# Noise comparison of smx15m5m, Basler acA3800-14um, and smx16e2 cameras

Document address:
https://docs.google.com/document/d/1lYz3xURAN-TkriMti8XoTqZO5TDZ6CinnPD9sBNdNeI/edit?usp=sharing

**Version 1.10**
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**Revision History**

| Name | Date | Reason For Changes | Version |
|---|---|---|---|
| O.Lytvynenko | 3/01/2016 | Initial revision. Comparison of smx15m5m and Basler acA3800-14um cameras | 0.80 |
| O.Lytvynenko | 8/11/2016 | Results for smx16E2 mono camera added | 1.10 |

**2016**

# Introduction

The main task of the experiment was an investigation of Basler acA3800-14um camera noise and its comparison with smx15m5m camera.
In the version 1.1 of the document results for noise measurement of smx16E2 mono camera were added. These results are put in a separate part of the document (see part 2).

**Main conclusion.** Basler acA3800-14um has a variance of temporal noise approximately 1.8 times as smx15m5m. Also this camera has a visible chess pattern noise. So acA3800-14um (or other camera with the same sensor) should not be recommended for installation into Sumix interferometers and microscopes.

The method of measurement and experiment results are given in the following parts of this document.

## Mathematical Model

We suppose both cameras to be linear cameras. The mathematical description of linear camera, noise definition, experiment setup, and calculation formulas are given in the EMVA Standard 1288 [1].

The only characteristic measured in the experiment was **Temporal variance of gray value**. Normally, the computation of the temporal variance would require the capture of many images. However on the assumptions the noise is stationary and homogenous, it is sufficient to take the mean of the squared difference of the two images ([1], sec.6.6):

$$\sigma_q^2 = 1/(2NM)\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}(y^A[m][n] - y^B[m][n])^2 \quad (1)$$

where:
$\sigma_q^2$ - temporal noise
A, B - two images
M- image width
N - image height

# Part 1. SMX15M5M and Basler acA3800-14um

## Experiment Setup

***1. Camera SMX15M5M***
*Equipment*: camera SMX15M5M, s/n 7110, installed in MAX interferometer.
*Environment Temperature*: 20 C
*Worm up*: grabbing frames for more than 15 min with max frequency
*Driver version*: 0.1.125 (sumix internal version)

*Irradiance (Brightness ) on the sensor surface*: 128 (setal etalon used as a reflector)
*Viewport*: 800*600, centered
*BPP*: 8
*Frequency*: 96
*Gain*: 1

***2. Camera* acA3800-14um**
*Equipment*: camera  Basler acA3800-14um, s/n 21802351, installed in MAX interferometer.
*Environment Temperature*: 20 C
*Worm up*: grabbing frames for than 5 min with default frequency
*Driver version*: 4.3.0.0
*Irradiance (Brightness ) on the sensor surface*: 128 (setal etalon used as a reflector)
*Viewport*: 800*600, centered
*Gain*: 0dB

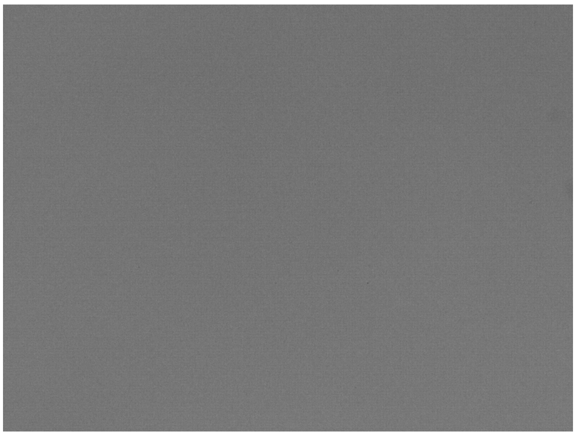
## Measurement results

Images from both devices were grabbed and processed with Python scripts (GrabImages.ipynb, Analyze noise from images.ipynb). Main calculations were done based on formula (1). Because noise stationarity and homogeneity was suggested, but not proven, a verification was made on a set of 100 randomly selected pixels averaged along time axis. The table below summarizes measurement results.

| Camera | Avg. brightness | Spatial noise (temporal + pattern) | Temporal noise | Temporal noise verification |
|---|---|---|---|---|
| SMX15M5M | 126.4 | 3.97 | 2.00 | 2.00 |
| acA3800-14um | 117.3 | 6.1 | 3.79 | 3.78 |

Sample images from cameras are given below (zoom in to see differences):

| | |
|---|---|
| SMX15M5M |  |

| | |
|---|---|
| acA3800-14um |  |

# Part 2. SMX16E2-mono

***1. Camera*** SMX16E2
*Equipment*: camera  SMX16E2, s/n 8804, installed in WIZ QS+ interferometer.
Device s/n:
*Environment Temperature*: 20 C
*Worm up*: grabbing frames for more than 15 min with max frequency
*Driver version*: 0.1.73 (sumix internal version)
*Led* = Switched on (device allows only two states of the LED)
*Irradiance (Brightness ) on the sensor surface*: 128 (setal etalon used as a reflector)
*BPP*: 8, 12
*Frequency*: 114, 80
*Gain*:  A range
*Frame rate:* 60

## Verification of Mathematical Model

The lighting in WIZ-QS+ is stationary and homogenous, - see image below. Because of this only a small image part is taken for experiments, with the squared viewport of size 100 in the center of the image.
To verify mathematical model (1) two experiments were made under the following conditions. Viewport, h=100. w=100, offsetX=750, offsetY=550, Gain (analog) = 1.5, Exposure = 1.43, frequency = 114.

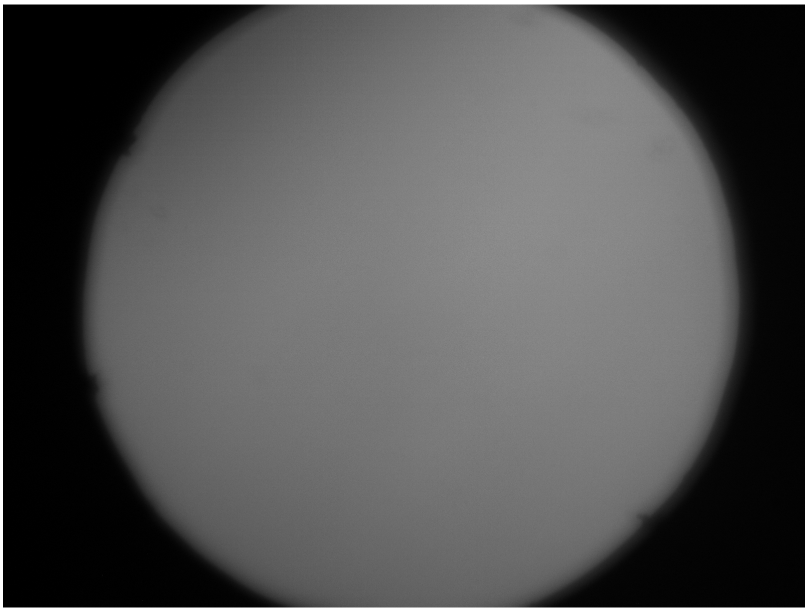
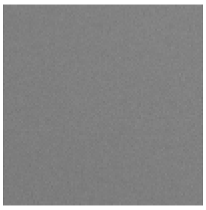
1. Experiment 1. Big number of frames grabbed (N=100). Stdev calculated along the time axis, then averaged.
2. Experiment 2. Two frames grabbed, Temporal noise calculated according to (1) .

Results of experiments are presented in the table:

| Experiment | Avg. brightness | Temporal noise |
|---|---|---|
| 1 | 128.4 | 2.028 |

| | | |
|---|---|---|
| 2 | 128.0 | 2.07 |

Experiments show that noise value calculated according to [1], is practically equal to the noise, obtained by averaging deviations calculated along time axis.

| | |
|---|---|
| Full viewport, Exp = 1.430, Gain = 1.5 |  |
| Viewport, h=100. w=100, offsetX=750, offsetY=550, Exp = 1.430, Gain = 1.5 Avg.Brightness = 127,5, zoom =2 |  |

## Measurement results

Images were grabbed and processed with Python scripts (NoiseGrabberAndMatter.ipynb). Main calculations were done based on formula (1).
The table below summarizes measurement results under standard conditions. Cameras SMX15M5M and acA3800-14um (see part 1) are added for comparison. SMX16E1, SMX16E2 (s/n 6963) frequency is 114 MHz.

| Camera | Average brightness, (0-255) | Analog gain | Temporal noise [1] (gray levels) | Pixel size, micron |
|---|---|---|---|---|
| SMX16E1 | 129.7 | 1.5 | 1.96 | 5.3 |
| SMX16E2 | 128.4 | 1.5 | 2.07 | 4.5 |

| | | | | |
|---|---|---|---|---|
| SMX15M5M | 126.4 | 1.0 | 2.00 | 2.2 |
| acA3800-14um | 117.3 | 0dB | 3.79 | 1.67 |

## Noise vs Frequency

If the camera frequency is reduced from 114 Mhz to 80 Mhz, and exposure remains untouched, image brightness should stay unchanged. But brightness does decrease. So, to compensate for brightness loss, someone has to increase exposure. Experiment shows that with increased exposure the noise decreases. That seems strange and still doesn't have an explanation (at least the camera is not saturated). See table below for measured values
Exposure = 2.080, sigma = 1.6

| Frequency | Brightness | Exposure | Noise sigma |
|---|---|---|---|
| 114 | 128.4 | 1.43 | 2.07 |
| 80 | 127.9 | 2.080 | 1.6 |
| 60 (Camera is saturated near 188) | 127.9 | 2.77 | 1.49 |

## Noise vs Gain

Noise is linearly dependent on Gain - see tables and figures below.
Table. Noise vs gain. Frequency = 80.

| Brightness | Gain | Exposure | Noise sigma |
|---|---|---|---|
| 127.9 | 1.5 | 2.080 | 1.6 |
| 129.34 | 2.0 | 1.56 | 1.94 |
| 128.7 | 3.0 | 1.04 | 2.52 |
| 129.4 | 4.0 | 0.775 | 2.96 |

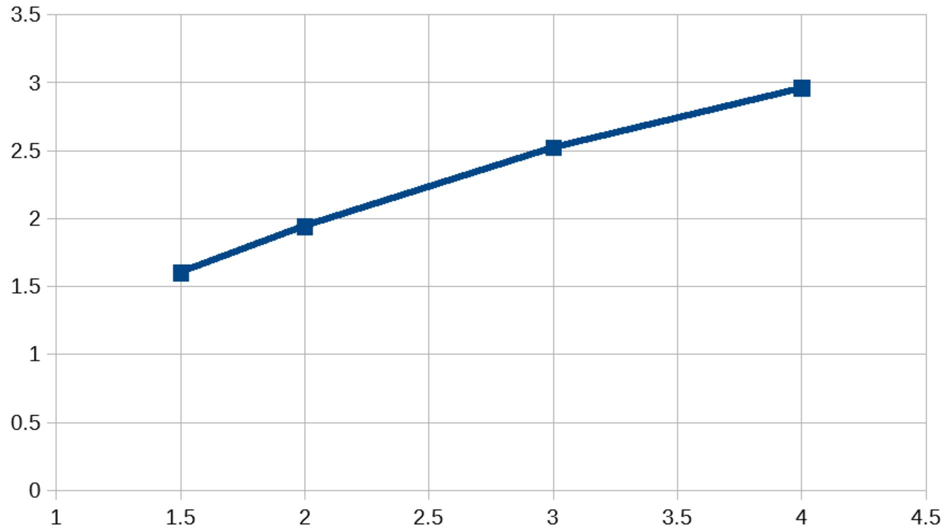



Fig. Noise vs Gaiv, Frequency = 80

Table. Noise vs gain. Frequency = 60.

| Brightness | Gain | Exposure | Noise sigma |
|---|---|---|---|
| 127.9 | 1.5 | 2.77 | 1.49 |
| 126.9 | 2.0 | 2.07 | 1.63 |
| 127.3 | 3.0 | 1.34 | 2.12 |
| 127.5 | 4.0 | 1.003 | 2.47 |

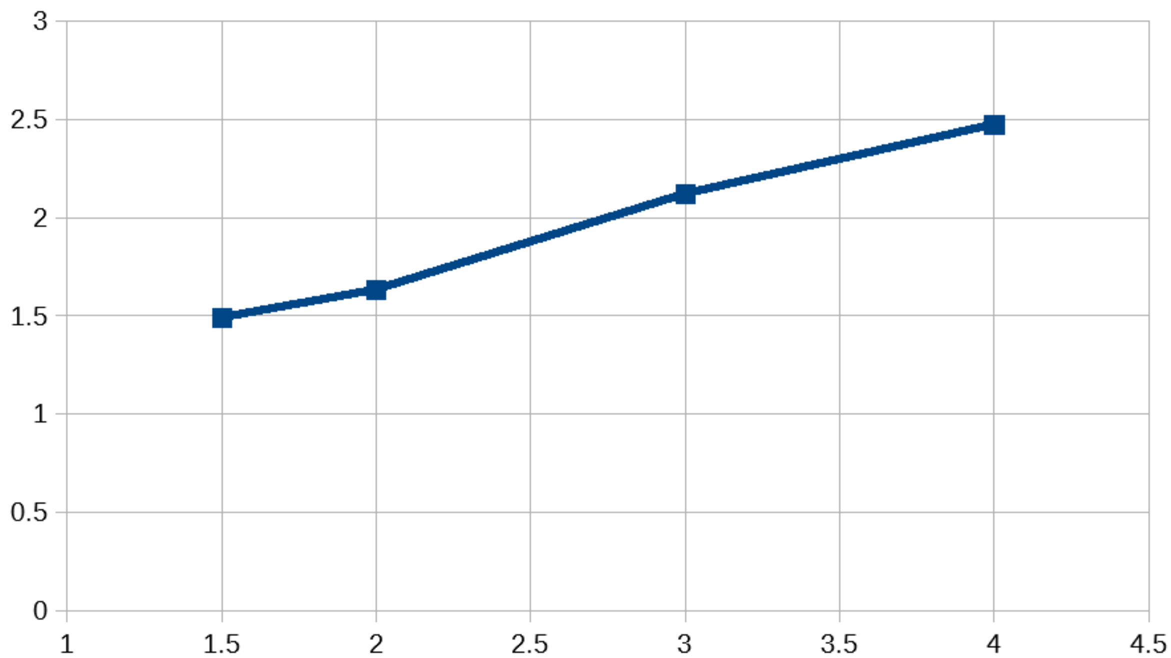



Fig. Noise vs Gaiv, Frequency = 60

Table. Noise vs gain. Frequency = 40.

| Brightness | Gain | Exposure | Noise sigma |
|---|---|---|---|
| Saturated on 132 | 1.5 | | |
| 128.8 | 2.0 | 3.15 | 1.41 |
| 127.2 | 3.0 | 2.05 | 1.61 |
| 130.4 | 4.0 | 1.55 | 1.95 |

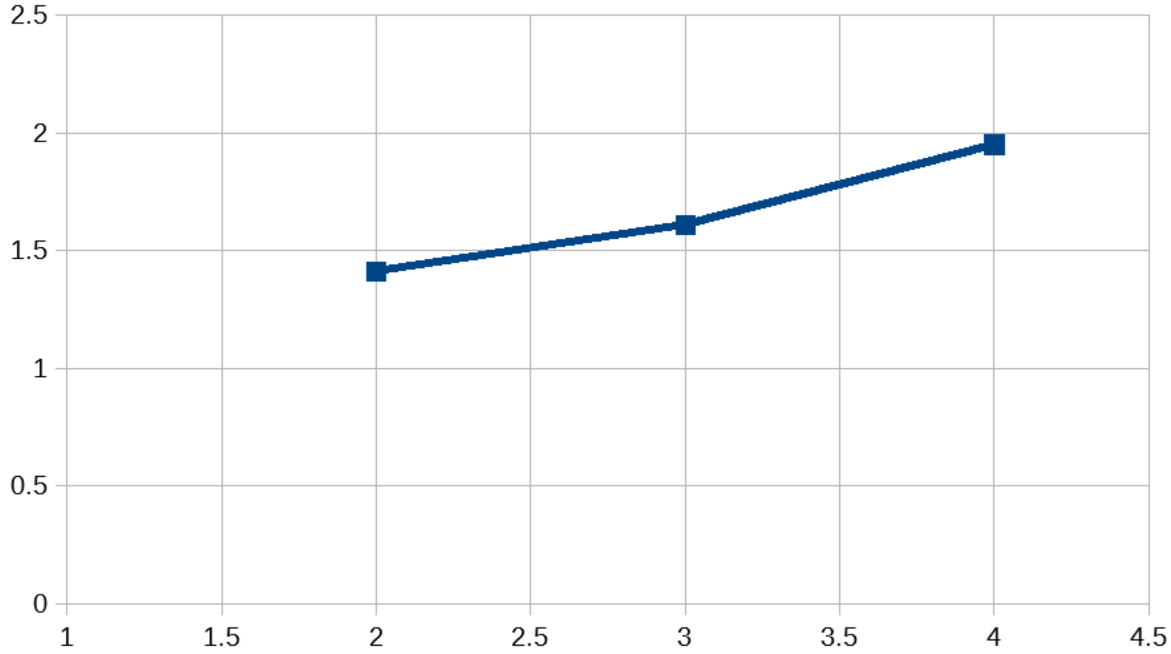



Fig. Noise vs Gaiv, Frequency = 40

## References

[1]. EMVA Standard 1288. Standard for Characterization of Image Sensors and Cameras. Release 3.0. November 29, 2010.
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