1288
EMVA Standard Compliant

emva
european machine vision association

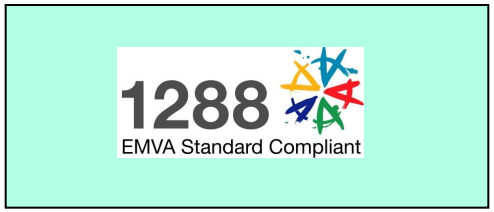
EMVA 1288 Standard for Measurement and Presentation of Specifications for Machine Vision Sensors and Cameras

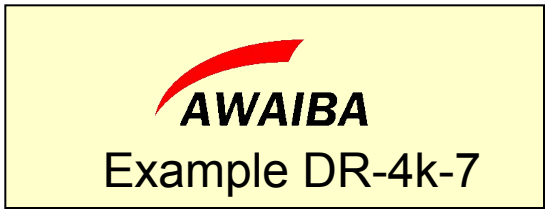
Clear definitions for a clear VISION

AWAIBA
CMOS IMAGE SENSORS

Agenda

- Why we need EMVA 1288 Standard
- EMVA 1288 Standard organization
- Measurement setup
- 1288 Module 1 “in 12 Slides”



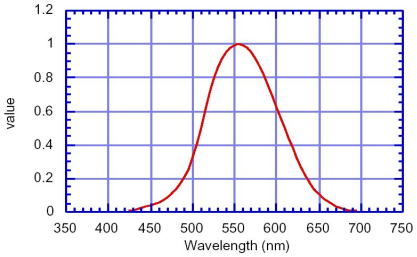


- Interpretation of the standard for the user

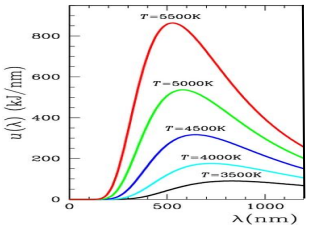
Motivation

- Existing Standards for cameras are not suitable for MV
- Each Sensor and Camera Manufacturer has it's own definitions
- The Customer is left guessing with datasheets
  - Today cameras and sensor are digital but manufacturers specify V/lux s ?!
  - Lux is a unit adapted vor human vision not for wider spectral band

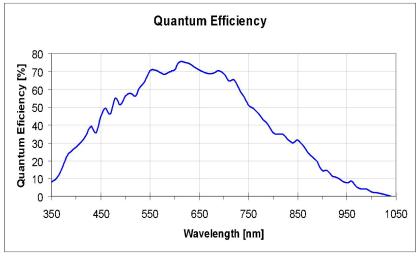
L(λ)−curve



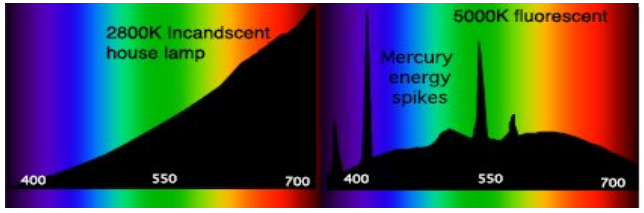
Illumination



QE-Sensor



= ?



$$L_0(T) = \frac{683 \int_{\lambda_{min}}^{\lambda_{max}} E_{\lambda.rel}(\lambda,T)\,d\lambda}{\int_{\lambda_{min}}^{\lambda_{max}} L_\lambda(\lambda) E_{\lambda.rel}(\lambda,T)\,d\lambda}$$

= 0 Lux!!

The EMVA 1288 Working Group

(logos status 2007)

The EMVA 1288 Working group is open! Contact info@emva.org

Current status

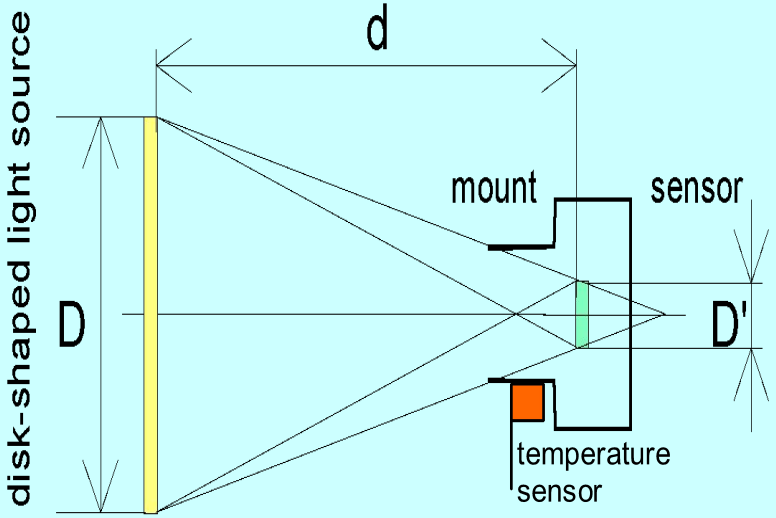
- Standard Release 2.0
  - Covers Sensitivity Spatial and Temporal Noise; Linearity
  - Adapted by many companies in Europe and World wide for internal use and on customer request.
  - Published data on www.standard1288.org from
    - AWAIBA
    - BASLER
    - PCO

Supported world wide by agreement between JIIA, AIA & EMVA on G3 standardization frame work

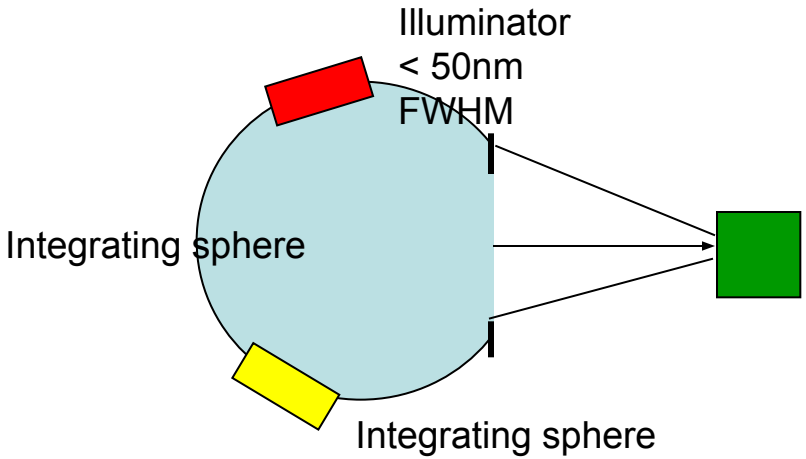
Standard 1288 Module 1
1) Measurement Setup

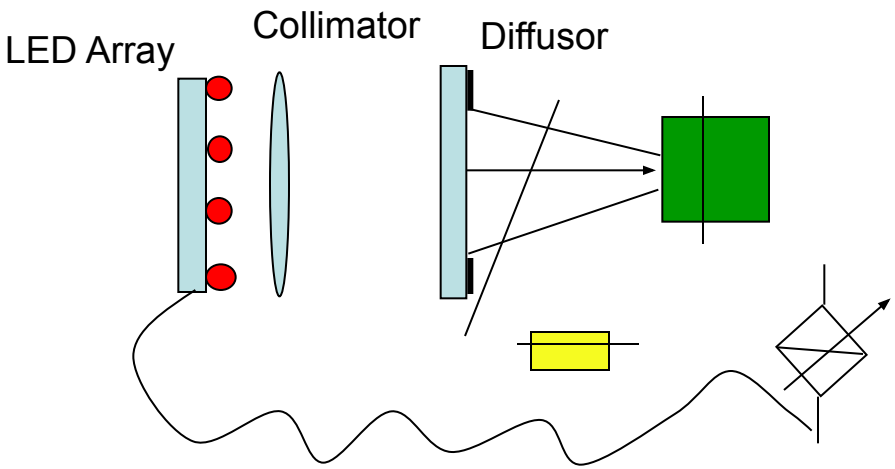
Standard requirements

- Illumination Setup from Module 1
  - Homogenous illumination
  - Without lens
  - F-number 8
  - Definition of temperature measurements

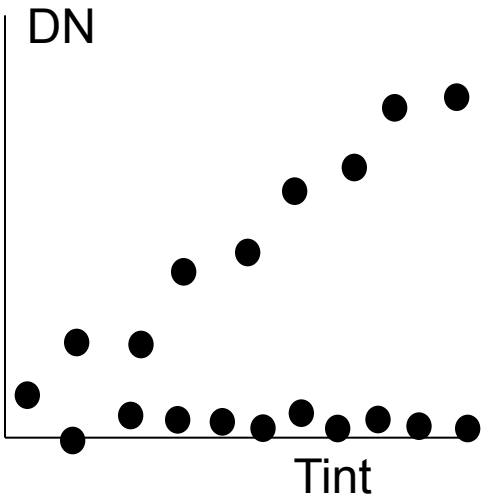


Possible realizations of set up

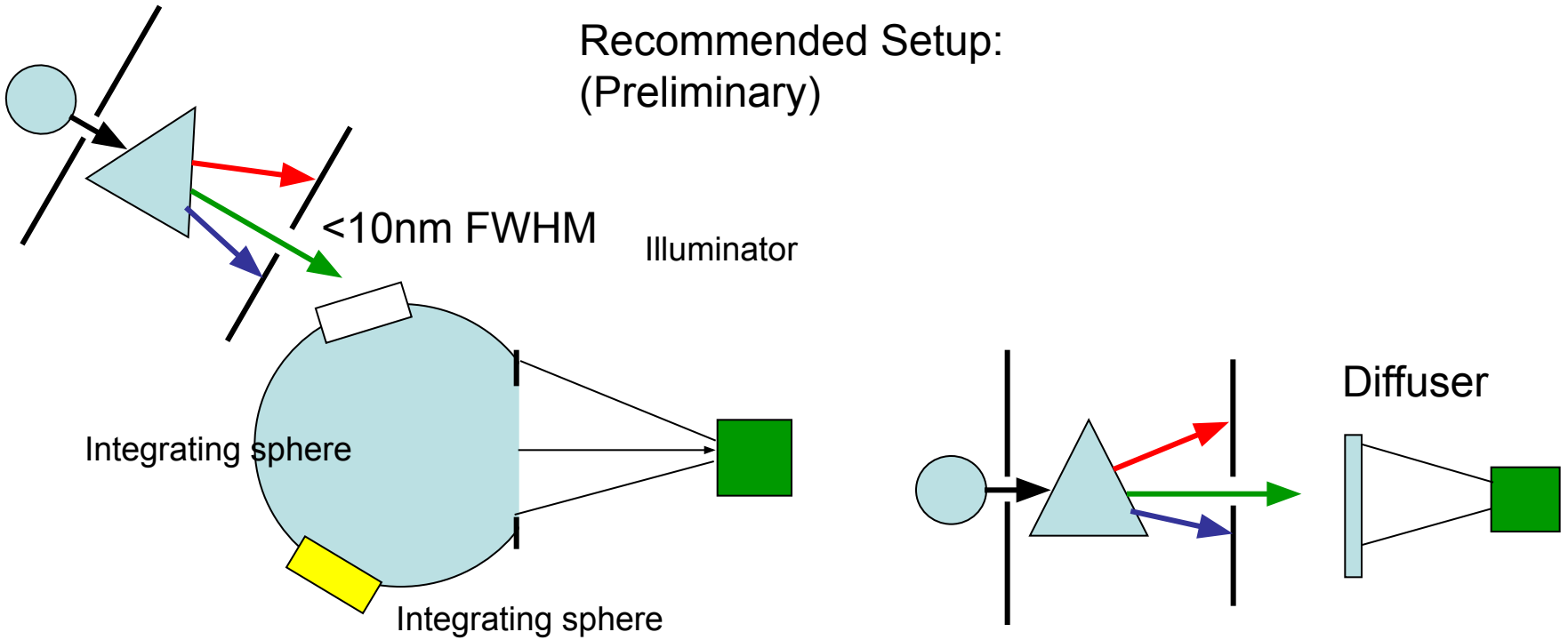




Module 1 measurement

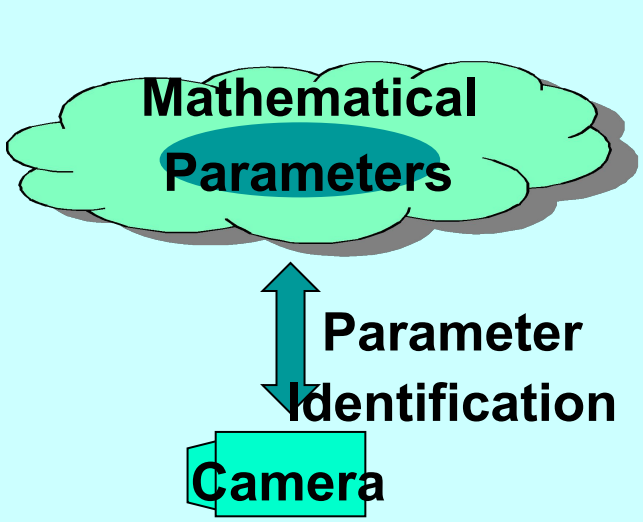


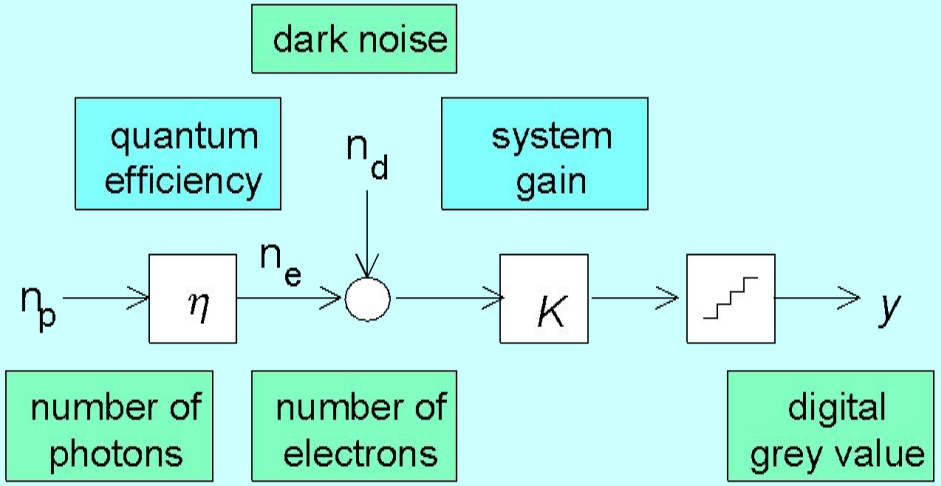
Outlook measurement setup variation for Color module



Standard 1288 Module 1
2) Mathematical Model

! The standard will only produce sense full results for cameras / sensors that follow the mathematical model !





Current module covers only linear integrating sensors

More sensor types to follow

Standard 1288 Module 1
3) Basic Information

This section delivers general information and information regarding the operation point at which data is acquired.

- **Vendor** name
- **Model** name
- **Type of data presented:** Typical; Guaranteed; Guaranteed over life time[1]
- **Sensor type** (CCD; CMOS; CID etc...)
- **Sensor diagonal** in [mm]; **Indication of lens category to be used** [inch]
- **Resolution; Pixel size** (width x height in [µm])
- **Readout type (CCD only) ; Transfer type (CCD only);**
- **Shutter type (CMOS only); Global; Rolling**
- **Overlap capabilities; (**readout of frame *n* and exposure of frame *n+1* can happen at the same time).
- Maximum **frame rate** at the given operation point. (no change of settings permitted)
- **Others** (Interface Type etc..)

EXAMPLE DR-4k-7

AVAILABLE under www.awaiba.com/en/products

Vendor Name	AWAIBA Lda
Model Name	DR-4k-7
Sensor Type	CMOS Digital Line Scan Sensor
Sensor diagonal in mm	28.67mm
Indication lens category (inch)	--
Resolution (width x height)	4096 x 1
Pixel size	7um x 7um
Readout type	4 Tap 40MHz 12bit parallel
Shutter type (Rolling/ Global)	Global Shutter
Overlap capabilities (Integration overlaps Readout)	Interleaved integration & Readout
Maximum frame rate at given operation point	9765 lines / second (40k lines / sec @ maximum operation point)
Type of presented data (typical /guaranteed/ guaranteed over live time)	typical
Definition of "typical" (number of samples etc..)	1 random sample
Other relevant information (interface type etc...)	12 bit digital parallel
Photodiode type (see QE plot)	Standard diode

Standard 1288 Module 1
4) Operation Point

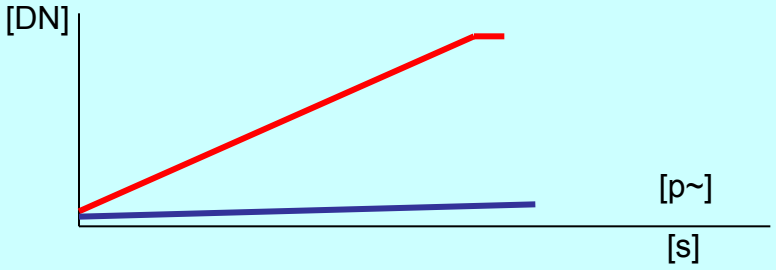
- This section describes exactly in what configuration the camera / Sensor is operated. I.e. all gain & register settings and environmental conditions.
- Unless for the scans of the integration time, **the camera / sensor has to be in the same operation point for all EMVA1288 measurements.**

EXAMPLE DR-4k7

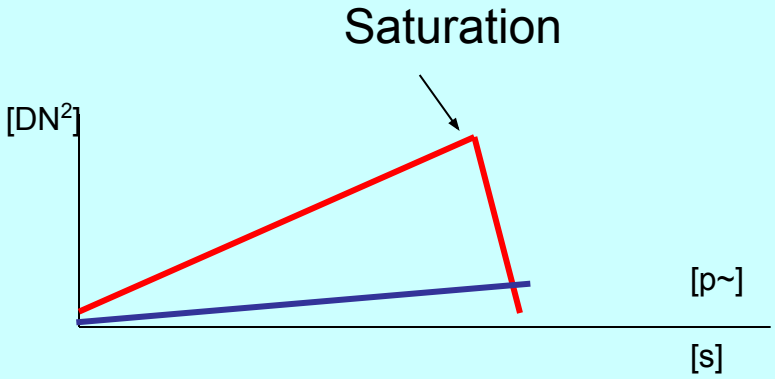
AVAILABLE under www.awaiba.com/en/products

Main Clock Frequency	40MHz
Line Period	205 us
ADC End Range Register	0x84
Illumination Wavelength	625nm
On chip ADC offset subtraction	Enabled
Config. Register 1	00100001
Config. Register 2	00110000
ADC Gain	0x20h

Standard 1288 Module 1
5) Measurement Scans



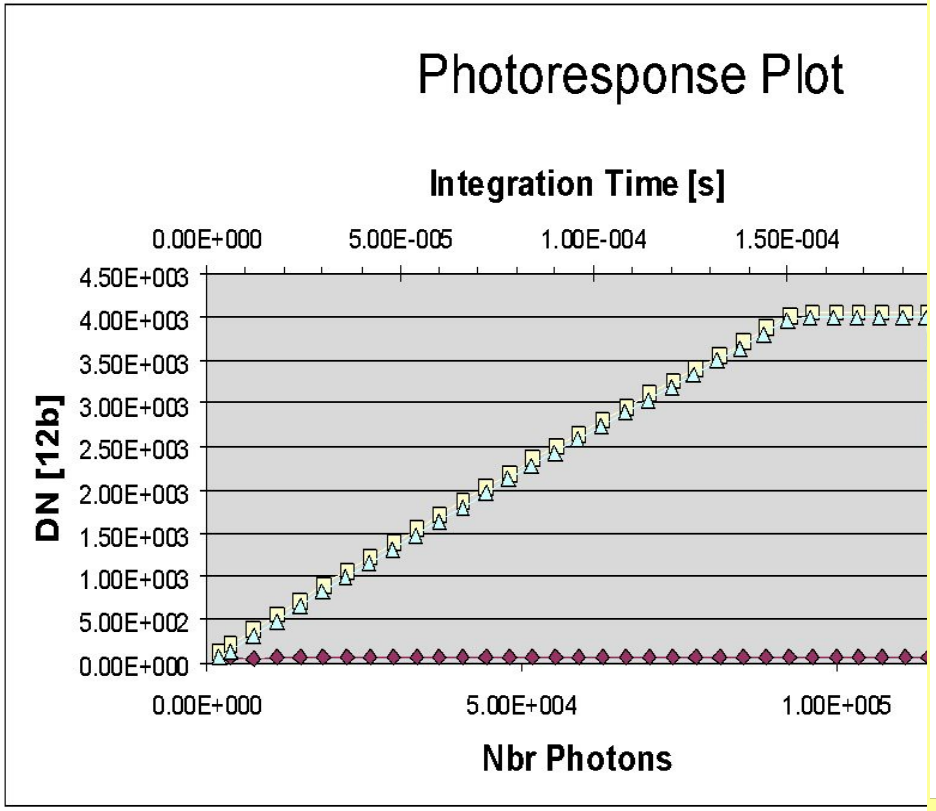
Acquire 2 series of images with increasing Exposure time. One series in dark, one with a constant illumination. Compute the mean value of The images, report the mean versus the integration time and the number of photons Collected in each pixel.

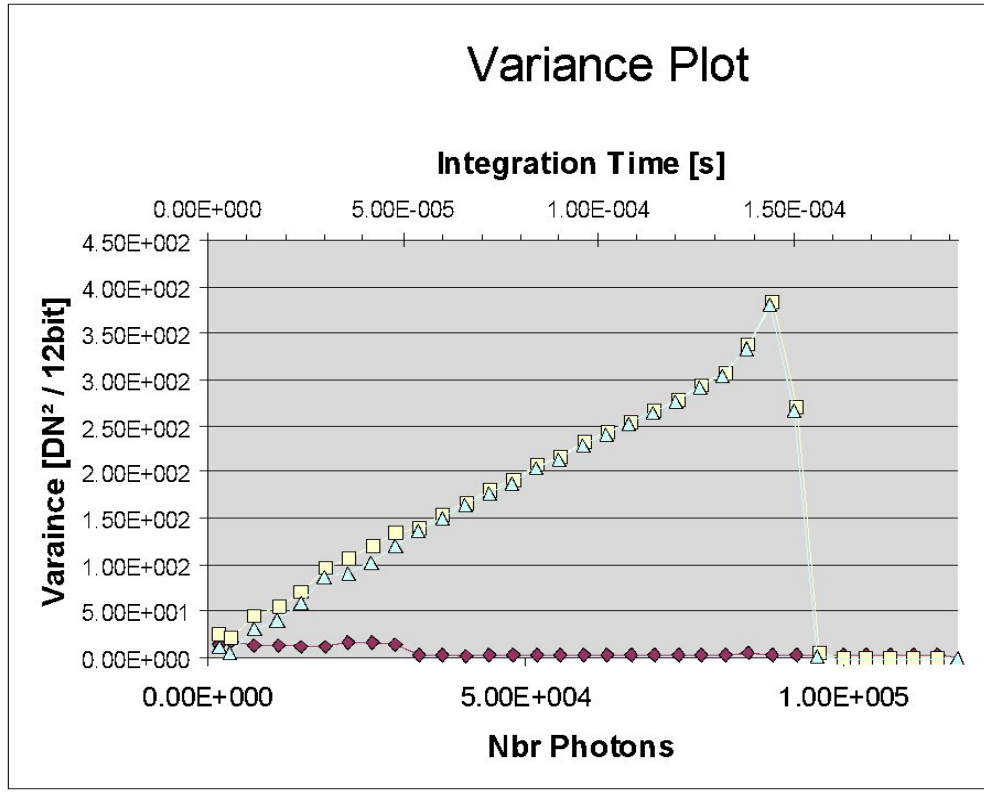


From 2 images at the same integration time, compute the square difference image. The mean of the squared difference image is the Variance. Report the variance for the series in dark and for the series with light versus integration time and number of photons. Saturation exposure is defined as the exposure where the variance is maximal

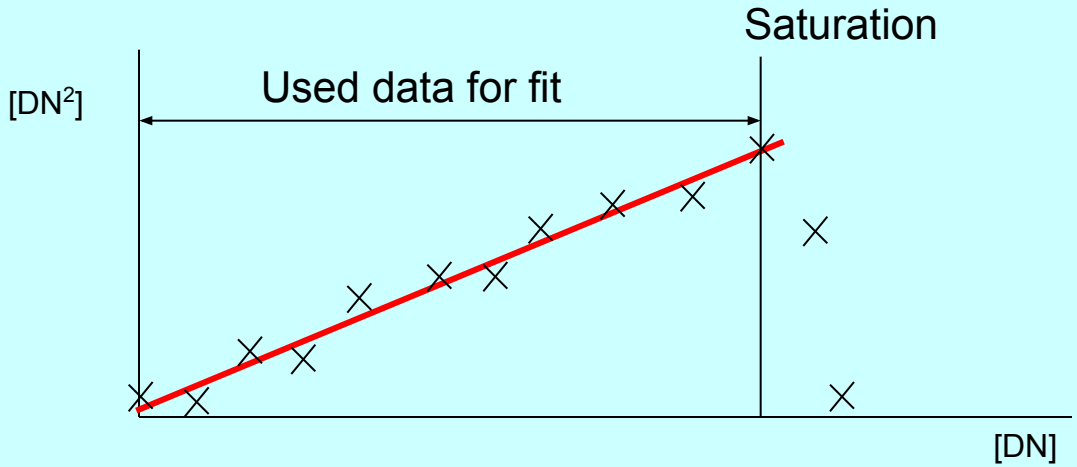
EXAMPLE DR-4k-7

AVAILABLE under www.awaiba.com/en/products





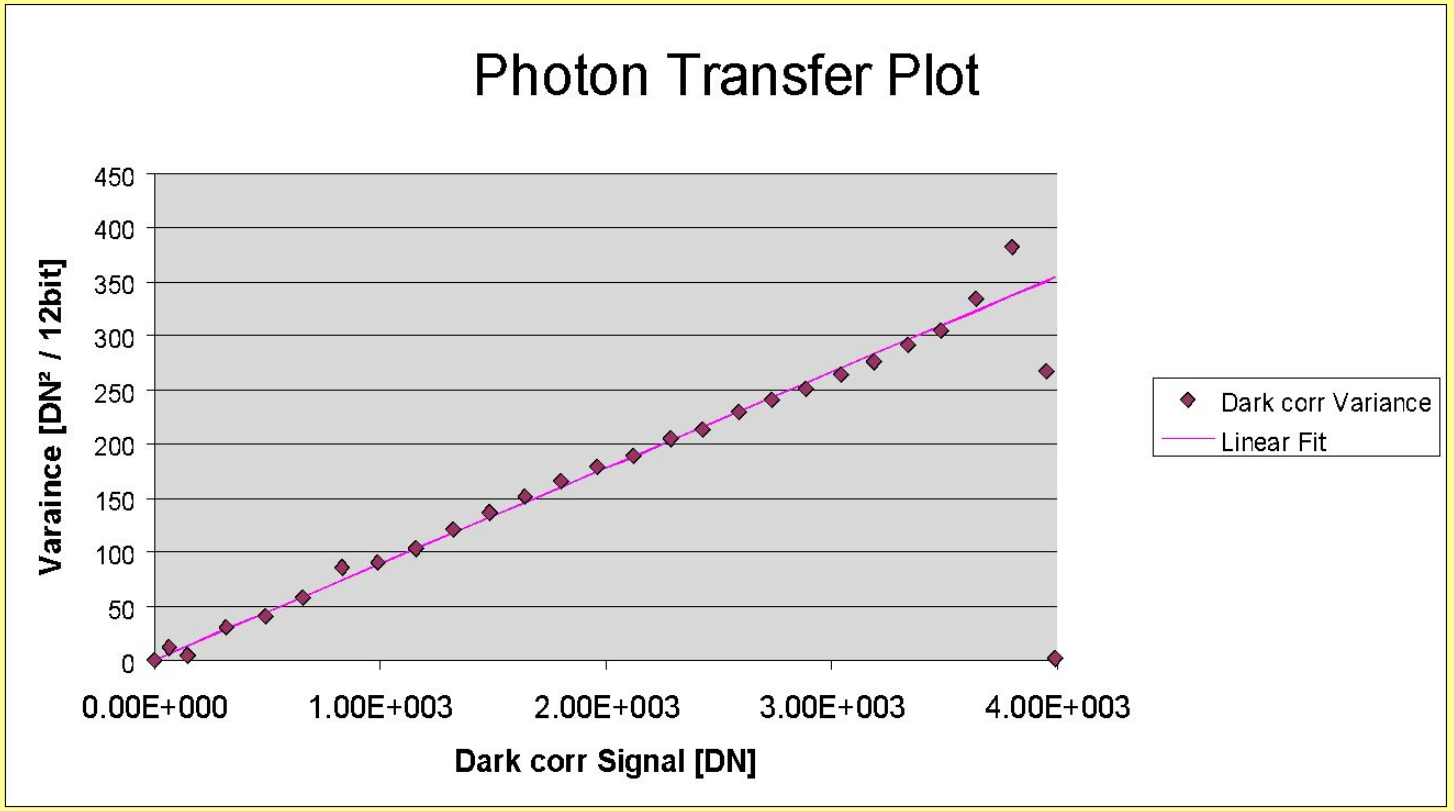
Standard 1288 Module 1
6) Photon Transfer Method



- Subtract the mean dark values from the mean values with illumination.
- Subtract the dark variance values form the bright variance values.
- Report the dark corrected variance versus the dark corrected mean values.
- Fit a line going through the origin through the data points until saturation
- The slope of this line gives the conversion gain in DN/e- or K

EXAMPLE DR-4k-7

AVAILABLE under www.awaiba.com/en/products



Standard 1288 Module 1
7) Derived Quantities

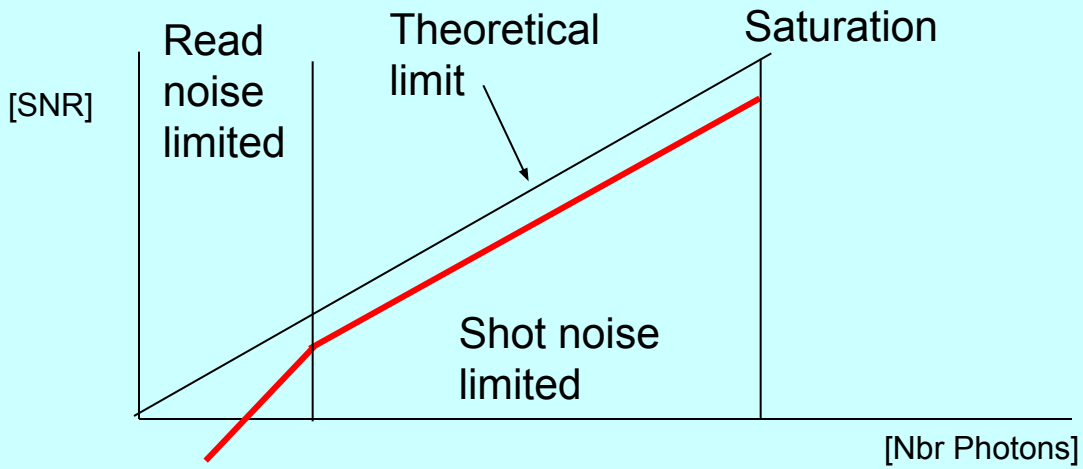
Quantity	Value
$\eta(\lambda)$: **Total quantum efficiency** in [%] at measurement wavelength	
σ_{d0}: Standard deviation of the **temporal dark noise** referenced to electrons for exposure time zero in [e-].	
N_{d30} : **Dark current** for a housing temperature of 30°C in [e-/s].	
$\frac{1}{K}$: **Inverse of overall system gain** in [e-/DN].	
$\mu_{e.sat}$: **Saturation capacity** referenced to electrons in [e-].	
$\mu_{p.\min}(\lambda)$: **Absolute sensitivity threshold** in [p~] at the measurement wavelength	
$SNR_y(\mu_p)$: **Signal to noise ratio** at saturation	
$DYN_{in} = DYN_{out}$: **Dynamic range** in [1]	
$DSNU_{1288}$	
$PRNU_{1288}$	
σ_o : Standard deviation of the **spatial offset noise** referenced to electrons in [e-]	
S_g : Standard deviation of the **spatial gain noise** in [%].	

EXAMPLE DR-4k-7

AVAILABLE under www.awaiba.com/en/products

Parameter	Value
Conversion Gain [DN/e-]	0.0886
QE*	49.58%
Saturation capacity [e-]	47’737
Responsivity [DN/nJ/cm2]**	67.9
Temporal dark noise [DN]	1.1
Temporal dark noise [e-]	12.9
Absolute sensitivity threshold [p/pix]	26
SNR emva1288	193
SNR emva1288[dB]	46
DYN (standard SNR)	1972
DYN [dB] (standard SNR in dB)	65.9
DSNU 1288 [e-]	13.4
DSNU [DN] (standard deviation of mean dark image)	1.4
PRNU 1288	1.9%
Dark Current 30C [e-/ms]	3
Dark current doubling temperature [C]	11.5

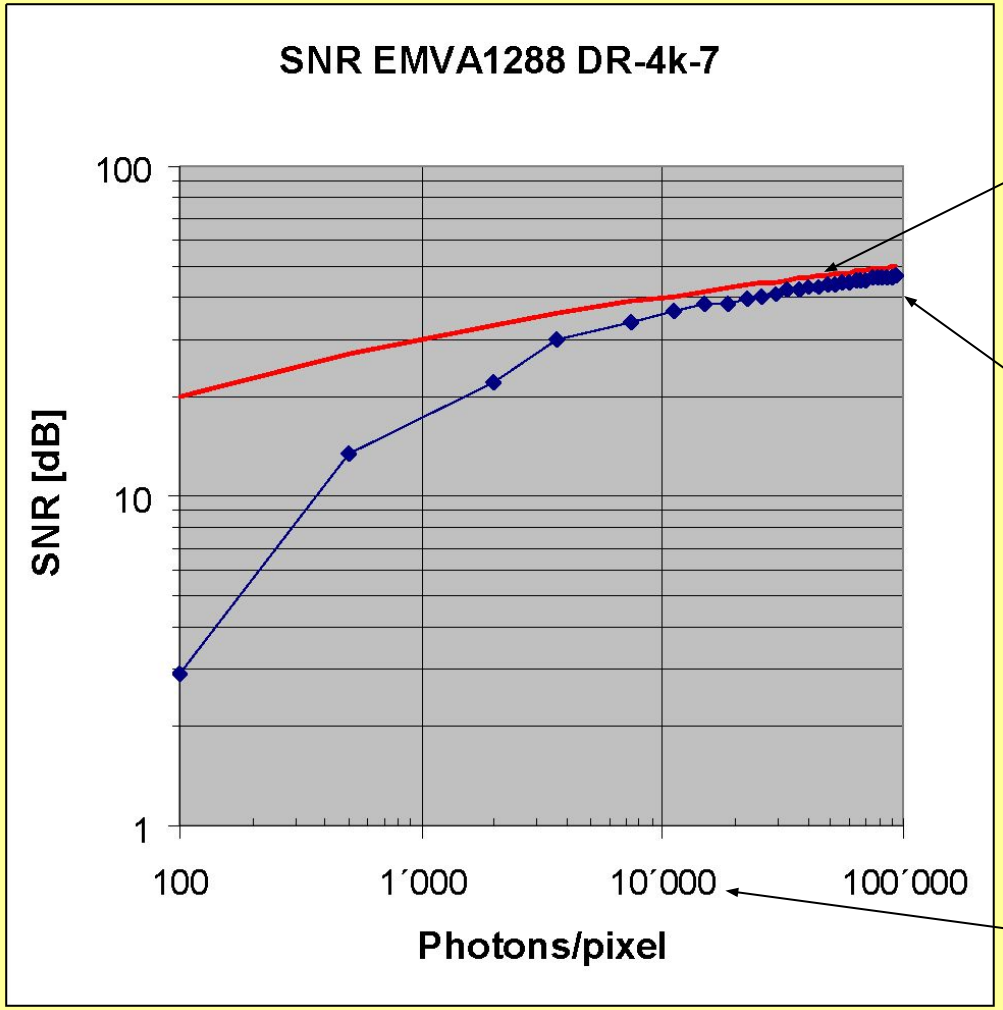
Standard 1288 Module 1
8) SNR Plot



- Plot the SNR values resulting from each integration time versus the number of photons impinging on a pixel during this integration time.
- Use Logarithmic scale (dB or bit (base log2)
- Plot values from lowest chosen integration time til saturation.

EXAMPLE DR-4k-7

AVAILABLE under www.awaiba.com/en/products

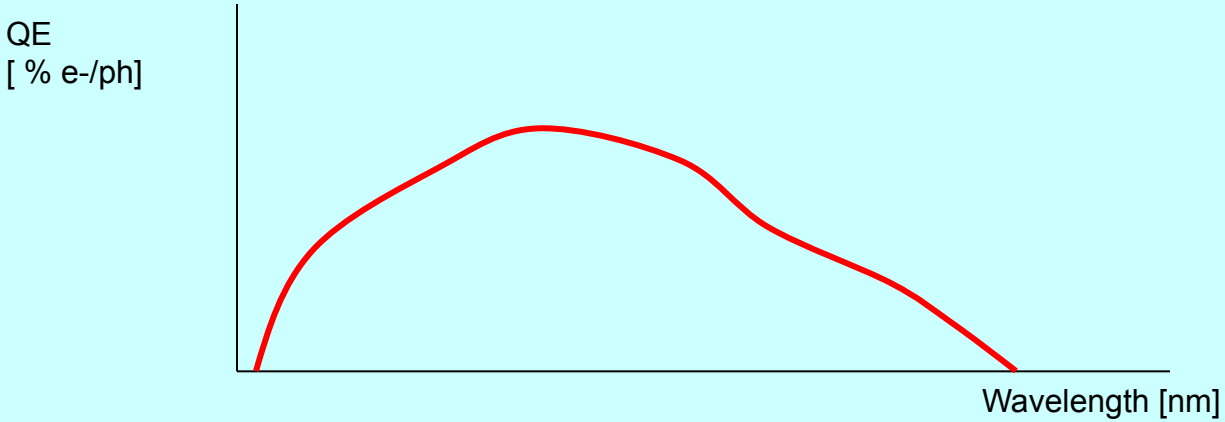


Theoretical limit
of SNR based on
photon shot noise
Of incoming signal

Maximum SNR

DYN = 66dB

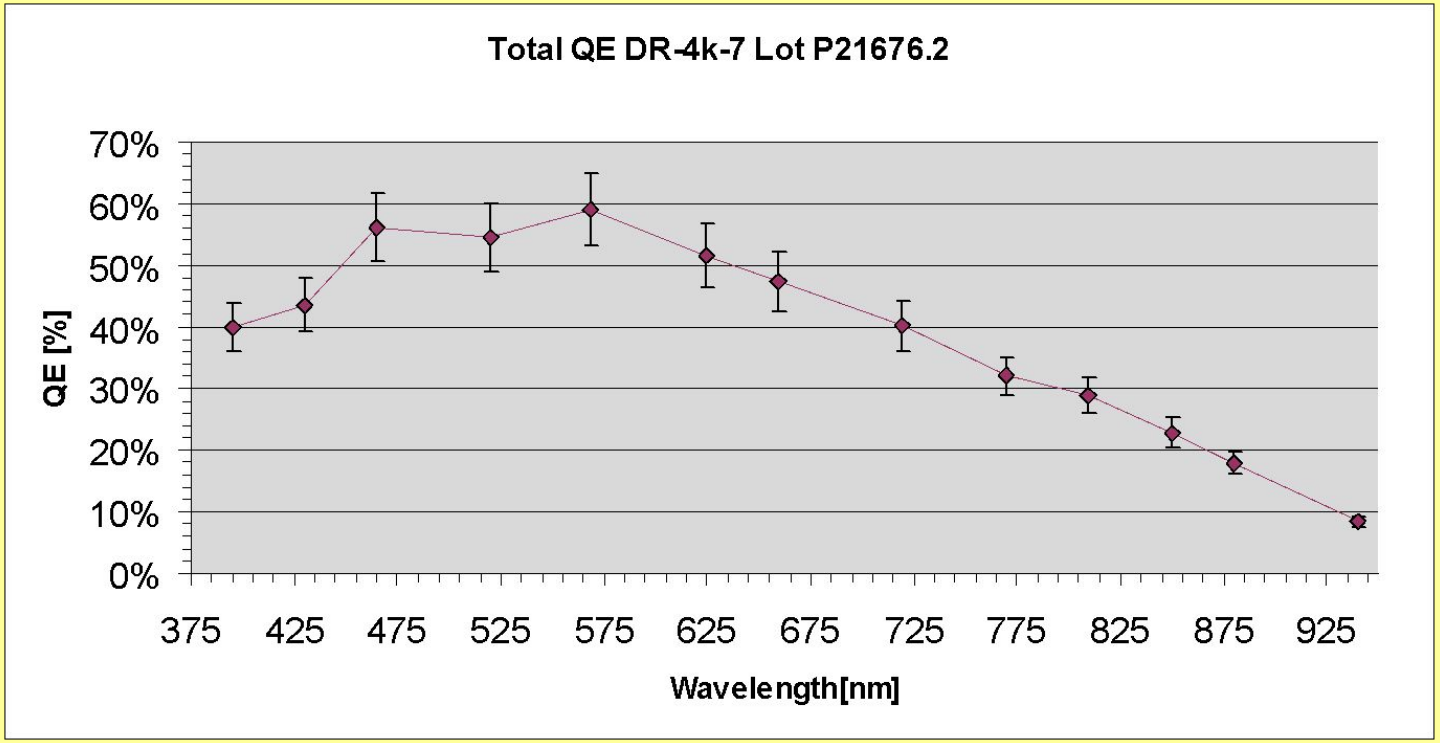
Standard 1288 Module 1
9) Quantum Efficiency Plot



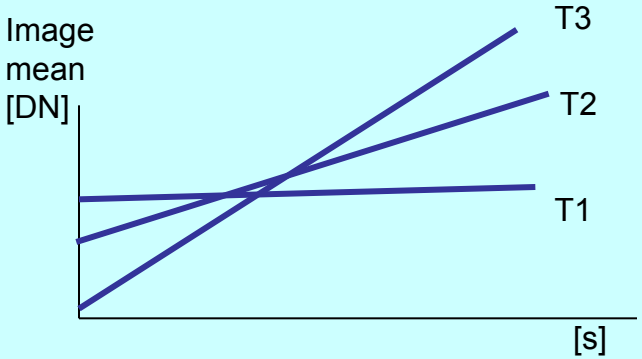
- From the conversion gain and the light intensity used during exposure compute the total QE.
- Report the QE versus measurement wavelengths.
  - Note for EMVA1288 data given per unit: When clearly stated this measurement can be based on typical data even for production data, however the curve should be scaled to the QE measured at the specific measurement wavelength of sample.

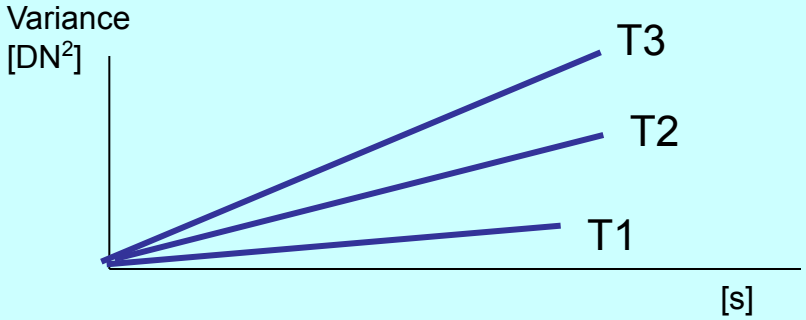
EXAMPLE DR-4k-7

AVAILABLE under www.awaiba.com/en/products



Standard 1288 Module 1
10) Dark Current





- Acquire series of dark images versus increasing integration times at different housing temperatures. (Measurement not applicable for cooled cameras)
- Report the increased signal values versus integration time.
- Report the increase of variance versus integration time.
- Subtract from each series the mean signal value and the variance value of the shortest integration time from each measurements point.
- From the increase in variance compute the dark current in [e-/s] and the dark current doubling temperature [K]

EXAMPLE DR-4k-7

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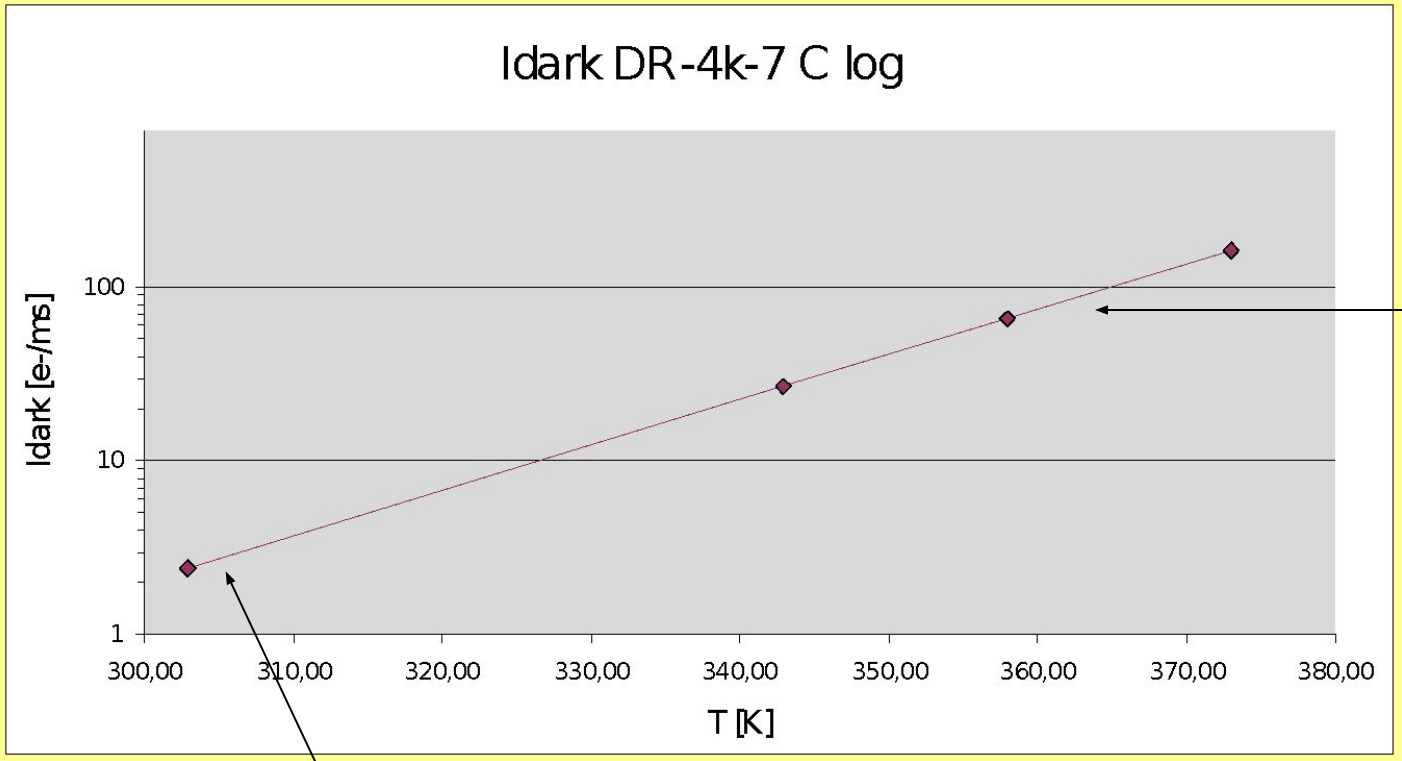
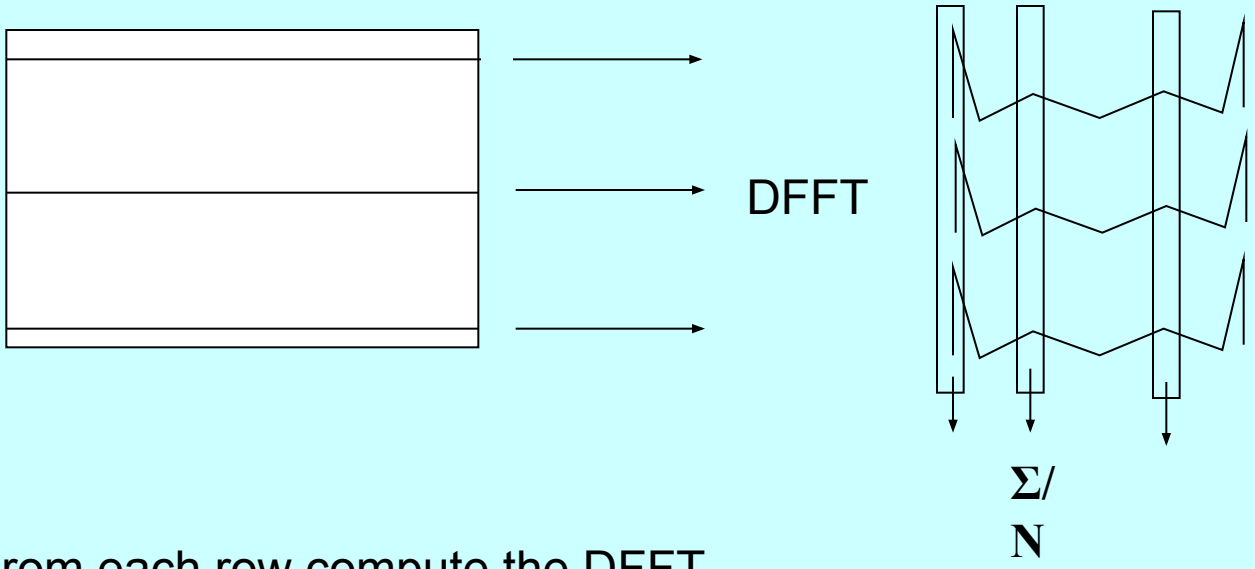


Dark current doubling temperature 11.2K

Dark current at ambient 3e-/ms

Standard 1288 Module 1
11) Spectrogram

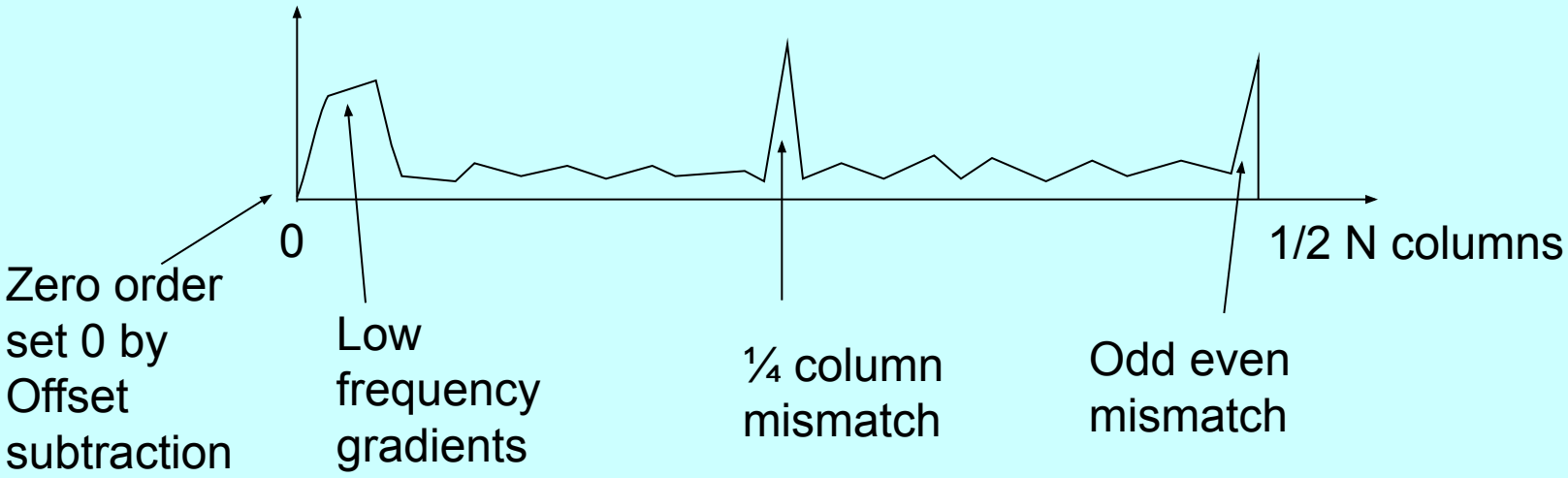
Idea: describe DSNU & PRNU effects in from of a spectral amplitude plot to Show high frequency (E.g. odd even mismatch) and low frequency (E.g. over all gradients) parts of spatial and temporal noise separately

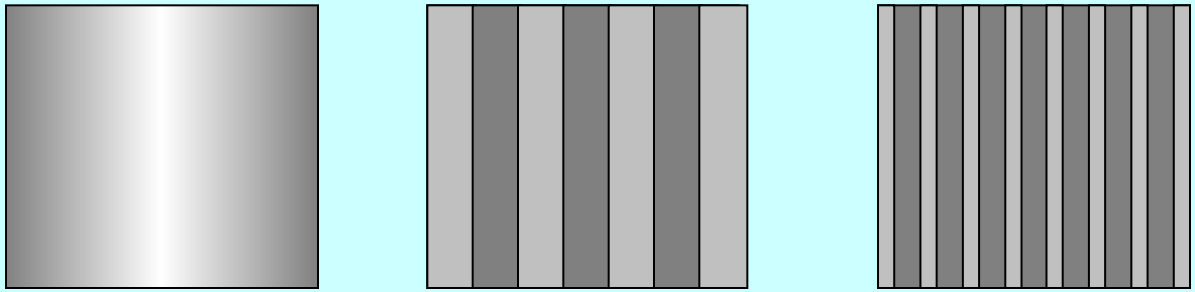


- From each row compute the DFFT
- Average the FFT values along each column of the FFT result matrix
- Plot the resulting spectrogram for Dark; 50% Saturation; 90% Saturation

Standard 1288 Module 1
12) Interpretation of Spectrogram

Interpretation:





EXAMPLE DR-4k-7

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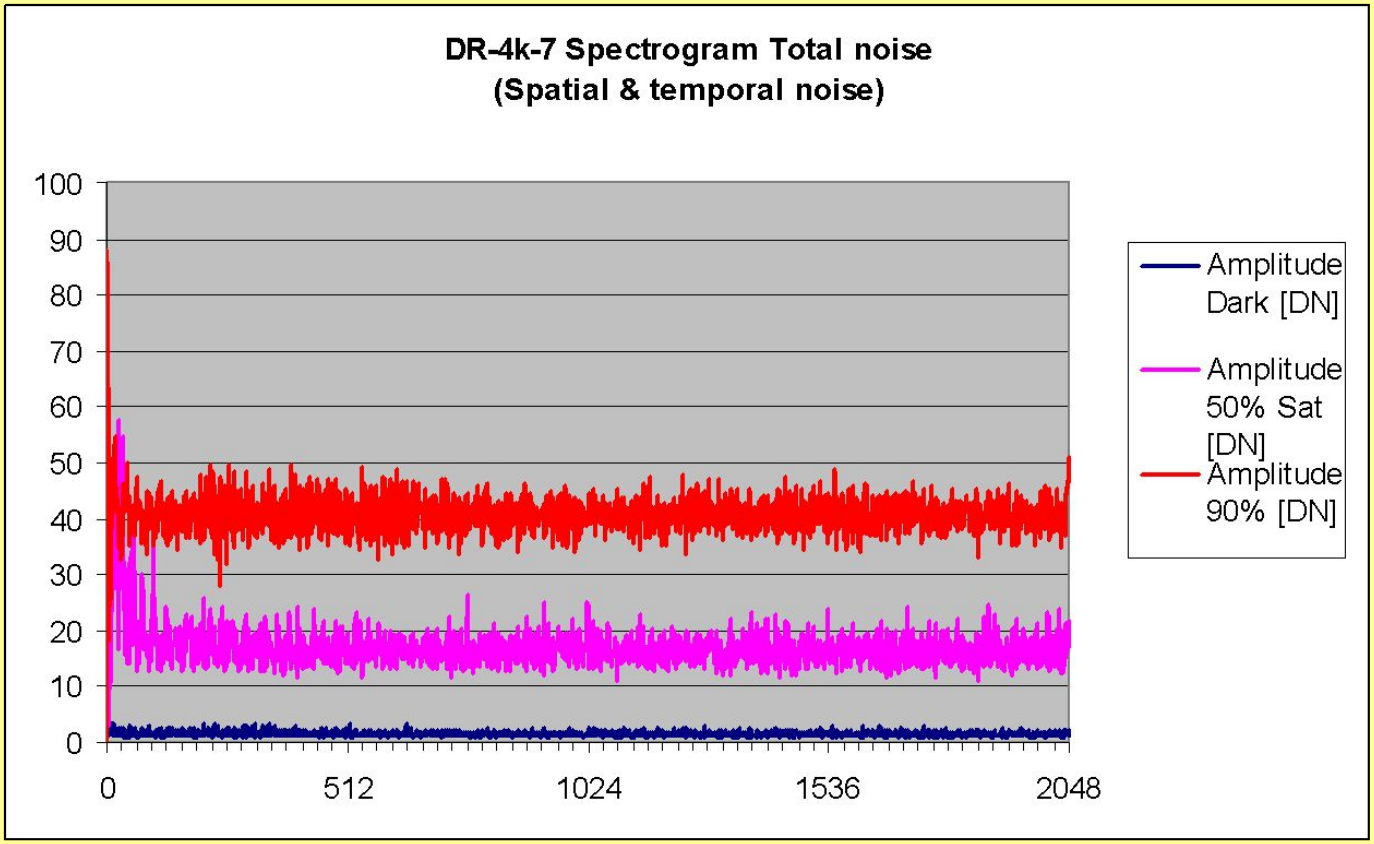
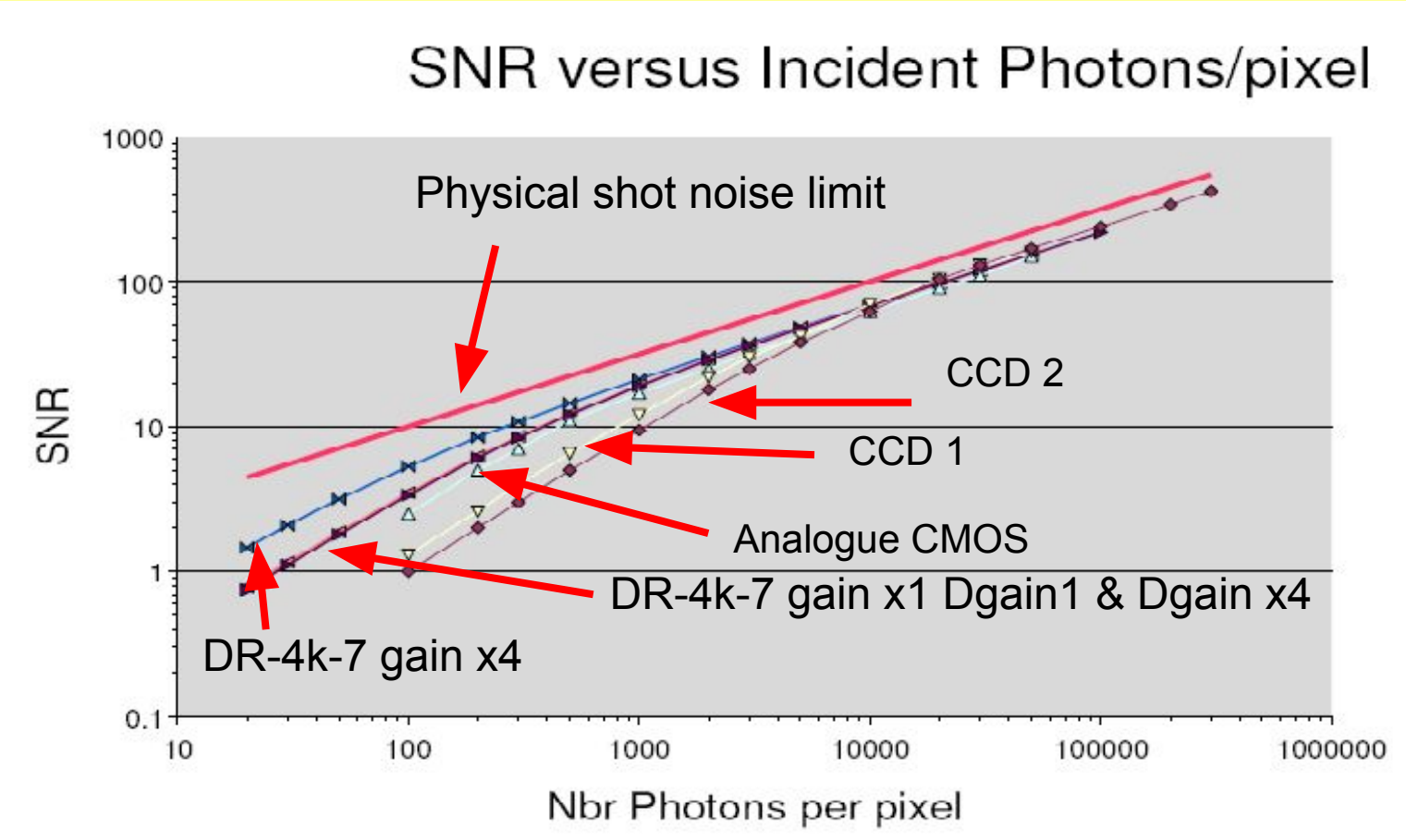


User Benefit 1288
Compare different Settings Objectively



Optimize performance based on real values rather than visual impression!

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Raw sample image DR-4k-7 at previously described operation point

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Thank you for your attention

- Current standard draft

  www.emva.org www.emva.org or www.standard1288.org

  Contact EMVA:

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  Contact me:

  waeny@awaiba.com

In God we trust, all other we measure