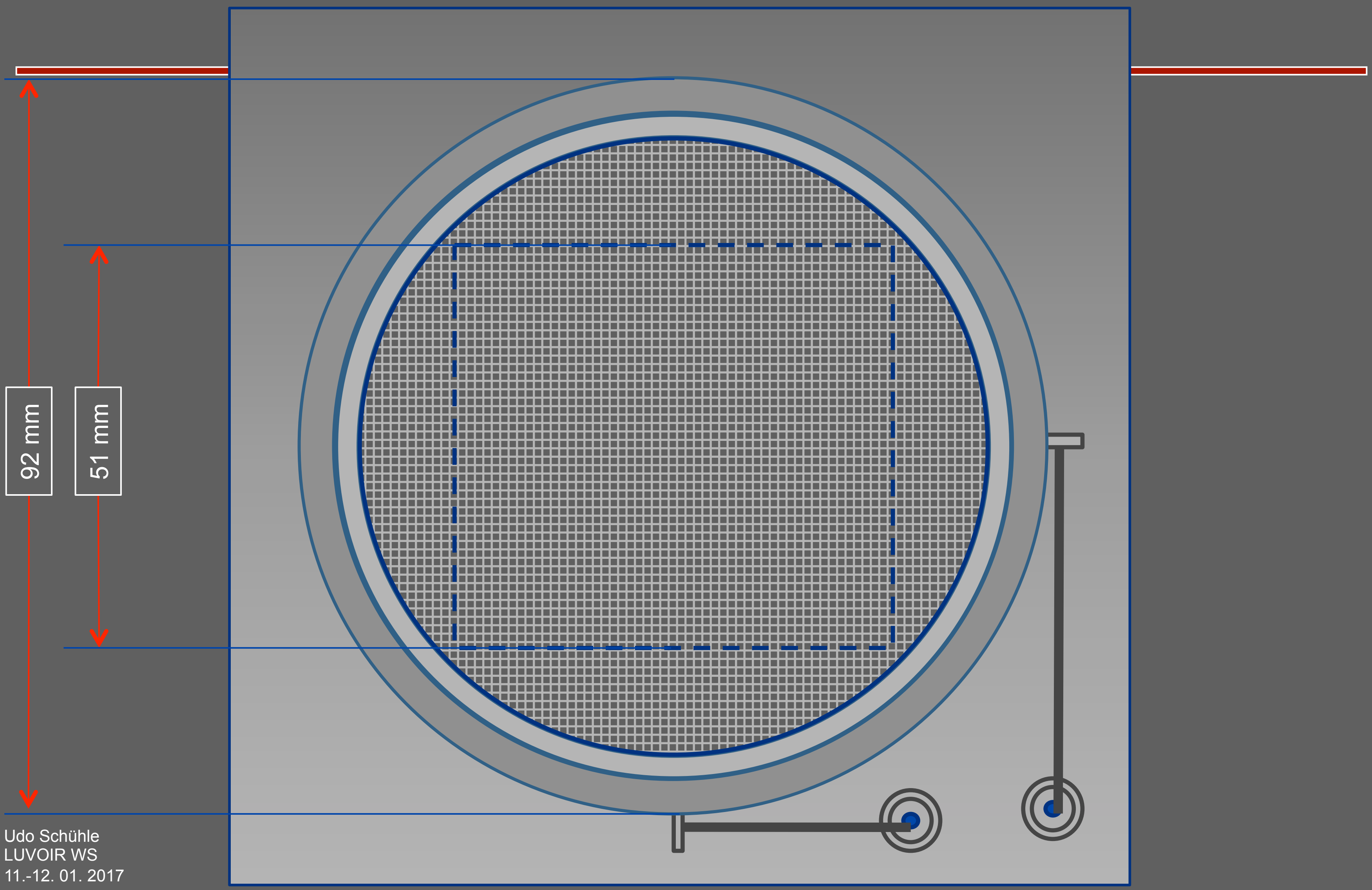
Intensifier general Design



Open-face MCP Intensifier



Detector with circular MCP

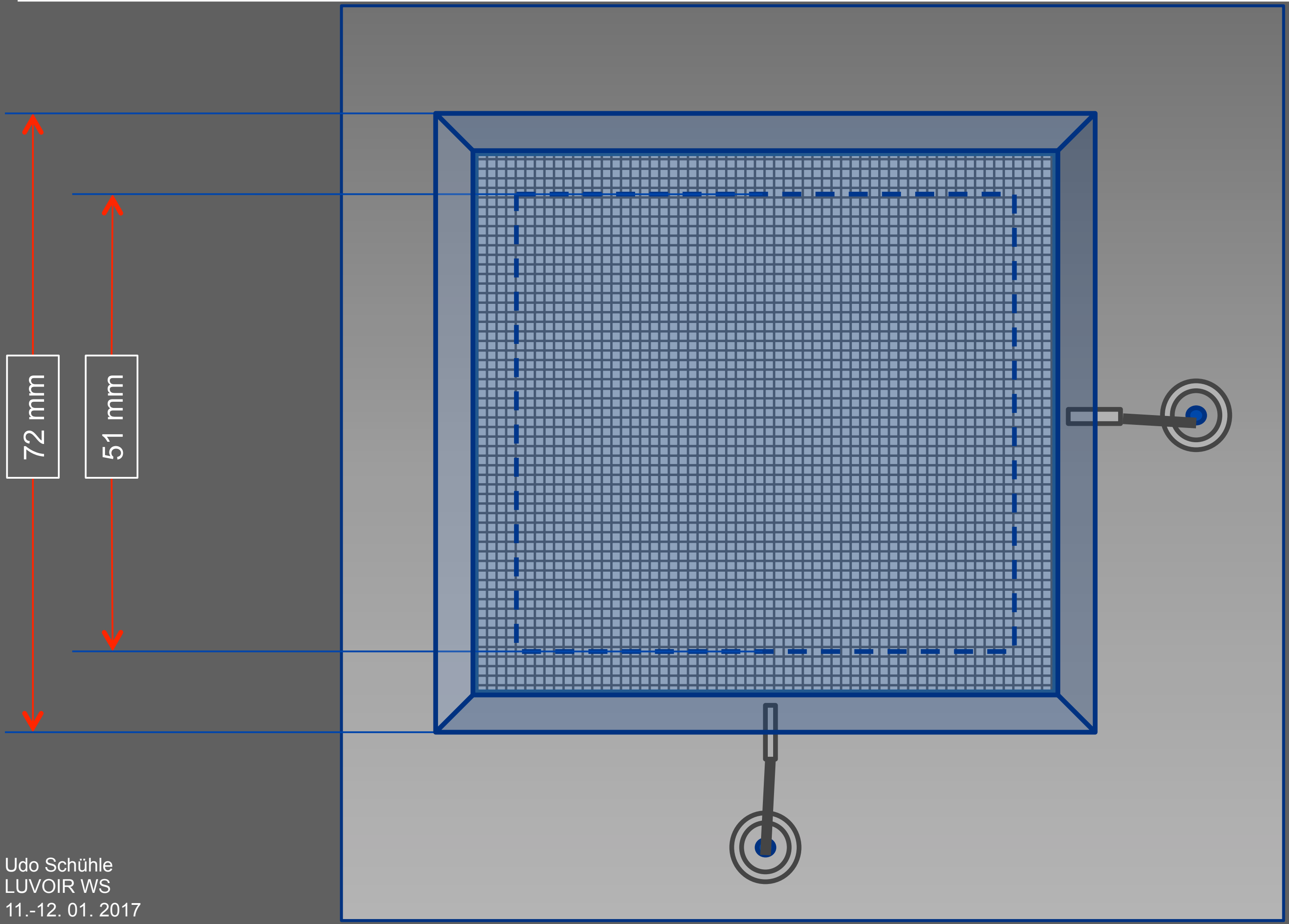


MCP specifications

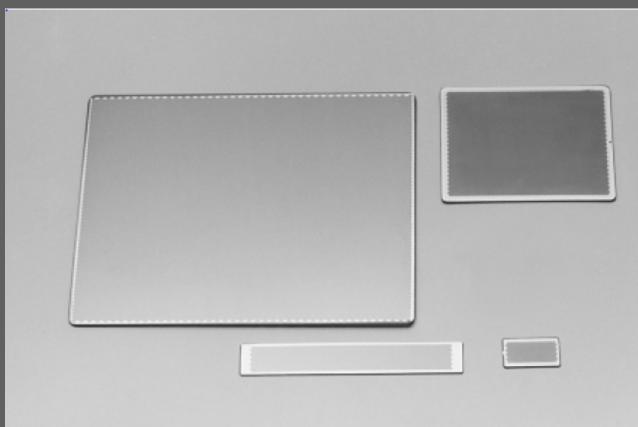
Custom made high-resolution MCP with concave toroidal curvature

- size: > 75 mm diameter
- quality diameter: >72 mm
- active area: 51 mm x 51 mm
- pore size: <10 microns
- large bias angle
- photocathode: CsI and CsTe coating

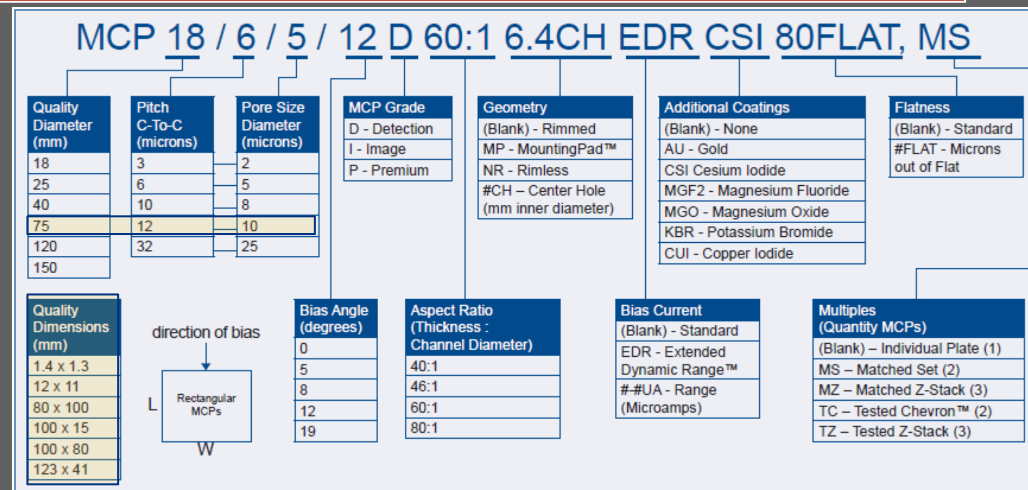
Detector with square MCP



Standard size MCPs

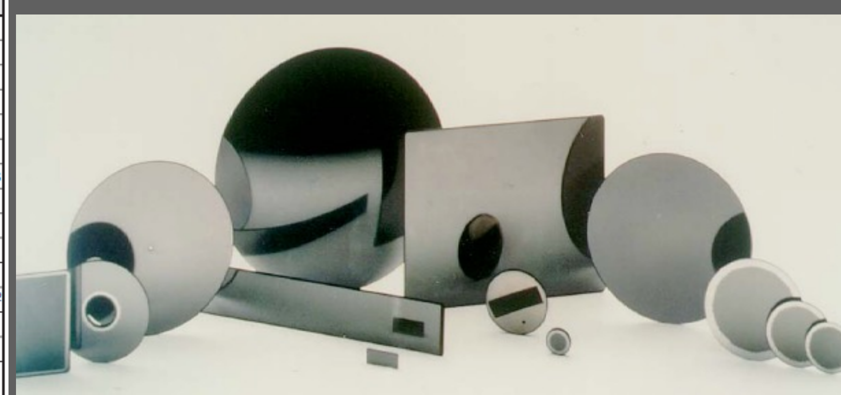


Hamamatsu rectangular standard size MCPs

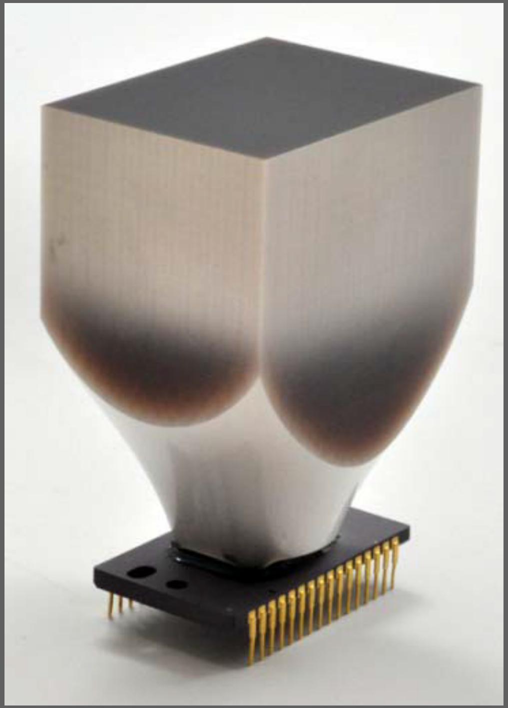


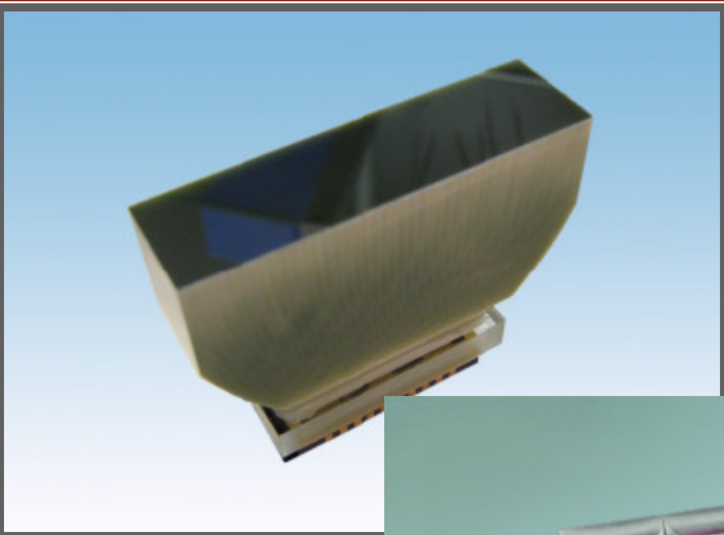
Photonis rectangular standard size MCPs

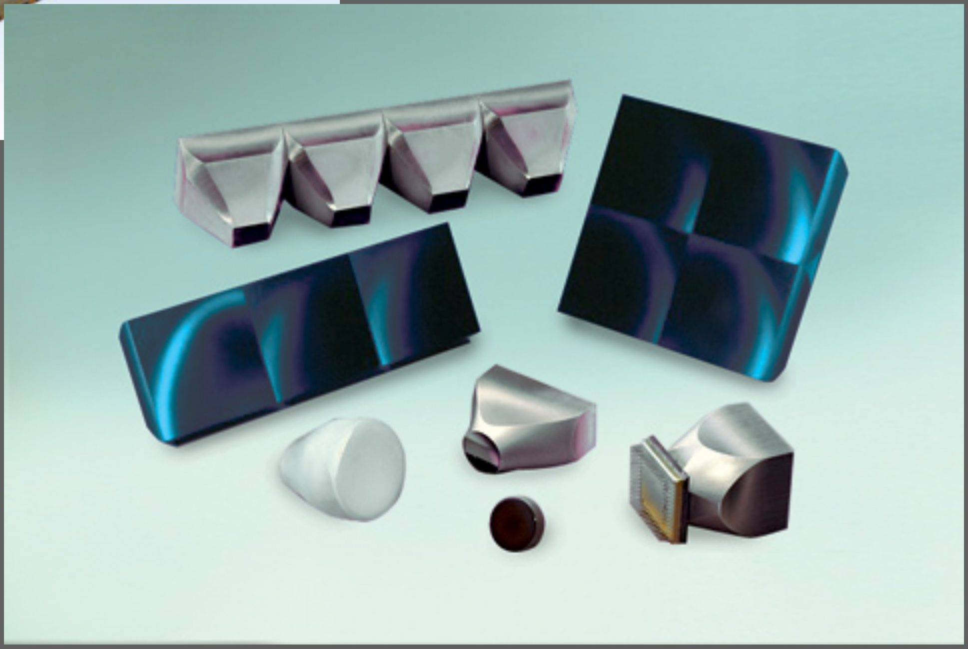
Parameter \ Type	F2370-01	F4772-01	F2806-01	F1943-02	F2805-03	F2396-04	Unit
Outer Size A×A'	15.9×9.4	61.9×13.9	49.9×39.9	87.9×37.9	59.9×59.9	96.9×78.9	mm
Electrode Size B×B'	15×8.5	61×13	49×39	87×37	58×58	95.6×77.3	mm
Effective Area C×C'	13×6.5	55×8	45×35	81×31	53×53	90×72	mm
Thickness D	0.48			0.60	0.80	1.00	mm
Channel Diameter	12			15	20	25	µm
Channel Pitch	15			19	25	31	µm
Bias Angle θ	8						degrees
Open Area Ratio	60						%
Electrode Material	Inconel						—
Gain (Min.) ③	10^4						—
Resistance ③	100 to 500	20 to 200			20 to 120	10 to 50	MΩ
Dark Current (Max.) ③	0.5						pA·cm^{-2}
Maximum Linear Output ③	7 % of Strip Current ②						—
Supply Voltage ④	1.0						kV
Operating Ambient Temperature ④	-50 to +70						°C



Fiber optic coupling





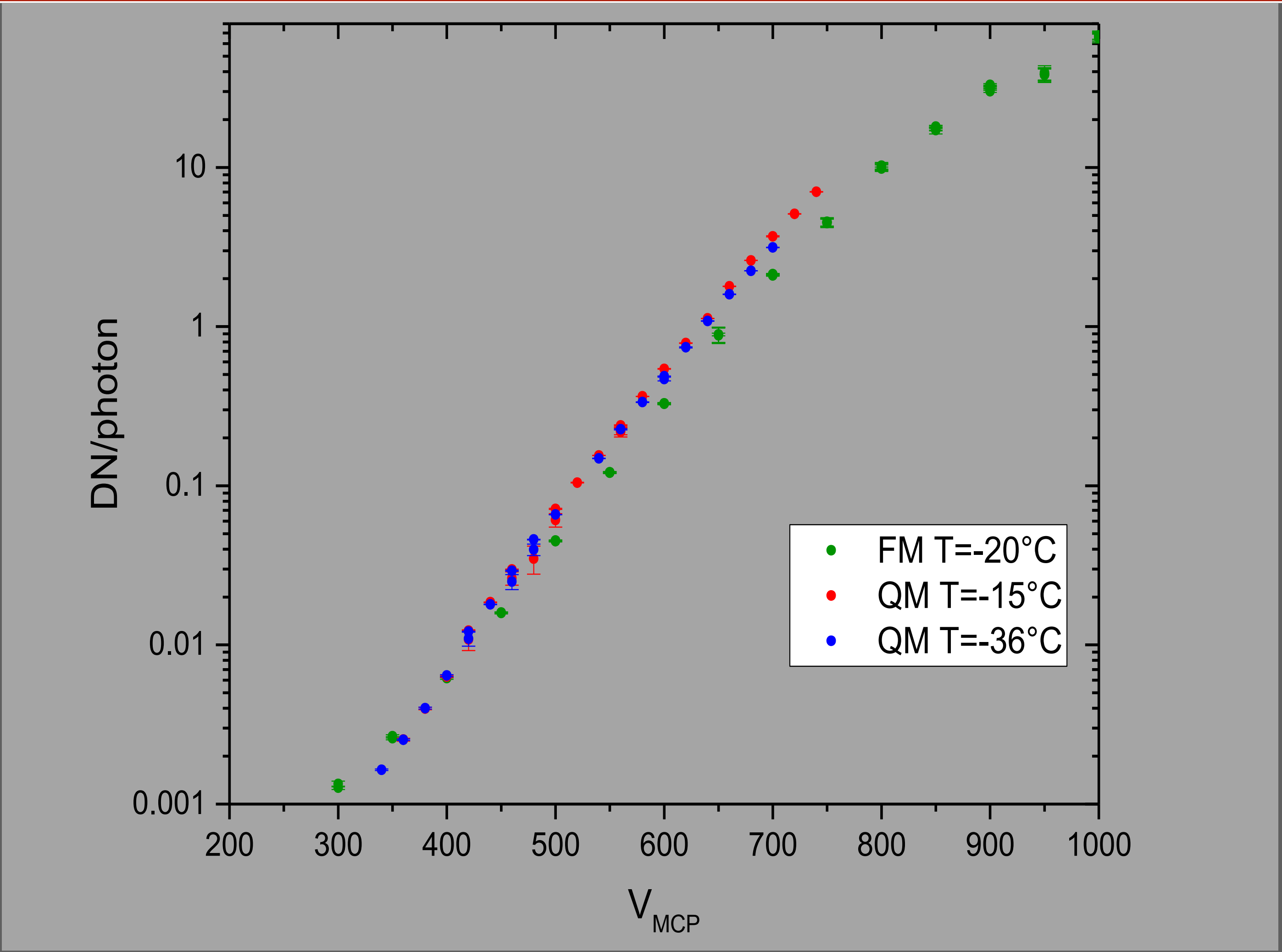


reduction of image size
in large possible ranges

Benefits of CMOS-APS sensor

- Shutterless operations
  - No charge transfer (under illumination)
- Radiation hardness
  - No charge transfer (of small signals)
- Ease of interfacing with ADC and other digital devices
  - Digital power supply (e.g. 3.3V), possibility of on-chip ADC & memory
- Fast readout and windowing
- Low electrical power consumption
- No blooming

MCP gain adjustable



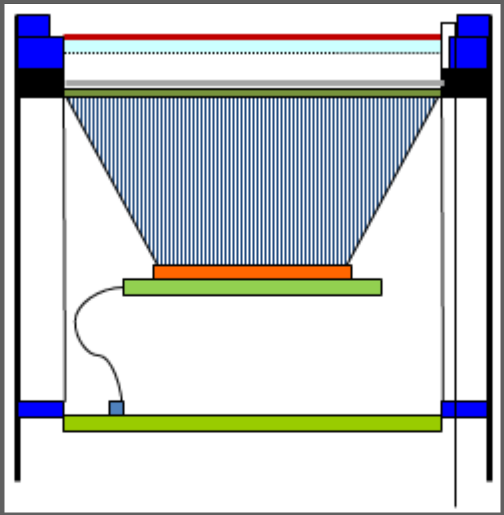
Concerns about UV-CCD without intensifier

- visible sensitivity – if a filter is needed, the sensitivity advantage is lost!
- back-side thinning is not a simple process, may affect the performance, price of chip development is high
- contamination sensitivity: vacuum enclosure is needed with thermal isolation (custom design and very heavy).
- radiation hardness: CTE degradation limits lifetime or heavy shielding required.

Advantages of I-APS

PROS:

– most flexible in terms of focal plane size:
  adjustable by fiber optic taper
– most flexible dynamic range: may be adjusted in several ways:
  • photocathode selection for spectral ranges
  • adjustable gain by HV
  • selectable attenuation of phosphor by ND-filter
– visible light rejection (saves a filter!)
– no shutter mechanism needed
– high responsivity in full VUV and EUV range
– no image distortion due to analog anode
– no “burn-in” (gain variation) with single MCP at low gain
– resolution of 20 micron pixels can be easily resolved



CONS:

– fragile multi-channel plates
– adjustable high voltage needed, up to 10 kV
– sensitive photocathode and MCP (requires low-humidity handling)
– initial burn-in of open MCP is necessary

Space heritage of open MCP detectors

Detectors on SOHO:

- 2 windowless VUV detectors for SUMER spectrograph

  with KBr photocathode, Z-stack MCP, XDL anode
- 2 windowless VUV detectors for UVCS spectrograph

  with KBr photocathode, Z-stack MCP, XDL anode
- 2 windowless VUV detectors for CDS spectrograph

  with Chevron MCP and CCD

Detector on FUSE:

- 2 windowless FUV detectors

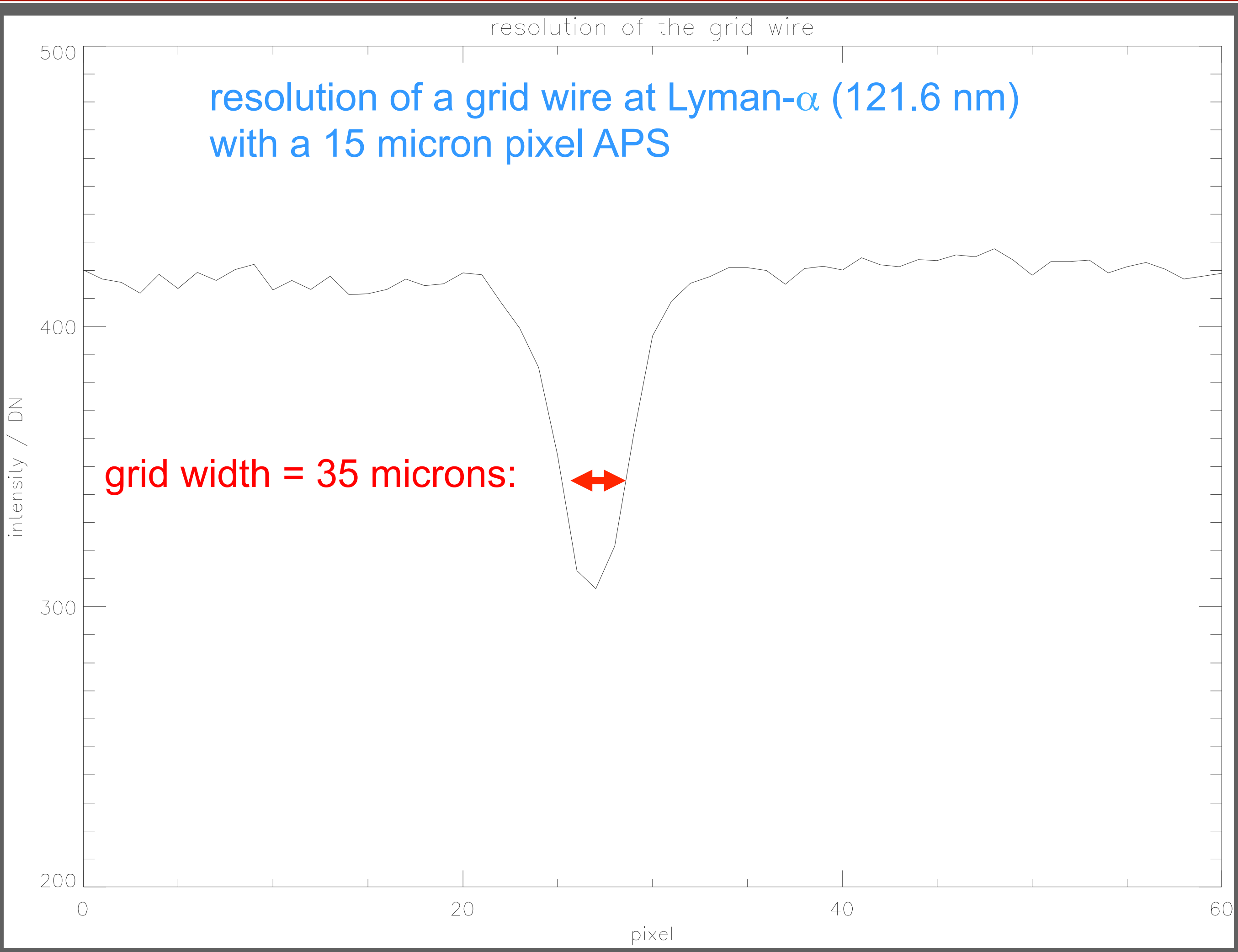
  with KBr photocathode, Z-stack MCP, DDL anode

Detector on HST:

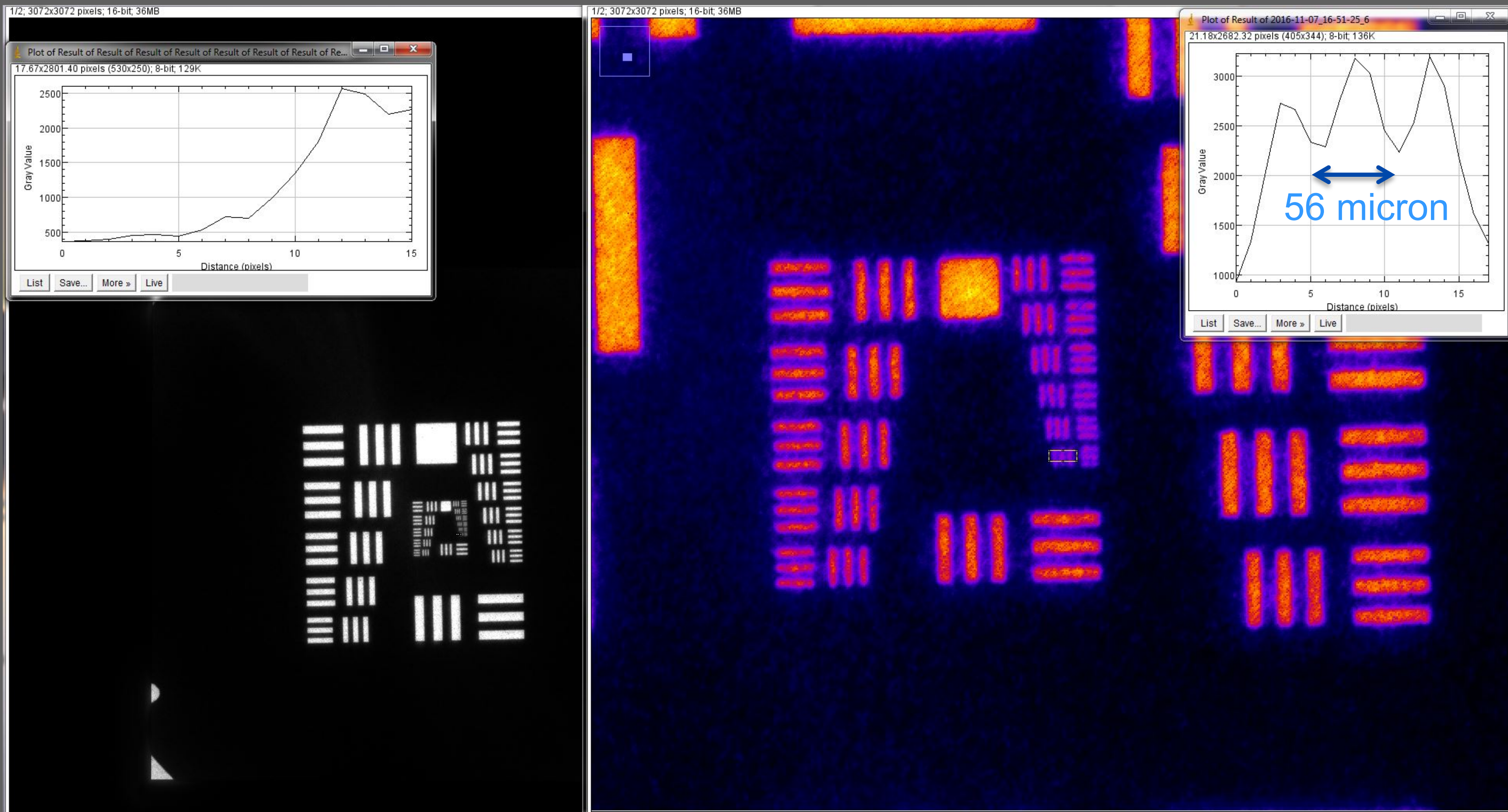
- 1 windowless FUV detector for COS

  with CsI photocathode, XDL anode

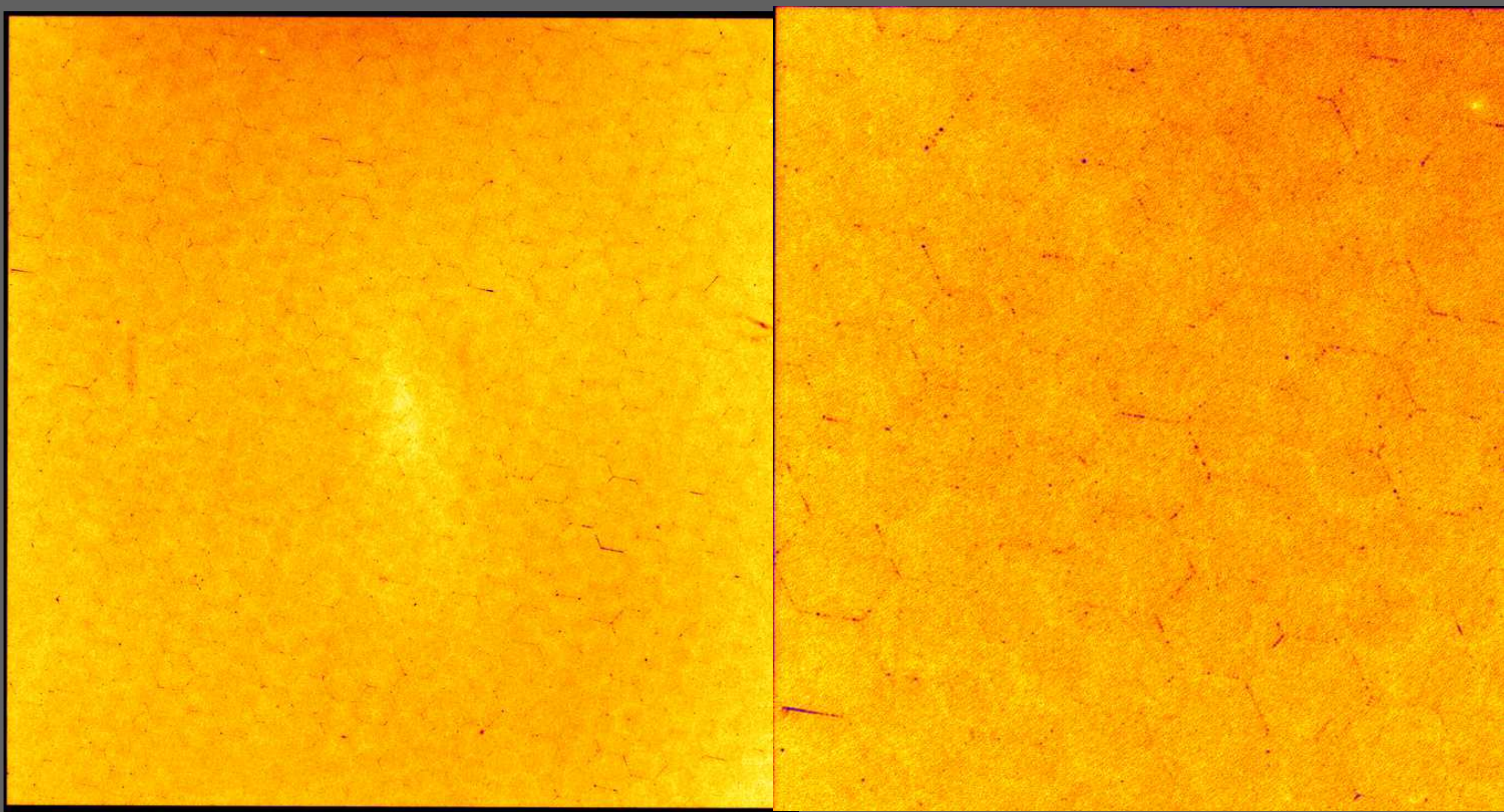
Resolution of single-MCP 10 μm pores intensifier with 15 μm APS



Resolution of single-MCP 10 μm pores intensifier with 10 μm APS



Resolution of single-MCP 10 μm pores intensifier with 10 μm APS



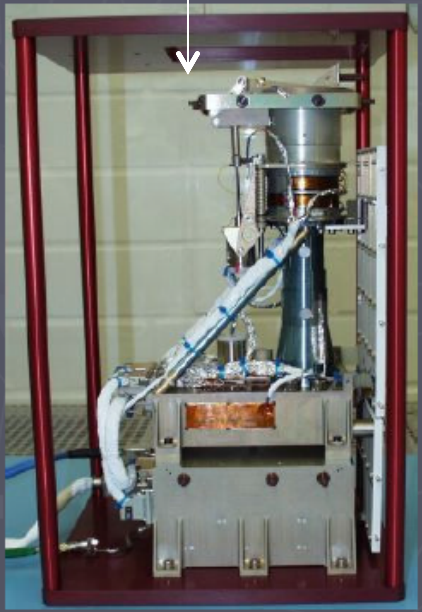
Possible contribution to the UV Spectropolarimeter by Max Planck Institute for Solar System Research:

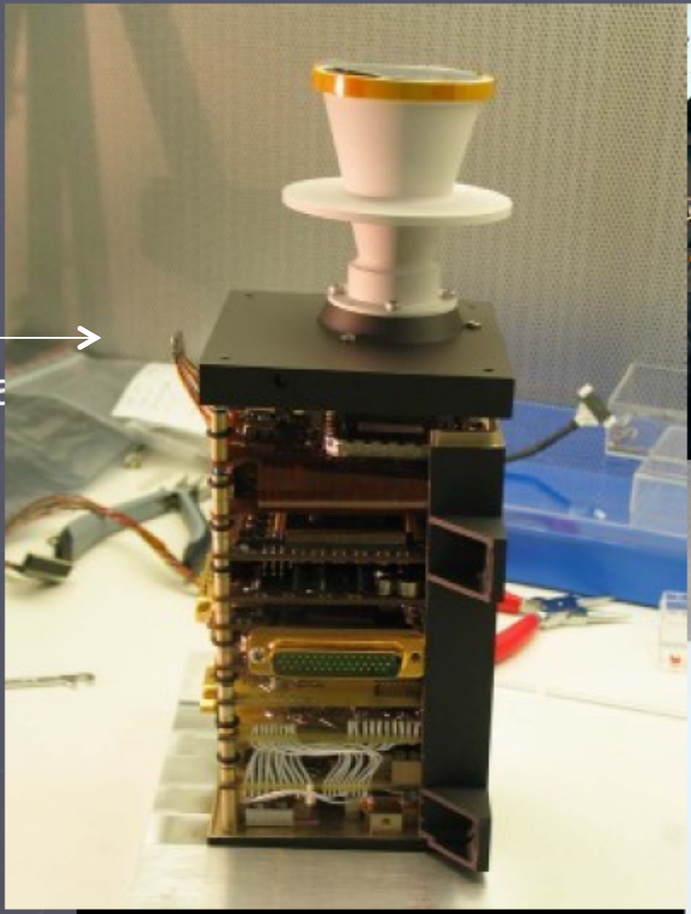
- VUV mirrors and coatings
- MCP detectors
- Cameras (incl. electronics)
- Mechanisms

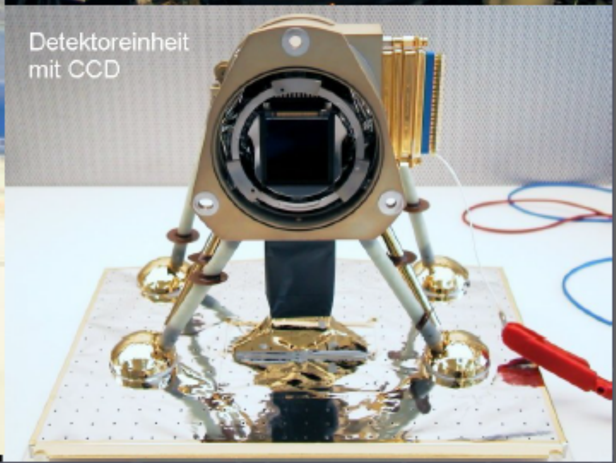
Imaging detectors for various space missions

Cameras for planetary missions built at MPS:

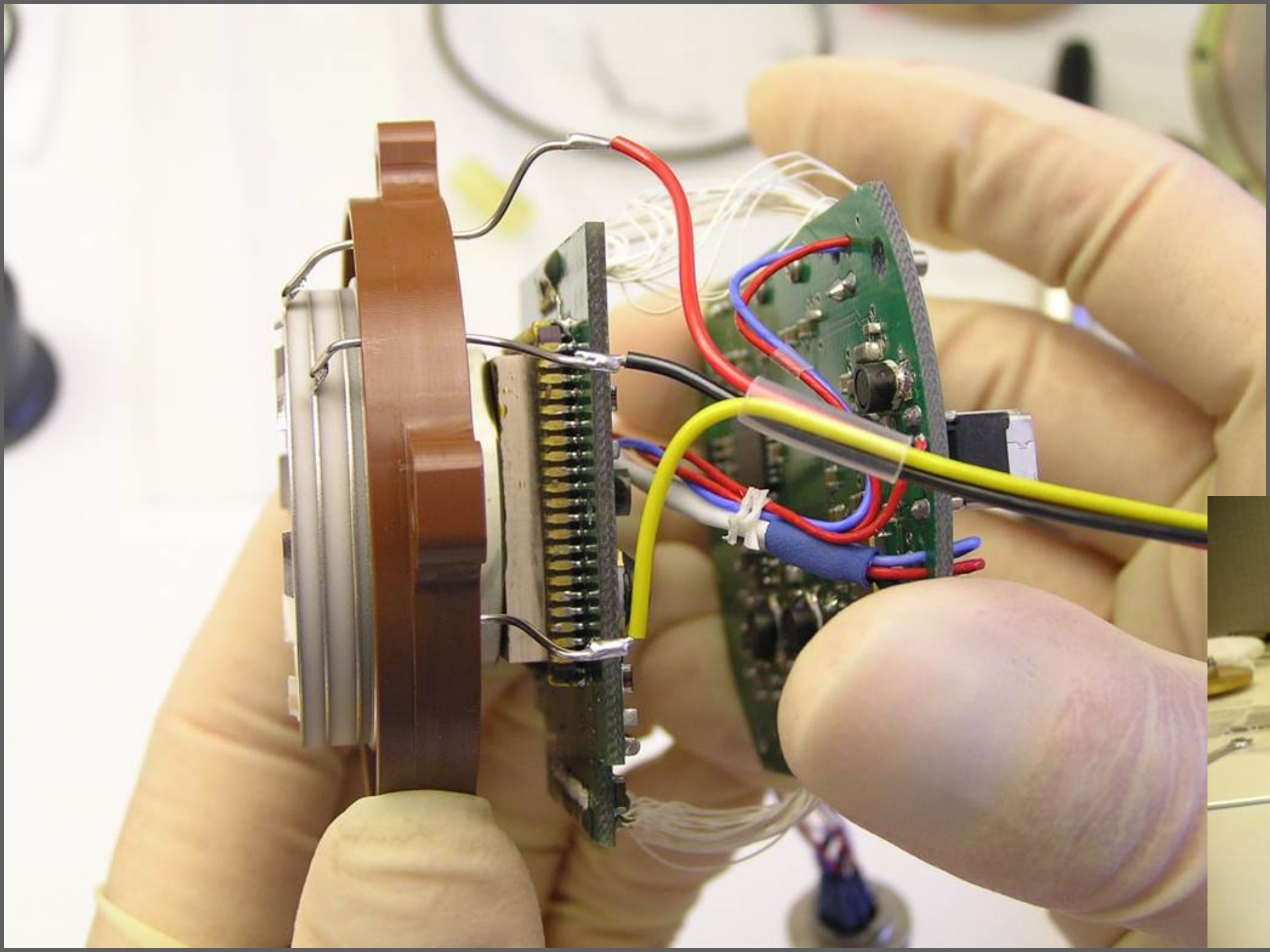
- ROSETTA-OSIRIS
- VMC (Venus M C)
- DAWN Framing Camera







VUV-camera system for the RAISE rocket spectrograph

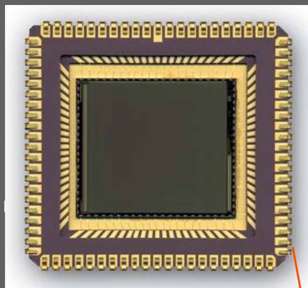


Single MCP intensifier

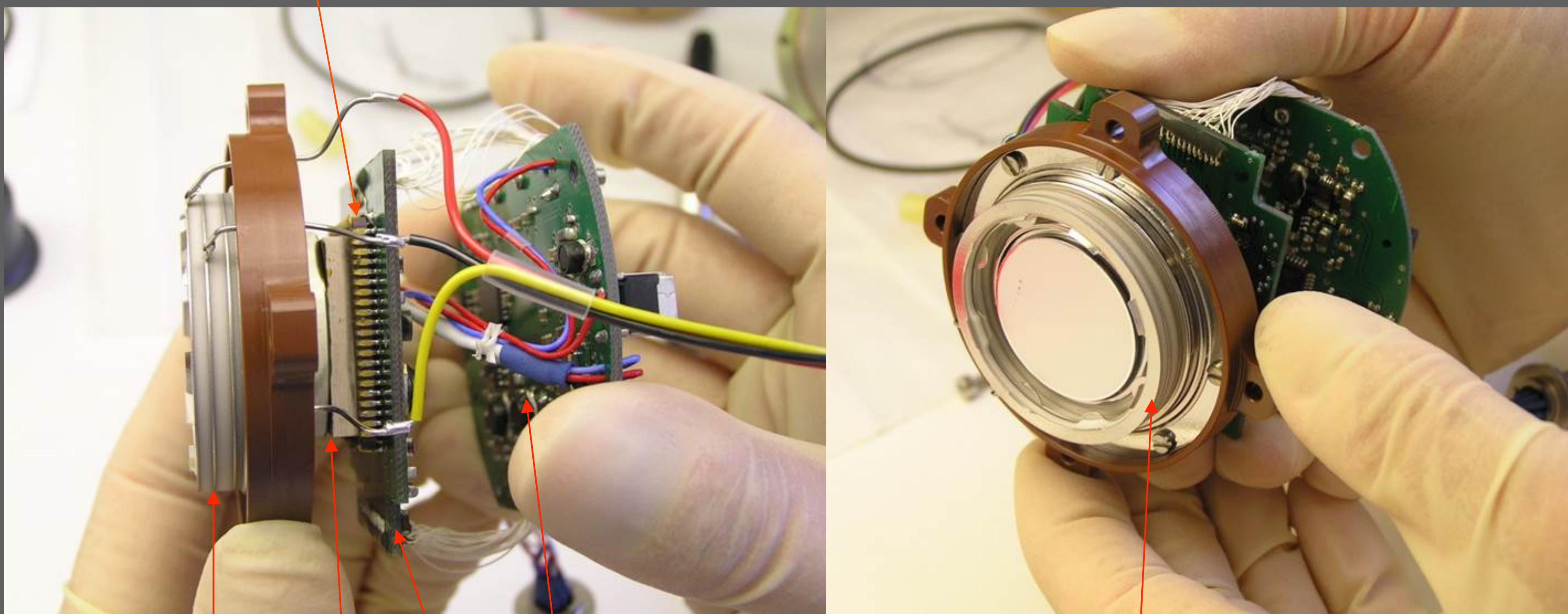
Fiber optic coupling

Star-1000 APS
(15 μm pixel size)

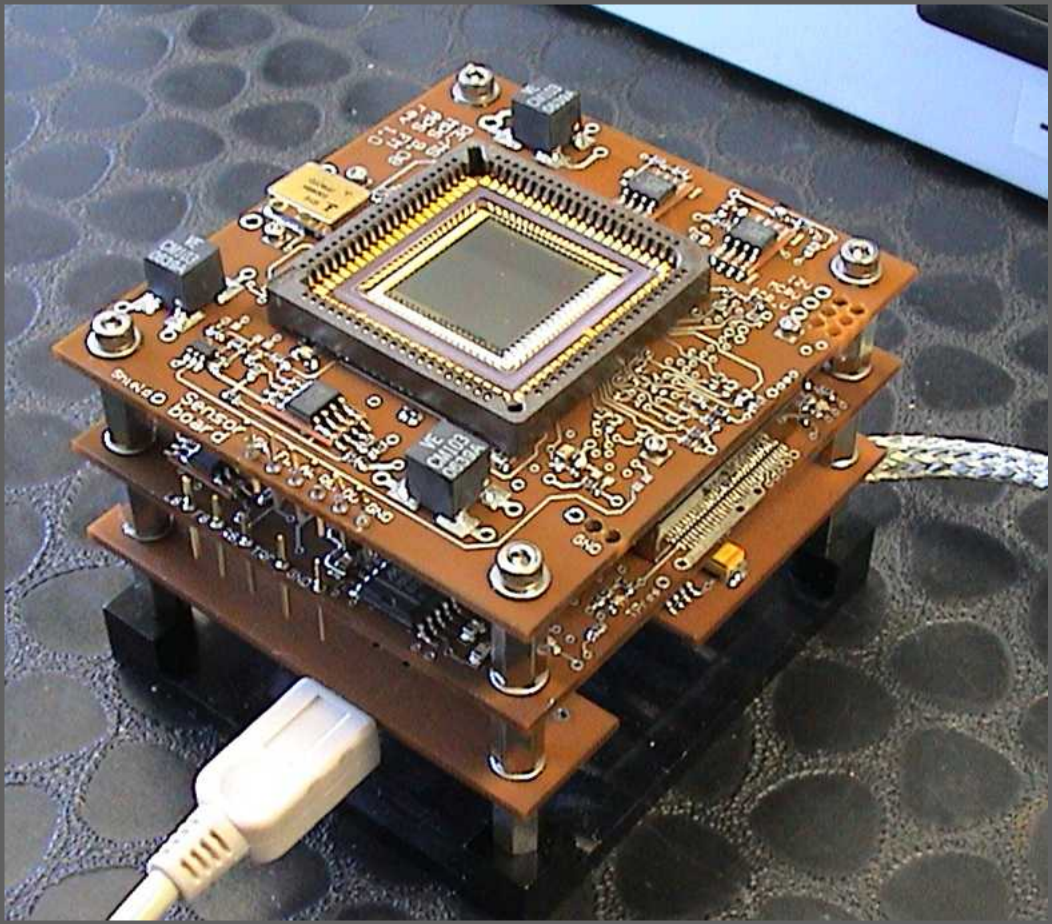
Coupling MCP intensifier with APS image sensor



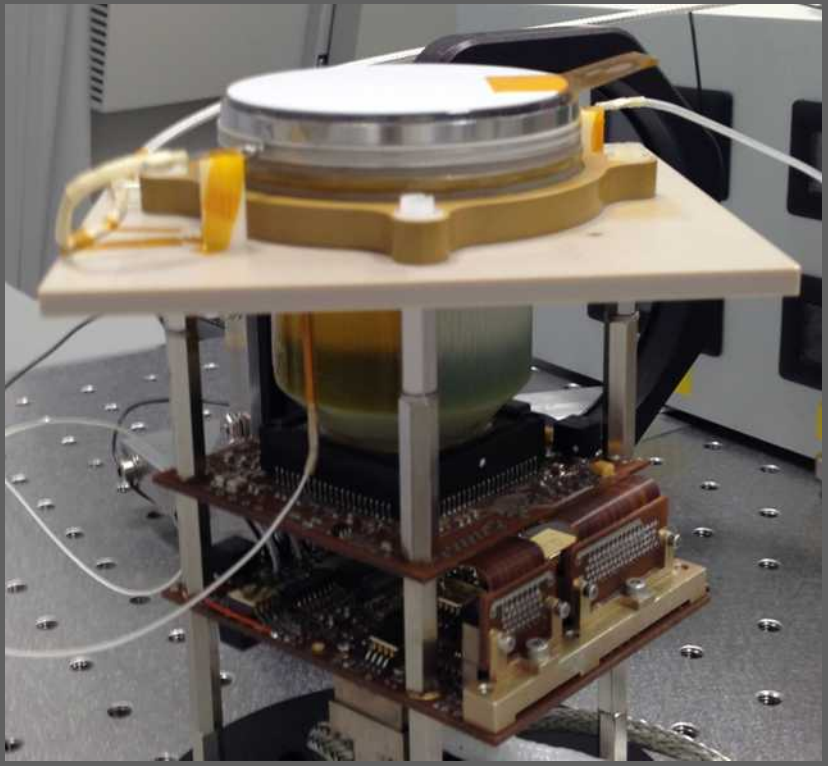
STAR 1000
visible CMOS-APS sensor



Space-qualified camera with the Star-1000 APS sensor



For the METIS UV camera



Performance characterization and calibration

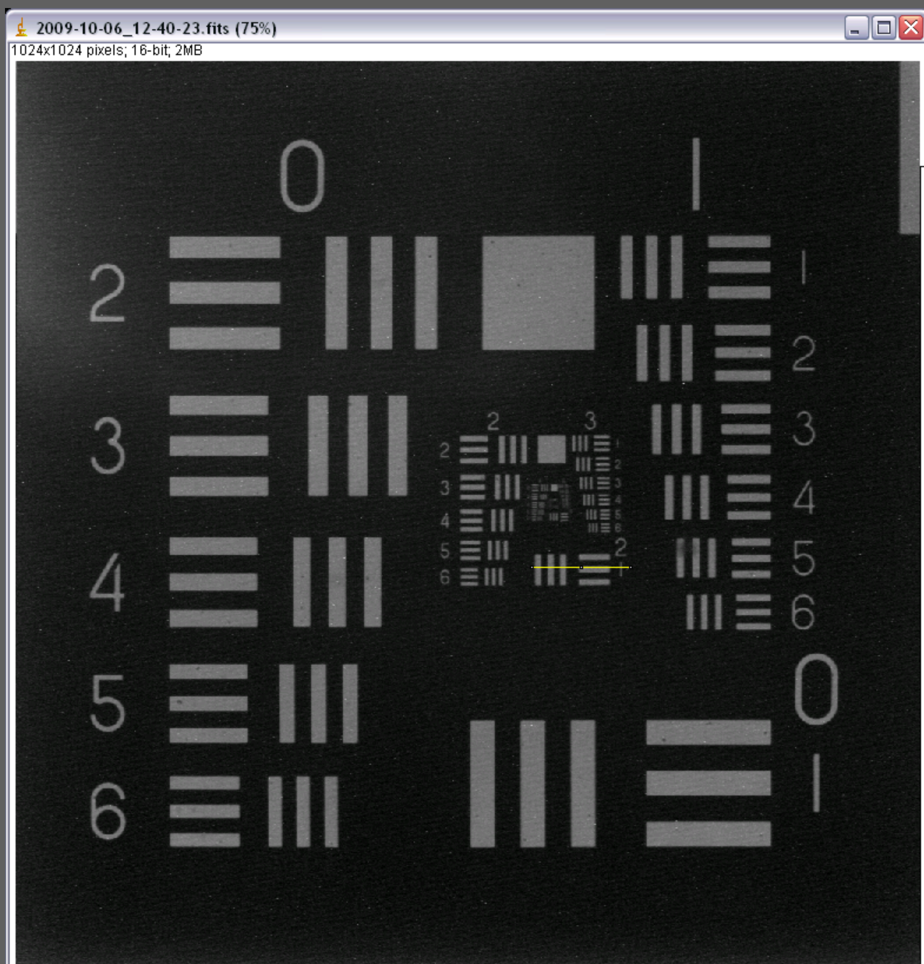
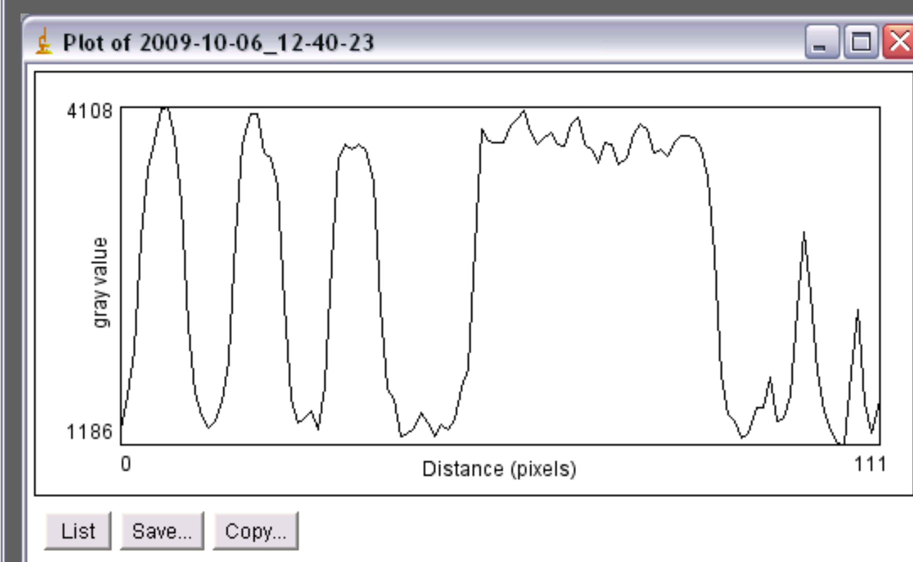


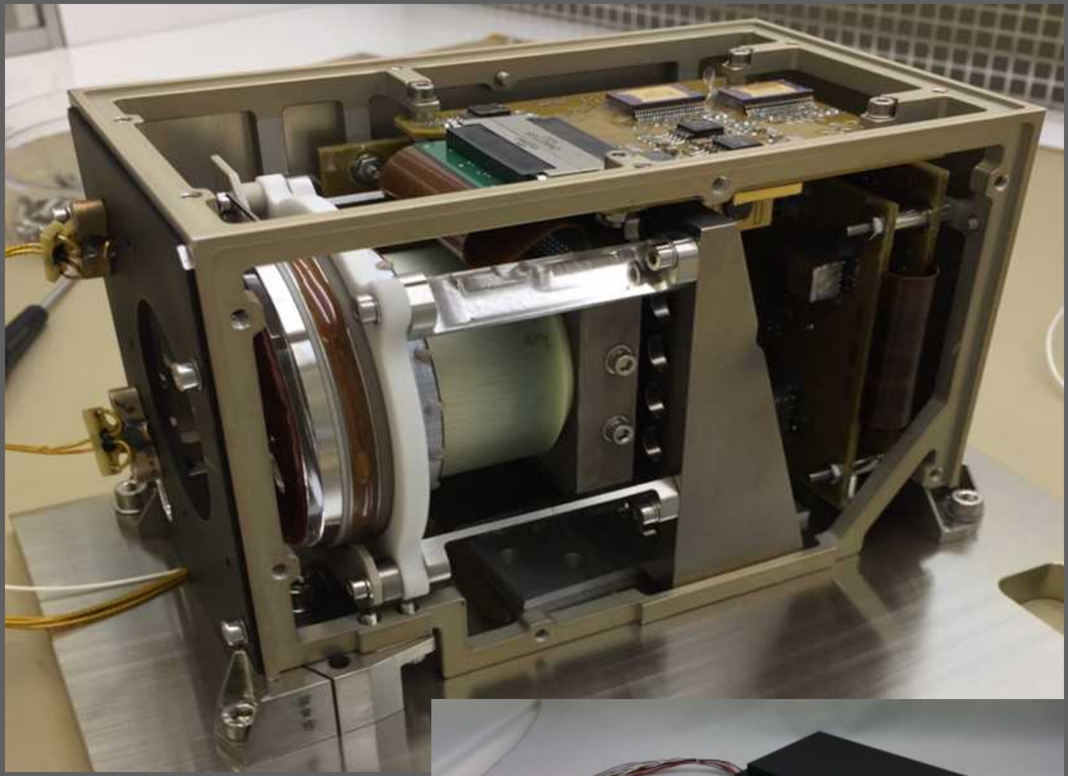
Image of a target. The yellow line is the location of the profile shown below



I-APS Cameras recently built for Solar Orbiter

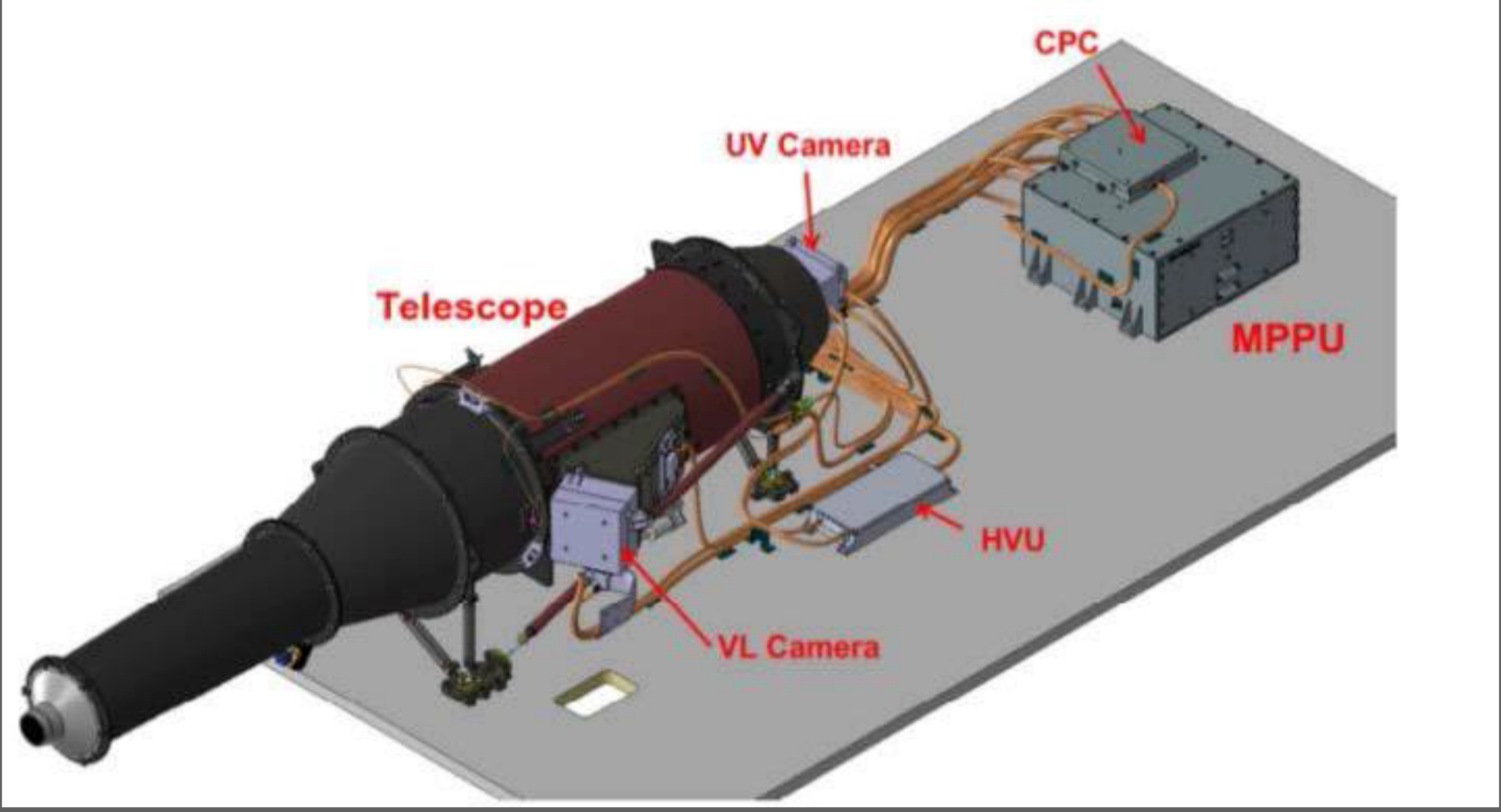
METIS Lyman-Alpha camera

EUI Lyman-Alpha camera

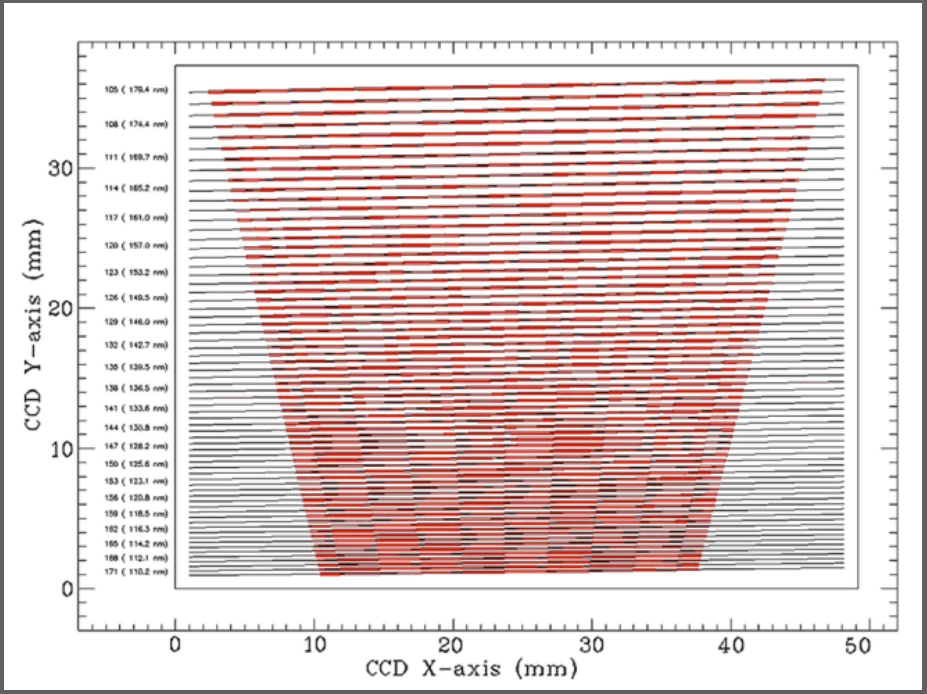


HV unit →

I-APS Cameras recently built for Solar Orbiter: METIS Detection System

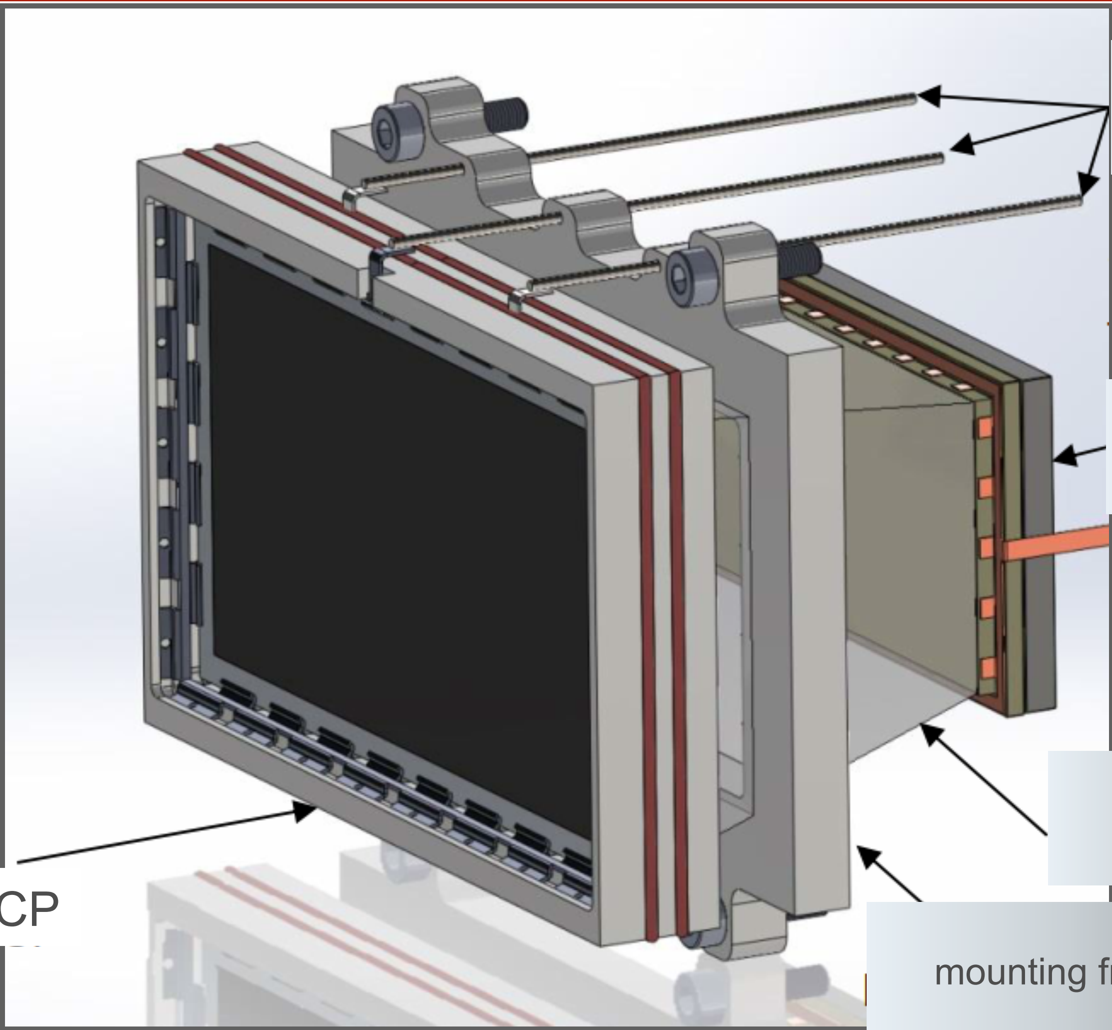


Proposed focal plane for ARAGO

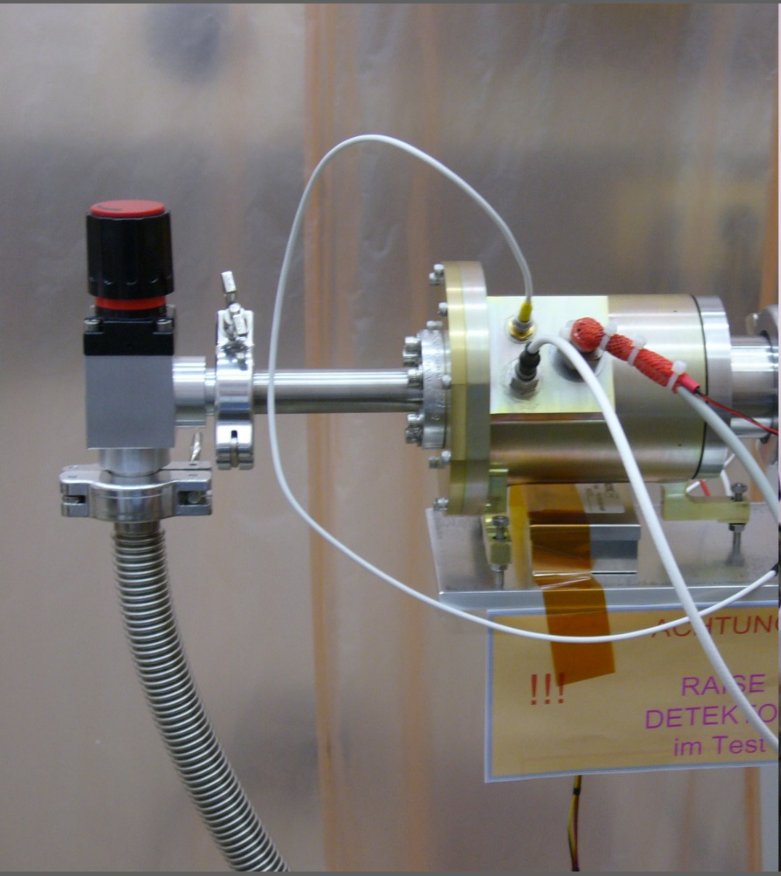


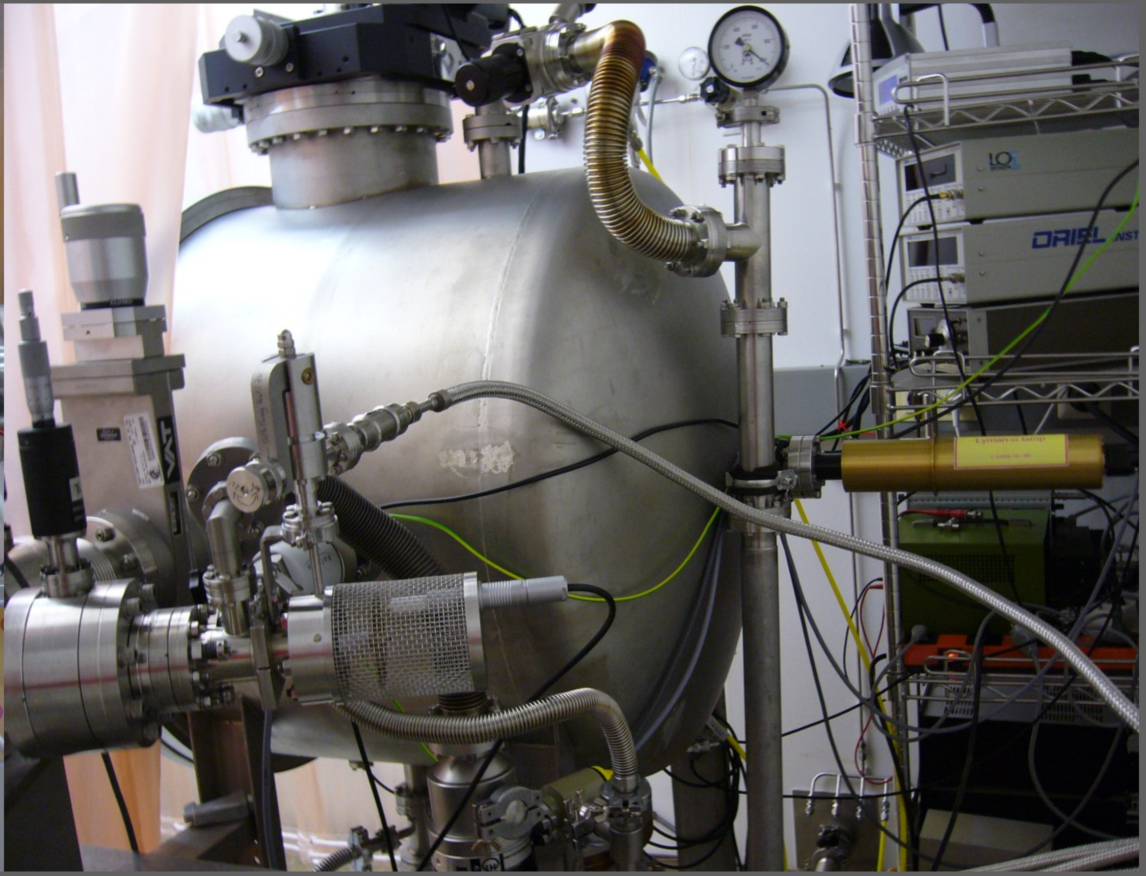
Type:	I-APS
Dimensions:	4096 x 4096
Pixel size:	12 µm
Size:	37 mm x 50 mm

Conceptual design of intensifier for ARAGO



Performance tests with Lyman-α and extreme UV lamp





Partners in our camera development

	• MPS	Camera design, Mechanics, Electronics, AIT/V
	• ProxiVision GmbH	MCP, Intensifier, fiber-optic coupling
	• UC Berkeley, Space Sciences Lab.	Intensifier design photocathode coating
	• PTB Metrology Light Source,Berlin	Radiometric calibration

Possible contribution to the UV Spectropolarimeter by Max Planck Institute for Solar System Research:

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- Cameras (incl. electronics)
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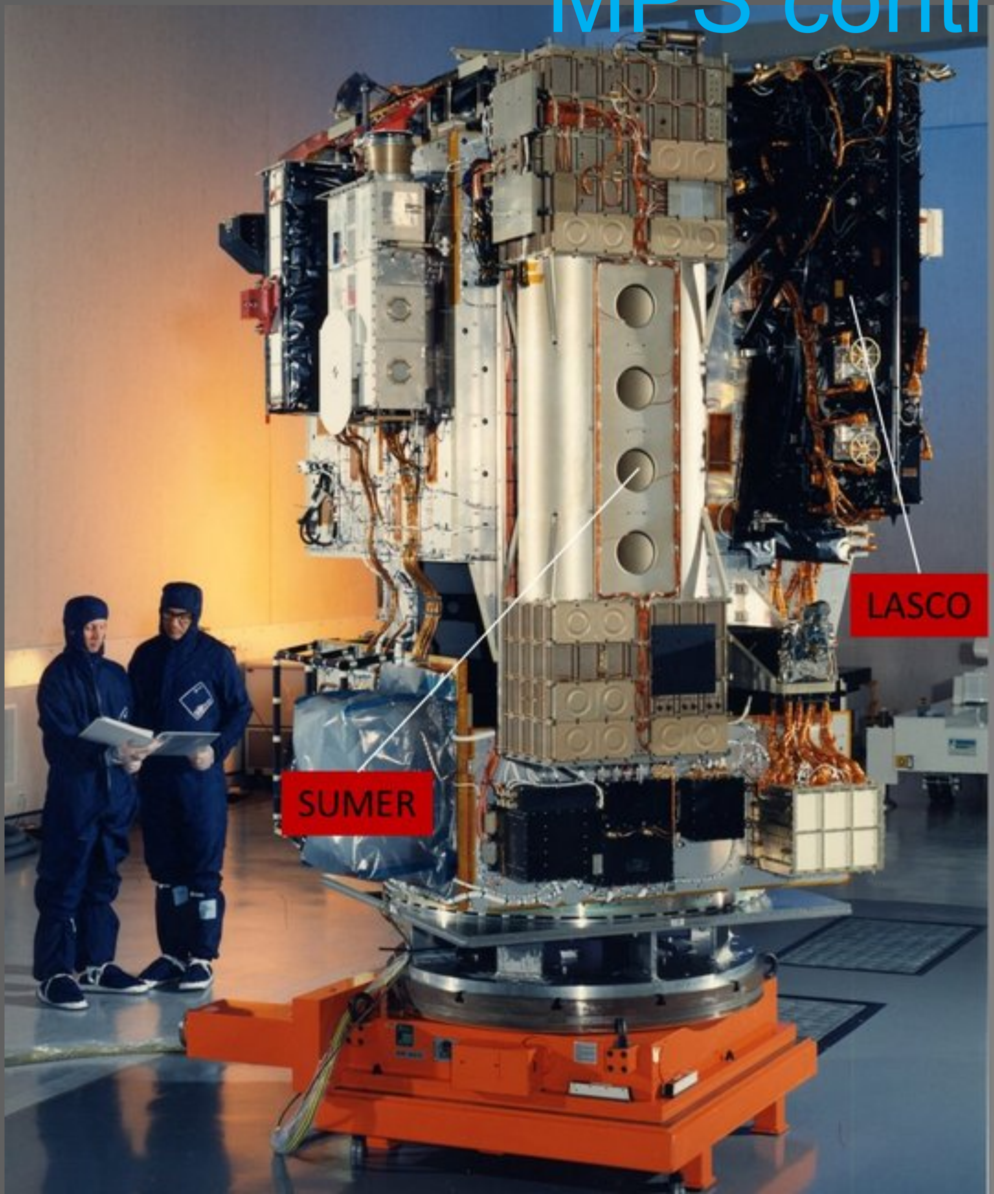
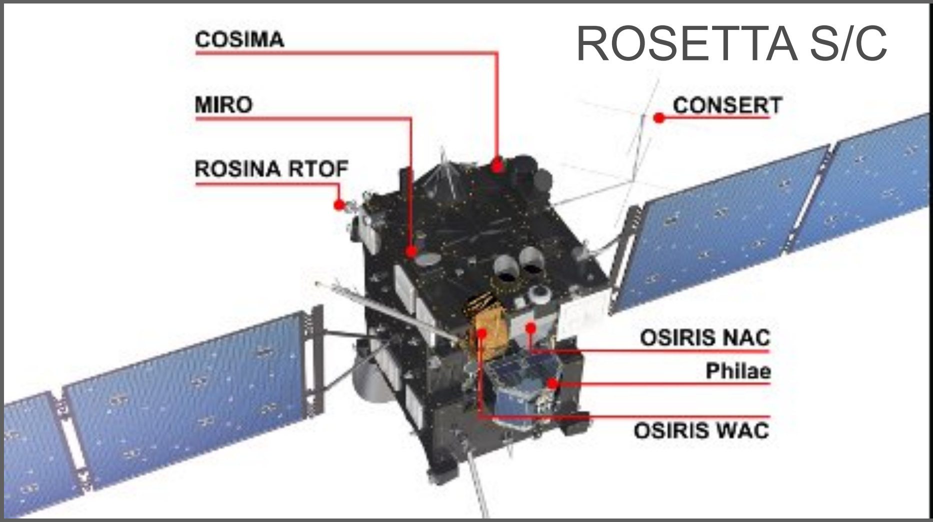
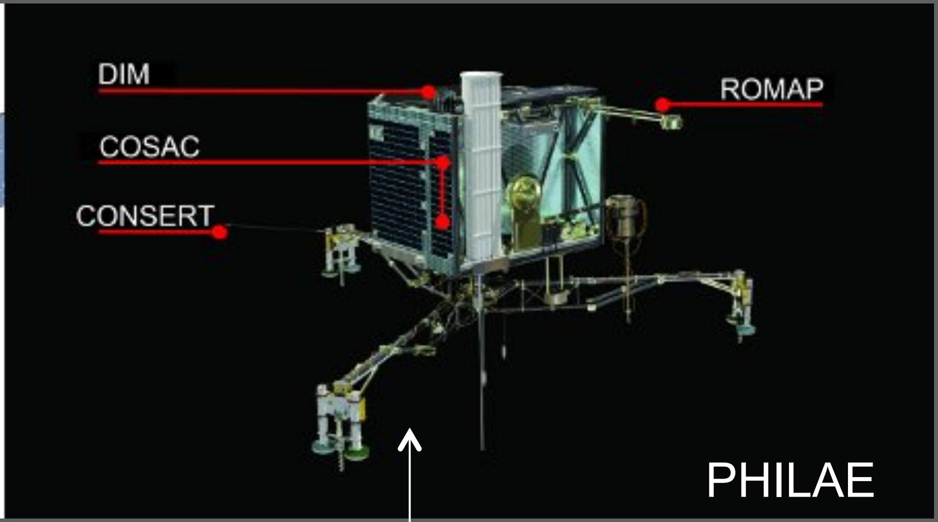
SoHO Instruments with MPS contributions



- Mechanisms
- Mechanical design
- AIV
- Space qualification

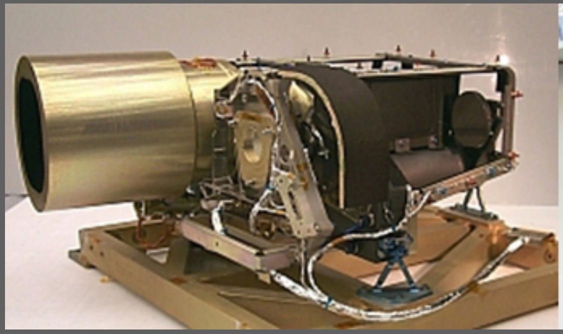
ROSETTA Instruments with MPS contributions





PHILAE Landing gear

OSIRIS NAC



OSIRIS WAC

Solar Orbiter Instruments with MPS contributions

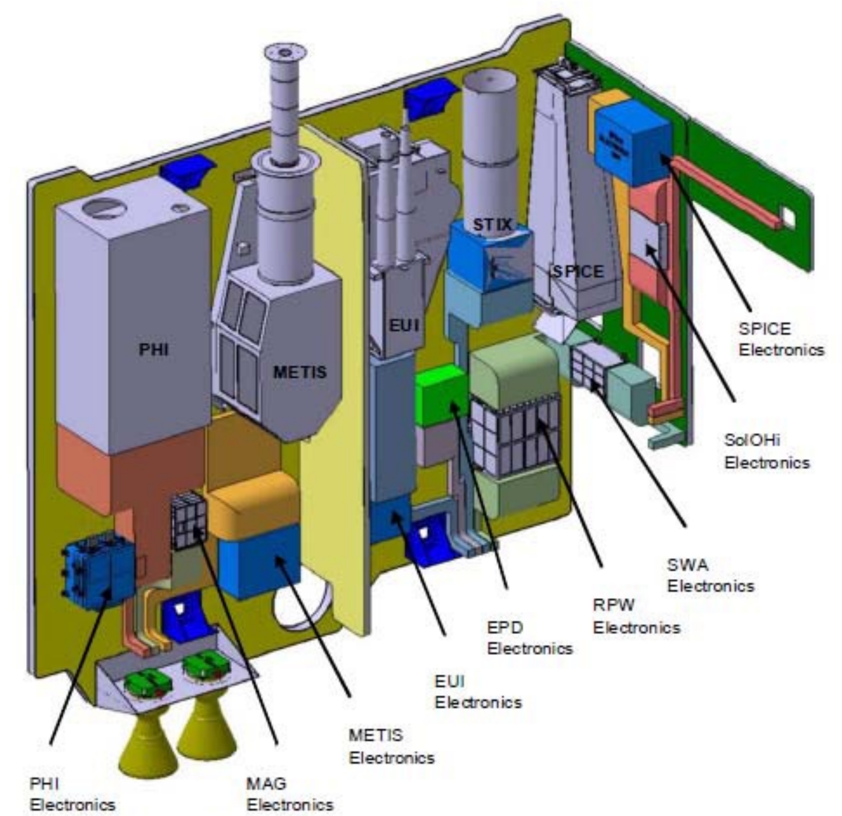


Figure 5-2 Internal Payload Accommodation on –Y Wall (including Harness Volume)

- **PHI: Polarimetric and Helioseismic Imager (PI instrument of MPS)**
  - Instrument responsibility
- **EUI: Extreme Ultraviolet Imager** (co-PI contribution of MPS)
  - HRI Lyman-alpha telescope
- **SPICE: Extreme Ultraviolet imaging Spectrograph** (EUS)
  - Primary mirror and coating
- **METIS: Imaging and Spectroscopy of the Corona**
  - METIS Detection System (VLDA, UVDA)

Fin

Recommended:
A. BenMoussa · S. Gissot · U. Schühle, et. al.
On-Orbit Degradation of Solar Instruments
Solar Phys (2013) 288:389–434
DOI 10.1007/s11207-013-0290-z