ULTRAVIOLET ASTRONOMY IN THE XXI CENTURY

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

A. S. Shugarov\textsuperscript{1}, E. A. Vishnyakov\textsuperscript{2,*}, A. D. Nikolenko\textsuperscript{3}, D. V. Ivlyushkin\textsuperscript{3}, P. S. Zavertkin\textsuperscript{3}, A. S. Kirichenko\textsuperscript{2}, S. V. Kuzin\textsuperscript{2}, A. A. Pertsov\textsuperscript{2}

\textsuperscript{1} Institute of Astronomy of RAS, Moscow, Russia
\textsuperscript{2} P.N.Lebedev Physical Institute of RAS, Moscow, Russia
\textsuperscript{3} Budker Institute of Nuclear Physics, Novosibirsk, Russia
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 $\sim$50000

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

3. Long Slit Spectrograph (LSS):
   Spectral range 115-305 nm, resolution $\sim$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: $4096 \times 3112$ 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.

CMOS with different surface treatment were tested

- (LB) Larger boron implantation dose
  - G400BSI-GP LB-SA
  - G400BSI-GP LB-WA
  - G400BSI-GP LB-SAWA

- (SB) Smaller boron implantation dose
  - G400BSI-GP SB-SA
  - G400BSI-GP SB-WA
  - G400BSI-GP SB-SAWA
„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“ diffraction grating (DG) EUV/VUV monochromator layout

\[ \alpha + \beta = \text{const} \]
Experimental Results for WUVS CCD

WUVS CCD272-64
Uncoated, 4mm MgF2 window

- Blue line: Without QY correction
- Green line: With theoretical QY correction (QY=E/3.5 eV)
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
SB/LB — Strong/Low Boron implantation dose
SA/WA — Strong/Weak Annealing

VUV
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
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- 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