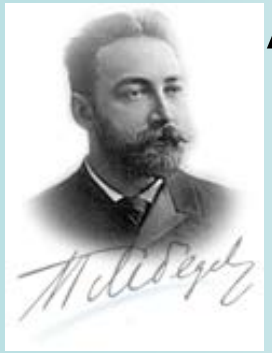
ULTRAVIOLET ASTRONOMY IN THE XXI CENTURY

e-Workshop 2020 – October 27-29

JcUVa

CCD and CMOS quantum efficiency evaluation in the EUV and VUV spectral ranges



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Outline

1. Introduction. WSO-UV spectrographs

2. Quantum efficiency (QE) evaluation procedures taken at „Kosmos“ metrological station (VEPP-4M, INP)

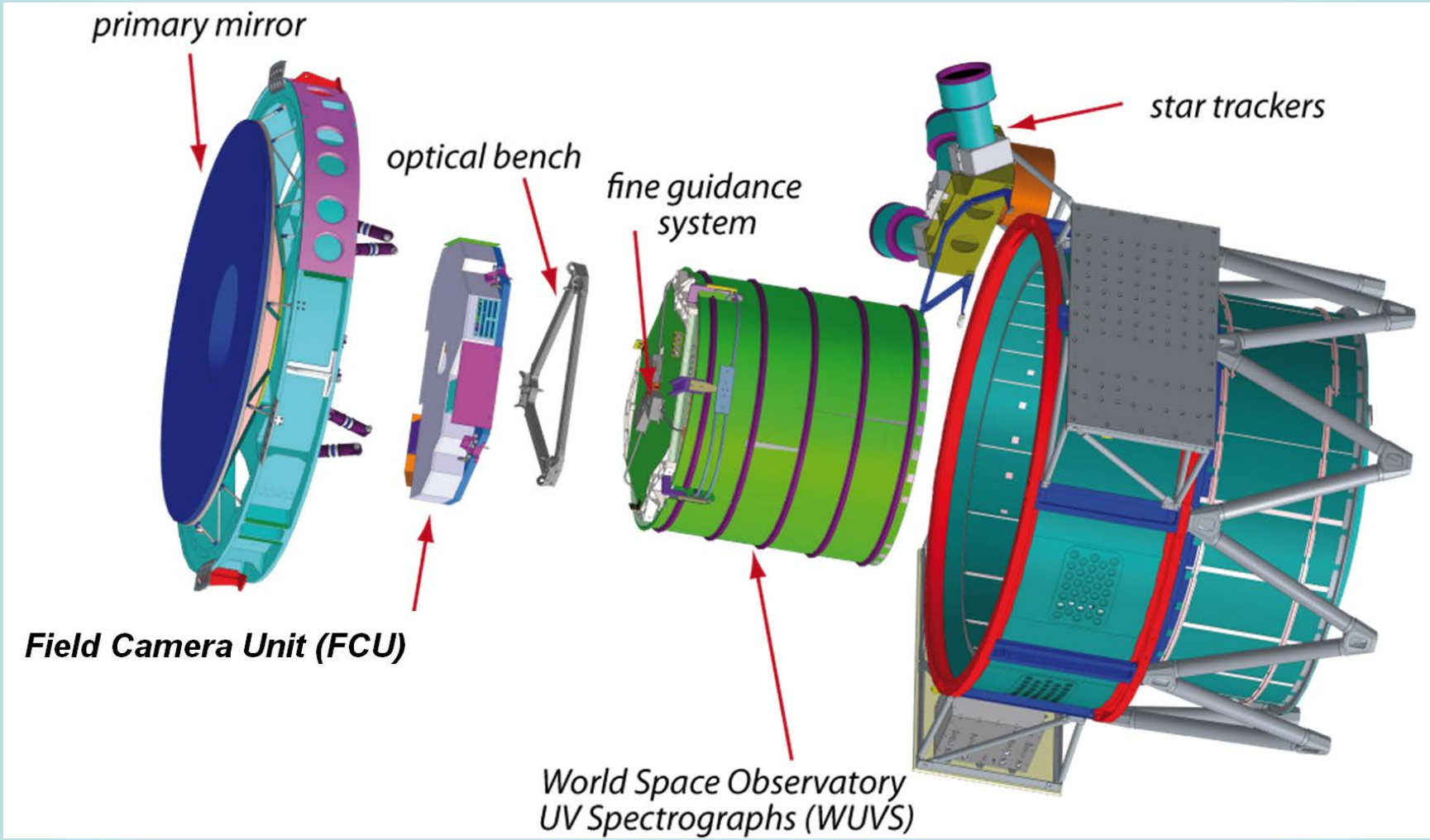
3. CCD and CMOS QE evaluation results in VUV and EUV spectral ranges

WSO-UV project objectives (World Space Observatory - UltraViolet)

- Physics of the Early Universe
- Star-forming processes in galaxies
- Formation and evolution of galaxies
- Observation of supermassive stars
- Exploring forming processes of our Galaxy
- Observation of protoplanetary disks
- Investigations of exoplanets` atmospheres
- Observation of remote objects of Solar system

*B.Shustov *et al.*, Solar System Research **48** (7), 467 (2014).

WSO-UV Instrumental Facility Layout



T-170M is 1.7 m Ritchey-Chretien telescope

World Space Observatory UV Spectrographs (WUVS)

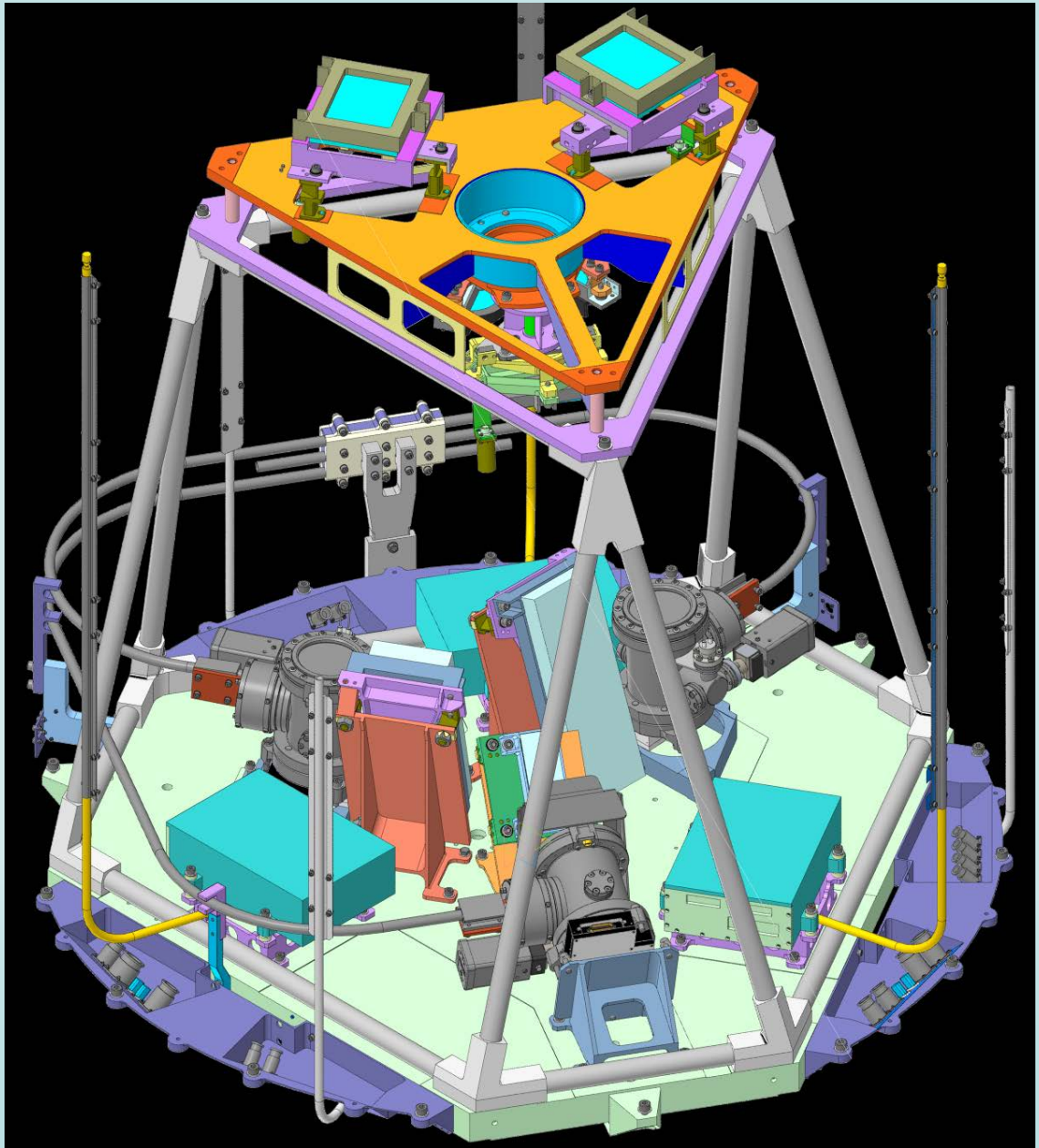
1. VUV echellé grating spectrometer (VUVES):
Spectral range 115-176 nm, resolution ~50000

2. UV echellé grating spectrometer (UVES):
Spectral range 174-310 nm, resolution ~50000

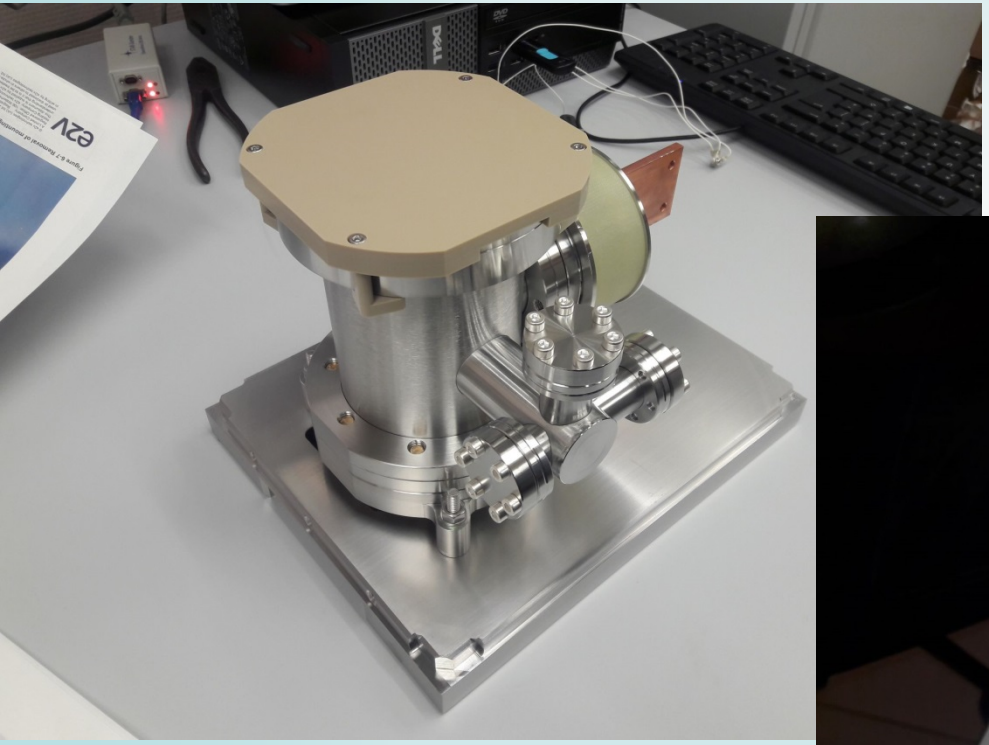
3. Long Slit Spectrograph (LSS):
Spectral range 115-305 nm, resolution ~1000

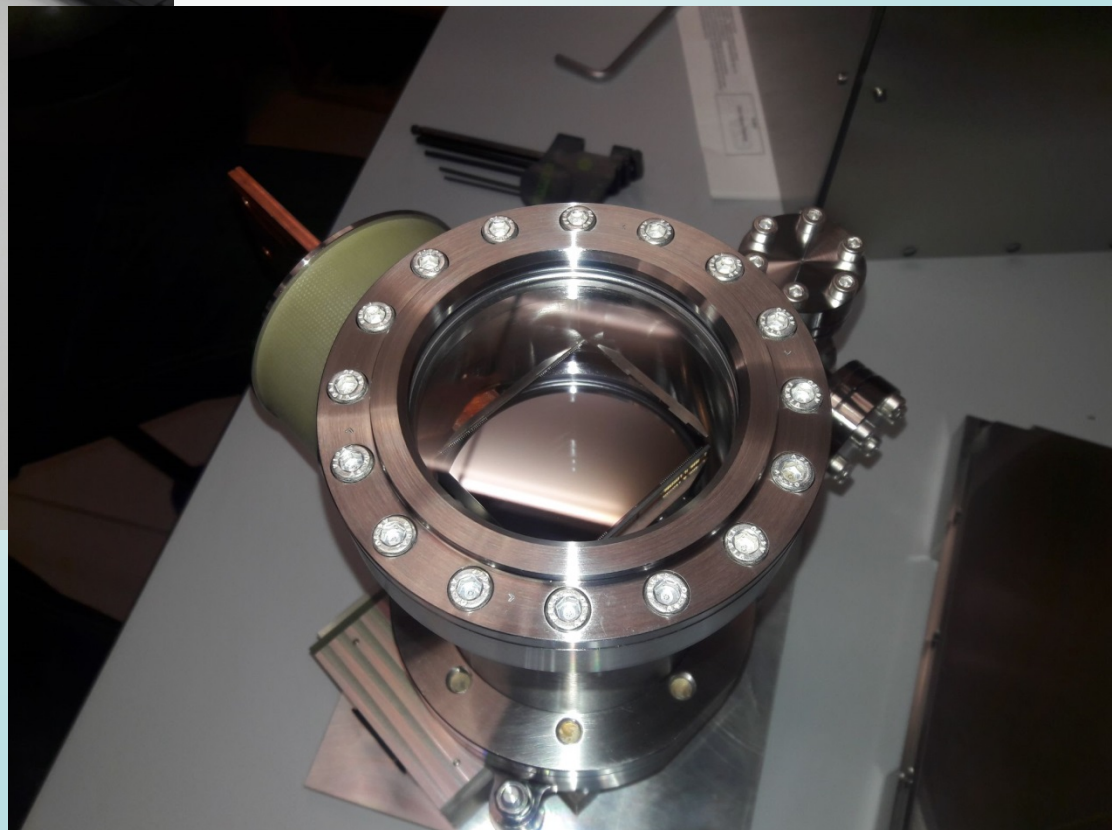
*B.Shustov *et al.*, *Astrophys. Space Sci.* **354**, 155 (2014).

WUVS optical unit with CCD detectors

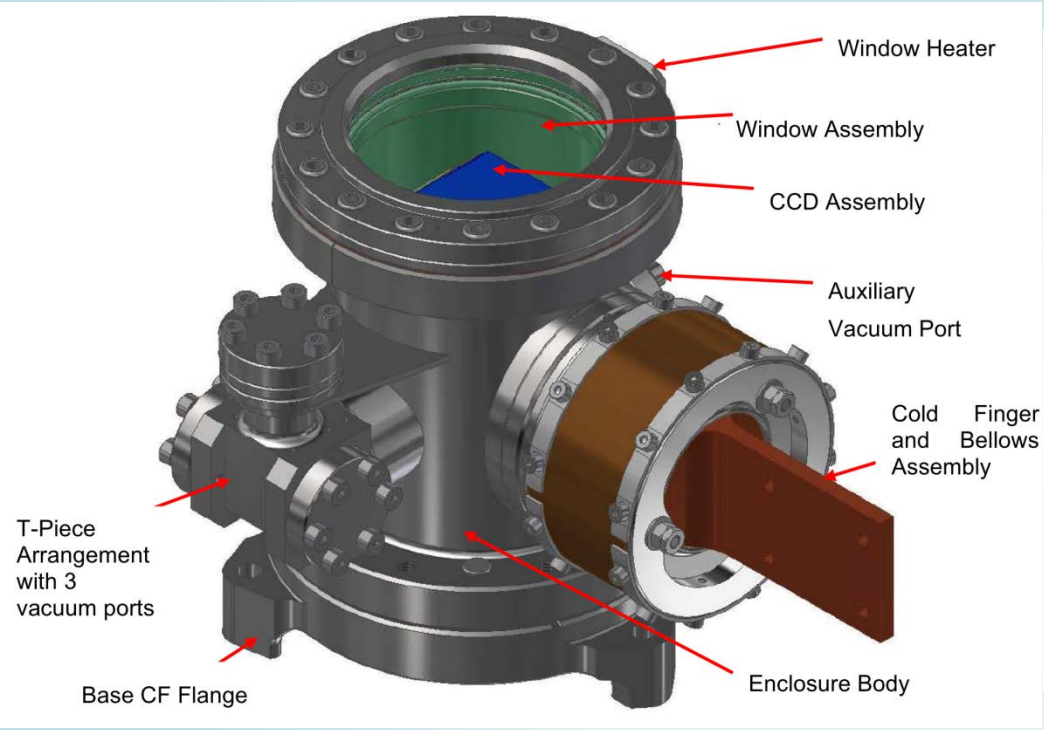


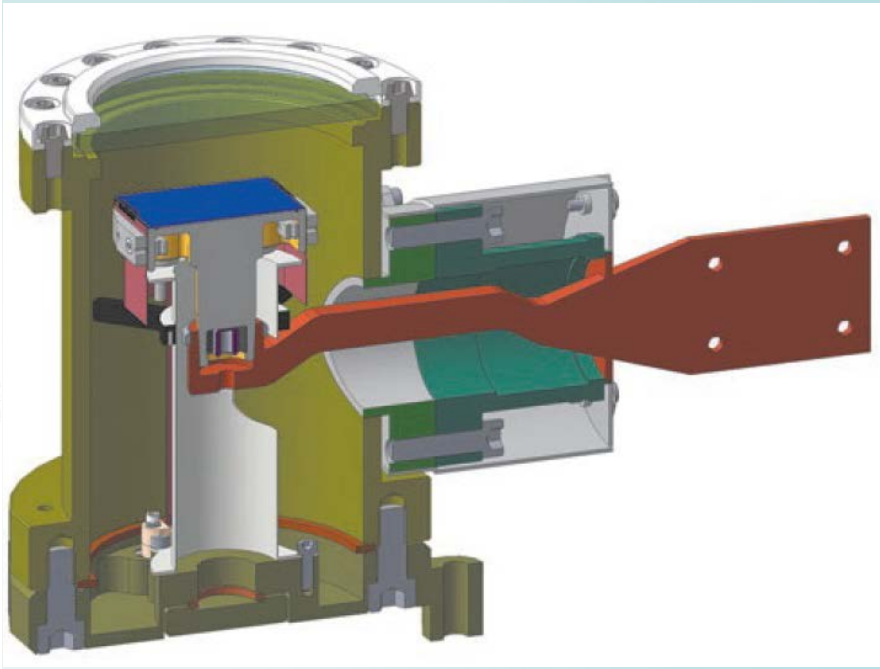
WUVS CCD detectors





WUVS CCD detectors



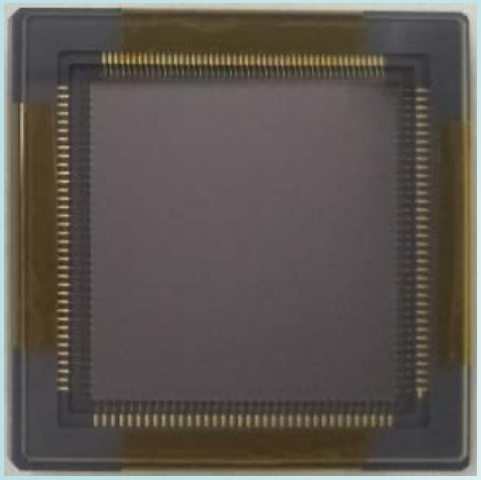


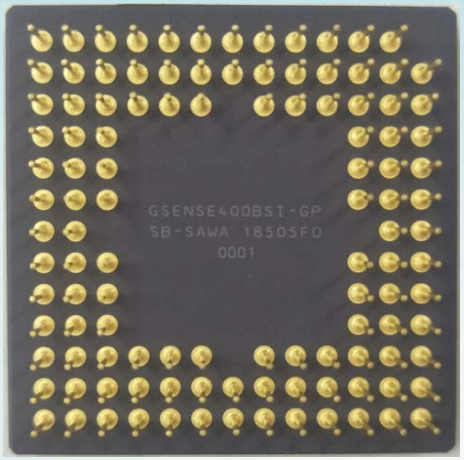
CCD format: 4096 × 3112 pixels of 12 μm

Protective UV-transparent window material: MgF_2

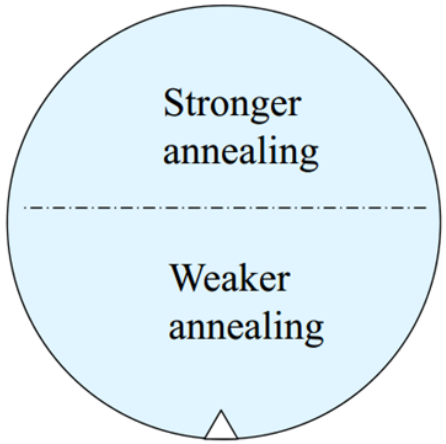
CCD operating temperature: -100 °C

CMOS sensors as alternative

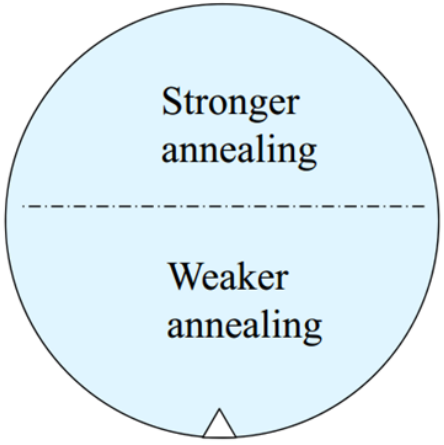




GPIXEL company (China) is able to produce various CMOS sensors sized up to 60x60mm. Back thinning process and back surface treatment were used to improve QE values in EUV and VUV spectral ranges.



- G400BSI-GP LB-SA
- G400BSI-GP LB-WA
- G400BSI-GP LB-SAWA



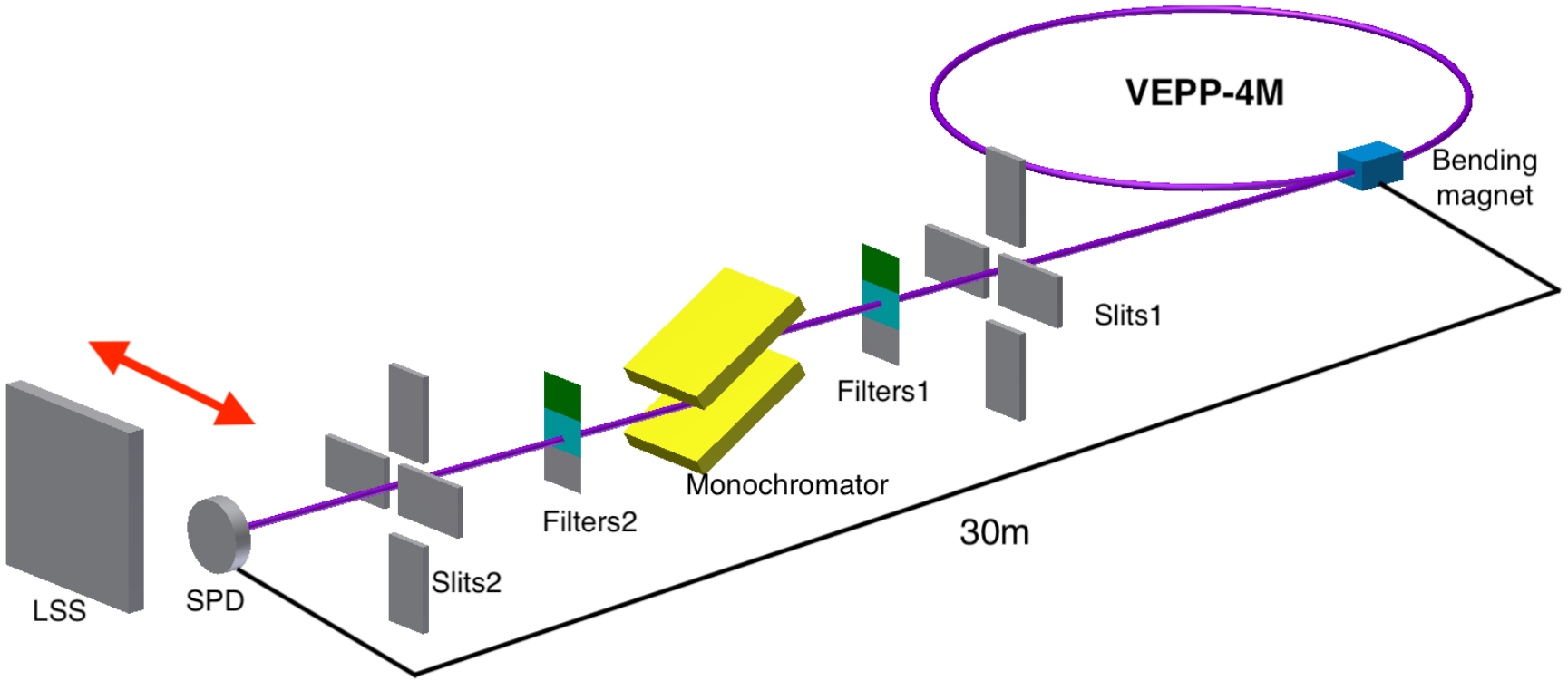
- G400BSI-GP SB-SA
- G400BSI-GP SB-WA
- G400BSI-GP SB-SAWA

- (LB) Larger boron implantation dose
- (SB) Smaller boron implantation dose

CMOS with different surface treatment were tested

„Kosmos“ metrological station layout

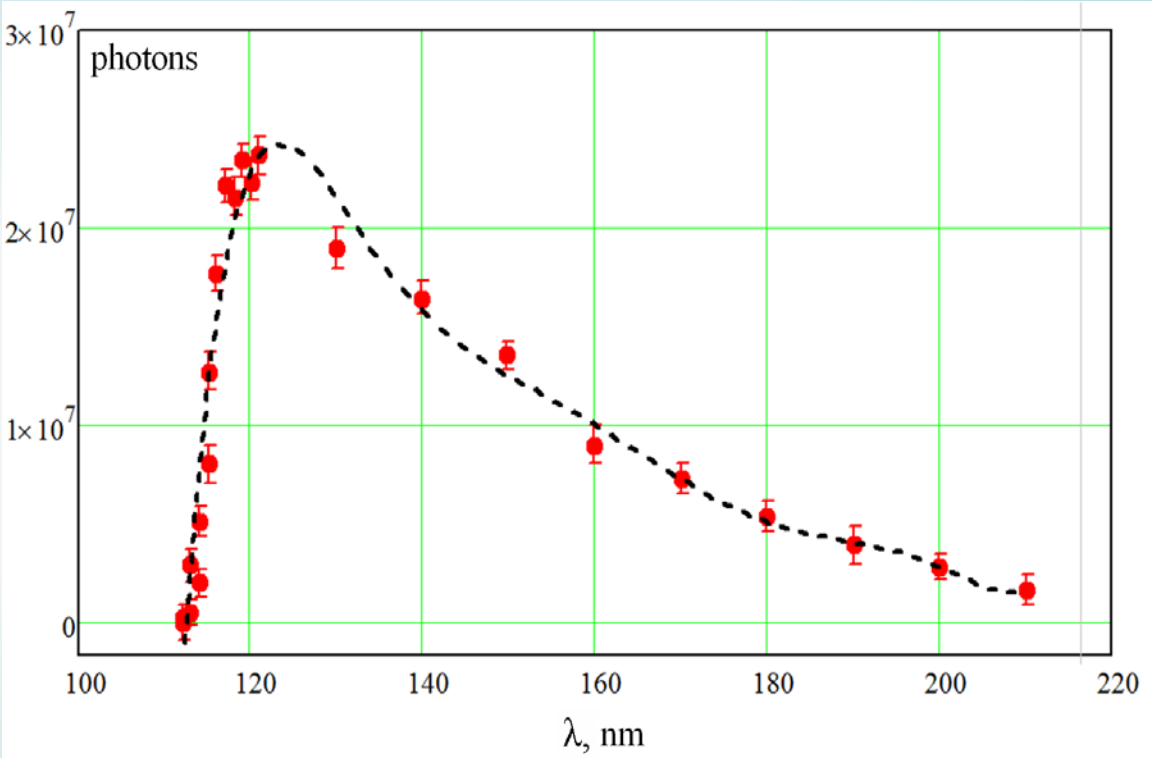
beamline №10 at VEPP-4M synchrotron radiation source
in Budker Institute of Nuclear Physics (INP), Novosibirsk



Absolutely calibrated reference detector — SPD

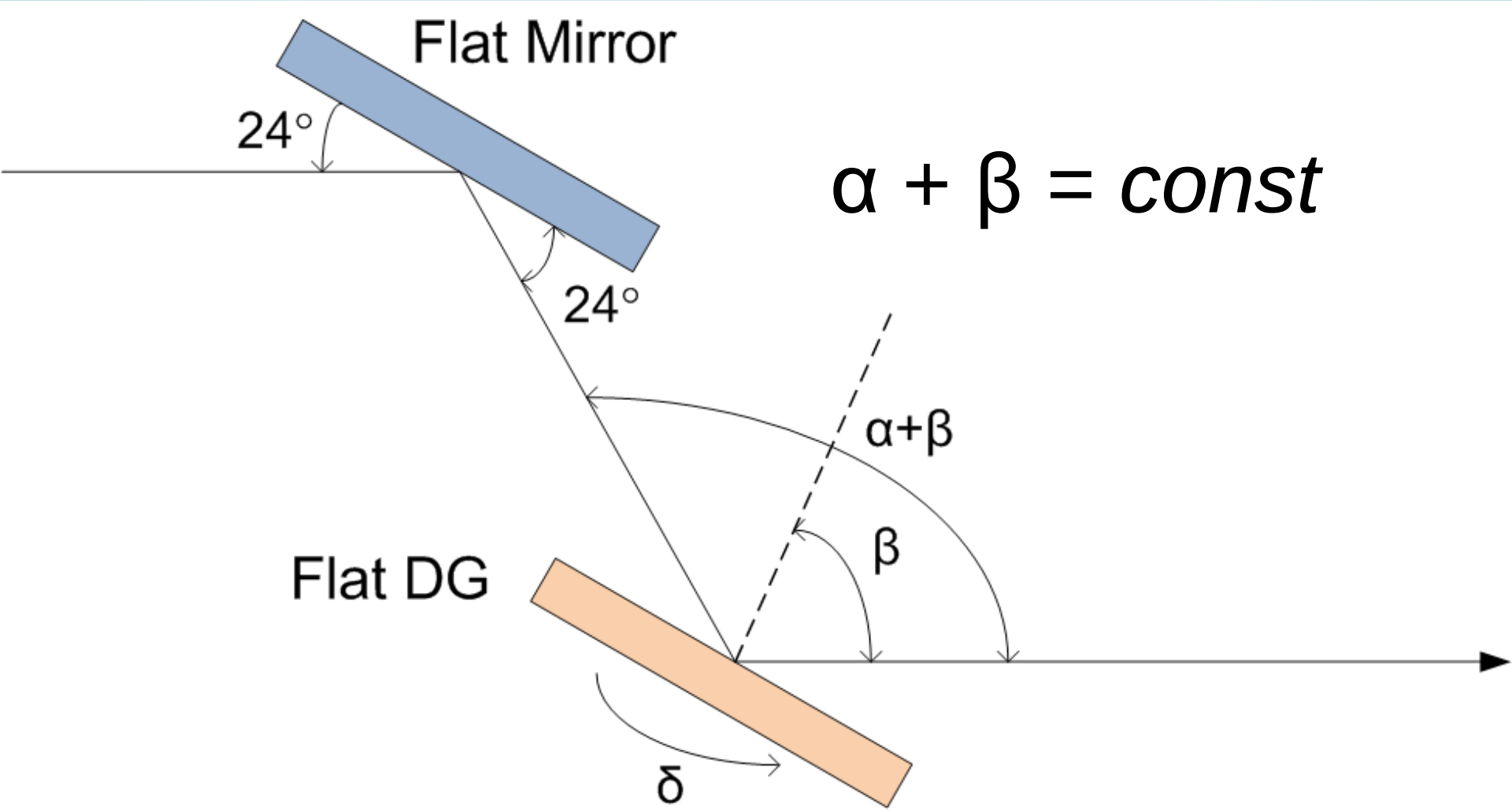
Sensitive surface
1 cm^2

Calibrated at PTB
2005, 2017



Photon flux at „Kosmos“ station in 110-220 nm spectral range (with MgF_2 filter).

„Kosmos“ diffration grating (DG) EUV/VUV monochromator layout



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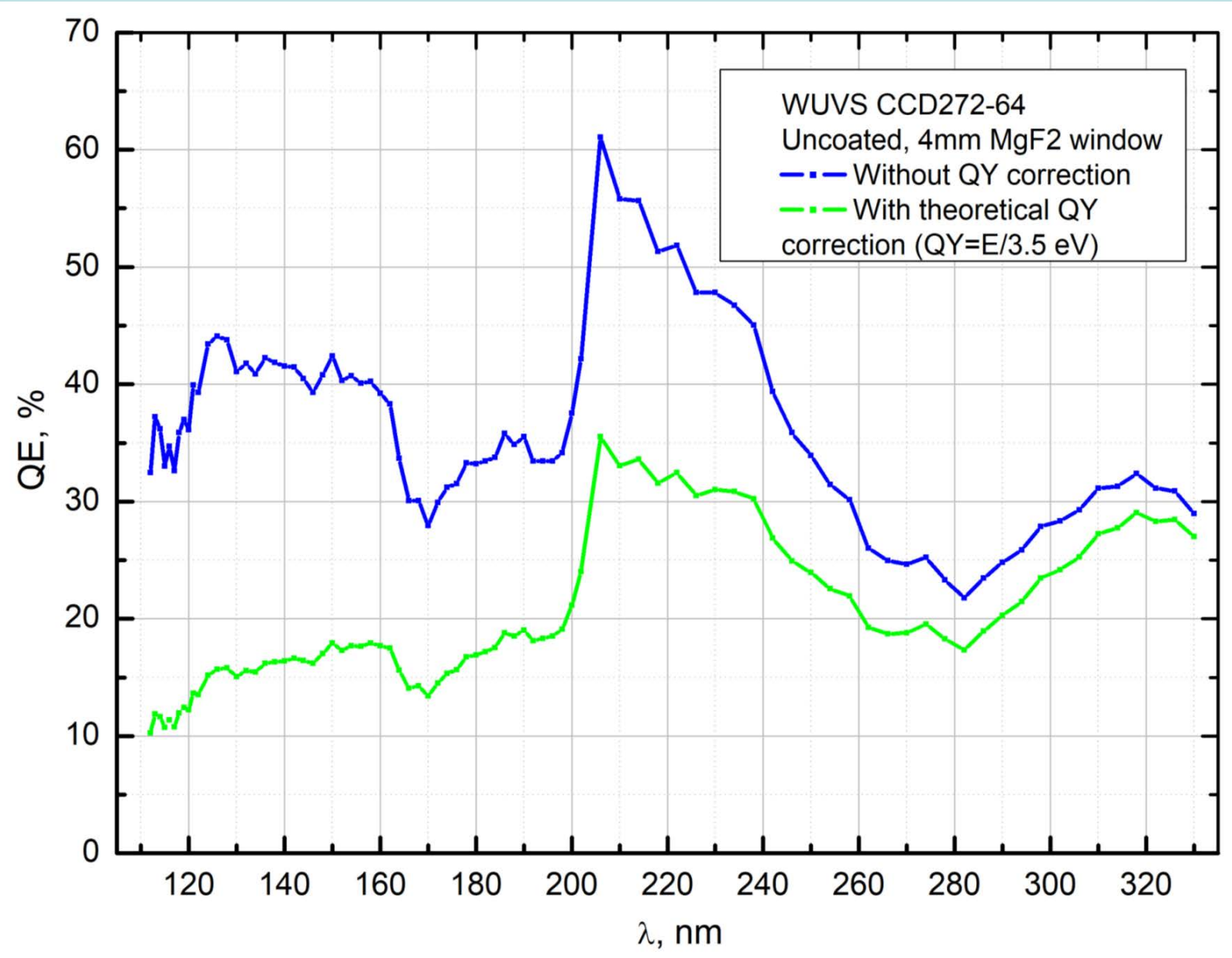
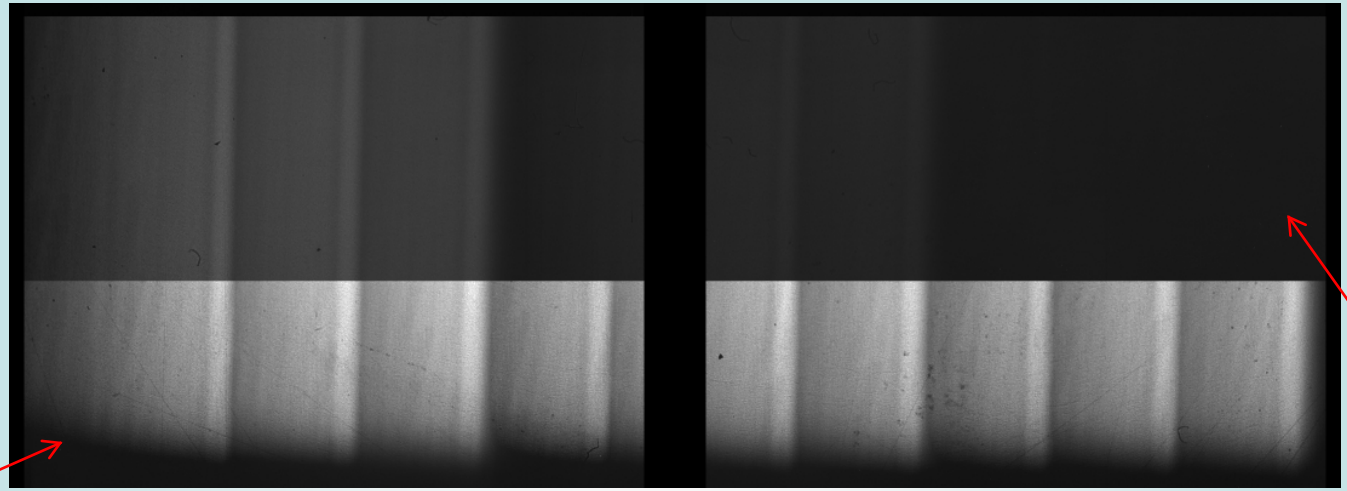
Experimental Results for WUVS CCD



Gradient anti-reflection coating

180 nm optimization

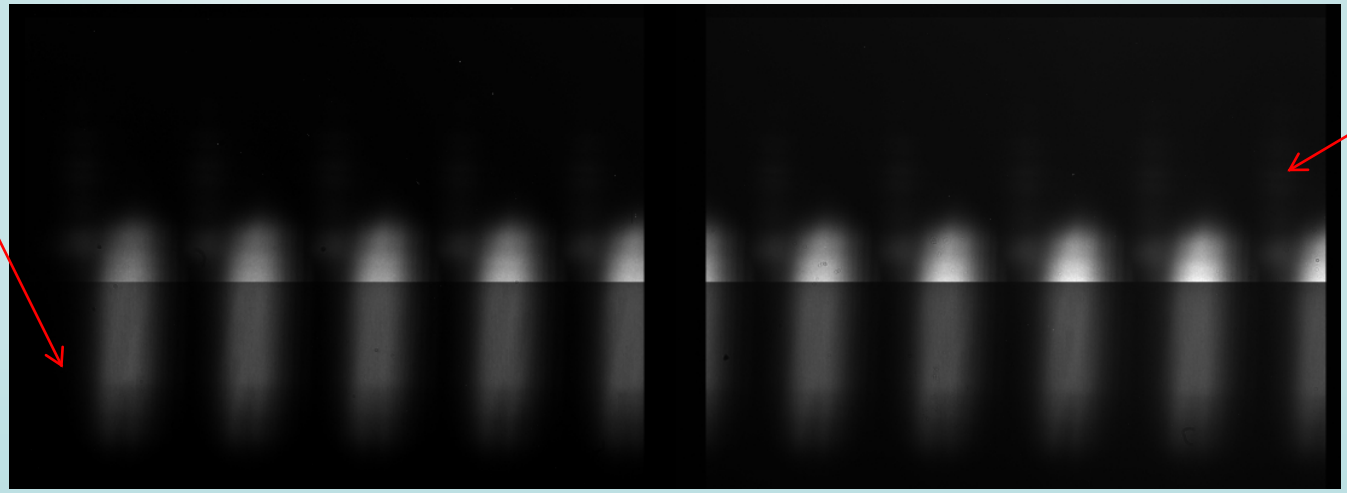
310 nm optimization



Illumination at 120 nm

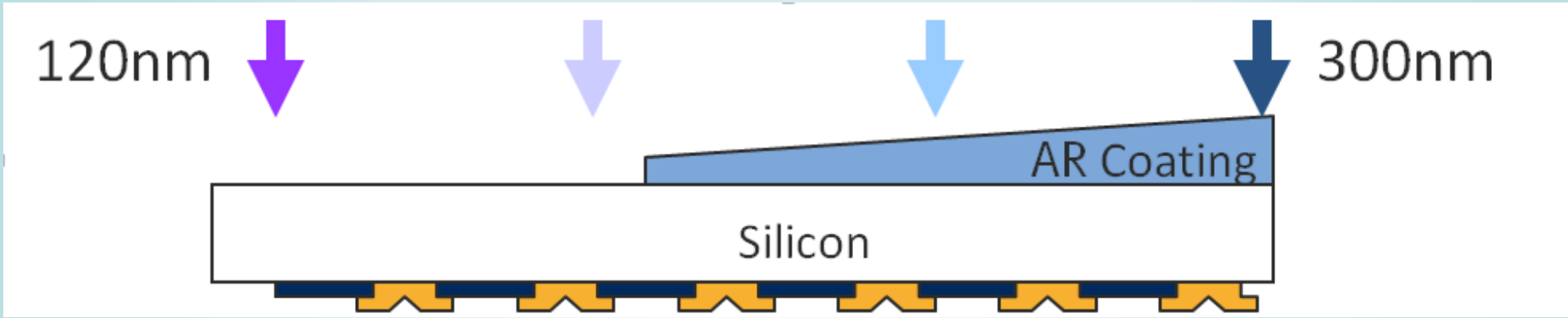
Uncoated

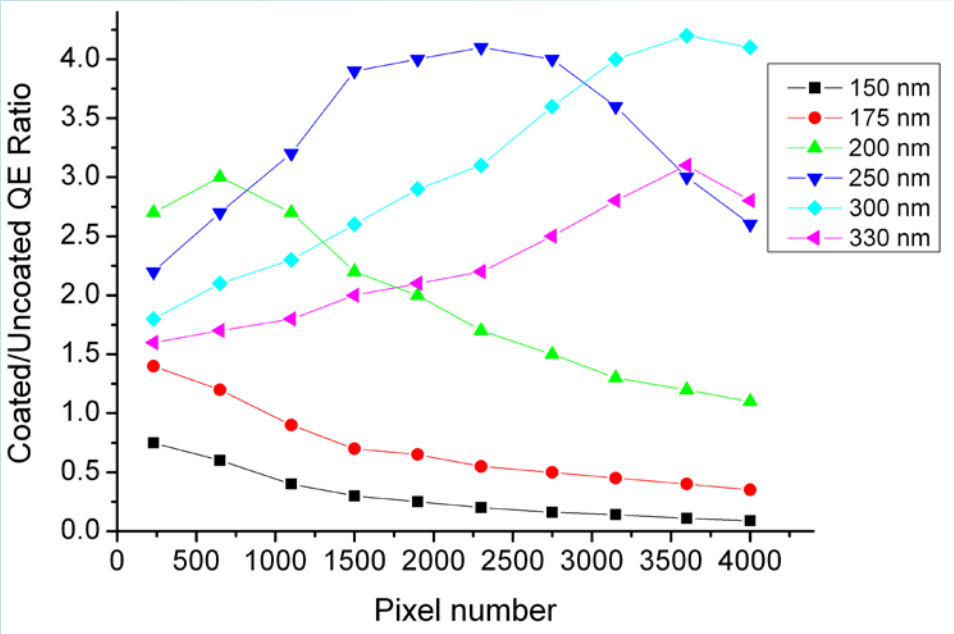
Gradient AR coating

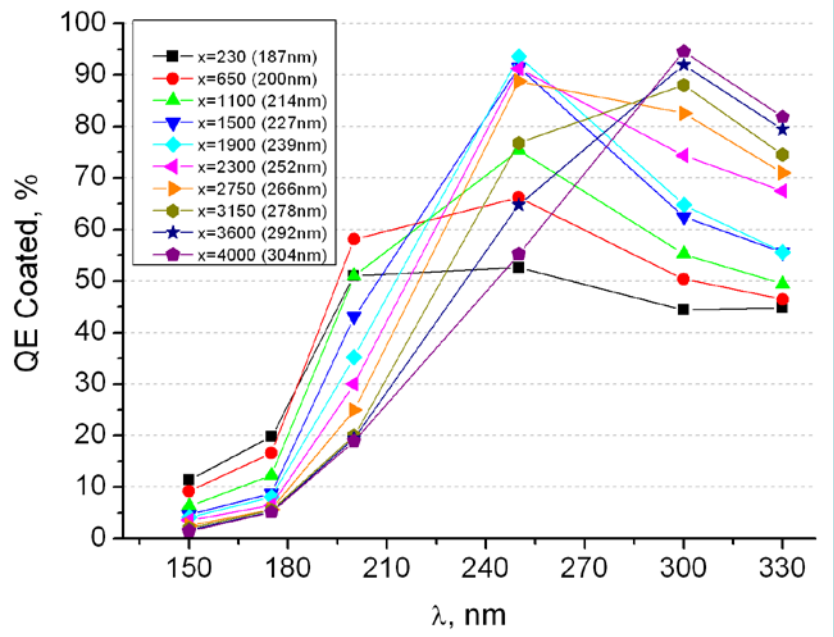


Illumination at 300 nm

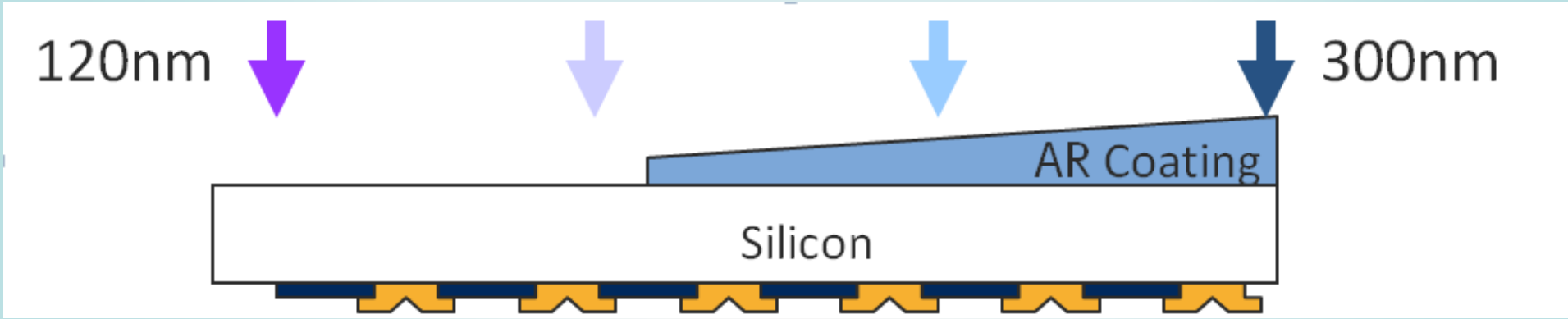
Experimental Results for WUVS CCD with gradient anti-reflection coating

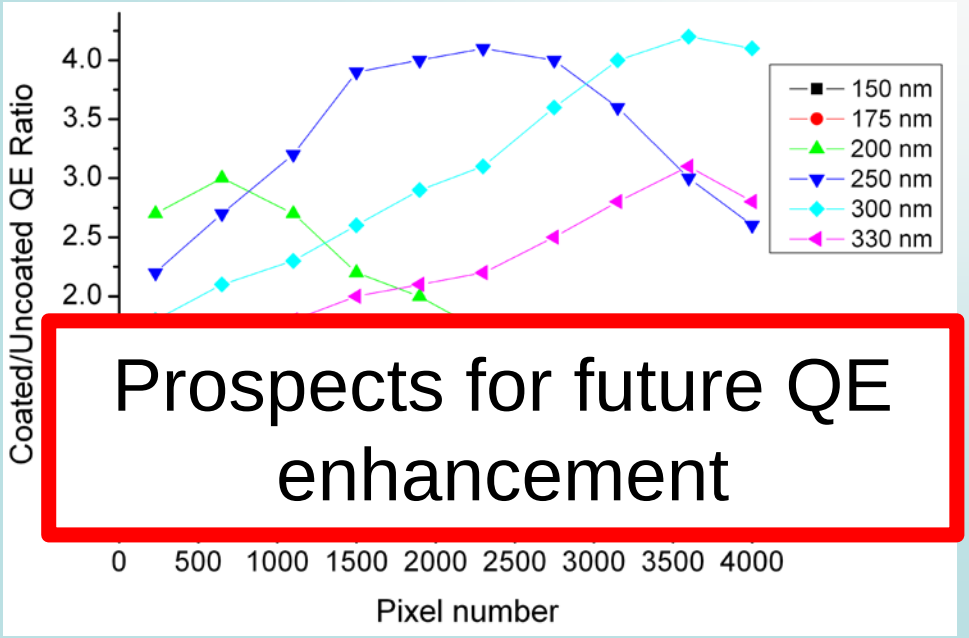




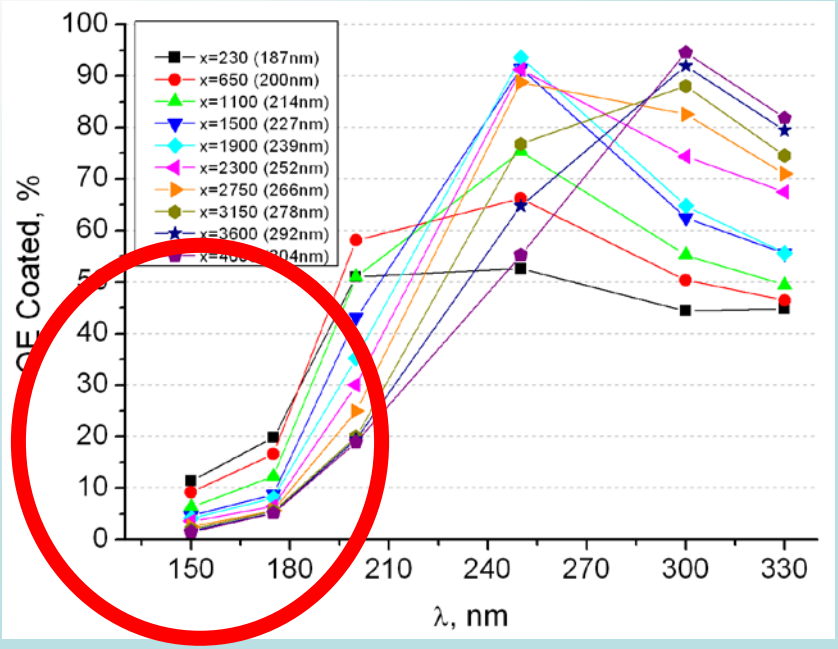


Experimental Results for WUVS CCD with gradient anti-reflection coating

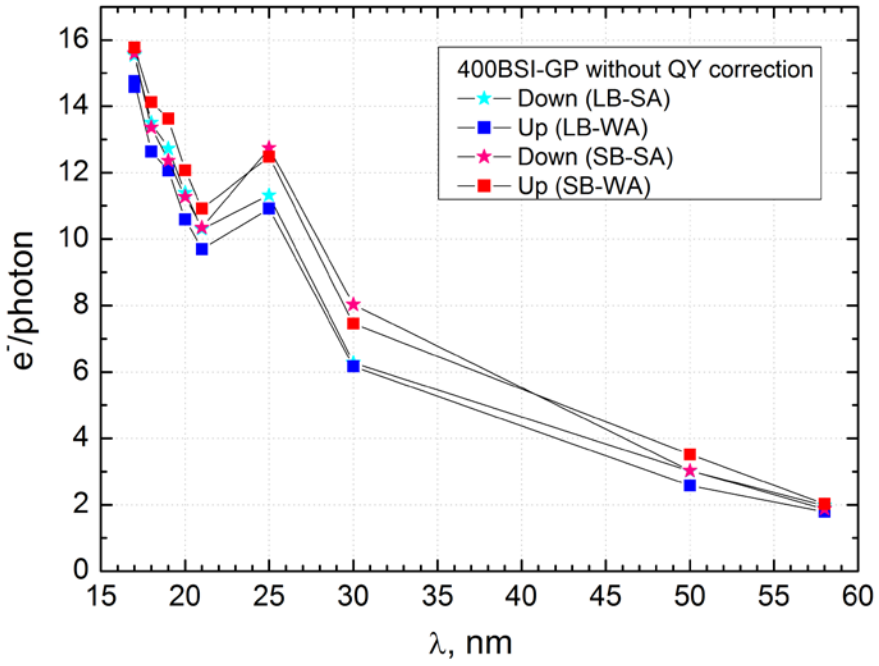


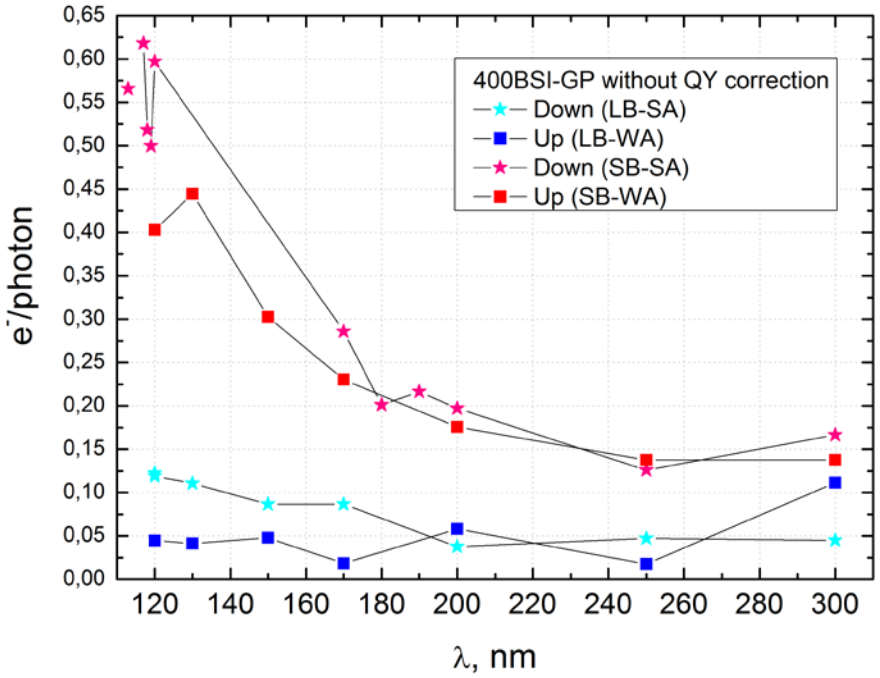


Prospects for future QE enhancement



CMOS Experimental Results





EUV VUV

SB/LB — Strong/Low Boron implantation dose

SA/WA — Strong/Weak Annealing

Summary

- Quantum efficiency measurements of VUV CCD and CMOS detectors were conducted using synchrotron radiation from VEPP-4M
- CCD+MgF_2 QE values are ~15% in 112-200 nm range, and ~30% (after QY correction) in 210-330 nm range
- CMOS QE values are ~10% in 112-330 nm VUV range, and ~80% in 17-58 nm EUV range
- Boron implantation increases CMOS QE in EUV&VUV
- Usage of special anti-reflection coatings paves the way to increase CCD QE values up to 4x in 220-310 nm range
- Design of new AR coatings could increase CCD QE values at shorter wavelengths

Acknowledgements

- We acknowledge VEPP-4M operating team for sustainable technical support and excellent synchrotron performance
- We acknowledge Teledyne e2v for the design and production of the CCD detectors for WSO-UV space project
- We express our gratitude to Gpixel company to provide the CMOS for QE evaluation