# Objective Characterization of Cameras using new EMVA 1288 Release 3.1 with Focus on Non-Uniformities

Bernd Jähne

Chair EMVA 1288 Standard Group
Heidelberg Collaboratory for Image Processing (HCI)
Interdisciplinary Center for Scientific Computing
University of Heidelberg Bernd.Jaehne@iwr.uni-heidelberg.de

AIT, Scientific Vision Days, Vision Fair, Stuttgart
November 10, 2016

1288
EMVA Standard Compliant

# Outline

1. Intention and goal
2. Camera model
3. Most important measurements
4. New in Release 3.1
5. Analysis of PRNU
6. Further information

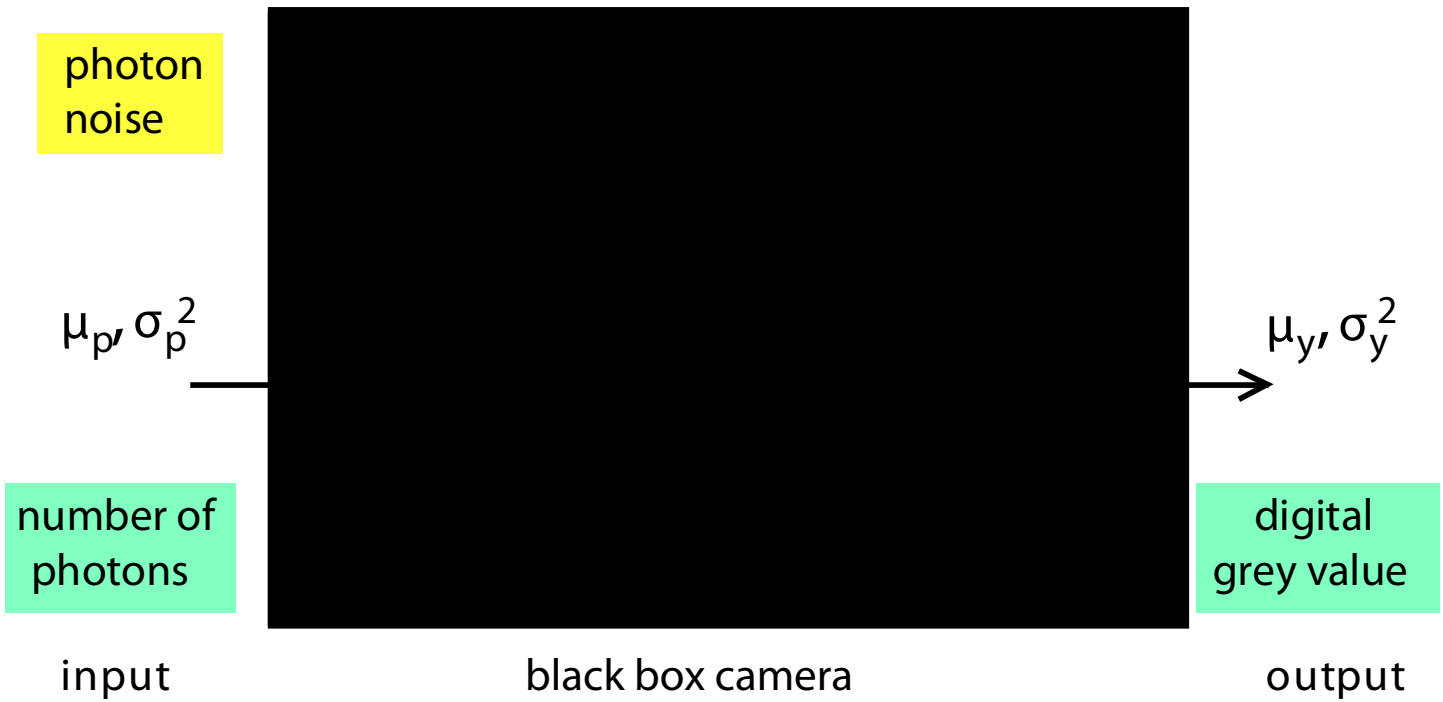
# What is the EMVA 1288 Standard about?

1. Objective specification of monochrome and color cameras, area scan and line scan
2. Based on well-defined physical parameters
   Ensures transparency and comparability.
3. Covers all important camera parameters
   Targeted for customers, distributors, and manufactures alike
4. Broad support from camera manufactures and distributors
5. Global acceptance (G3: AIA, CMVU, EMVA, JIIA, VDMA)

1288
EMVA Standard Compliant

# How can it work at all?

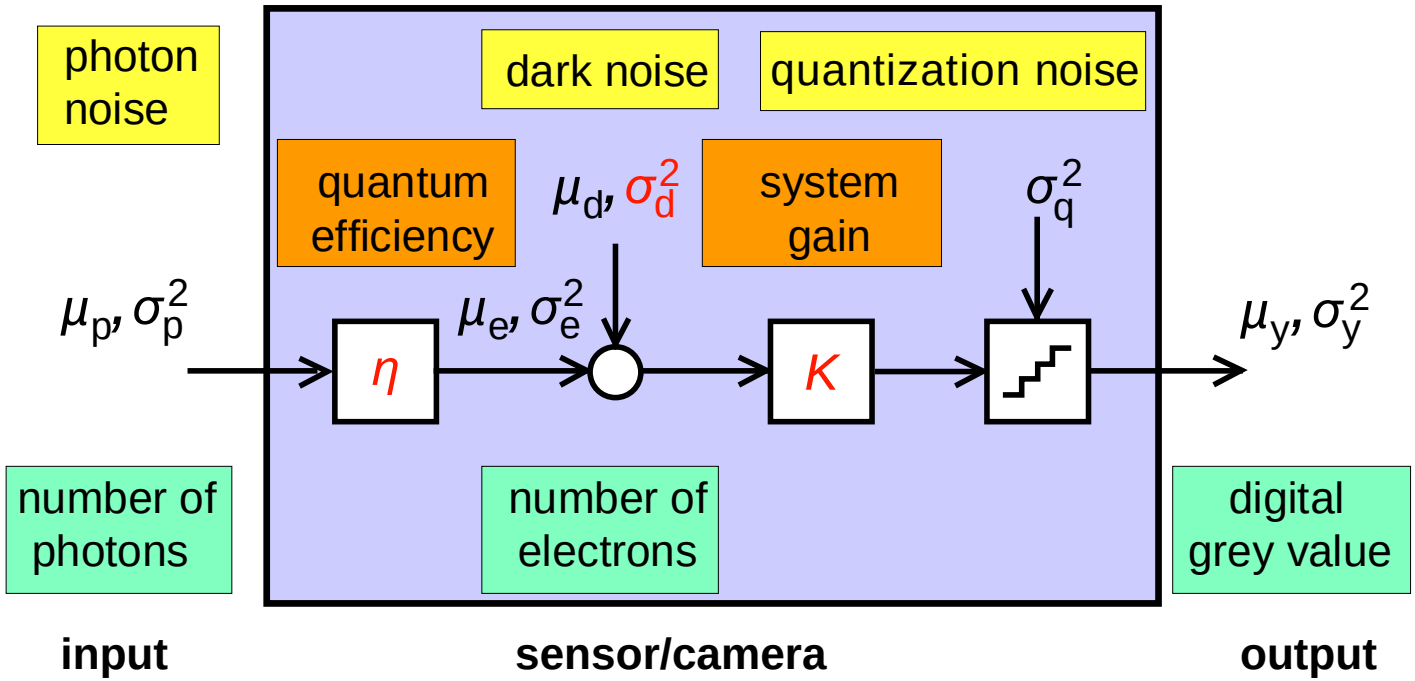
Take a black box . . .




Input: photons, output: digital numbers

# How can it work at all?

. . . and the take the necessary parameters for a linear camera:




Tree unknowns:
quantum efficiency $\eta$, camera gain $K$, dark noise $\sigma_d$

# Signal/Noise-Ratio SNR

Key quantity for signal quality

$$\boxed{\mathrm{SNR}(\mu_p) = \frac{\text{Mean signal}}{\text{Standard dev. noise}} = \frac{\mu_y}{\sigma_y} = \frac{\eta\mu_p}{\sqrt{\sigma_d^2 + \eta\mu_p}}} \quad (1)$$

(neglecting quantization noise)

Ideal camera ($\eta = 1$, $\sigma_d = 0$):

$$\mathrm{SNR}_{\mathrm{ideal}} = \sqrt{\mu_p} \quad (2)$$

# Measurements: Two Curves

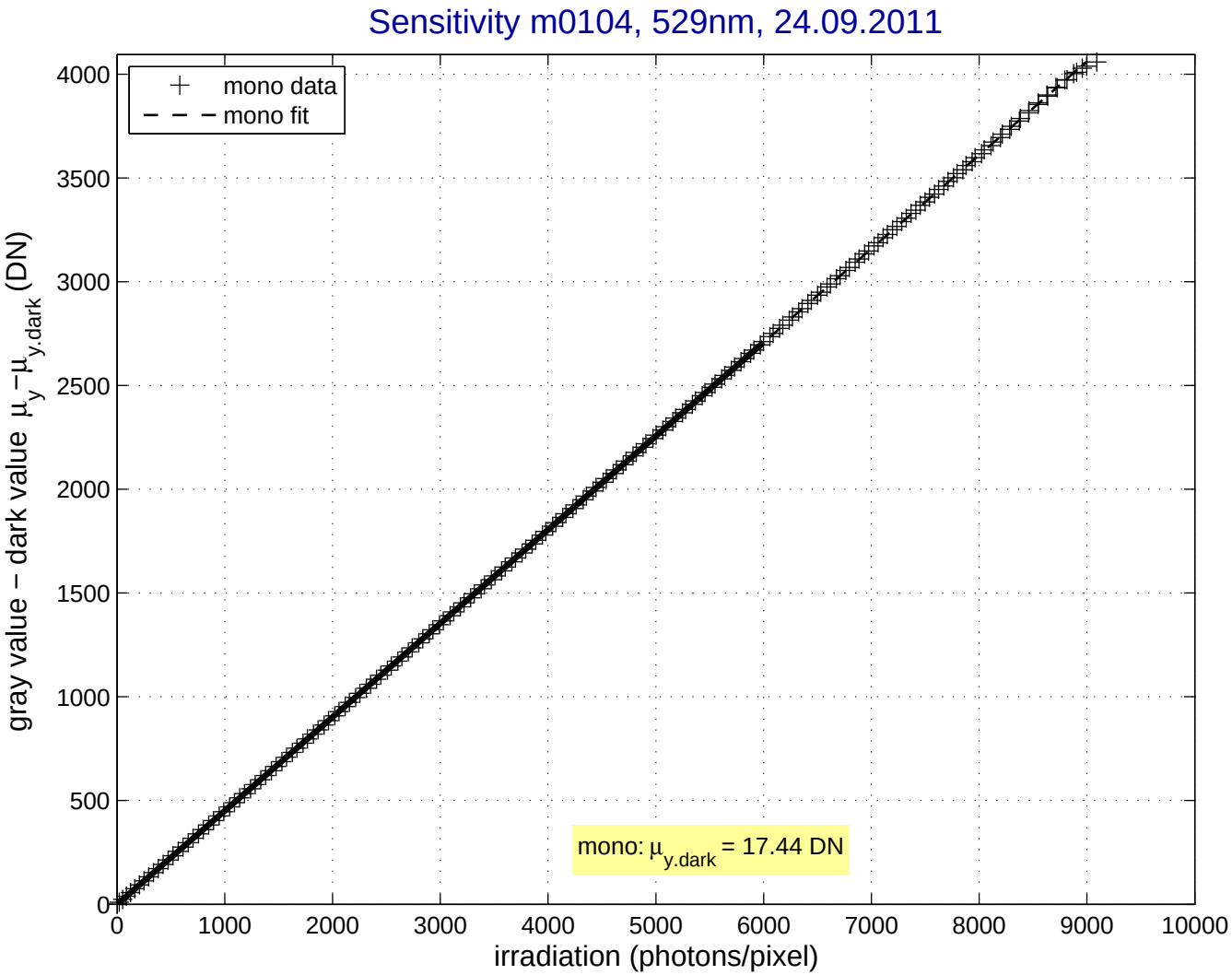
1. Sensitivity: Mean signal $\mu_y$ versus number of photons $\mu_p$:

$$\boxed{\mu_y - \mu_{y.\text{dark}} = \underbrace{K\eta}_{\text{slope } b_1} \cdot \mu_p} \tag{3}$$

2. Photon transfer: Noise variance $\sigma_y^2$ versus mean of signal $\mu_y$

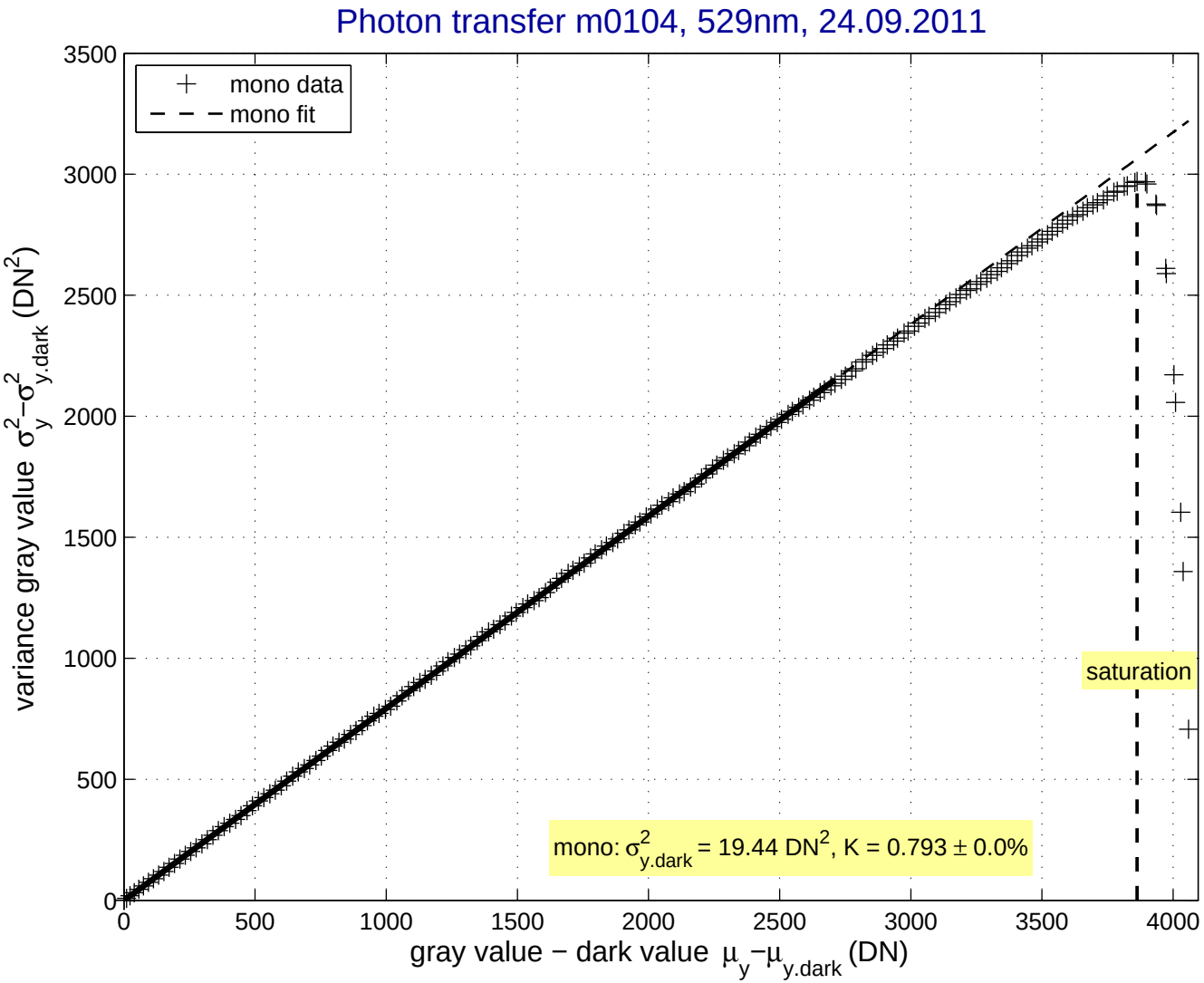
$$\boxed{\sigma_y^2 = \underbrace{K^2\sigma_d^2 + \sigma_q^2}_{\text{offset}} + \underbrace{K}_{\text{slope } a_1} \cdot (\mu_y - \mu_{y.\text{dark}})} \tag{4}$$

# Measurements I: Characteristic Curve



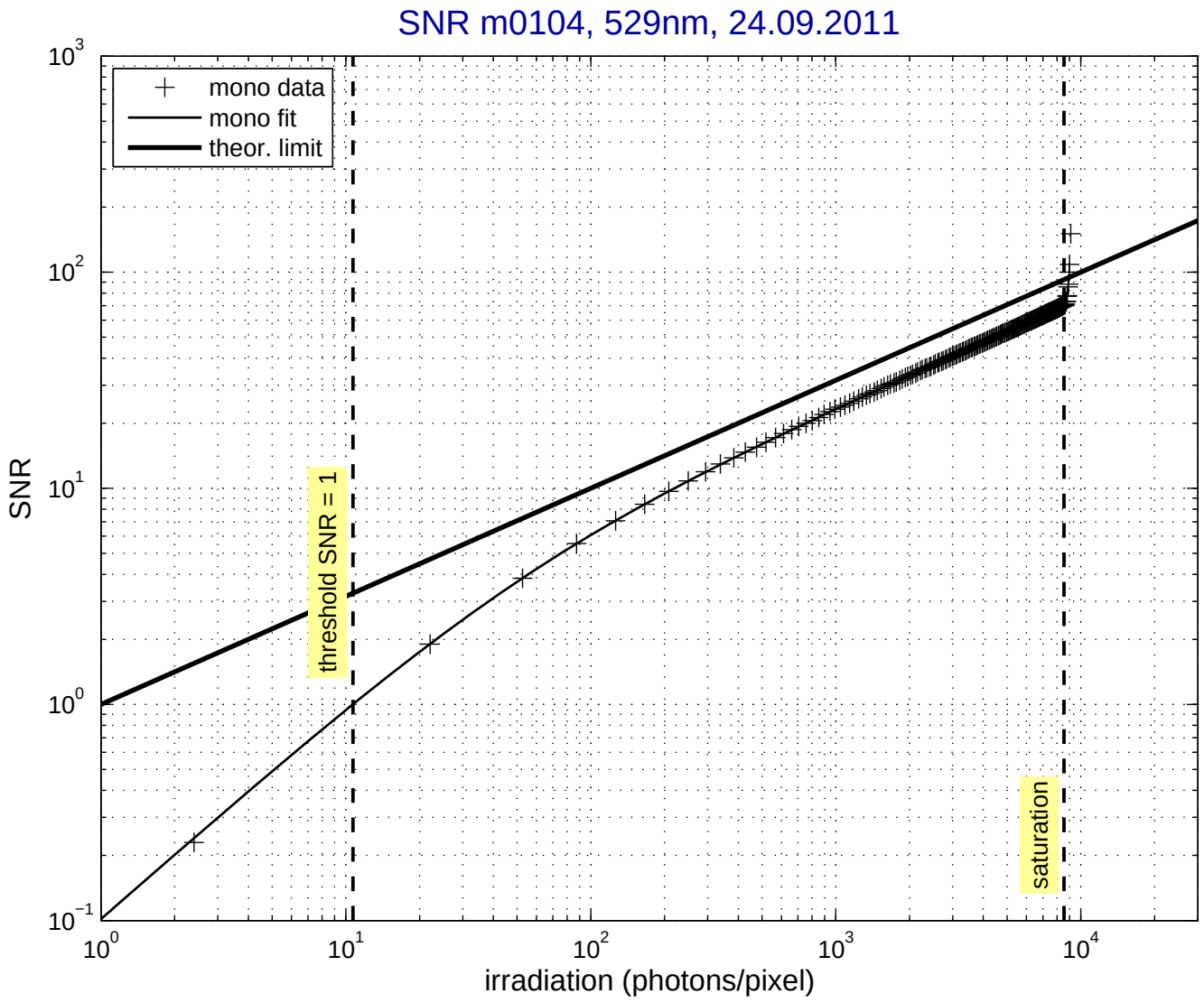

1288
EMVA Standard Compliant

# Measurements II: Photon Transfer Curve




1288
EMVA Standard Compliant

# Signal/Noise Ratio




1288
EMVA Standard Compliant

# Standardized Summary Datasheet

1288 EMVA Standard Compliant

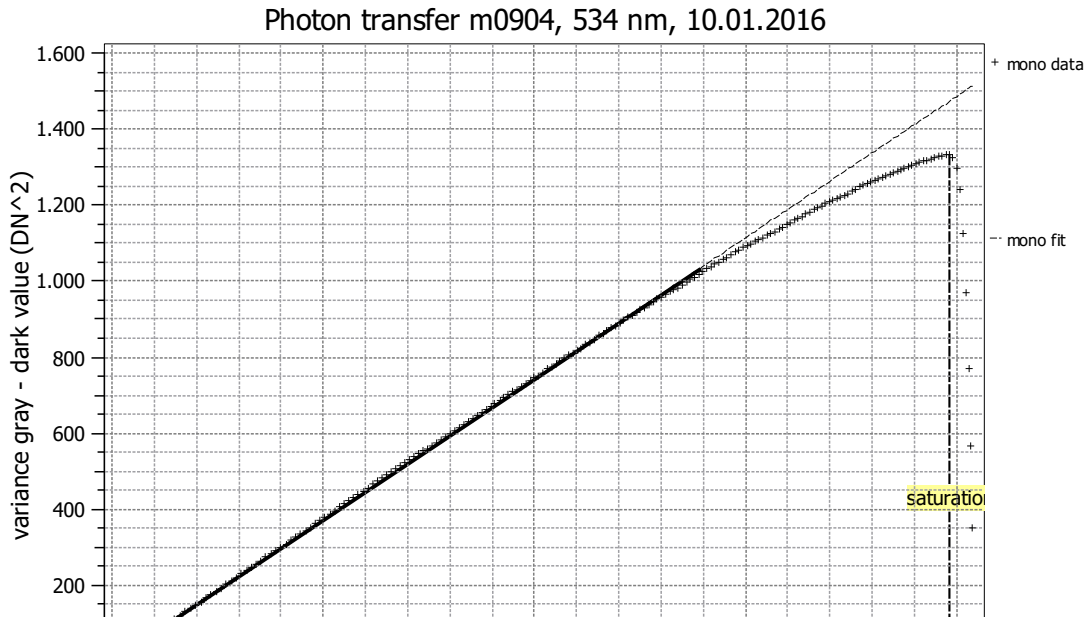
Point Grey Research, Grasshopper3 GS3-U3-51S5M, 15390428, 10.01.2016

AEON

## Summary Sheet for Operating Point 1 at a Wavelength of 534 nm

| | | | |
|---|---|---|---|
| Type of data | Single | Gain, black-level | 0.0 dB, 0.122 |
| Exposure control | By irradiance | Environmental temperature | 20.2°C |
| Exposure time | 1.00 ms | Camera body temperature | 30.6°C |
| Frame rate | 38.9 Hz | Internal temperature(s) | — |
| Data transfer mode | Mono12Packed, Mode 7 | Wavelength, centr., FWHM | 534 nm, 31.3 nm |

### Photon Transfer




**Quantum efficiency**

| | |
|---|---|
| $\eta$ | 65.2% |

**Overall system gain**

| | |
|---|---|
| $K$ | 0.371 DN/e$^-$ |
| $1/K$ | 2.692 e$^-$/DN |

**Temporal dark noise**

| | |
|---|---|
| $\sigma_d$ | 2.17 e$^-$ |
| $\sigma_{y.dark}$ | 0.86 DN |

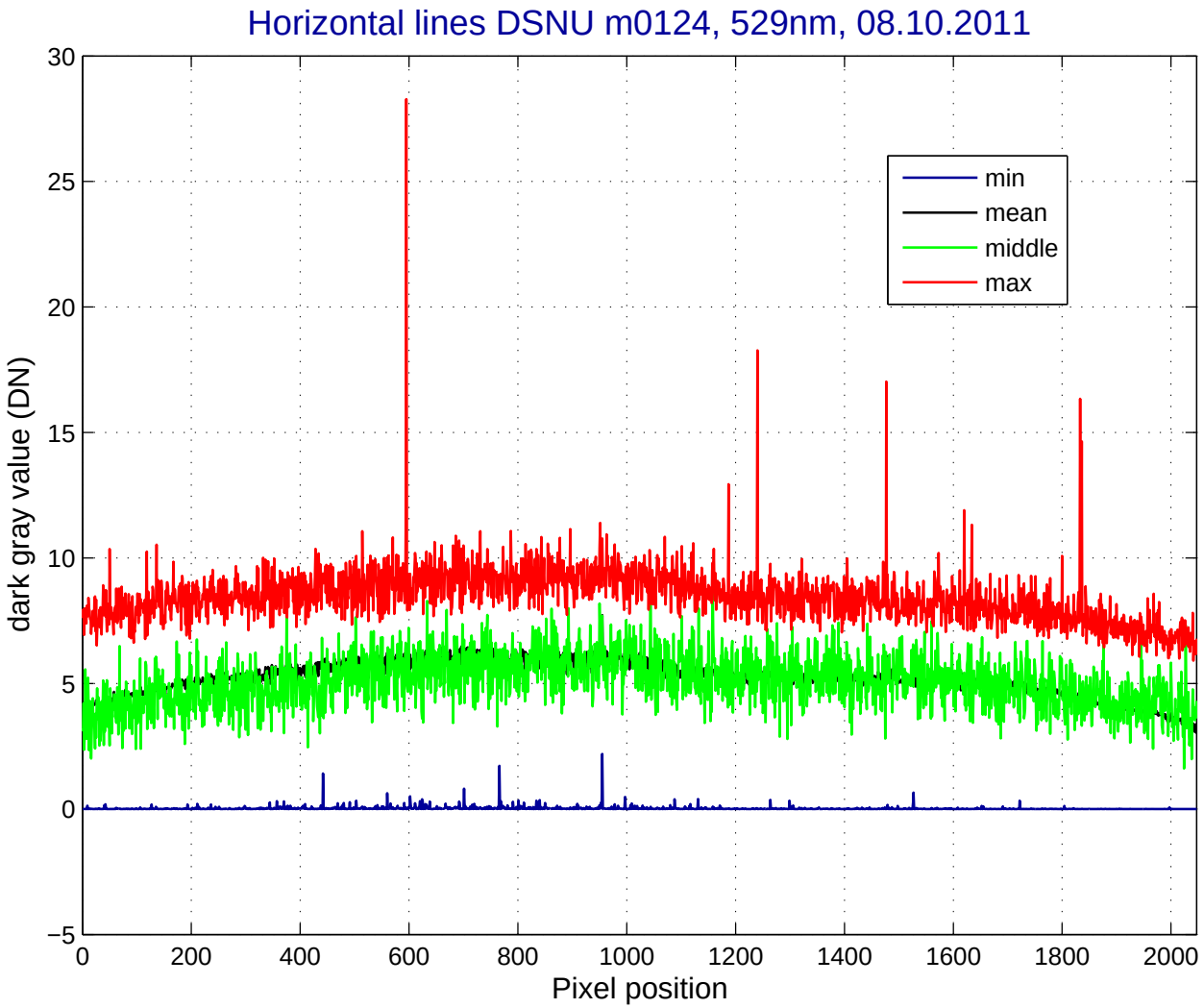
**Signal-to-noise ratio**

| | |
|---|---|
| $SNR_{max}$ | 103 |
| | 40.3 dB |
| | 6.7 bit |
| $1/SNR_{max}$ | 0.97 % |

**Absolute sensitivity threshold**

| | |
|---|---|
| $\mu_{p.min}$ | 4.38 p |
| $\mu_{p.min.area}$ | 0.368 p/$\mu$m$^2$ |

# Characterization of Nonuniformities by Profiles




Dark signal nonuniformity (DSNU)

1288 EMVA Standard Compliant

# Characterization of Nonuniformities by Profiles

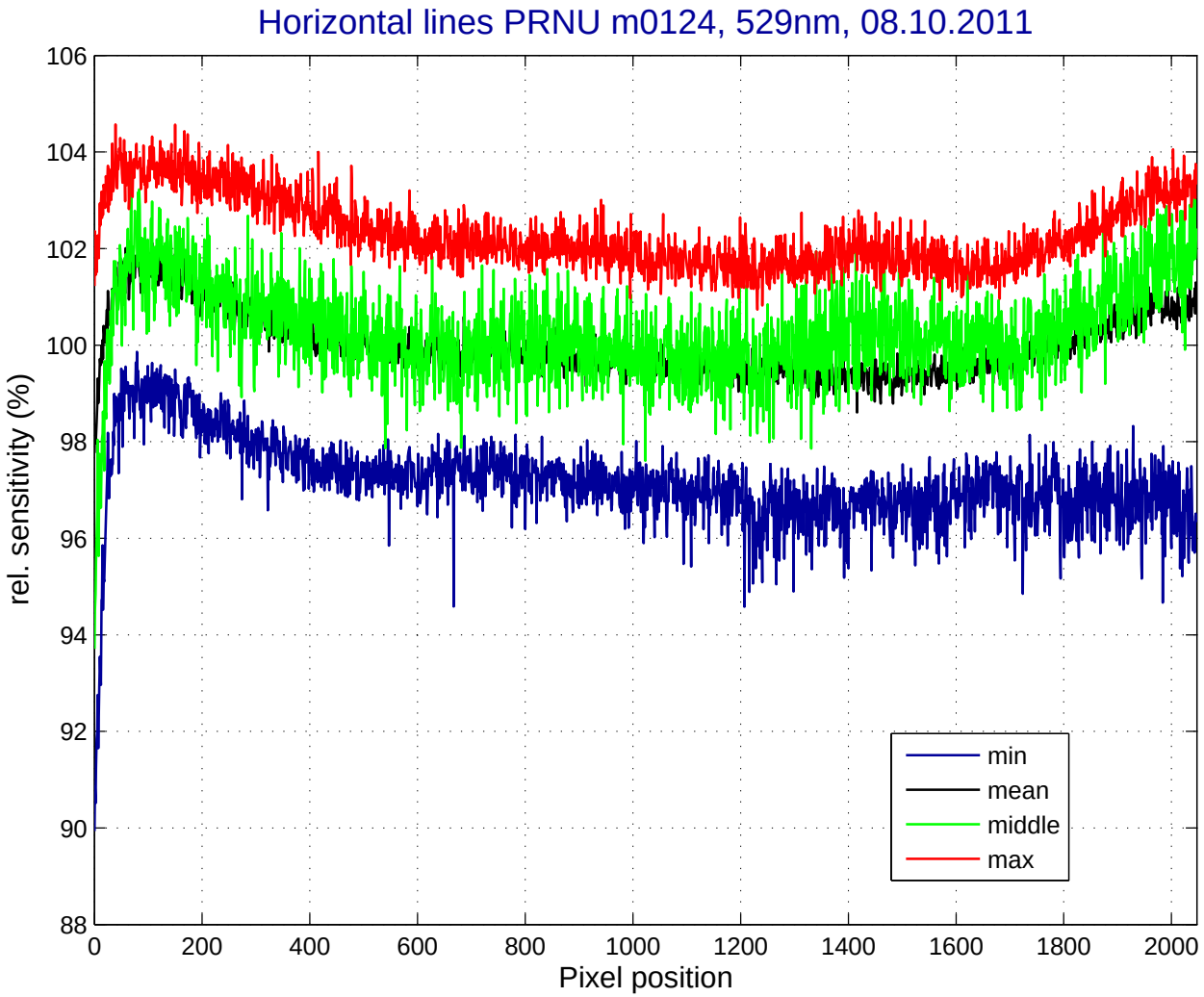



Photo response nonuniformity (PRNU)

1288 EMVA Standard Compliant

# Why is PRNU not better corrected?

Possible explanations:

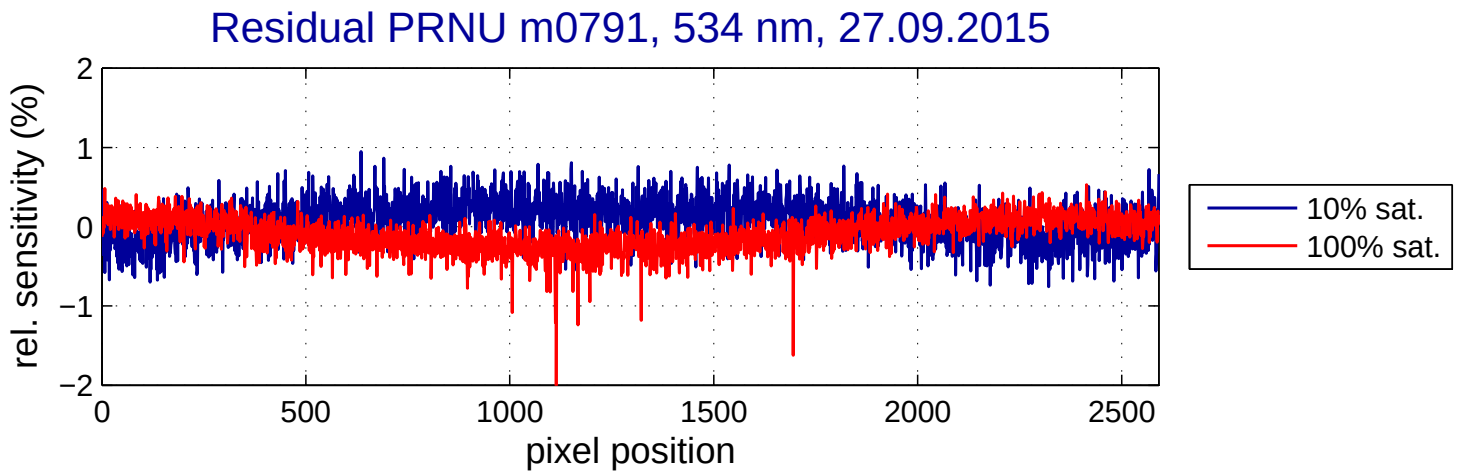
1. Pixel-dependent deviation from linear camera modelc
2. Drifts or instabilities
3. Wavelength dependency of PRNU

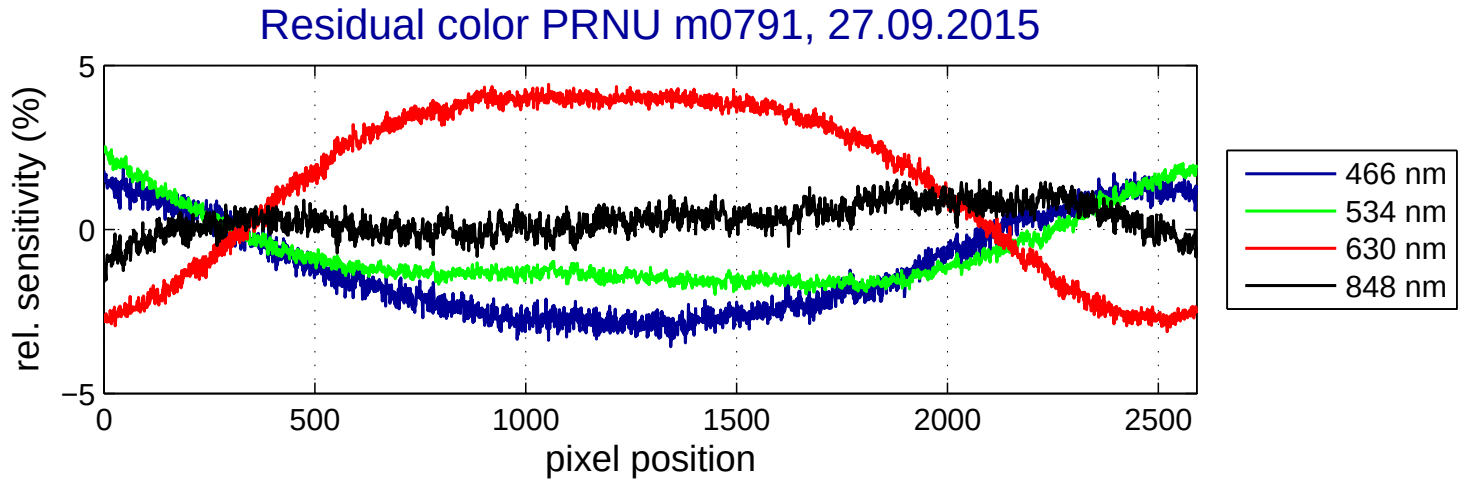
Test by

- Two-point calibration using DSNU and PRNU measurements at 50% saturation
- Measurment of PRNU at different wavelengths

# Residual PRNU: Rolling-Shutter CMOS On MT9P031

Measured PRNU 1.78%, residual $PRNU_{1288} < 0.27\%$

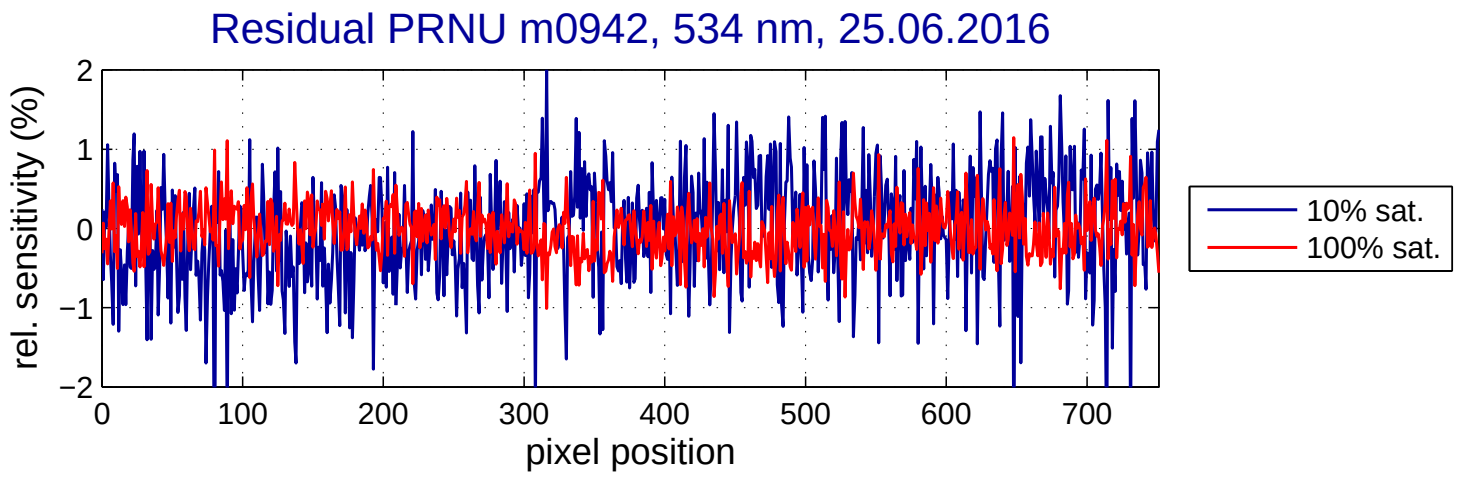


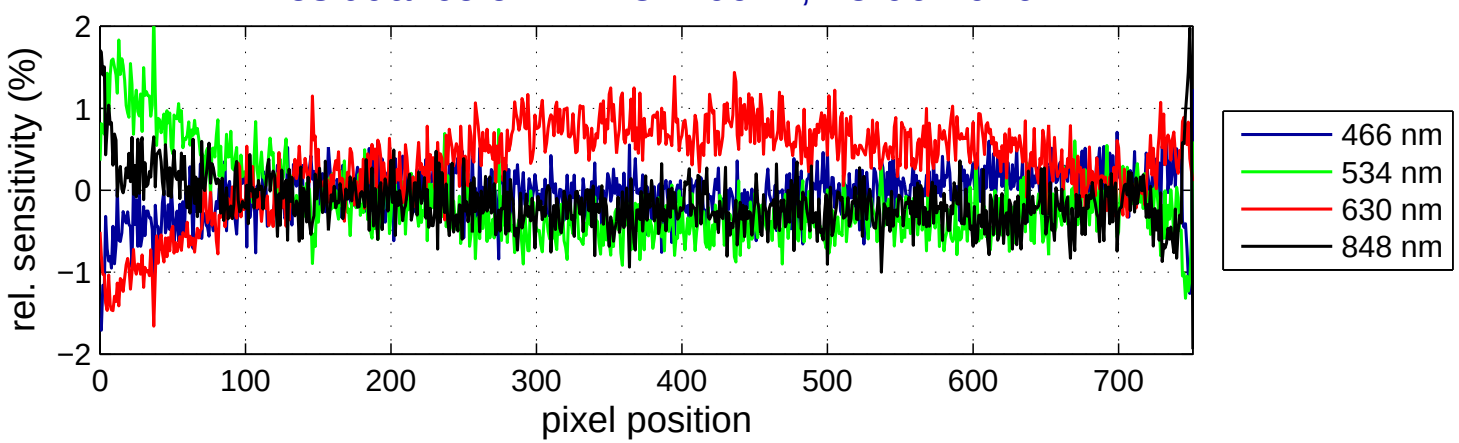




1288 EMVA Standard Compliant

# Residual PRNU: Global-Shutter CMOS On MT9V032

Measured PRNU 1.7%, residual $\text{PRNU}_{1288} < 0.72\%$

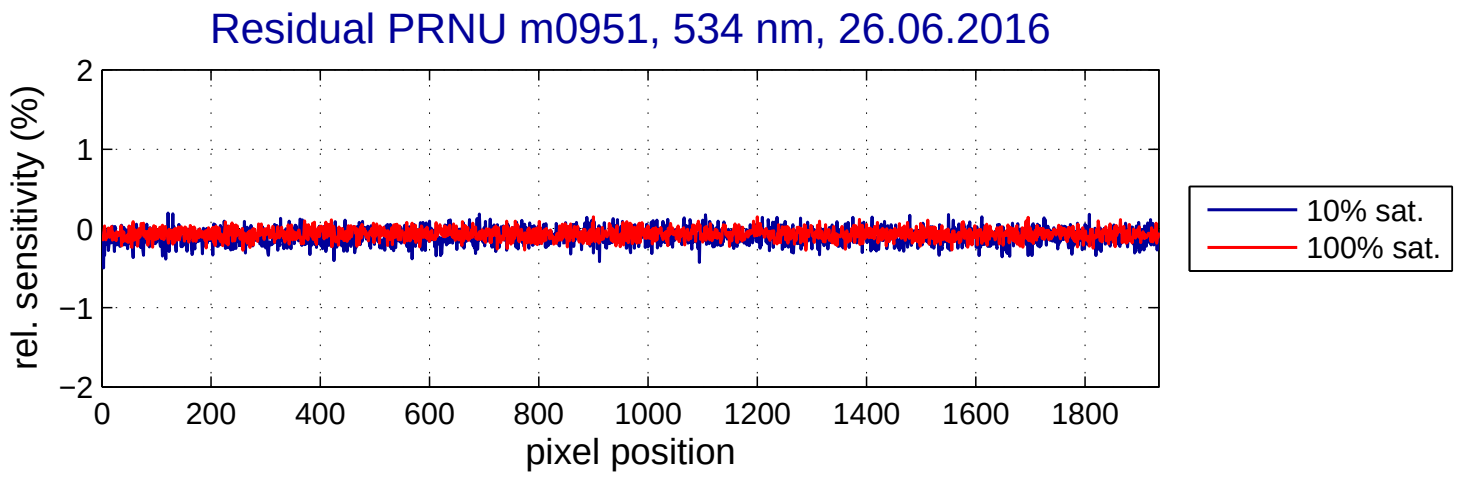


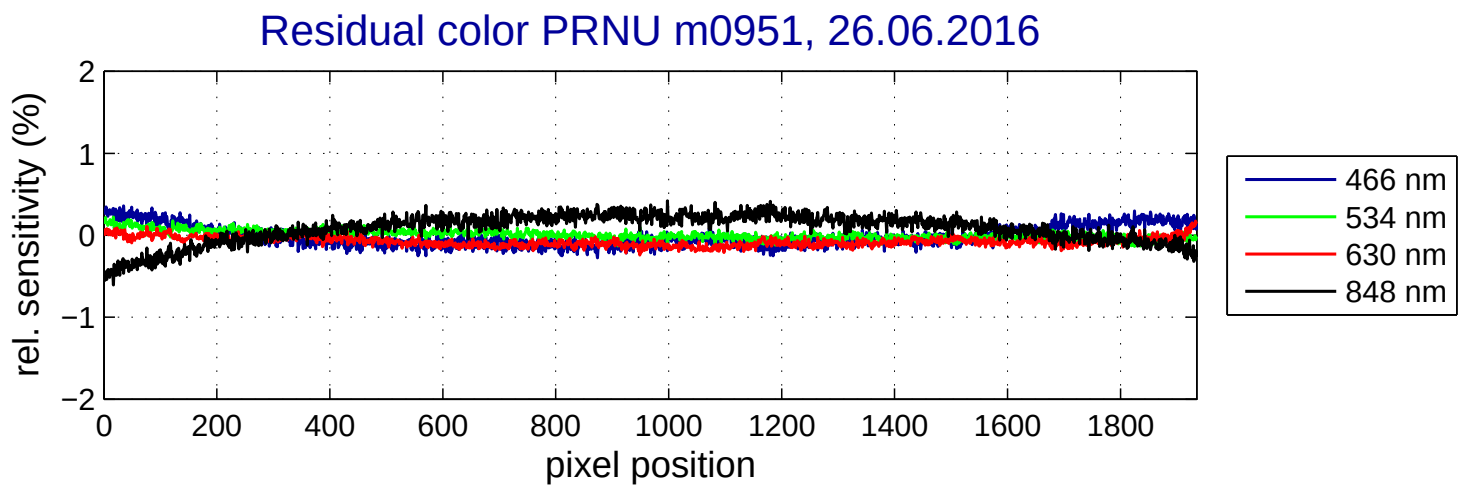




1288 EMVA Standard Compliant

# Residual PRNU: Global-Shutter CMOS Sony IMX174

Measured PRNU 0.40%, residual $\text{PRNU}_{1288} < 0.14\%$




1288 EMVA Standard Compliant

# Where to Learn More

- EMVA1288 in action: demos at Vision Stuttgart 2016 "International Vision Standards" Booth
- Standard documents & data sheets
  `https://zenodo.org/collection/user-emva1288`
- EMVA 1288 Seminars (German & English):
  - Framos, Munich, December 6/7, 2016
    `https://www.framos.com/news-events/trainings/emva-1288/`
  - AEON, Hanau, February 08–10, 2017
    `www.schulung.aeon.de`