Solar instruments and images

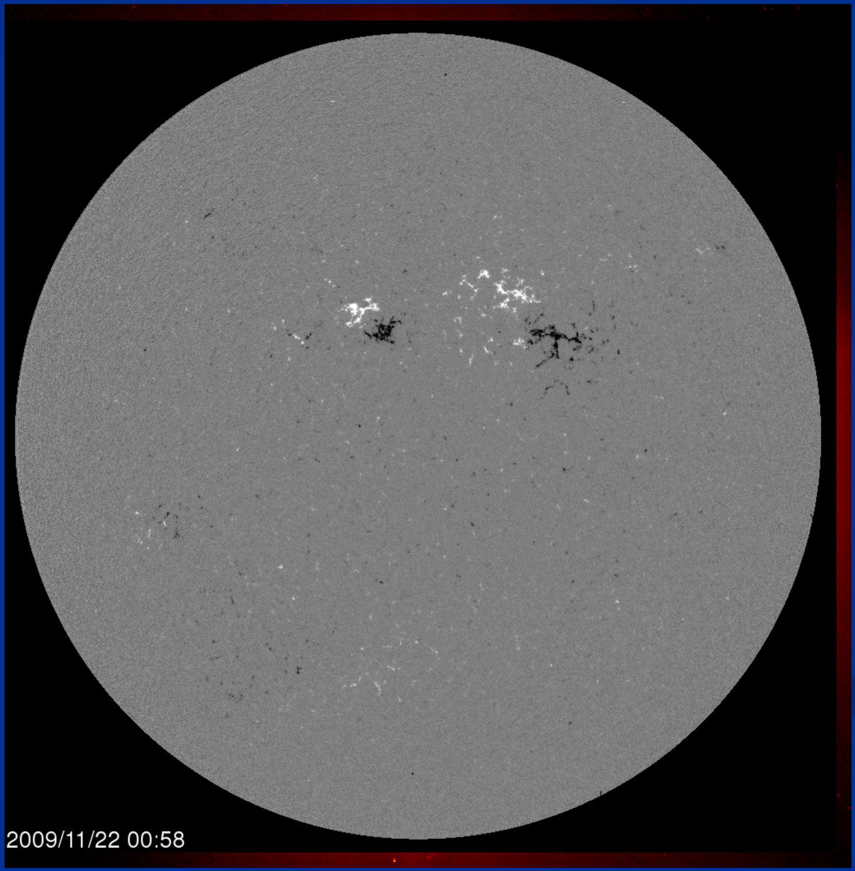
Detectors for Solar Instrumentation

Udo Schühle
Detector Mtg, 23. 11. 2009

The Sun – solar images

Visible light

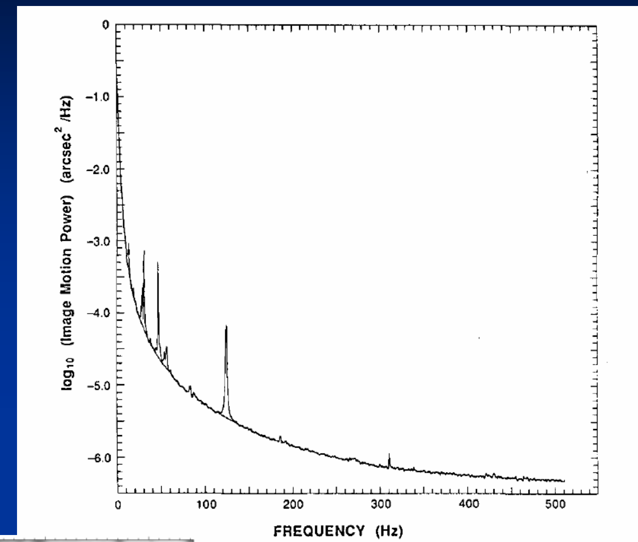
Magnetogramme

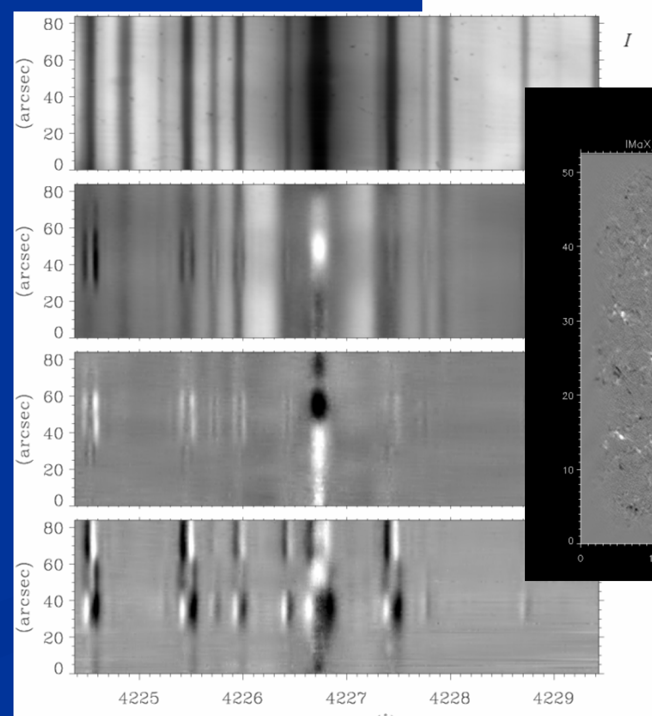


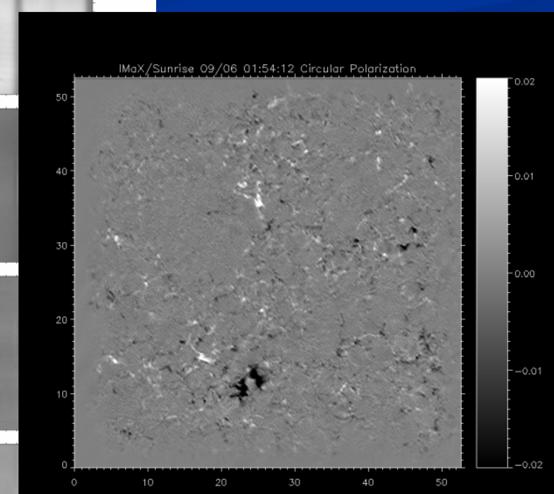
Imaging spectro-polarimeter for ground-based solar telescopes

- Project financed by the MPG, 2010-2013
- Basic requirements on detector:
  - 1k x 1k pixels
  - Spectral range: VIS down to 390 nm
  - High framerate (of order 100 frames/s)
  - Low readout noise: $\leq 10\ e^-$

Power spectrum of atmospheric turbulence







Example data from ZIMPOL (left) and IMaX

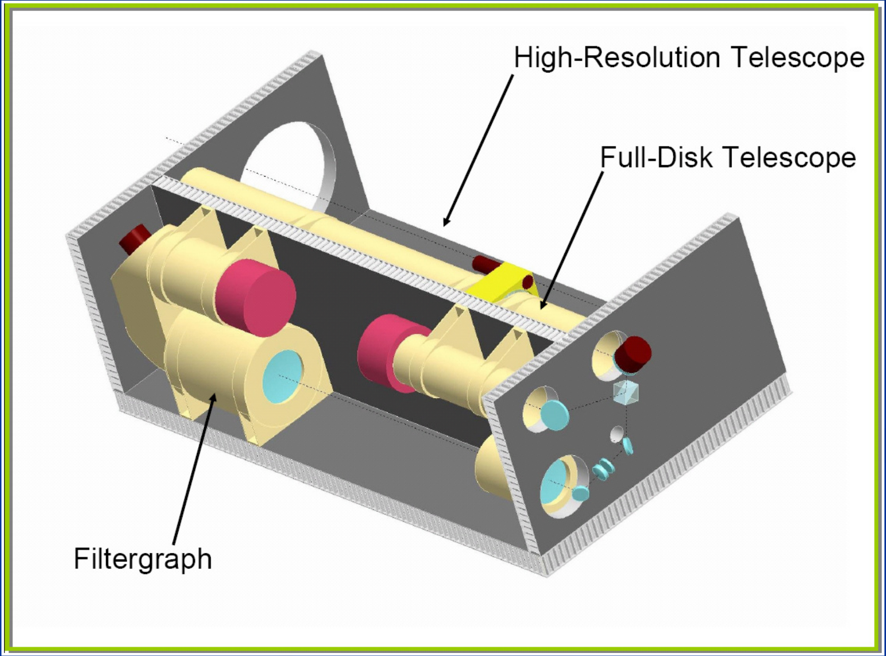
Solar Orbiter Instruments

- PHI: Polarimetric and Helioseismic Imager
- EUI: Extreme Ultraviolet Imager
- SPICE: Extreme Ultraviolet imaging Spectrograph (EUS)
- METIS/ICOR: Multi Element Telescope for Imaging and Spectroscopy

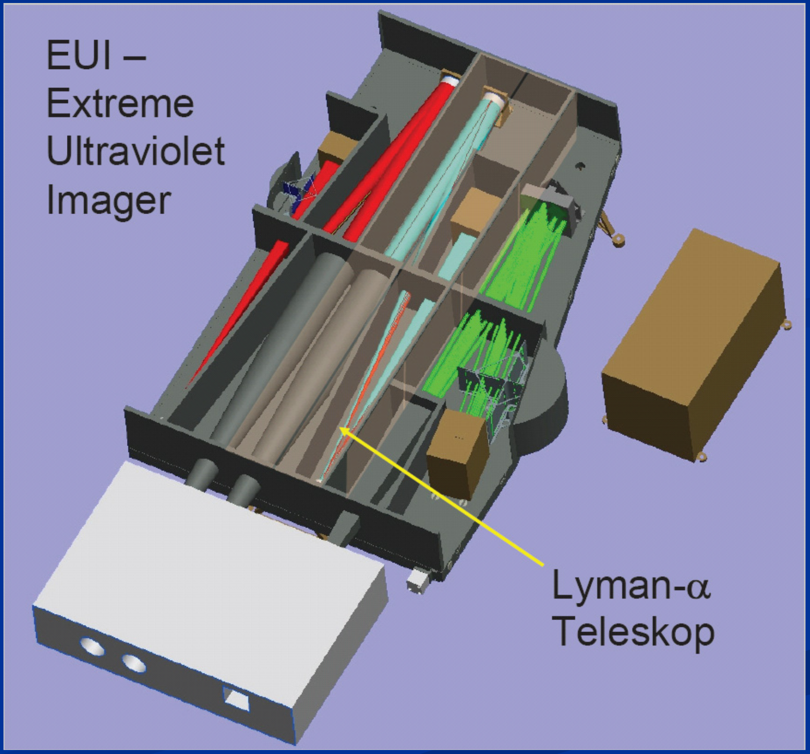
Solar Orbiter Instruments
PHI

PHI – Polarimetric and Helioseismic Imager

PHI will be composed of two telescopes. The off-axis Ritchey-Chrétien High Resolution Telescope (HRT) will image a fraction of the solar disk at a resolution reaching 150 km at perihelion (the same resolution as the Extreme Ultraviolet Imager's high resolution channels will have). The refractor Full Disk Telescope (FDT) will be able to image the full solar disk at all phases of the orbit. It incorporates an off-pointing capability. Each telescope will have its own Polarization Modulation Package (PMP) located early in the optical path in order to minimize polarisation cross-talk effects. Polarimetry at a signal to noise level of 10^3 is baselined for PHI. The HRT and the FDT will sequentially send light to a Fabry-Perot filtergraph system (~ 100 mÅ spectral resolution) and on to a 2048 × 2048 pixel CMOS sensor. PHI will have its own Image Stabilization System (ISS) that will compensate spacecraft jitter or other disturbances. This system will be composed of a limb sensor and separate rapid tip-tilt mirrors for the FDT and the HRT.



Solar Orbiter Instruments
EUI



EUI – Extreme-Ultraviolet Teleskope:

The EUI instrument suite is composed of two high resolution imagers (HRI), one at Lyman-α 121.6 nm and one dual-band in the extreme UV, alternatively at 17.4 nm and 33.5 nm, respectively named "HRILy-α" and "HRIEUV", and one dual-band full-sun imager (FSI) working alternatively at the 17.4 nm and 30.4 nm EUV passbands, named "FSI174/304".

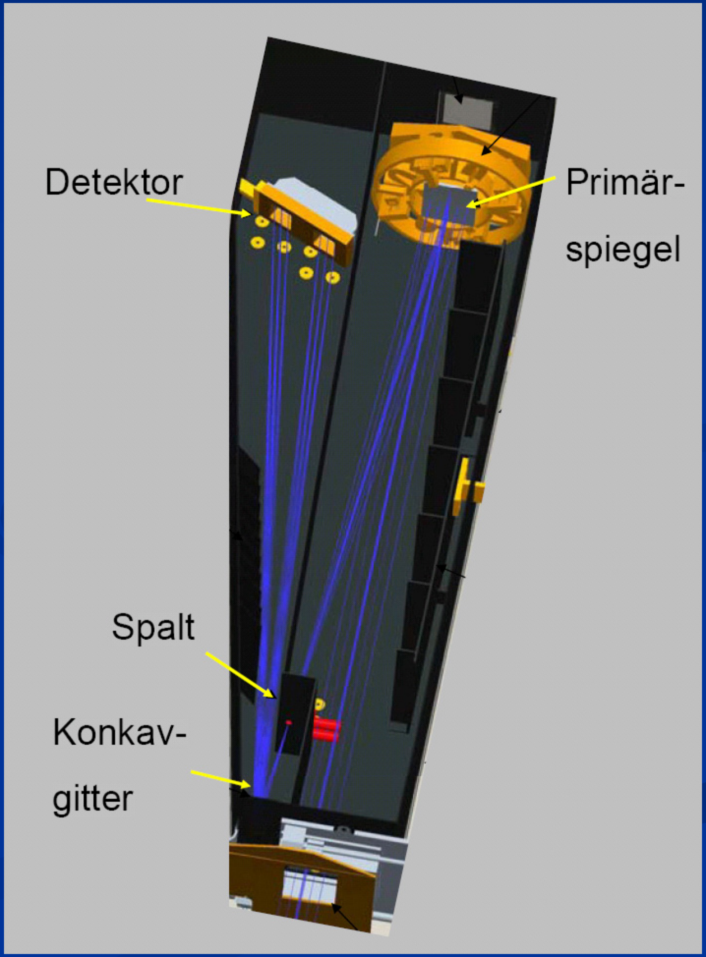
In all channels, the image is produced by a two-mirror telescope, working in near normal incidence. The EUV reflectivity of the optical surfaces is obtained with specific EUV multilayer coatings, providing the spectral selection of the units. The spectral selection is complemented with filters rejecting the visible and IR radiation. For the Lyman-α HRI a special "solar-blind" camera is being developed.

Solar Orbiter Instruments
SPICE

EUS – Extreme-Ultraviolet Spektrograph: SPICE

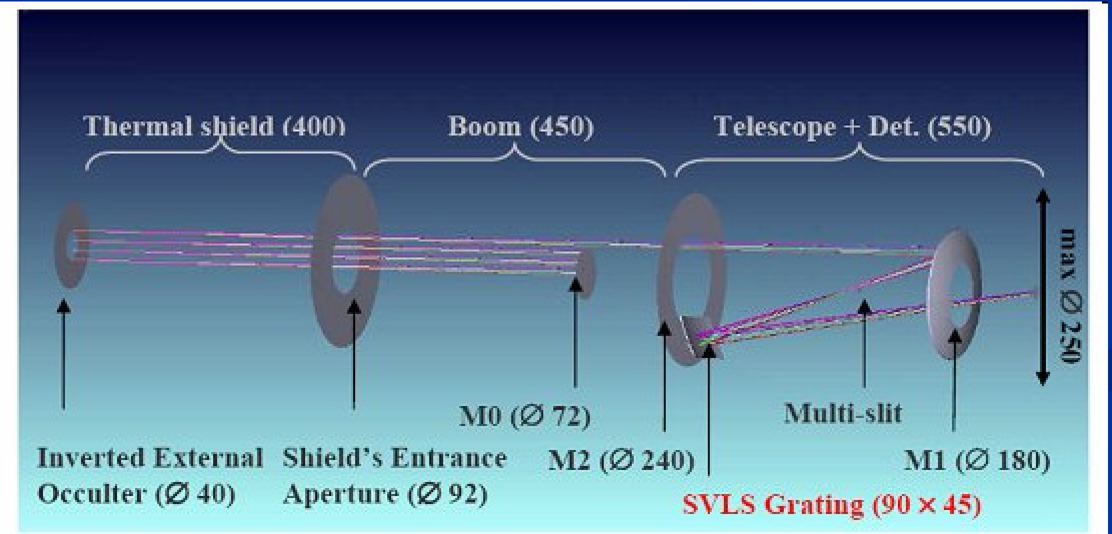
The SPICE instrument is a high-resolution imaging spectrograph with a movable occulter to observe the solar corona both on the solar disk and off limb out to 3 solar radii. For outer coronal observations the occulter is used to reduce stray light by fully occulting the solar disk.

To optimize throughput, the instrument consists of only two optical elements: a single off-axis parabolic telescope mirror and a toroidal variable line-spaced grating which re-images the spectrally dispersed radiation onto two array detectors. Two spectral passbands are recorded simultaneously with two intensified active pixel sensor (IAPS) detectors. The spectrograph will cover the extreme ultraviolet wavelength bands from 70.2 nm to 79.2 nm and from 97.2 nm to 105.0 nm (and 48.5 nm to 52.5 nm in 2nd order).

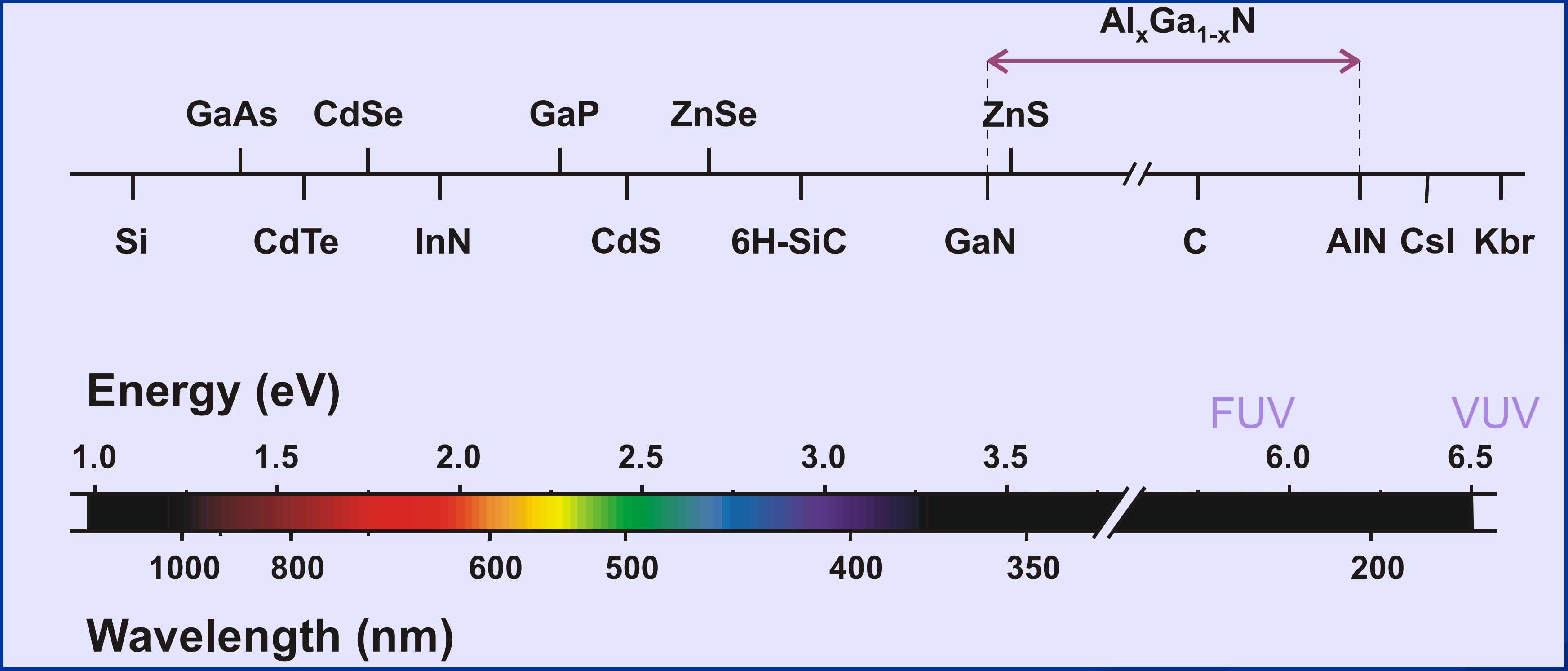


Solar Orbiter Instruments
METIS

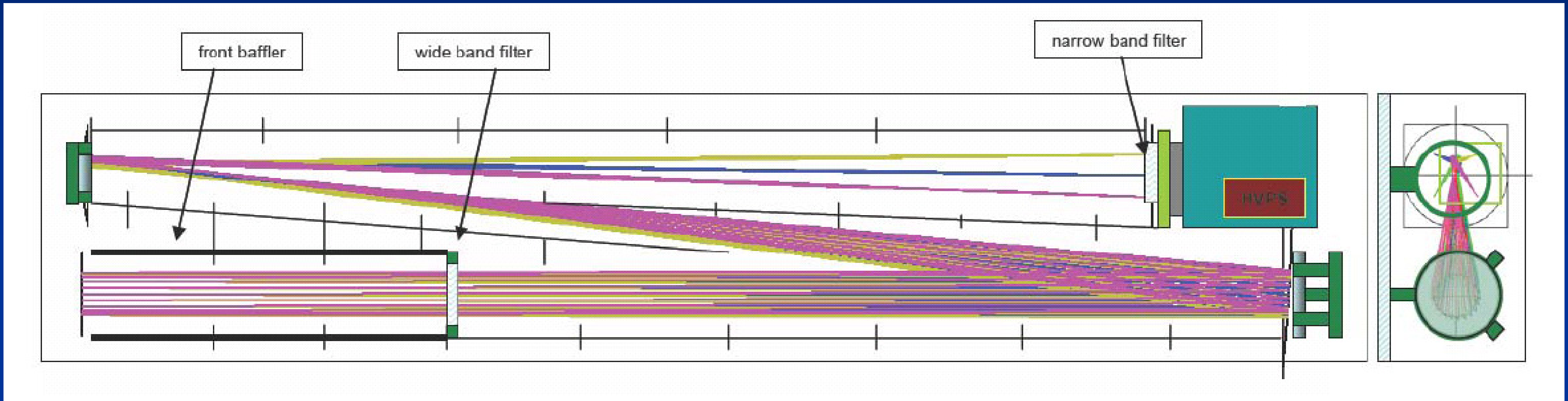
The Multi Element Telescope for Imaging and Spectroscopy is an inverted-occultation coronagraph that will image the solar corona in three different wavelengths (visible light between 450 and 650 nm, and the two Lyman-a lines of hydrogen and helium, H I 121.6 nm and He II 30.4 nm) by a combination of multilayer coatings and spectral bandpass filters. The visible channel also includes a polarimeter assembly to observe the linearly polarized component of the K corona. Inclusion of spectroscopic capabilities, which allows us to record spectra of the H I and He II Lyman a lines simultaneously at three different heights (accomplished by a multiple slit) in a 32° sector of the corona, is being proposed to ESA.



Photocathode materials

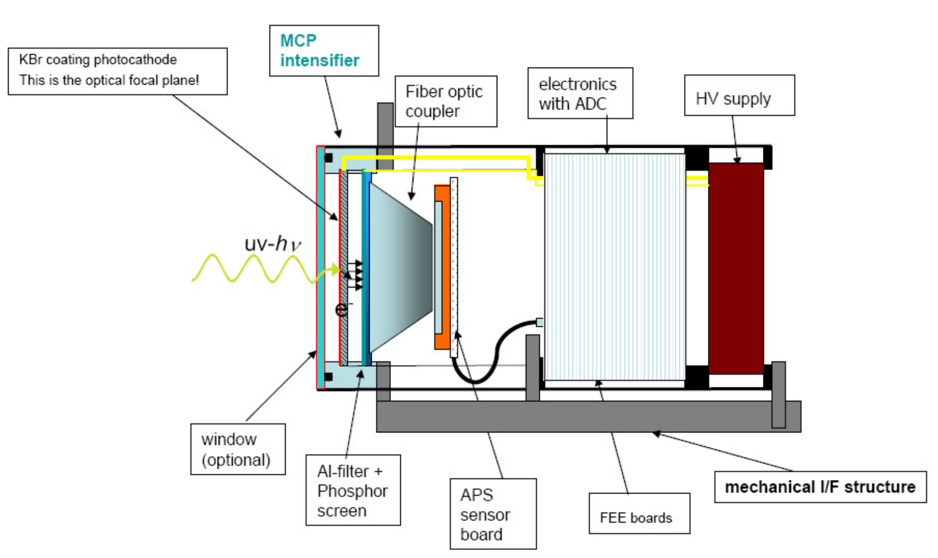


EUI Lyman-α channel detector



The Lyman-α detector:

a solar-blind intensified CMOS/APS camera



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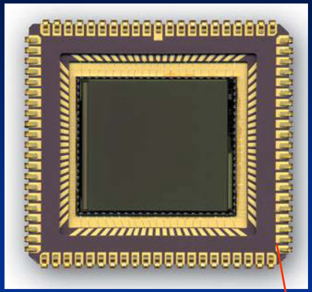
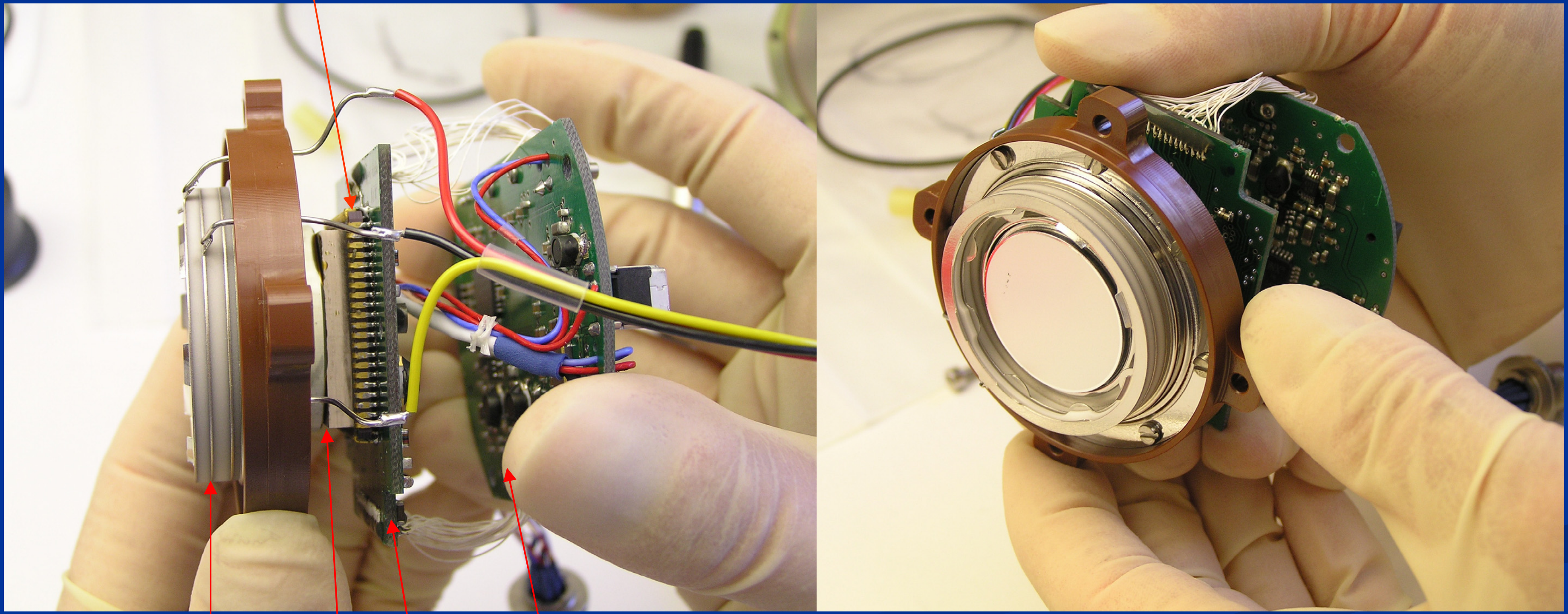
Intensified APS



STAR 1000
visible CMOS-APS sensor



MCP stack
fiber optic blocks
APS sensor board
FEE board

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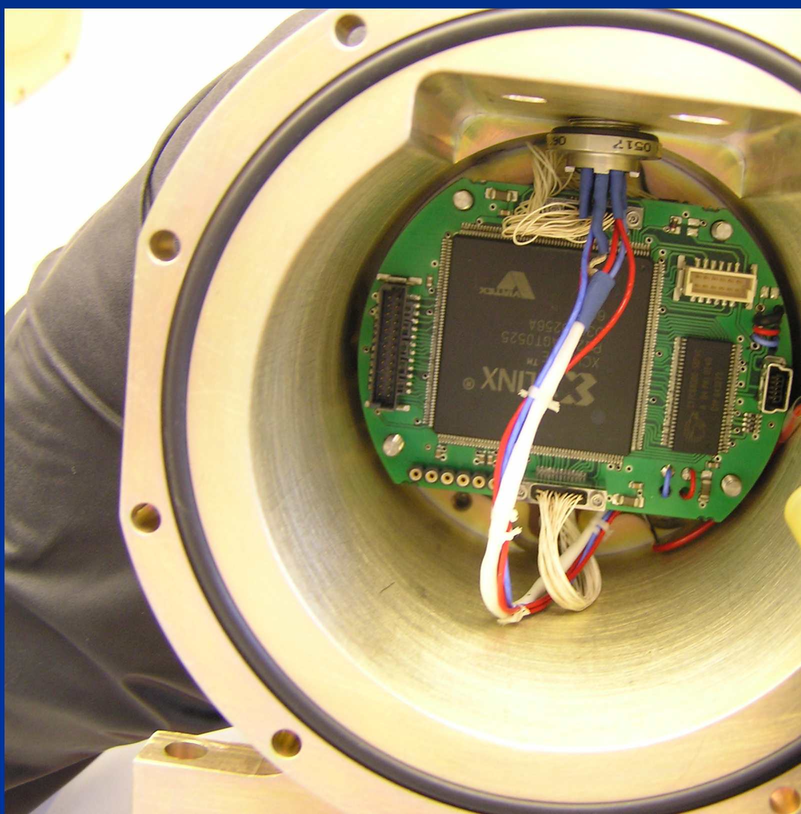
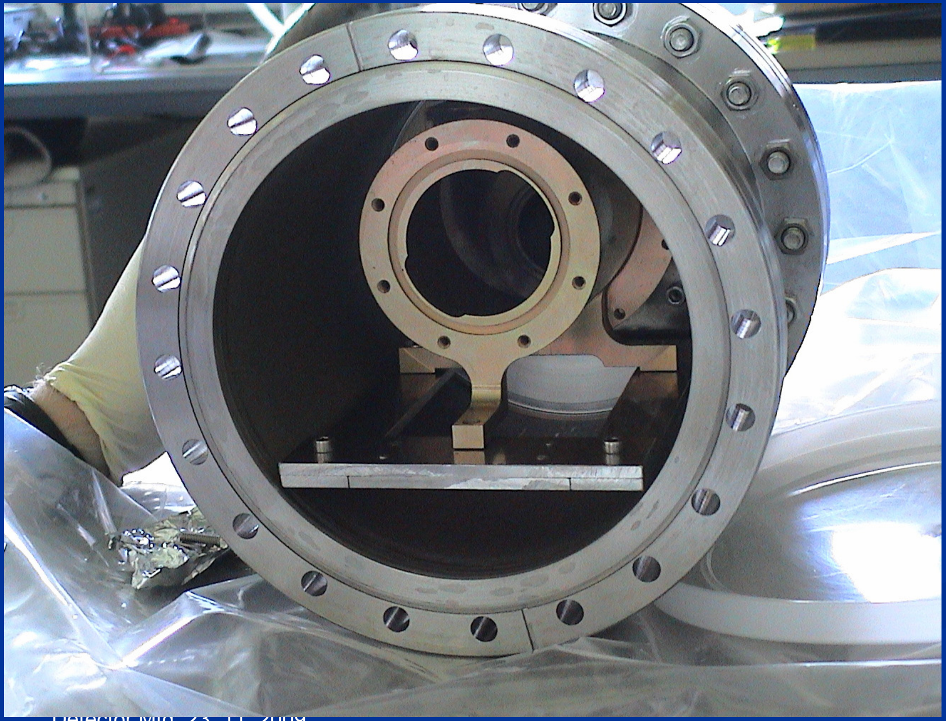
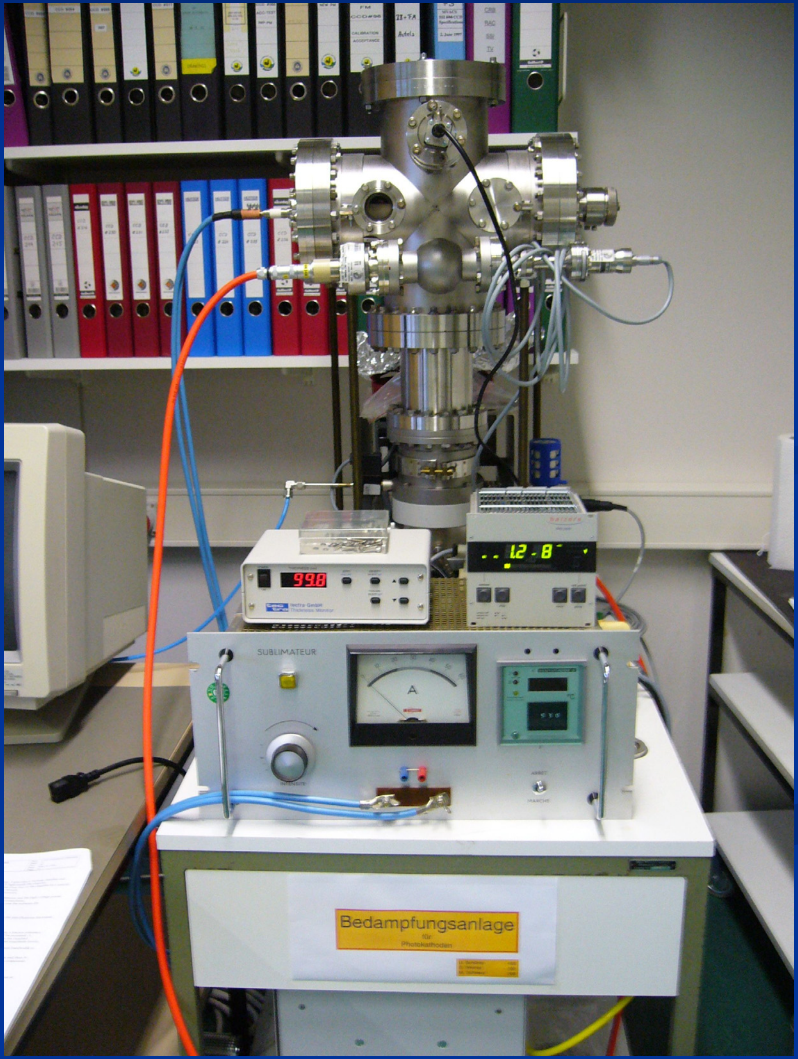
camera unit assembly and vibration test



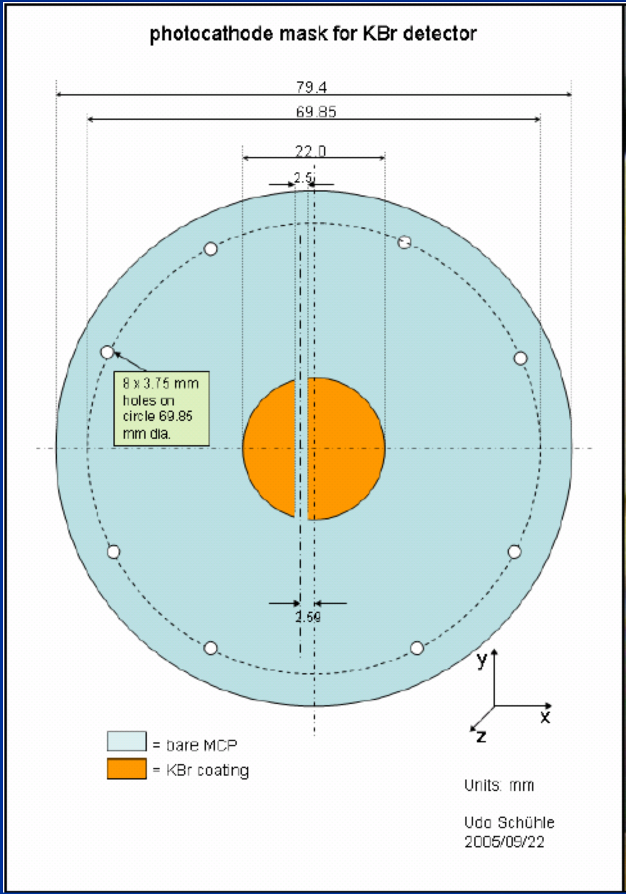
photocathode deposition chamber at MPS

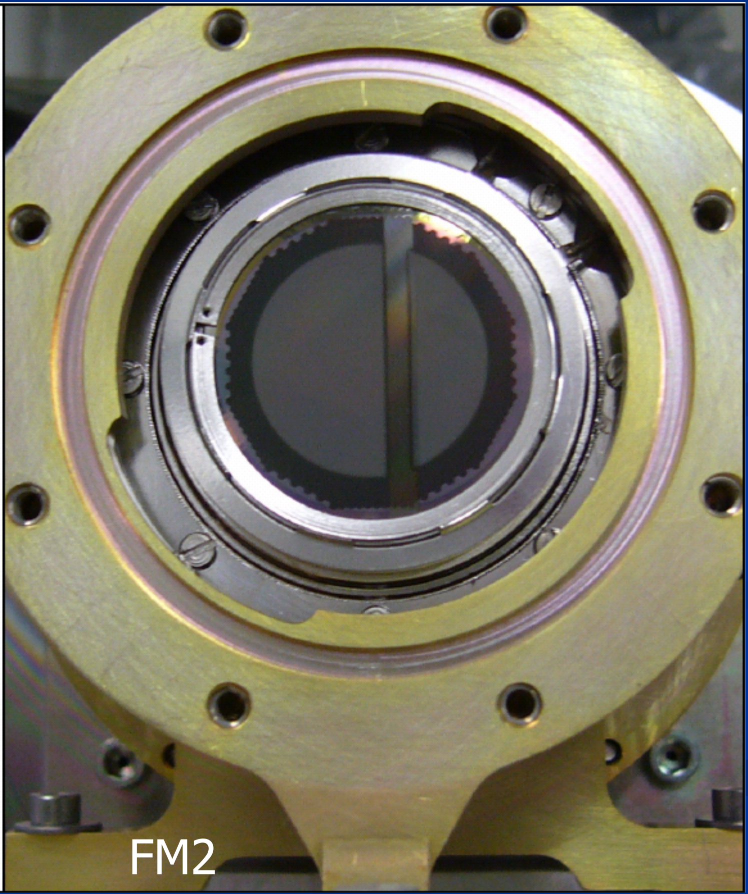
- done deposition of CsI and KBr up to thickness of 1000 nm with 1 nm resolution





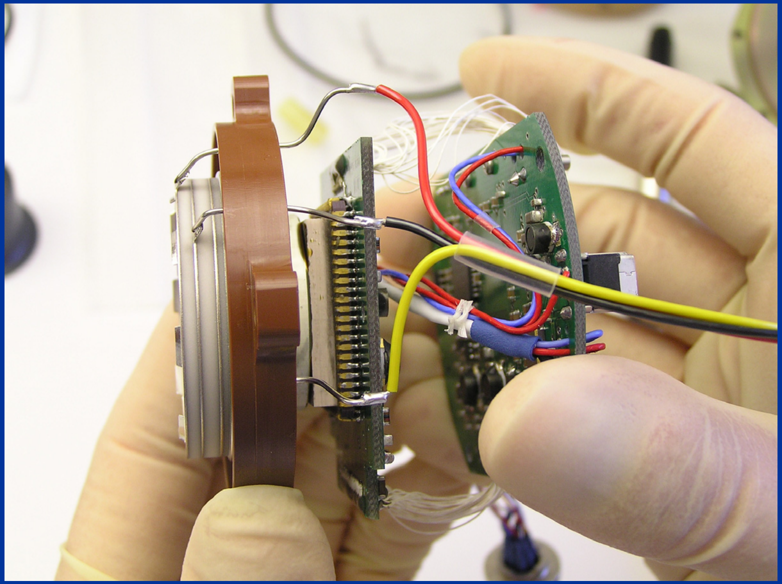
RAISE-FM2 camera unit
KBr photocathode deposition





R&D activities: Development of I-APS detector

- intensifier based on microchannel plates with KBr photocathode coating
- coupling with active pixel sensor (APS)
- APS electronic readout circuitry
- space qualification: vibration, acoustic, thermal, radiation hard



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Advantages of I-APS

PROS:

- most flexible in terms of focal plane size: may be adjusted by fiber optic taper
- most flexible dynamic range: may be adjusted from photon-counting to current-integration mode in several ways:
  - photocathode selection for spectral ranges
  - adjustable gain by HV
  - selectable attenuation of phosphor by ND-filter
- solar blindness (saves a filter!)
- operation at room temperature (less cooling needed, no contamination problem)
- high responsivity in full VUV and EUV range

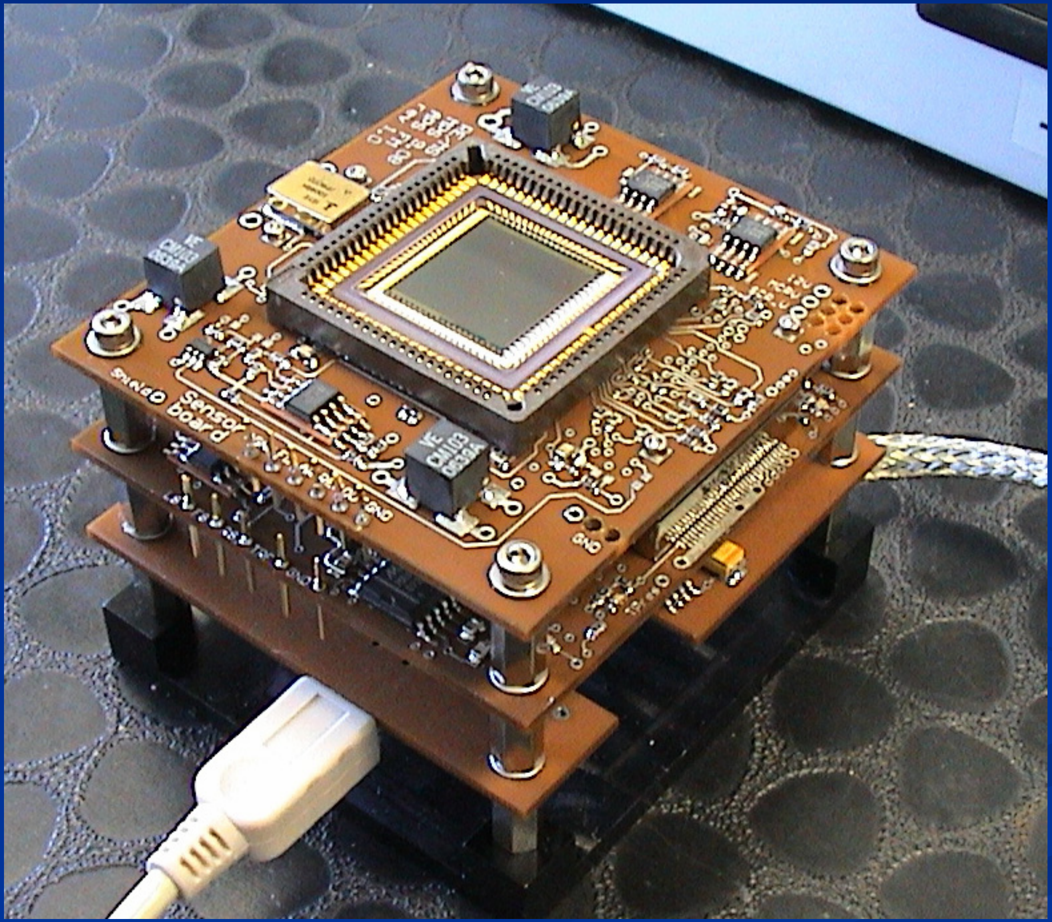
CONS:

- fragile multi-channel plates
- adjustable high voltage needed, up to 10 kV
- limited spatial resolution of MCPs: MTF of ~50 lines/mm

Milestones / Achievements at MPS

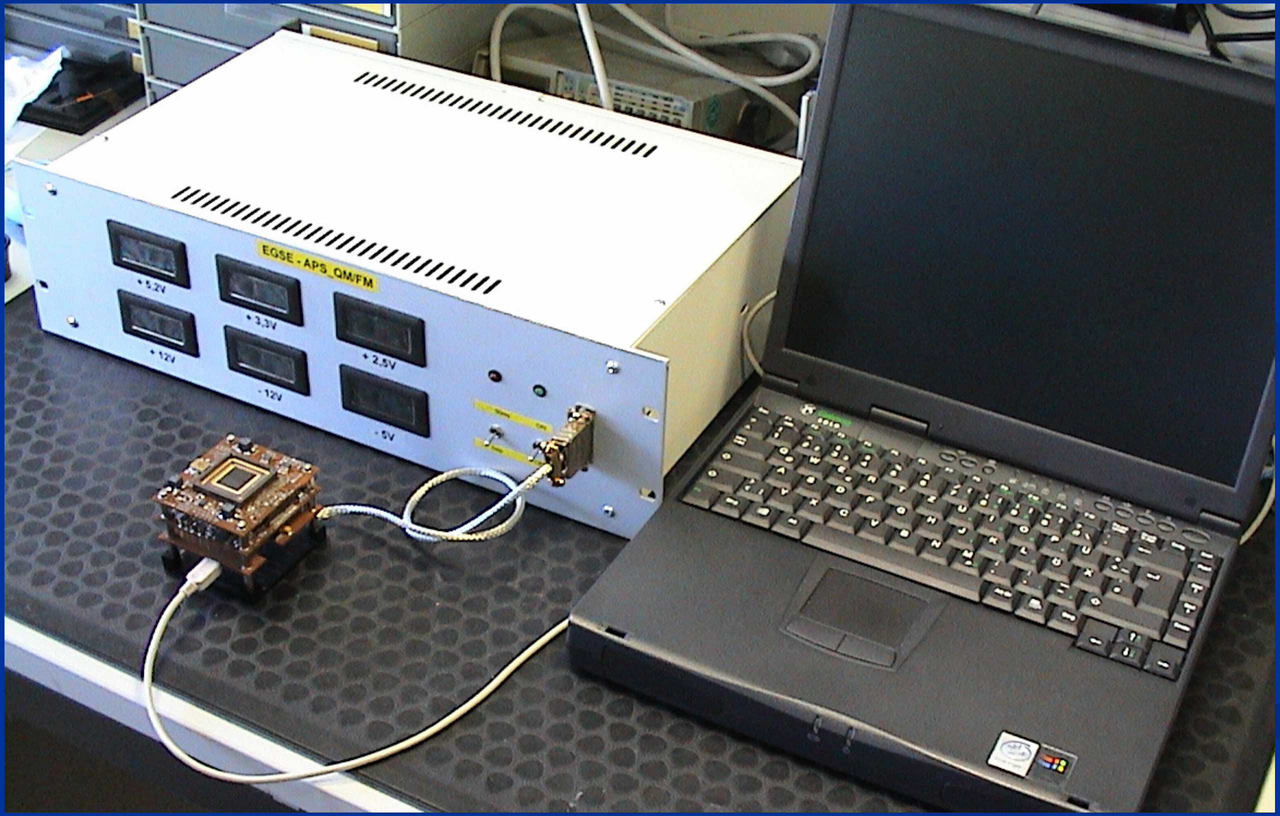
- first coupling of intensifier with fiber optic faceplate and APS sensor achieved in March 2007
- build-up of photocathode deposition system at MPS in 2007
- photocathode deposition with (CsI and KBr) in January 2008
- development of 14-bit electronic readout for 1kx1k APS sensor in 2007
- design of electronic readout with high-rel parts in July 2008
- built first radhard system in 2009

Space-qualifiable camera for the Star-1000 APS sensor



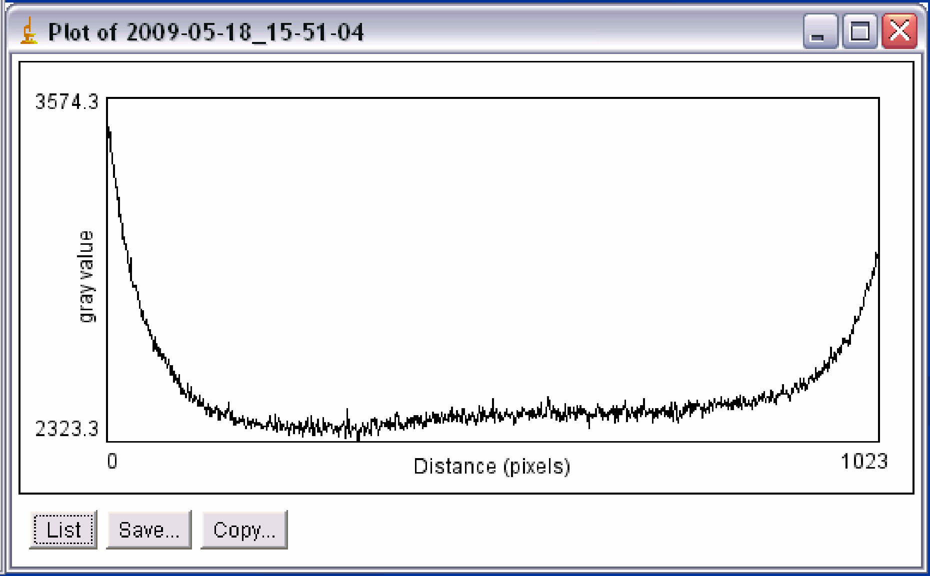
Design description

- The compact camera system is powered by external power system, supplying all voltages needed by the readout system



Performance

Dark exposure with long integration time showing enhanced dark noise at the edges



Performance

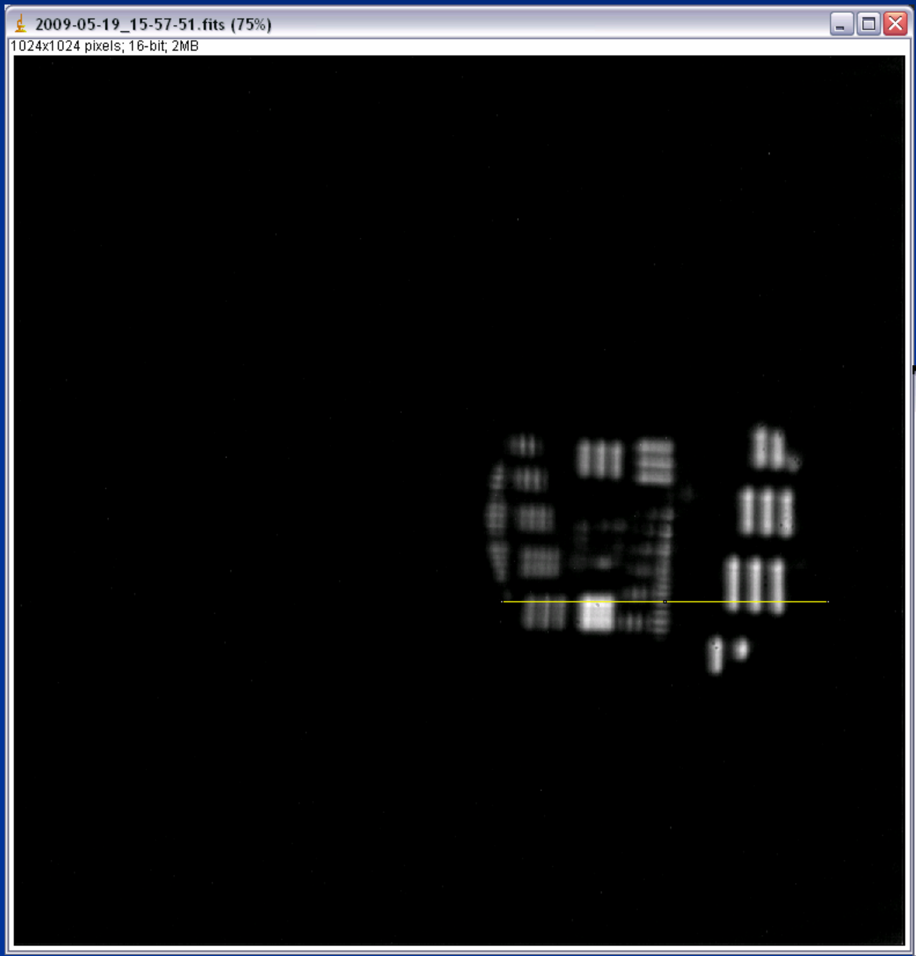
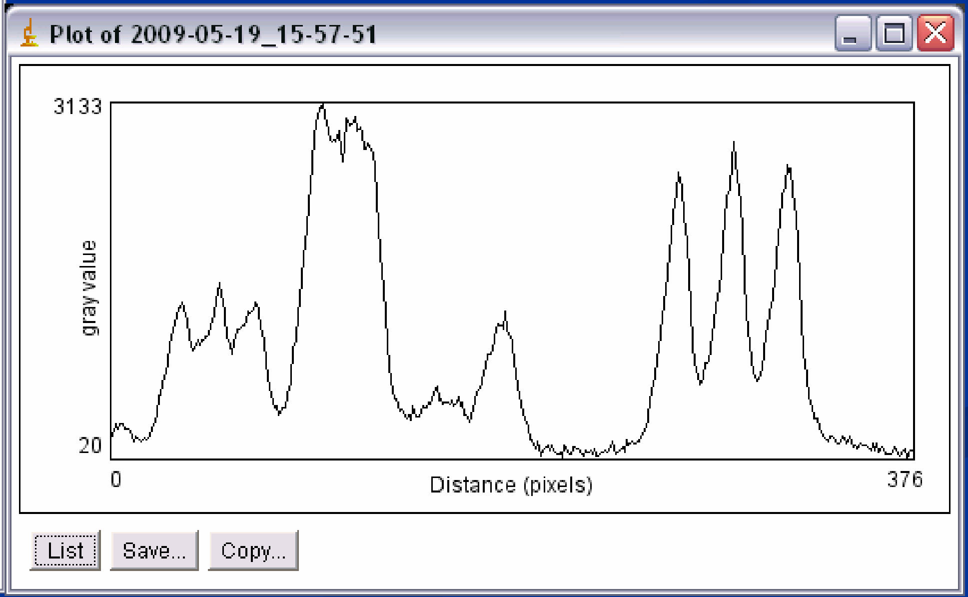
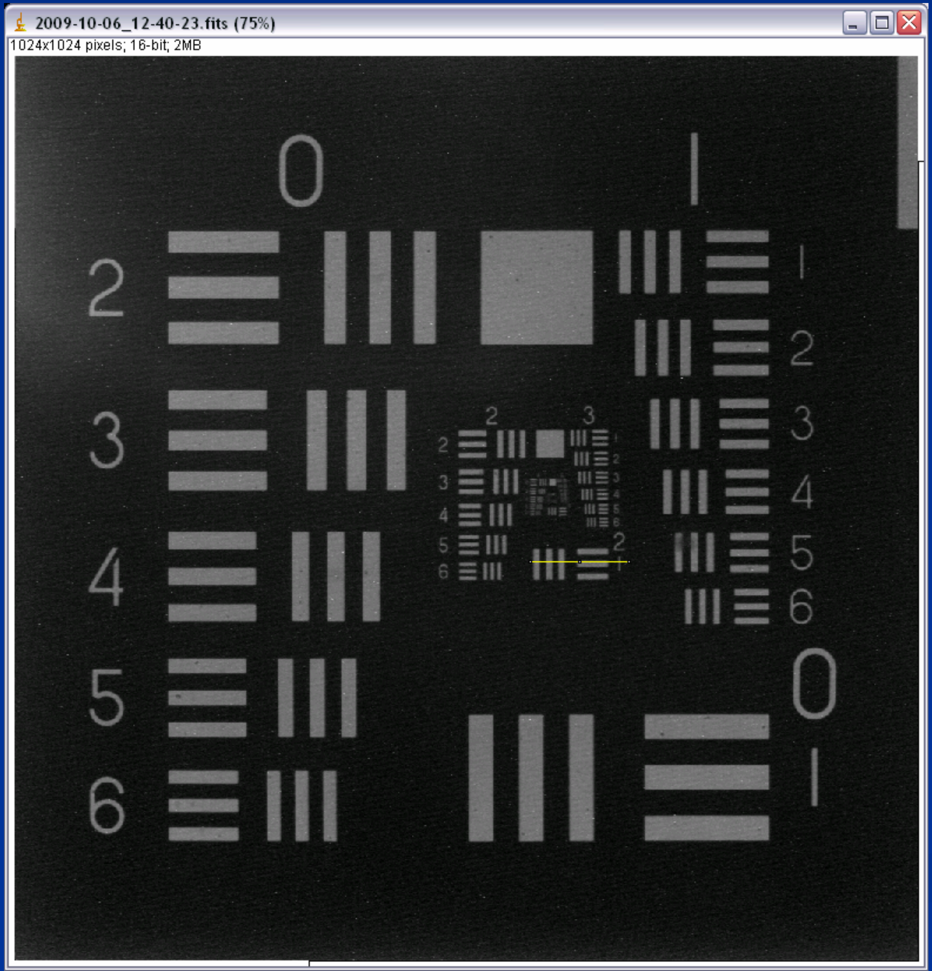


Image of a target. The yellow line is the location of the profile shown below



Performance



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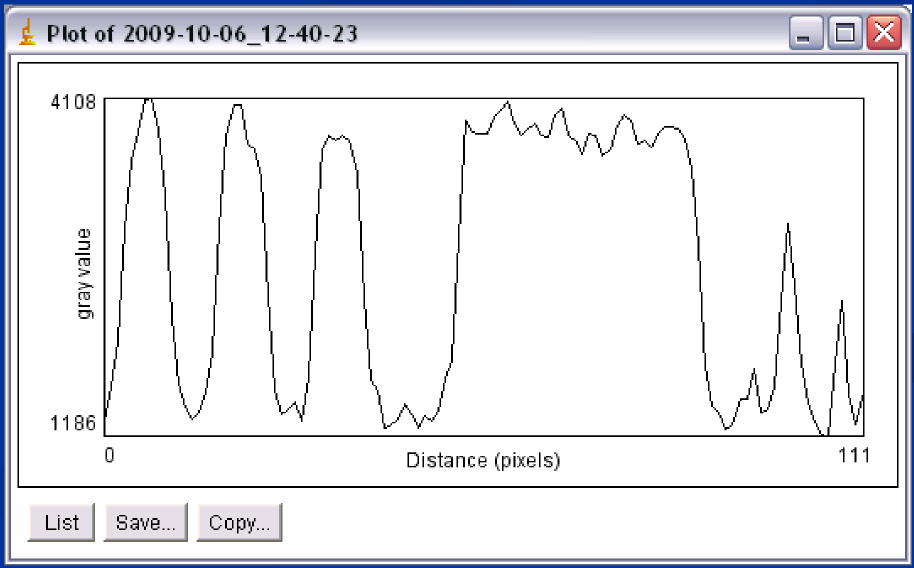
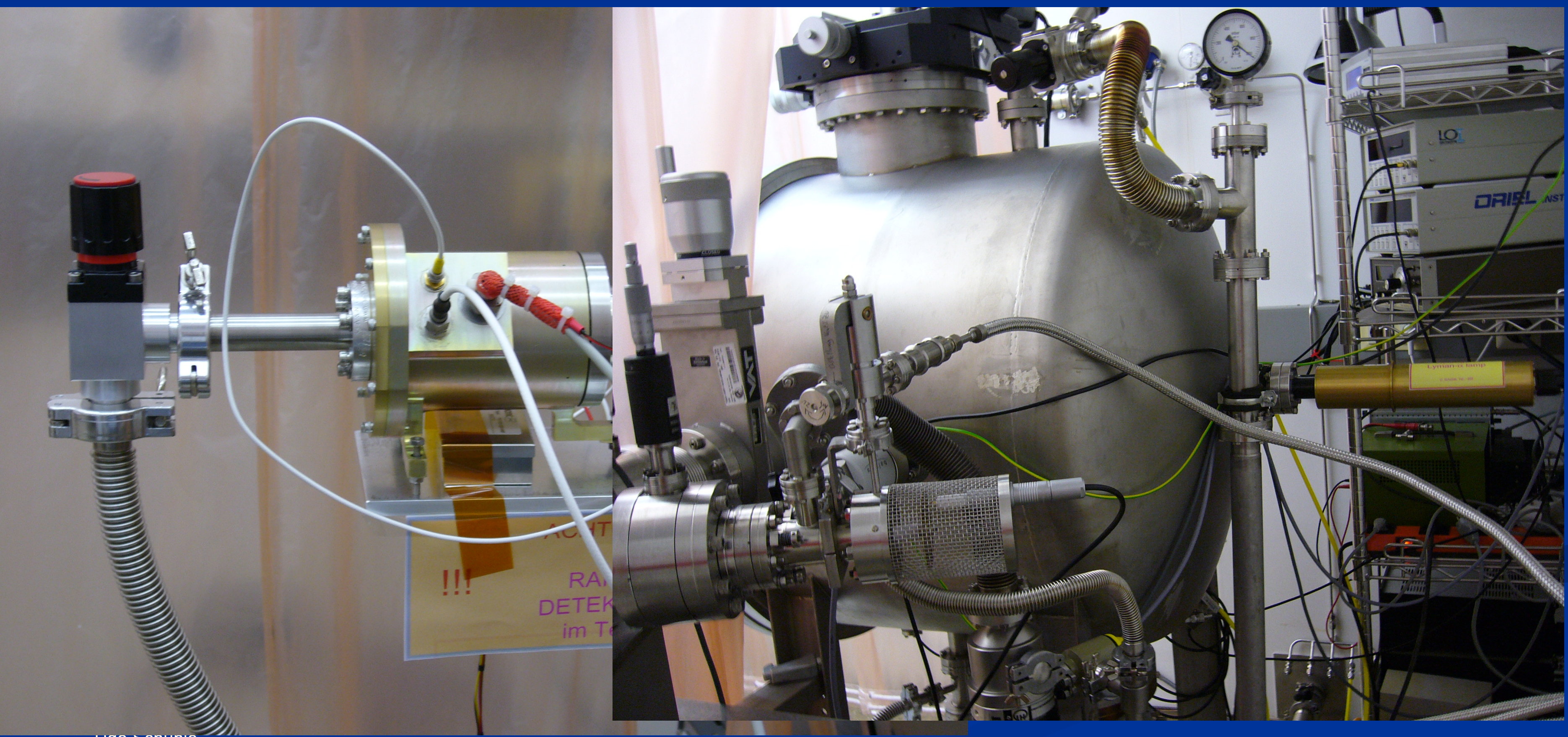


perfomance test with Lyman-α lamp and extreme UV lamp



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PHI Detector Requirements

PHI detector requirements

Parameter	Requirement	Unit	Comment
Optoelectronic			
Row pixels	2048		
Column pixels	2048		
Pixel size	10 x 10	µm x µm	
Electronic Shutter	Snapshot or Rolling		
Spectral range	400-900	nm	
Non linearity	<2.5	%	
Sensitivity	>50	%	FF*QE. Even lower could be admissible.
Readout noise	< 100	e- RMS	
Dark signal	<1000	e-/pix s	
Dynamic range	>12	bits	
Electrical			
Power consumption	<0.5	W	
Output type	Analog or Digital		Internal ADCs is an option.
Specific needs			
Vacuum compatible	$<10^{-5}$	mbar	
Operational temperature	-80 / +80	°C	
Radiation hardness	> 30-50	krad	
Chip functionality	Integrate while read would be desired		