



# Vacuum-ultraviolet response of a GSENSE2020BSI-PS CMOS camera

Synchrotron calibration from 58 to 200 nm

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NUVA e-meeting 2026 ■ 7 October 2026

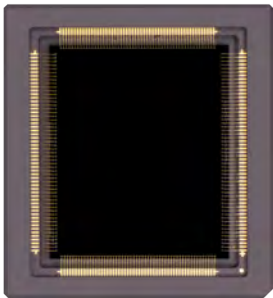
# Why characterize CMOS sensors in the VUV?

- The 58–200 nm band contains key diagnostics including H I Ly $\alpha$ , O VI, and C IV.
- MCP detectors remain the natural choice for extremely faint, photon-counting observations.
- Backside-illuminated scientific CMOS offers a complementary path for selected brighter targets:
  - large, buttible focal-plane formats;
  - fine spatial sampling and high frame rate;
  - direct imaging with mature readout electronics.



**This work:** absolute camera-level response of a VUV-processed CMOS sensor from 58 to 200 nm.

# Detector under test



Gpixel GSENSE2020BSI-PS sensor

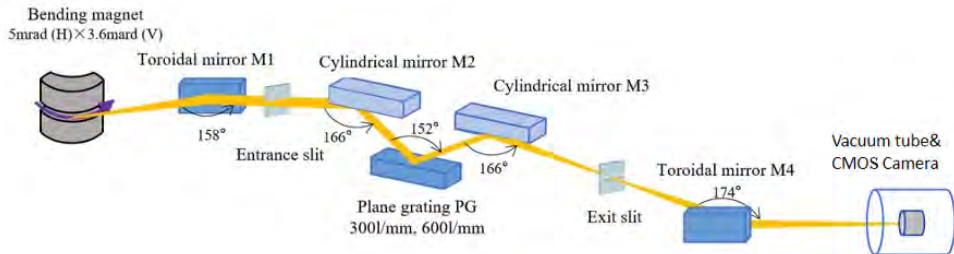
QHYCCD camera system

|                 |                             |
|-----------------|-----------------------------|
| Array           | 2048 × 2048 pixels          |
| Pixel size      | 6.5 × 6.5 $\mu\text{m}^2$   |
| Active area     | 13.3 × 13.3 mm <sup>2</sup> |
| Architecture    | backside illuminated        |
| Surface process | PulSar, uncoated            |
| Readout         | 12-bit, STD MODE LGC        |
| Camera settings | gain 22, offset 11          |
| Operation       | room temperature            |

## Why PulSar improves VUV response

No conventional antireflection coating and a thinner insensitive surface layer allow more short-wavelength photons to reach active silicon.

# Synchrotron calibration experiment



- NSRL metrology beamline B: **58–200 nm**
- Grazing-incidence monochromator with two gratings
- Ne gas filter below 105 nm; LiF filter above 105 nm
- Spectral purity > 99.9%

- Pressure <  $10^{-4}$  Torr
- Beam spot  $\sim 0.5 \times 3.0$  mm<sup>2</sup>
- Local detector response measured

# Measurement strategy

The photodiode and camera were measured sequentially during the same continuous beamline run.

## 1. Incident photons

AXUV-100G photodiode

Absolute photon rate  $N_p(\lambda)$

## 2. Camera signal

VUV exposure and dark frames

Dark-subtracted ADU

## 3. Electronic gain

Visible-light flat-field PTC

Conversion gain  $G_{\text{vis}}$

**Derived response: QE, photon detection probability, and QY**

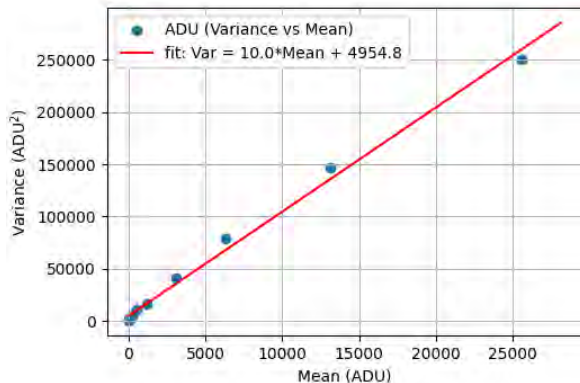
## Photodiode reference

100 current samples per wavelength at  $\sim 0.5$  s intervals; PTB responsivity uncertainty: 3.35–5.49%.

## Beam stability

Independent one-hour test: 0.33% relative standard deviation. Residual drift remains a systematic limitation.

# Electronic conversion gain from visible light



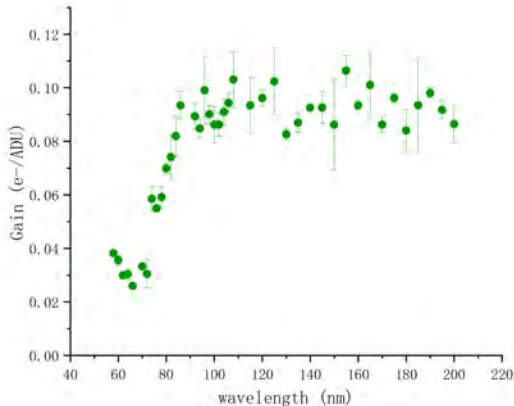
## Visible-light PTC

$$G_{\text{vis}} = (0.100 \pm 0.003) e^-/\text{ADU}$$

- Read noise from fit intercept:  
 $7.06 e^-_{\text{rms}}$
- Independent bias-pair estimate:  
 $\sim 5.8 e^-_{\text{rms}}$
- Dark current near 19°C:  
 $29.6 e^- \text{ pixel}^{-1} \text{ s}^{-1}$

This gain, rather than the wavelength-dependent VUV PTC slope, converts ADU into generated electrons.

# VUV photon-transfer curves encode quantum yield

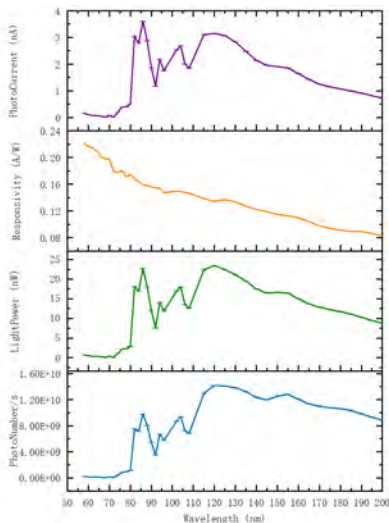


- A VUV photon can generate multiple electron-hole pairs.
- Signal and variance are both modified by impact ionization.
- The VUV PTC slope therefore gives an **apparent gain**  $G_{\text{VUV}}(\lambda)$ .

## Quantum yield estimate

$$Y(\lambda) = \frac{G_{\text{vis}}}{G_{\text{VUV}}(\lambda)}$$

# Absolute photon flux

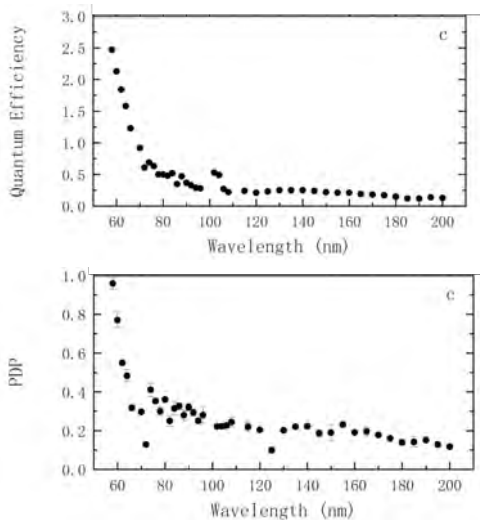


$$P(\lambda) = \frac{I_{\text{diode}}}{R(\lambda)},$$
$$N_p(\lambda) = \frac{P(\lambda)\lambda}{hc}.$$

- 100 mm<sup>2</sup> photodiode active area fully enclosed the beam.
- The camera signal was summed over an ROI enclosing the same beam spot.
- No active-area normalization was required: both measurements represent the spatially integrated beam.

PTB responsivity uncertainty: 3.35–5.49%.

# Quantum efficiency and photon detection probability



## Two useful quantities

$$QE = \frac{N_e}{N_p}$$

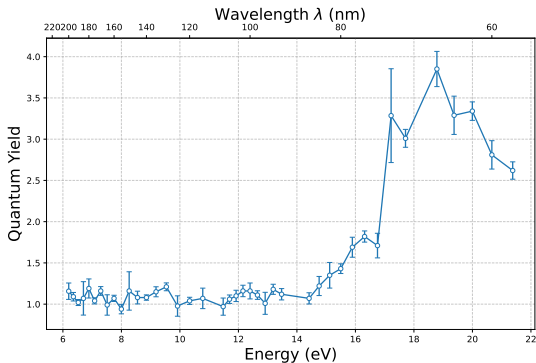
counts generated electrons per incident photon and can exceed unity in the VUV.

$$PDP = \frac{N_{\text{detected photons}}}{N_p}$$

estimates the probability of detecting an incident photon.

- QE reaches  $\sim 2.5$  at 58 nm because  $QE > 1$ .
- The corresponding PDP is  $\sim 0.96$ .
- Response declines toward 200 nm.

# Quantum yield and interpretation



- QY is clearly wavelength dependent and exceeds unity at short wavelengths.
- The apparent local maximum near 66 nm should be treated cautiously.
- Lower photon flux and longer exposures below 70 nm increase sensitivity to dark current, source variation, and sparse illumination levels.

We report this as an effective camera-level measurement, not as an intrinsic silicon QY curve.

# Scope and limitations

## What was demonstrated

- Absolute VUV response from 58 to 200 nm
- Independent electronic gain calibration
- Separation of QE, PDP, and effective QY
- Commercial camera-level performance

## What remains

- Full-focal-plane response mapping
- Cooled operation and temperature dependence
- Simultaneous flux monitoring
- Denser PTC sampling below 70 nm

**The reported values apply to the illuminated central region and room-temperature operation.**

# Take-home messages

- ① The PulSar-processed GSENSE2020BSI-PS camera shows substantial sensitivity across **58–200 nm**.
- ② A visible-light PTC gives the electronic gain; VUV PTC slopes additionally encode wavelength-dependent quantum yield.
- ③ At 58 nm, the measured camera-level **QE is about 2.5** while the inferred **PDP is about 0.96**.
- ④ This CMOS sensor is a promising complement to MCPs for UV imaging and photometry of selected sources where large format and spatial sampling matter more than event-by-event photon counting.

Thank you