Test Report

EMVA 1288 Standard - Release 3.1

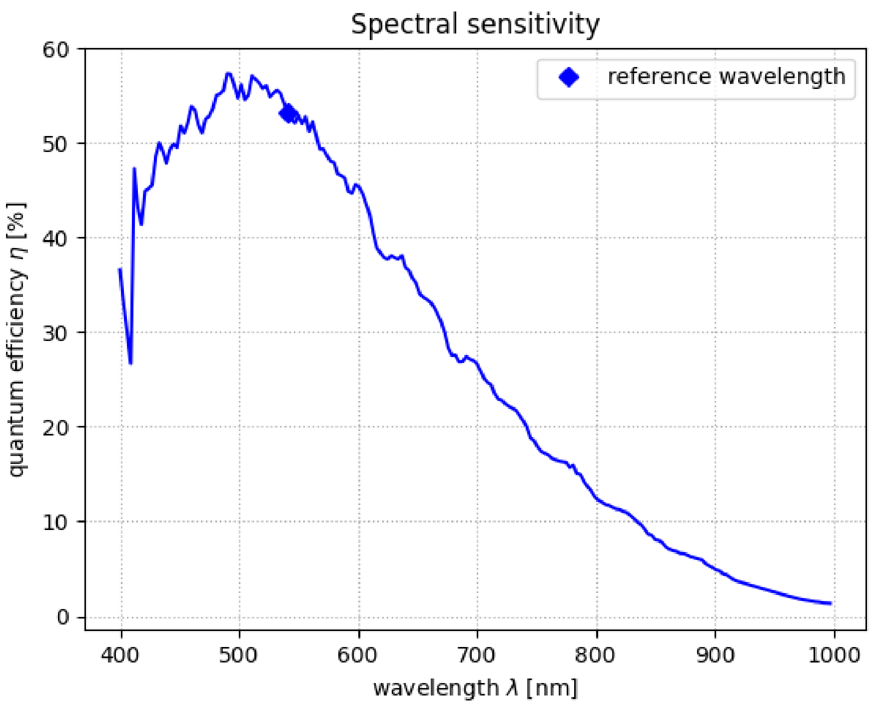
a2A4200-40um

a2A4200-40um EMVA 1288 Datasheet

This datasheet describes the specification according to the standard 1288 Standard for Characterization and Presentation of Specification Data for Image Sensors and Cameras of European Machine Vision Association (EMVA) (See www.standard1288.org).

Sensor Specification

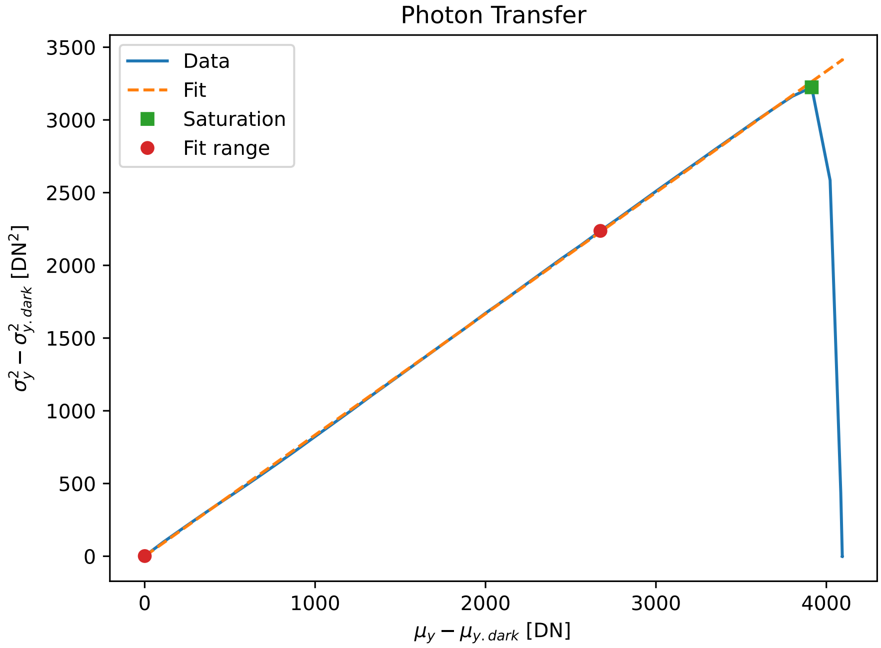
Vendor	Basler	Shutter mode	None
Model	a2A4200-40um	Light source	Integrating sphere
Sensor	GMAX2509	EMVA1288 standard version	3.1
Resolution	4200 px x 2160 px		
Pixel size	2.5 x 2.5 μm^2		

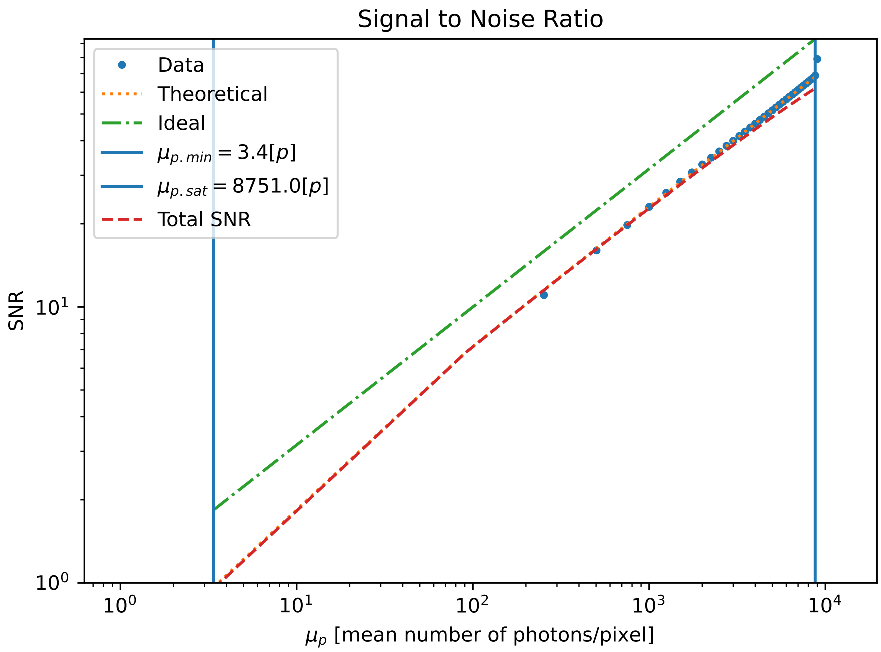


Operating Point

Camera setting	
Pixel format	Mono12
Gain	0.0
Black level	0.0
Bit depth	12 bit
Grab mode	Continuous
Non overlapped	True
Frame rate	10 fps
Operating point parameters	
Exposure control	By camera exposure time
Exposure minimum	2 μs
Exposure maximum	16941 μs

Exposure time steps	50
Spatial exposure time	6362 μs
Spatial image count	150
Housing temperature	32.09 °C
Internal temperature	43.38 °C
Ambient temperature	24.48 °C
Illumination	LED
Illumination wavelength	541 nm
Spectral width (FWHM)	38 nm
Irradiance	4.26 μW/cm^2





Performance

Quantum efficiency
η 53.28 %

System gain
K 0.834 DN/e^-
1/K 1.199 e^-/DN

Temporal dark noise
σ_d 1.248 e^-
$\sigma_{y.dark}$ 1.080 DN

Signal-to-noise ratio
SNR_{max} 68
36.69 dB
6.1 bit
SNR_{max}^{-1} 1.464 %

Absolute sensitivity threshold
$\mu_{p.min}$ 3.369 p
$\mu_{e.min}$ 1.795 e^-

Saturation capacity
$\mu_{p.sat}$ 8751 p
$\mu_{e.sat}$ 4663 e^-

Dynamic range
DR 2597
68.3 dB
11.3 bit

Spatial nonuniformities
$DSNU_{1288}$ 0.3 e^-
0.3 DN
$PRNU_{1288}$ 0.7 %

Linearity error
LE_{min} -0.430 %
LE_{max} 0.466 %

Dark current
$\mu_{I.mean}$ 2.431 e^-/s
$\mu_{I.var}$ 2.421 e^-/s

Contents

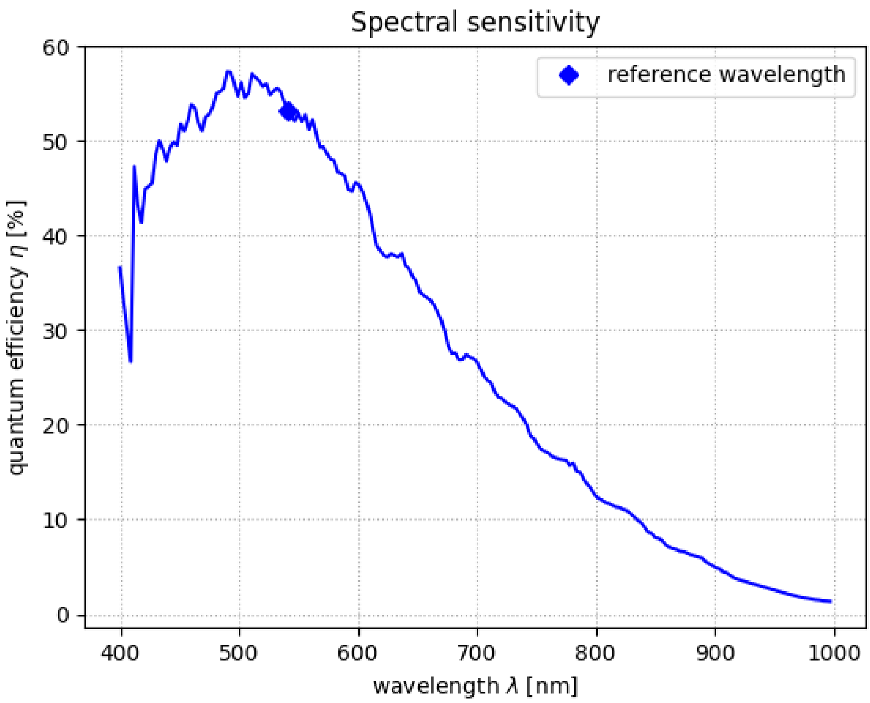
1 Spectral Sensitivity

1.1 Spectral Light Source Setup

The spectral light source setup consisted of a broadband light source (Xenon) and a universal grating monochromator (Amko, MulitMode4, Germany). The intensity and the spectrum of the emitted light between 400 nm and 1000 nm (stepwidth = 10 nm) was measured using the radiospectrometer USB4000-VIS-NIR from OceanOptics (calibrated by the manufacturer, SN = USB4J00368). The relative quantum efficiency of the device under test was calculated based on the emitted light intensity and the resulting image intensity at the respective wavelength.

1.2 Measuring Conditions

The camera was operated at the specified operating point before the measurement until thermal equilibrium was reached. Where available, the internal camera temperature was monitored using the internal temperature sensor, otherwise the temperature of the camera mount was used to determine thermal equilibrium. All measurements were performed in an air-conditioned room at room temperature. Custom-built thermometers based on PT100 sensors were used for all temperature measurements, which were calibrated against a thermometer calibrated by the manufacturer (PCE-T390 with the sensor WTD280, SN = H369851).



2 Illumination

2.1 Illumination Setup for the Basler EMVA Test

All measurements were performed using an integrating sphere (Gigahertz Optik UMBB-300, SN = 4510aw) with an LED light source (Luxeonstar, Luxeon V Star DS30). The peak wavelength of the emitted light was λ = 541 nm with a FWHM bandwidth of 38 nm. The spectrum of the LED was measured with the radiospectrometer USB4000-VIS-NIR from OceanOptics (calibrated by the manufacturer, SN = USB4J00368).
The optical setup featured an aperture of $f_{\#} = 8$ according to the requirements of the standard.
The camera was operated at the specified operating point before the measurement until thermal equilibrium was reached. Where available, the internal camera temperature was monitored using the internal temperature sensor, otherwise the temperature of the camera mount was used to determine thermal equilibrium. All measurements were performed in an air-conditioned room at room temperature. Custom-built thermometers based on PT100 sensors were used for all temperature measurements, which were calibrated against a thermometer calibrated by the manufacturer (PCE-T390 with the sensor WTD280).

2.2 Measurement of Irradiance

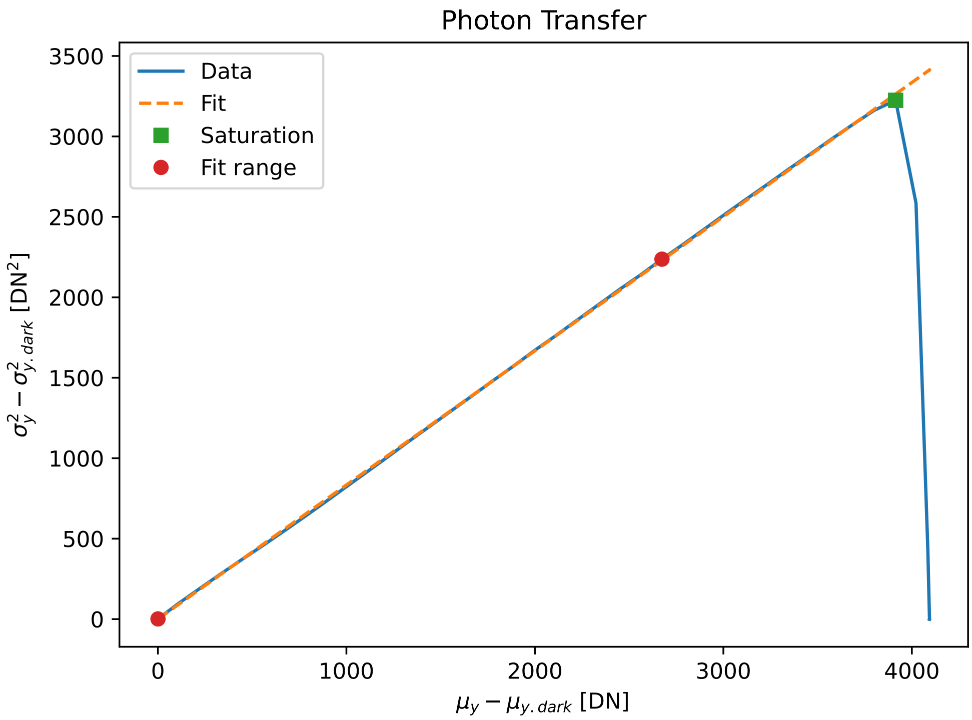
The irradiance was measured with a Gigahertz Optik detector RW-3705-4 (SN = 34881) regularly calibrated by the manufacturer. The accuracy of the device is specified as $\pm$ 5 %.

3 Characterizing Temporal Noise, Sensitivity and Linearity

3.1 Photon Transfer

The graph shows the measured photo-induced variance $\sigma_y^2 - \sigma_{y.dark}^2$ in units DN^2 versus the mean photo-induced gray value $\mu_y - \mu_{y.dark}$ in units DN and the linear regression line to determine the overall system gain K. The dots mark the 0 - 70 % range of saturation that is used for the linear regression. The system gain K is given with its one-sigma statistical uncertainty in percent, computed from the linear regression.

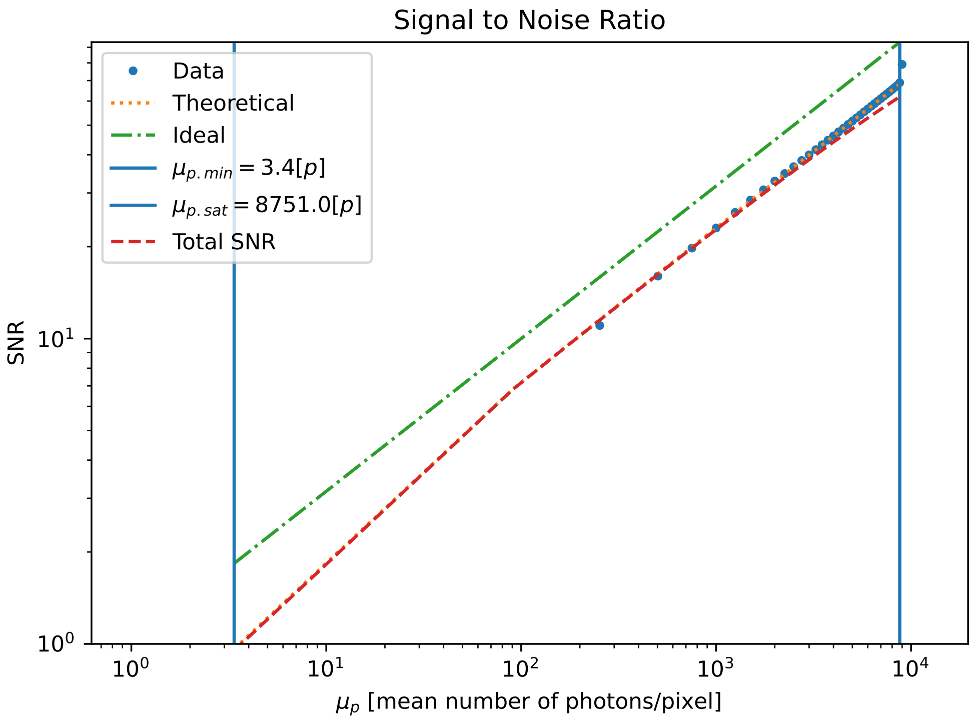
$$\sigma_y^2 - \sigma_{y.dark}^2 = K(\mu_y - \mu_{y.dark}) \tag{1}$$



3.2 Signal-to-Noise Ratio

Signal-to-noise ratio $\mathrm{SNR}(\mu_p)$ is plotted in a double logarithmic plot versus number of photons μ_p in units p collected in a pixel during exposure time. Additionally the theoretical curve for the linear camera model using the measured quantum efficiency η and the temporal dark noise σ_d and the quantization noise is plotted. Furthermore, the theoretical curve including the effect of spatial nonuniformities, and the SNR curve for an ideal sensor is plotted. The sensitivity threshold $\mu_{p.\mathrm{min}}$ in units p and the saturation capacity $\mu_{p.\mathrm{sat}}$ in units p are marked by vertical lines.

$$\mathrm{SNR} = \frac{\mu_y - \mu_{y.dark}}{\sigma_y} \tag{2}$$



The maximum achievable $\mathrm{SNR}_{\mathrm{max}}$ is given as:

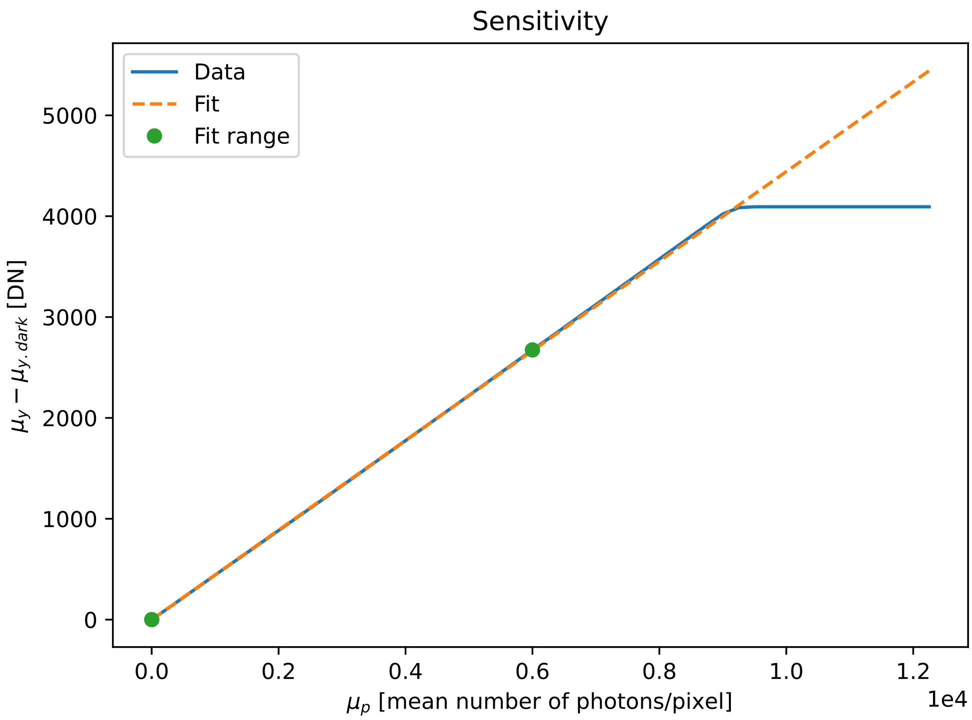
$$\mathrm{SNR}_{\mathrm{max}} = \sqrt{\mu_{e.\mathrm{sat}}} \tag{3}$$

The ratio of the signal saturation to the sensitivity threshold is defined as the dynamic range DR:

$$\mathrm{DR} = \frac{\mu_{p.\mathrm{sat}}}{\mu_{p.\mathrm{min}}} \tag{4}$$

3.3 Sensitivity

The photo-induced mean gray value $\mu_y - \mu_{y.dark}$ in units DN is plotted versus the number of photons μ_p in units p collected in a pixel during exposure time and the linear regression line to dertermine the responsivity $R = K\eta$. The dots mark the 0 - 70 % range of saturation that is used for the linear regression.



The slope of the relation

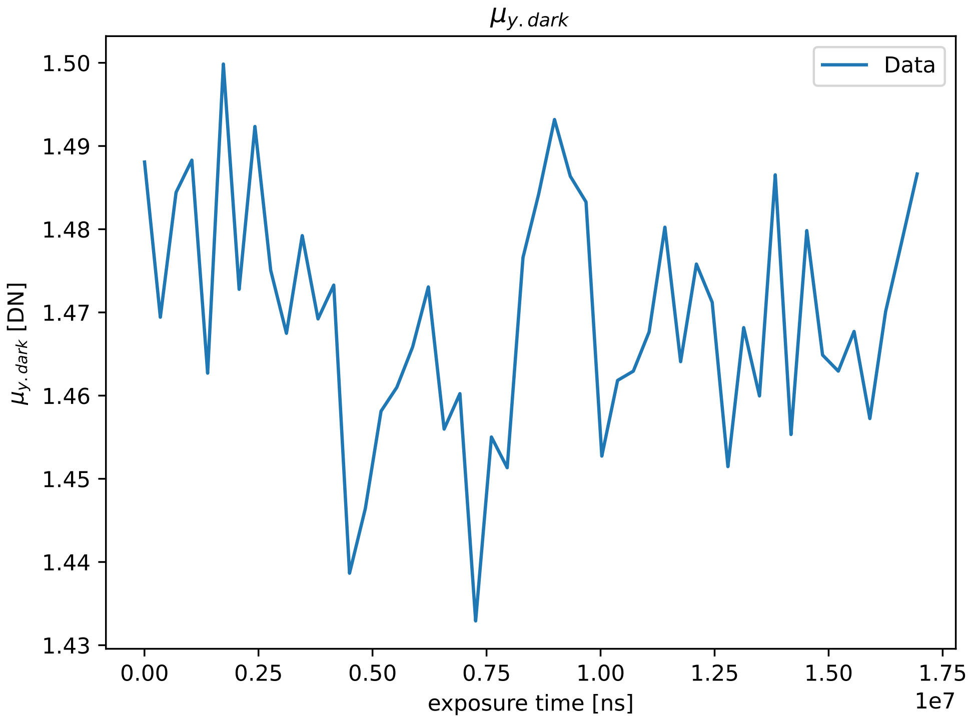
$$\mu_y - \mu_{y.dark} = R\mu_p \tag{5}$$

(with zero offset) gives the responsivity $R = K\eta$. The quantum efficiency η is given as the ratio of the responsivity $R = K\eta$ and the overall system gain K:

$$\eta = \frac{R}{K} \tag{6}$$

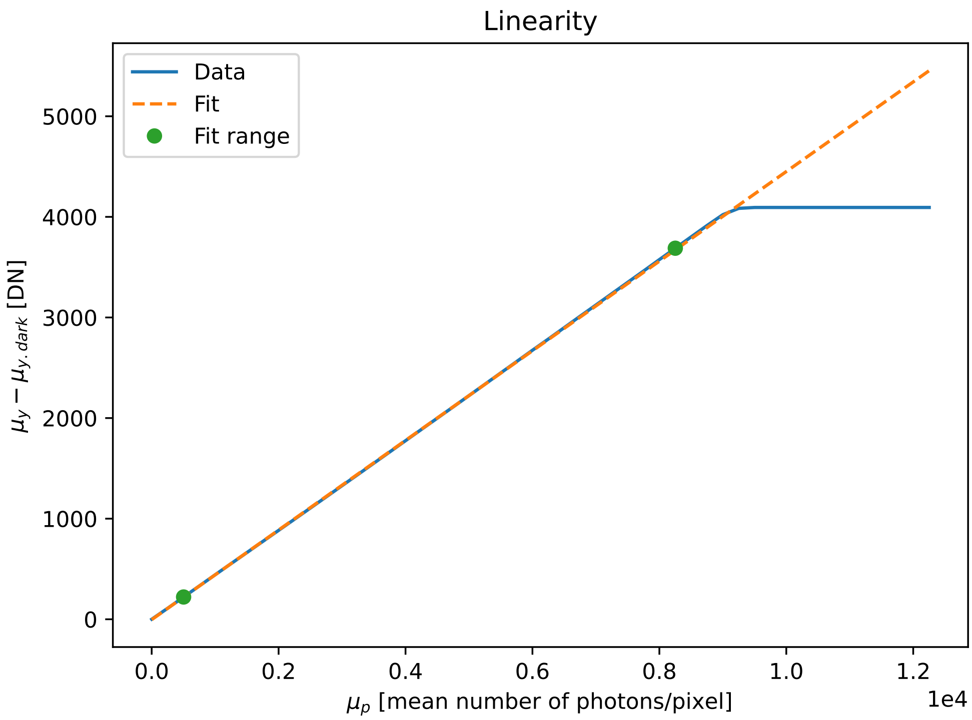
3.4 Mean Gray Values of the Dark Signal

Mean gray values of the dark signal $\mu_{y.dark}(T_{exp})$ in units DN is plotted versus exposure time in units ns.

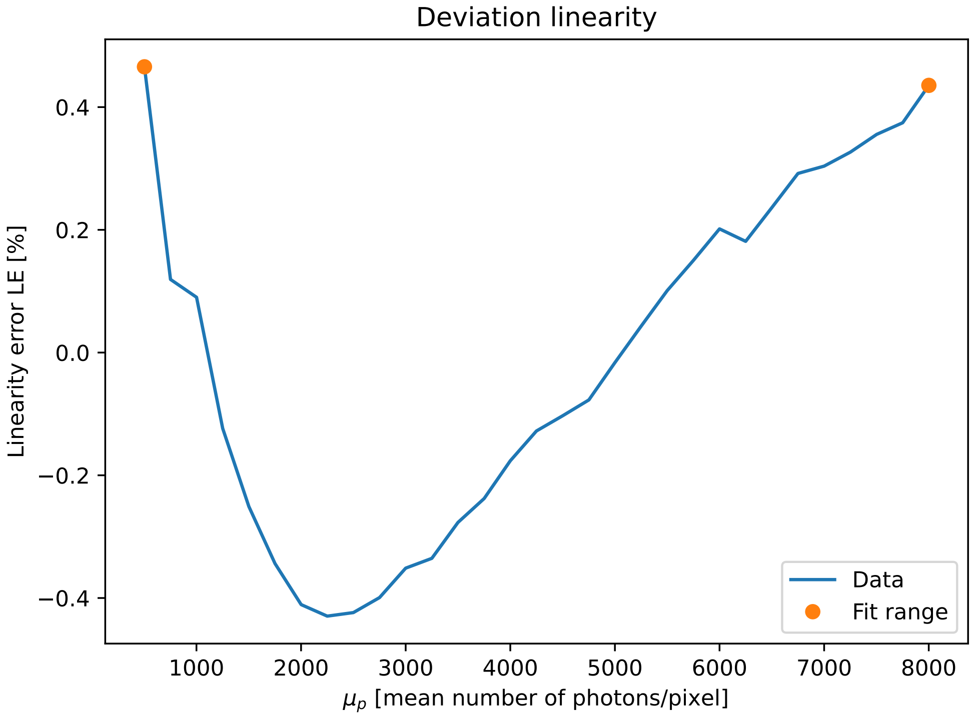


3.5 Linearity

Mean gray values minus the dark values $\mu_y - \mu_{y.dark}$ in units DN are plotted versus the irradiation in units p plus the regression curve covering the 5 % - 95 % range of saturation. The linearity is determined by computing a least-squares linear regression minimizing the *relative* deviation in the digital gray value axis. The dots mark the range that is used for the linearity regression.



Percentage of the deviation from the linear regression is plotted versus the irradiation in units p to determine the linearity error LE. The linearity error is defined as the maximal deviation and the minimal deviation in the range between 5 % and 95 % of the saturation capacity, and thus describes the maxima of the positive and negative deviation from the linear regression. The 5 % and 95 % saturation points are marked by dots.



4 Characterizing Spatial Nonuniformity and Defect Pixel

All quantities describing nonuniformities must be computed from mean gray values averaged over many images.This is because the variances of the temporal noise ($\sigma_y \approx 1\%$) is typically larger than the variance of the spatial variations ($\sigma_y \approx 0.3\% - 0.5\%$). The temporal noise can be suppressed by averaging over L images **y**, where L is the spatial image count.

$$\langle \mathbf{y} \rangle = \frac{1}{L} \sum_{l=0}^{L-1} \mathbf{y}[l] \tag{7}$$

This procedure has to be applied to a sequence of dark images and a sequence of images at 50 % saturation, resulting in $\langle \mathbf{y}_{dark} \rangle$ and $\langle \mathbf{y}_{50} \rangle$, respectively.

4.1 Horizontal and Vertical Spectrograms

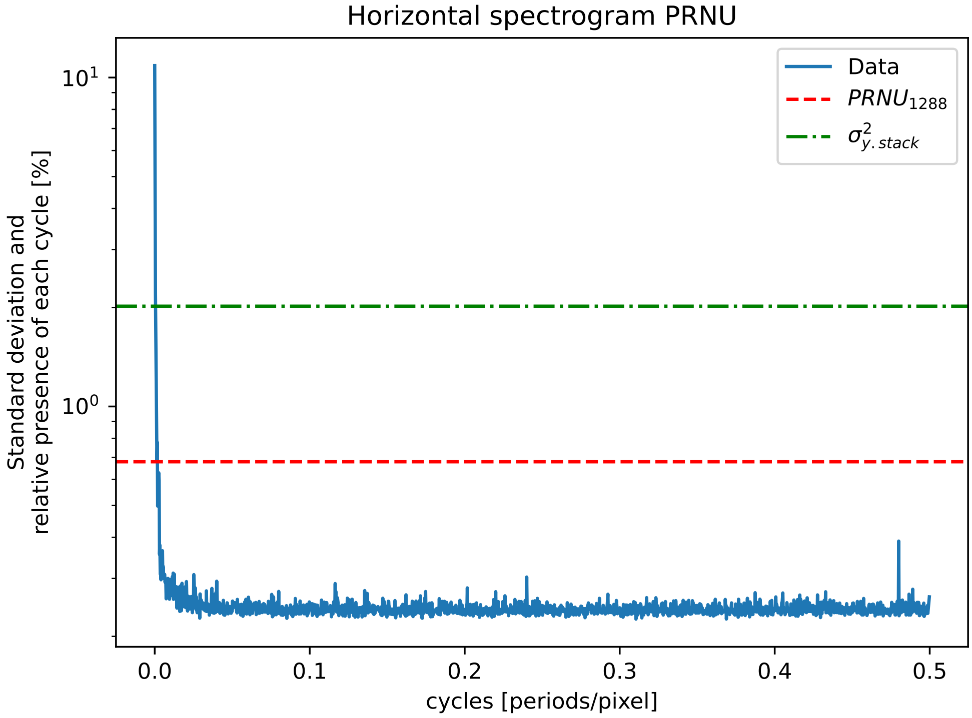
Horizontal and vertical spectrograms are computed from the DSNU (dark signal nonuniformity) image $\langle \mathbf{y}_{dark} \rangle$ with no light and the PRNU (photoresponse nonuniformity) image $\langle \mathbf{y}_{50} \rangle - \langle \mathbf{y}_{dark} \rangle$ at 50 % saturation. In the spectrograms the square root of the power spectrum is displayed as a function of the spatial frequency.

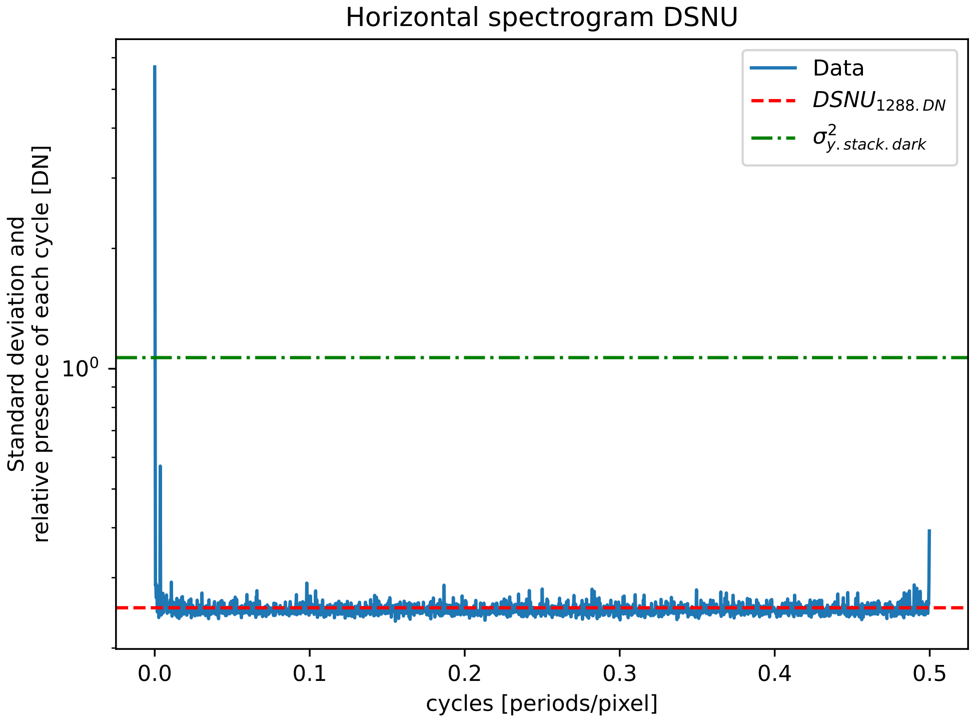
In the according spectrogram, lines with the DSNU_{1288} and PRNU_{1288} are plotted as well as a line with the variance of the temporal noise $\sigma^2_{y.\mathrm{stack}}$. In this way, it is easy to compare spatial and temporal noise.

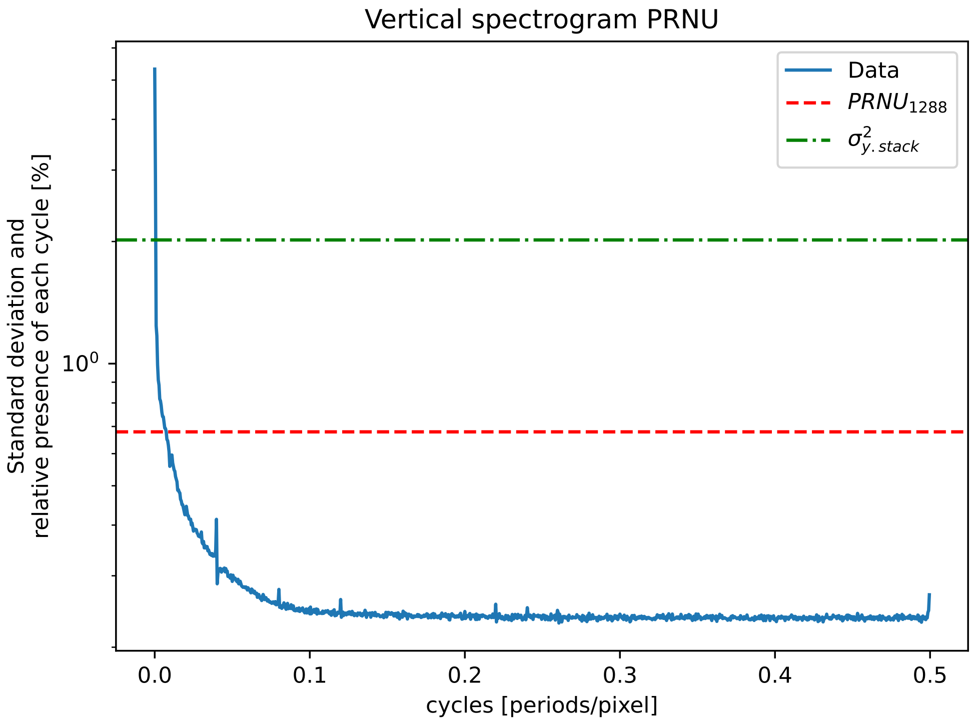
The DSNU_{1288} is expressed in units e^-; by multiplying with the overall system gain K it can also be given in units DN. The PRNU_{1288} is defined as the standard deviation relative to the mean value. In this way, the PRNU_{1288} gives the spatial standard deviation of the photoresponse nonuniformity in % from the mean.

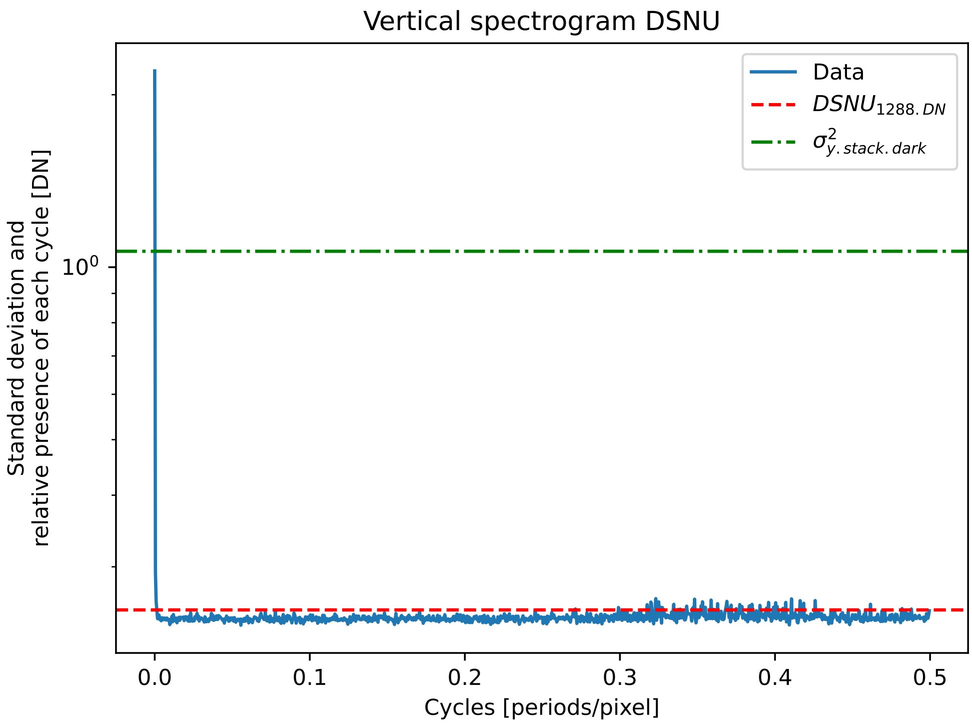
$$\mathrm{DSNU}_{1288} = \frac{\sigma_{y.spat.dark}}{K} \tag{8}$$

$$\mathrm{PRNU}_{1288} = \frac{\sqrt{\sigma^2_{y.spat.50} - \sigma^2_{y.spat.dark}}}{\mu_{y.50} - \mu_{y.dark}} \tag{9}$$


Horizontal spectrogram PRNU
Data
$PRNU_{1288}$
$\sigma^2_{y.stack}$
Standard deviation and
relative presence of each cycle [%]
10^1
10^0
0.0
0.1
0.2
0.3
0.4
0.5
cycles [periods/pixel]

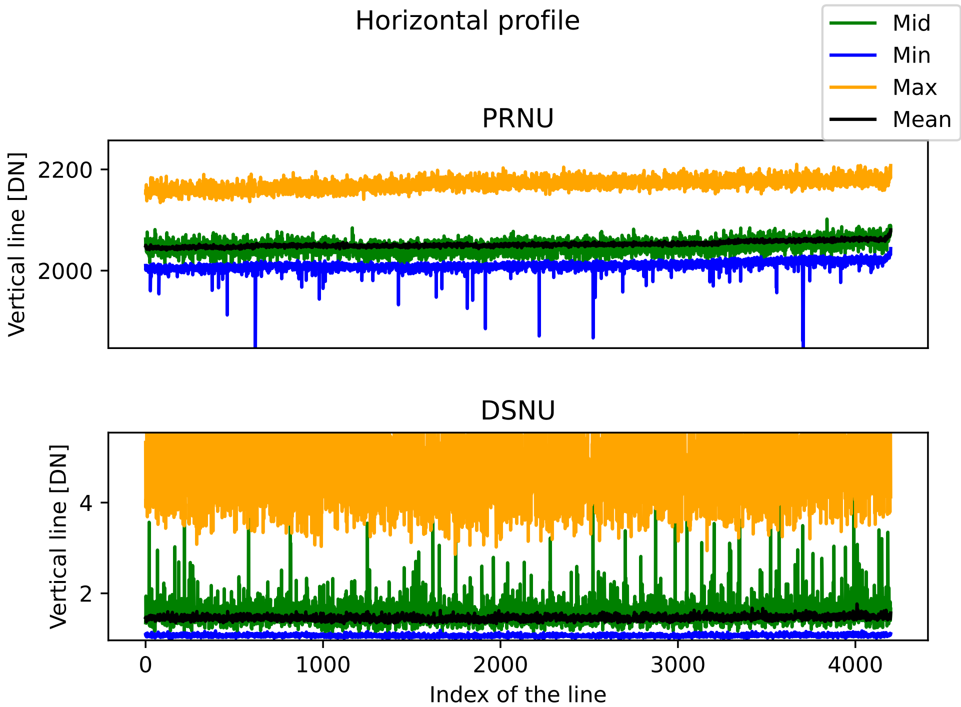

Horizontal spectrogram DSNU
Data
$DSNU_{1288.DN}$
$\sigma^2_{y.stack.dark}$
Standard deviation and
relative presence of each cycle [DN]
10^0
0.0
0.1
0.2
0.3
0.4
0.5
cycles [periods/pixel]

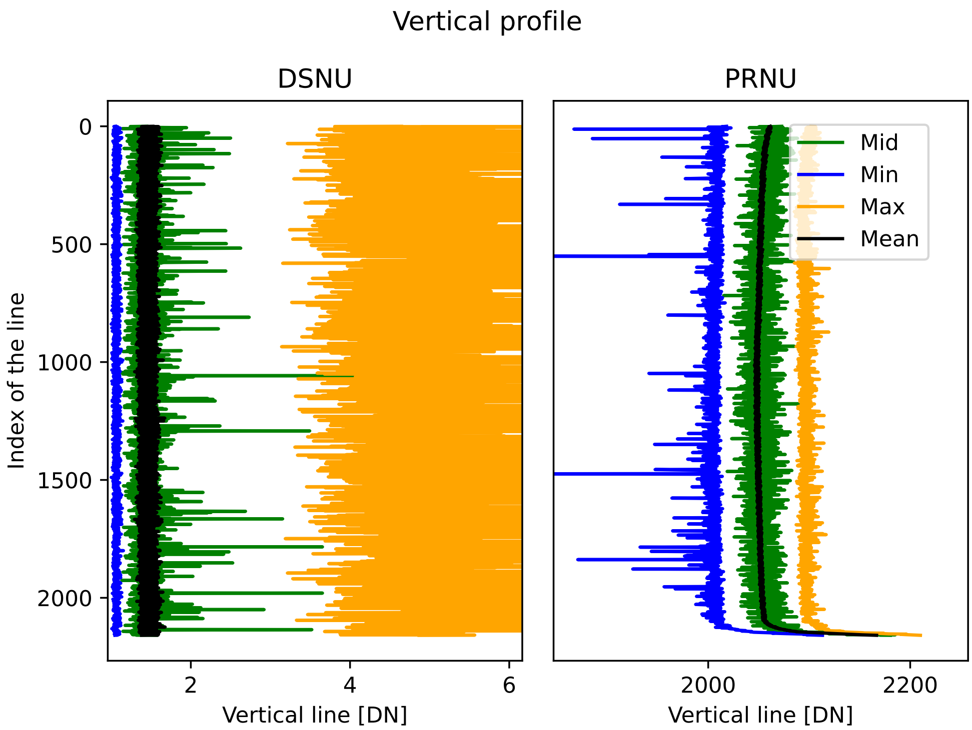

Vertical spectrogram PRNU
Data
$PRNU_{1288}$
$\sigma^2_{y.stack}$
Standard deviation and
relative presence of each cycle [%]
10^0
0.0
0.1
0.2
0.3
0.4
0.5
cycles [periods/pixel]


Vertical spectrogram DSNU
Data
$DSNU_{1288.DN}$
$\sigma^2_{y.stack.dark}$
Standard deviation and
relative presence of each cycle [DN]
10^0
0.0
0.1
0.2
0.3
0.4
0.5
Cycles [periods/pixel]

4.2 Horizontal and Vertical Profiles

The spatial nonuniformities are illustrated by plots of horizontal and vertical profiles of the DSNU and PRNU. The profiles are directly computed from the averaged dark image $\langle \mathbf{y}_{dark} \rangle$ and the PRNU image $\langle \mathbf{y}_{50} \rangle - \langle \mathbf{y}_{dark} \rangle$ without applying any corrections or filtering.





Each plot contains four profiles:

Mid: Horizontal / vertical profile of a single line / column through the center of the image.

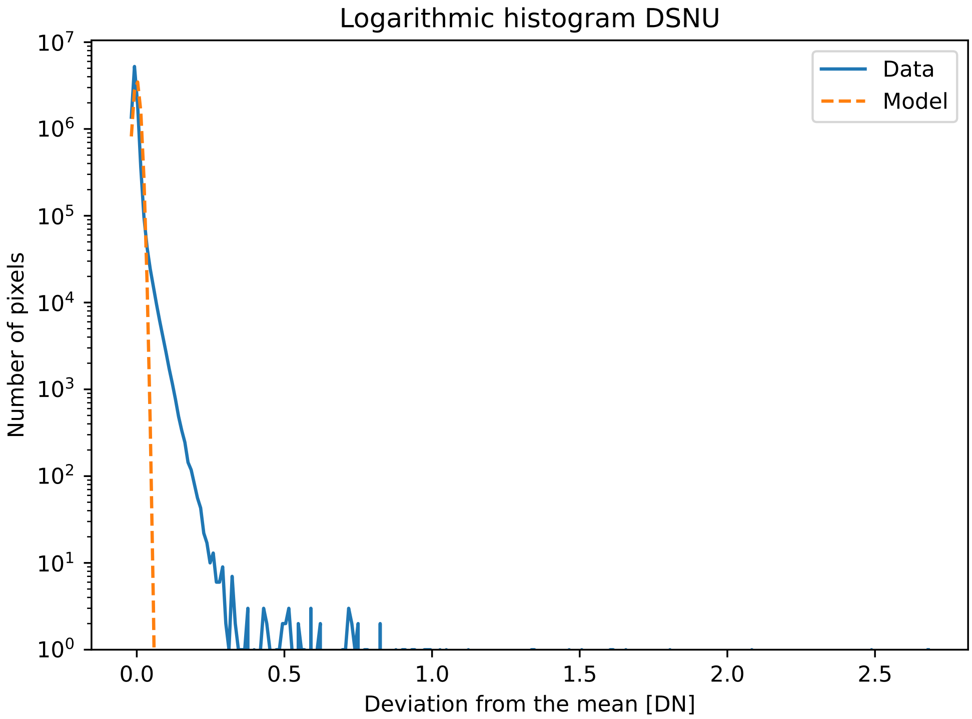
Min: Minimum of all rows / columns at each horizontal / vertical position. These profiles nicely show even only few pixels with negative outliers, e.g. less sensitive pixel in the PRNU image.

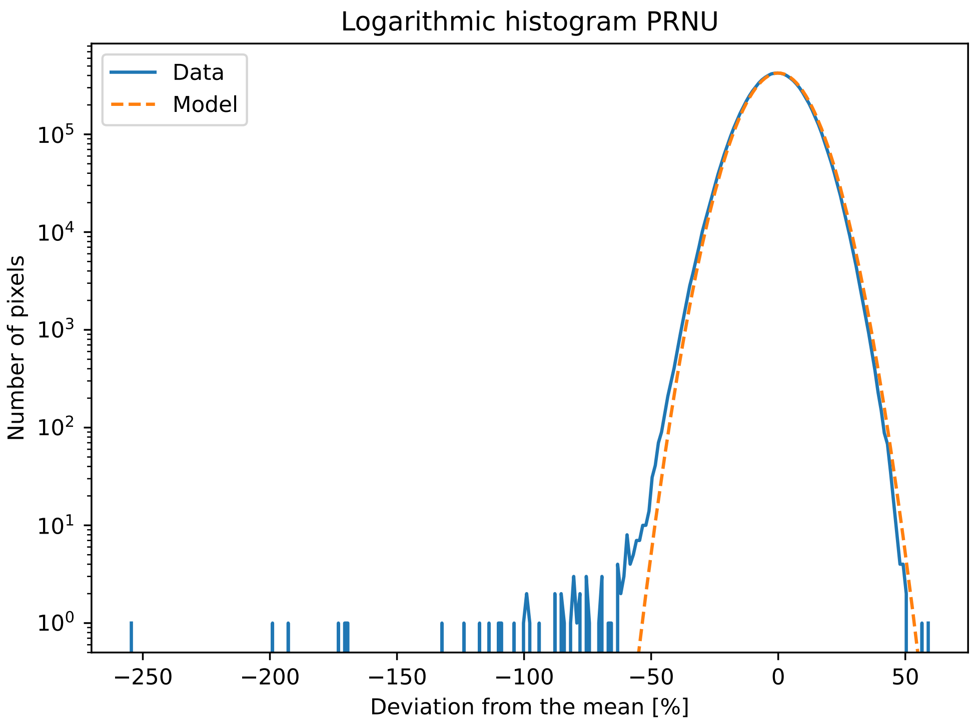
Max: Maximum of all rows / columns at each horizontal / vertical position. These profiles nicely show even only few pixels with positive outliers, e.g. hot pixel in the DSNU image.

Mean: Average of all rows / columns.

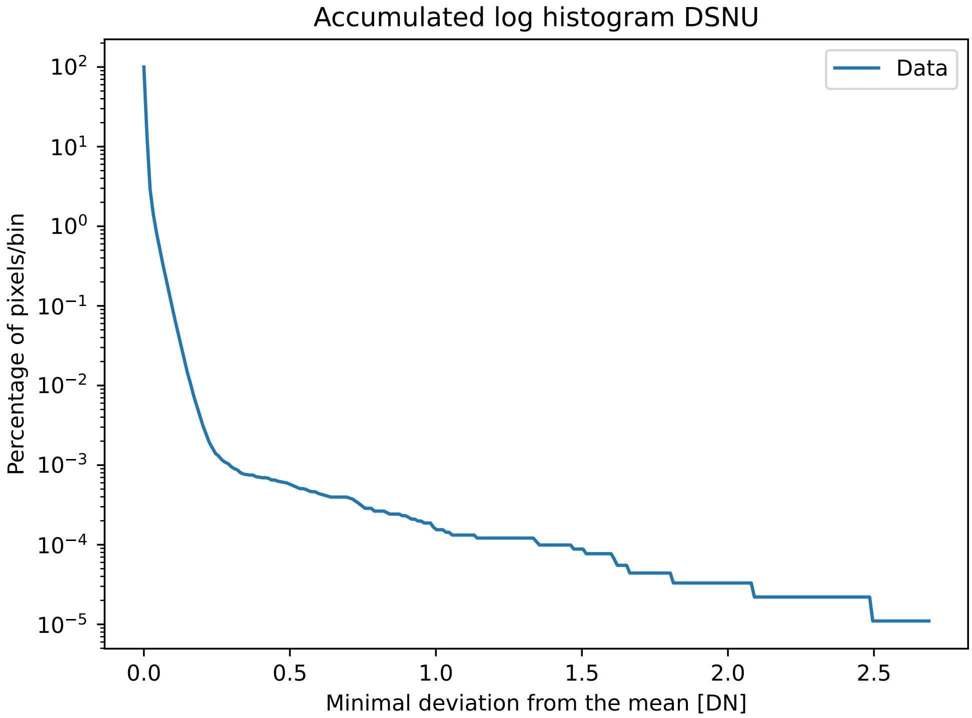
4.3 Defect Pixel Characterization

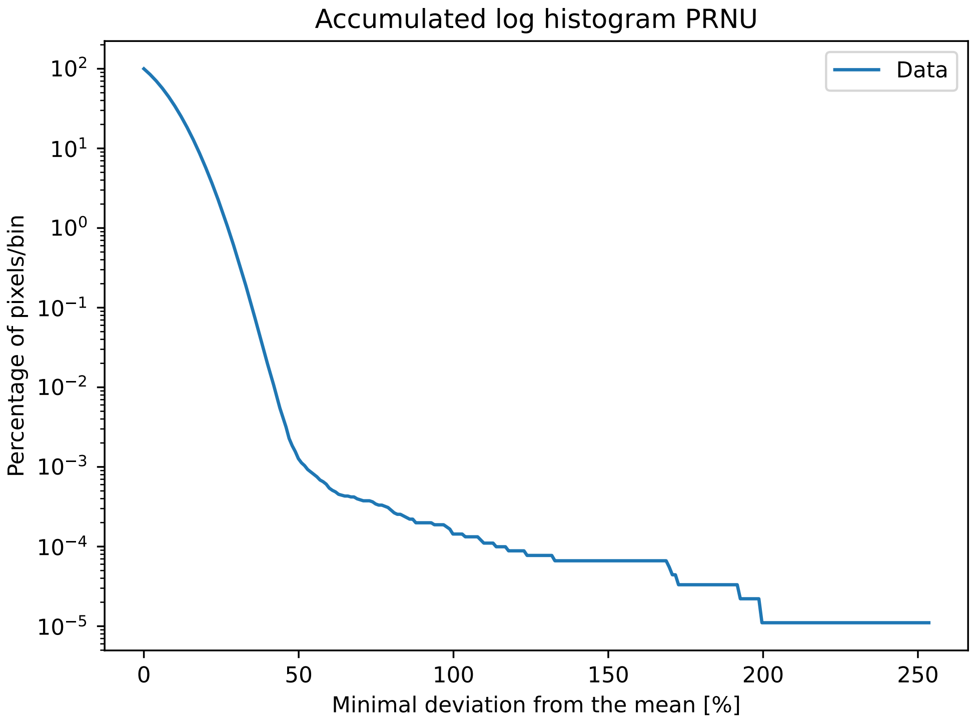
Logarithmic histograms for dark signal nonuniformity (DSNU) and photoresponse nonuniformity (PRNU) are plotted versus the deviation from the mean gray value of the image. The dashed line represents the model probability density distribution.





Accumulated logarithmic histograms for dark signal nonuniformity (DSNU) and photoresponse non-uniformity (PRNU) are plotted versus the deviation from the mean gray value of the image. This yields the probability distribution of the absolute deviation from the mean value. Thus it gives the number of pixels that show at least a certain absolute deviation from the mean.





5 References

[1] EUROPEAN MACHINE VISION ASSOCIATION (EMVA): EMVA Standard 1288 - Standard for Characterization and Presentation of Specification Data for Image Sensors and Cameras (Release 3.1). December 30, 2016

How Does Basler Measure and Define Image Quality?

Basler is leading the effort to standardize image quality and sensitivity measurement for cameras and sensors. We are giving the EMVA 1288 standard our strongest support because it describes a unified method to measure, compute, and present the specification parameters for cameras and image sensors. Our cameras are characterized and measured in 100% compliance with the EMVA 1288 standard. Measurement reports can be downloaded from our website.

How Does Basler Ensure Superior Quality and Reliable High Performance?

Our approach to quality assurance is rigorous: we continually audit all facets of our business to ensure powerful performance, increase efficiency and reduce costs for our customers. We are compliant with all major quality standards including ISO 9001, CE, RoHS, and more. To ensure consistently high product quality, we employ several quality inspection procedures during manufacturing.

Every Basler camera is subjected to exhaustive optical and mechanical tests before leaving the factory. We have developed a unique combination of optics, hardware, and software tools that can quickly and efficiently calibrate a camera and measure its performance against a set of standard performance criteria. Regardless of what technology or camera model you choose you can be assured of consistent performance.

3-Year Warranty

Basler offers a 3-year warranty for their cameras and the Basler Lenses 1/2.5". We make this unprecedented promise because we have unparalleled confidence in our products. We continually reinvest in research, development and superior manufacturing capabilities so that our customers can fully rely on the products we manufacture.

About Basler

Basler is a leading manufacturer of high-quality digital cameras and accessories for industry, medicine, traffic and a variety of other markets. The company's product portfolio encompasses area scan and line scan cameras in compact housing dimensions, camera modules in board level variants for embedded solutions, and 3D cameras. The catalog is rounded off by our user-friendly pylon SDK and a broad spectrum of accessories, including a number developed specially for Basler and optimally harmonized for our cameras.

Basler has 30 years of experience in computer vision. The company is home to approximately 500 employees at its headquarters in Ahrensburg, Germany, and its subsidiaries and sales offices in Europe, Asia, and North America.

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