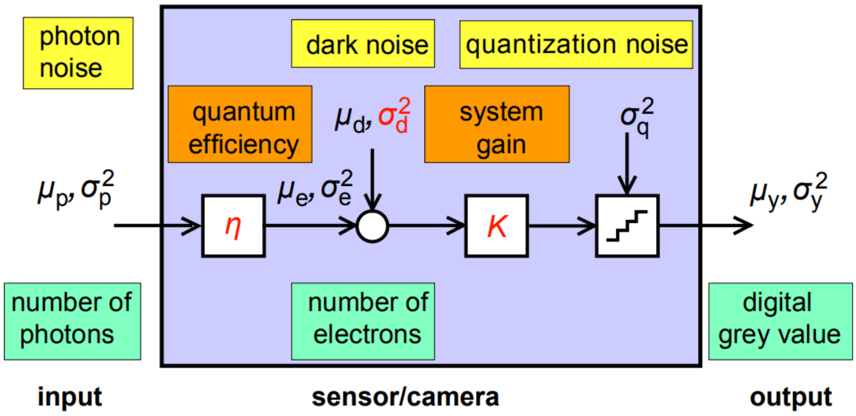
EMVA1288 测试记录

前期准备

1. 不能有镜头（P16）
2. 均匀光，最好是积分球；公式 42 就是其中的规定，max-min 在一定范围内（P17）
3. 距离和光源半径的比例有要求，推荐为 8 左右（似乎有点苛刻）（P16）
4. 传感器如果有微透镜会影响结果（P18）
5. 温度需要稳定、比特数尽量选最高、gain 尽可能小（P20）
6. 至少 50 个曝光时间，每个曝光时间两幅亮场、两幅暗场（P20）

公式说明：光子数是 p、电子数是 e、像素值是 y



时间噪声

1. 曝光时间和光子数的转换

在曝光时间t_{exp}内，入射到面积为 A 的像元上的平均光子数由下式计算，其中，E 为传感器表面的辐照度，单位为$\mathrm{W/m^2}$，$h\nu$ 为单光子能量。

$$\mu_p = \frac{AEt_{exp}}{h\nu} = \frac{AEt_{exp}}{h\,c/\lambda} \tag{2}$$

代入光的速度$c = 2.99792458 \times 10^8 \mathrm{m/s}$ 和普朗克常量$h = 6.6260755 \times 10^{-34}$ Js。则有：

$$\mu_p[\text{photons}] = 5.034 \cdot 10^{24} \cdot A[\mathrm{m^2}] \cdot t_{exp}[\mathrm{s}] \cdot \lambda[\mathrm{m}] \cdot E[\frac{\mathrm{W}}{\mathrm{m^2}}] \tag{3}$$

或者应用图像传感器常用的单位：

$$\mu_p[\text{photons}] = 50.34 \cdot A[\mu\mathrm{m^2}] \cdot t_{exp}[\mathrm{ms}] \cdot \lambda[\mu\mathrm{m}] \cdot E[\frac{\mu\mathrm{W}}{\mathrm{cm^2}}] \tag{4}$$

2. 特征曲线的斜率（P21）

resulting in a digital output signal with a mean μ_y and a variance σ_y^2. Still it is possible to measure the input/output relation, the *characteristic curve*

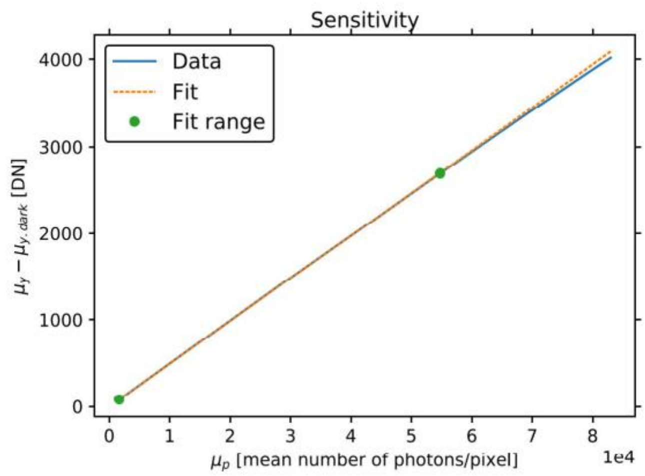
$$\mu_y - \mu_{y.\mathrm{dark}} = R(\mu_p), \tag{5}$$

两个 y 的平均值就不说了，直接平均（用两张，毕竟采了两张）。

p 的平均值有三种方式（P19），不过后两种是保持曝光时间改变光源，对光源有一定要求，所以就用第一种：曝光时间。

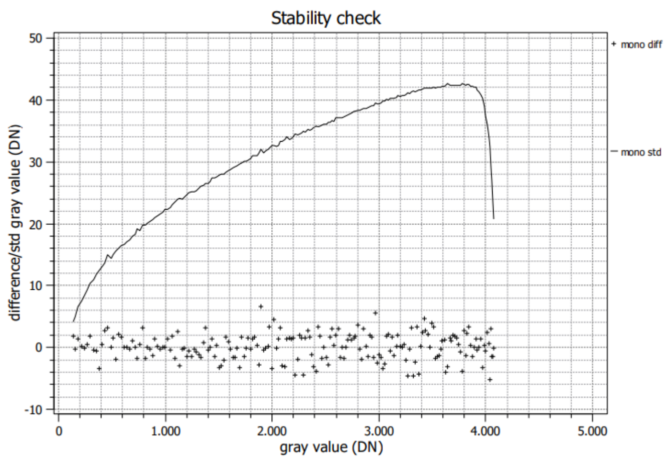
要给两张图：

- 光子数（从曝光时间计算而来）和两个 y 的差
- 光子数（从曝光时间计算而来）和暗场 y



3. 稳定性：稳定就是指方差

加号是两张图片（同一曝光时间连续采的图）平均值的差值；上面的曲线就是利用这两张图片计算的标准差的变化。

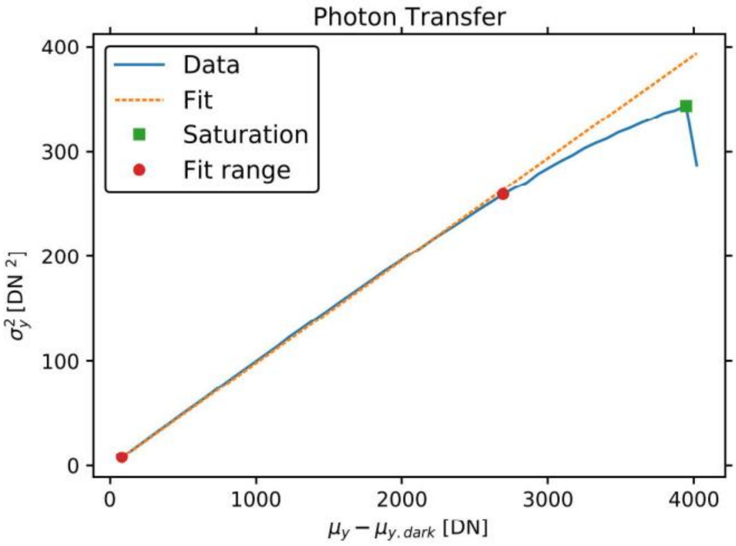


两张图片计算标准差：

$$\begin{aligned}\sigma_y^2 &= \frac{1}{2NM}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}\left[(y[0][m][n]-\mu[0])-(y[1][m][n]-\mu[1])\right]^2\\ &= \frac{1}{2NM}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}(y[0][m][n]-y[1][m][n])^2-\frac{1}{2}(\mu[0]-\mu[1])^2.\end{aligned}$$

4. 响应度 R、整体增益 K、量子效率（P23）

响应度 R 就是第 2 节中的第一张图的斜率（即第 2 节下面的图片）



整体增益 K 按照下面的公式计算就行。

$$\sigma_y^2 = \sigma_{y.\text{dark}}^2 + K(\mu_y - \mu_{y.\text{dark}}) \quad \textit{Photon transfer curve}$$

量子效率 η 就是 R/K，需要不同波长下的结果，就可以画出量子效率图了。

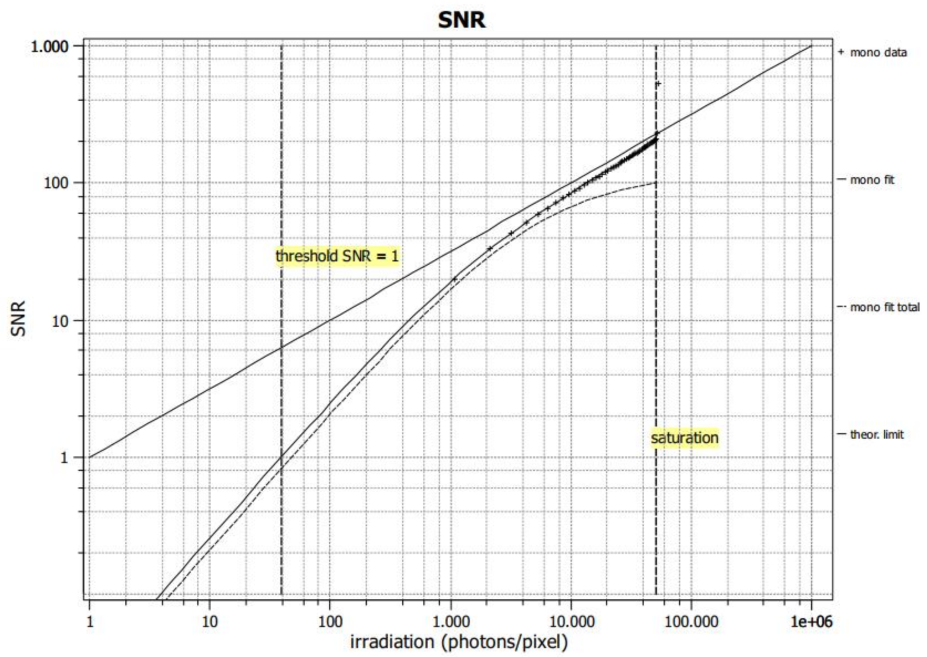
5. 最大饱和灰度值（P10）：时域标准差取最大值时的平均灰度值，也就是说像素到了最大值的时候，由于有噪声，其实实际有效值应该更小的。

Saturation. The saturation gray value $\mu_{y.\text{sat}}$ is given as the mean gray value where the histogram of the gray value distribution is not significantly cut-off so that the estimate of the mean value and especially the variance is not biased. With this technique it is required to first find the maximum possible value. For a sensor with a resolution of k bits, this is normally the value $2^k - 1$. But for some sensors, this may be a smaller value. Therefore it is first required to find the maximum possible value y. Then set the exposure by adjusting the exposure time and/or radiance of the light source just as high that between 0.1 - 0.2% of the total number of pixels show the maximum value. With this setting, the bias in the variance estimation is less than 0.37% for a normal distribution. Accumulate the histogram from one or two images without any averaging.

6. 最大最小光子数

最大	**Saturation capacity** $\mu_{p.\text{sat}}$. The saturation capacity $\mu_{p.\text{sat}}$ is the number of photons which corresponds to the maximum measured digital value $\mu_{y.\text{sat}}$ as described at the beginning of this section. The saturation capacity $\mu_{e.\text{sat}}$ in e$^-$ is given by Eq. (24).
最小	$$\mu_{p.\min} = \frac{1}{\eta}\left(\sqrt{\sigma_d^2 + \sigma_q^2/K^2 + 1/4} + \frac{1}{2}\right) = \frac{1}{\eta}\left(\sqrt{\sigma_{y.\text{dark}}^2/K^2 + 1/4} + \frac{1}{2}\right) \geq \frac{1}{\eta}. \quad (26)$$

7. SNR：



Mono fit total	$$\text{SNR}_{\text{total}}(\mu_p) = \frac{\eta\mu_p}{\sqrt{\sigma_d^2 + \text{DSNU}_{1288}^2 + \sigma_q^2/K^2 + \eta\mu_p + \text{PRNU}_{1288}^2\,(\eta\mu_p)^2}}.$$
Mono data	$$\text{SNR} = \frac{\mu_y - \mu_{y.\text{dark}}}{\sigma_y}.$$
threshold	$$\text{SNR}_{\text{ideal}} = \sqrt{\mu_p}.$$
saturation	第 6 小点

8. 线性度

就是用了第 2 小点中的图，相当于求 y=a0+a1*H（H 就是 x），最小化有区别：

with an offset a_0 and a slope a_1 (Fig. 9a). In the following equations the abbreviation $y[i] = \mu_y[i] - \mu_{\mathrm{y.dark}}[i]$ is used.[7] Because *relative* deviations are minimized, not

$$\sum_i [y[i] - (a_0 + a_1 H[i])]^2$$

is minimized but

$$\sum_i \frac{1}{y[i]^2} [y[i] - (a_0 + a_1 H[i])]^2 .$$

最后的结果：

$$a_0 = \frac{1}{\Delta}\left[\sum H[i]/y[i] \sum H[i]/y[i]^2 - \sum H[i]^2/y[i]^2 \sum 1/y[i]\right] \quad (59)$$

and

$$a_1 = \frac{1}{\Delta}\left[\sum H[i]/y[i]^2 \sum 1/y[i] - \sum H[i]/y[i] \sum 1/y[i]^2\right] \quad (60)$$

with

$$\Delta = \left(\sum H[i]/y[i]^2\right)^2 - \sum H[i]^2/y[i]^2 \sum 1/y[i]^2 \quad (61)$$

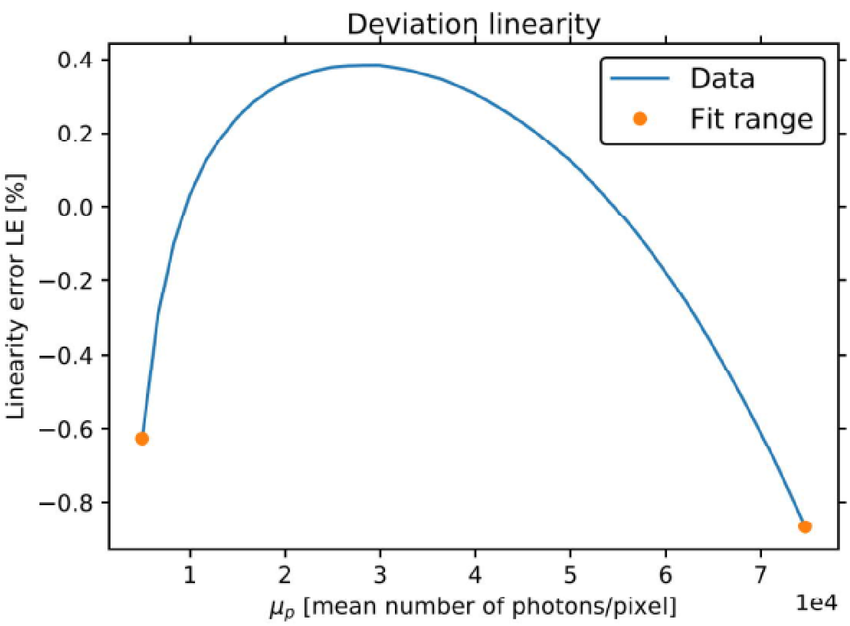
需要计算出各个曝光时间的 error：

$$\delta_y[i]\ [\%] = 100\,\frac{y[i] - (a_0 + a_1 H[i])}{a_0 + a_1 H[i]}. \quad (62)$$

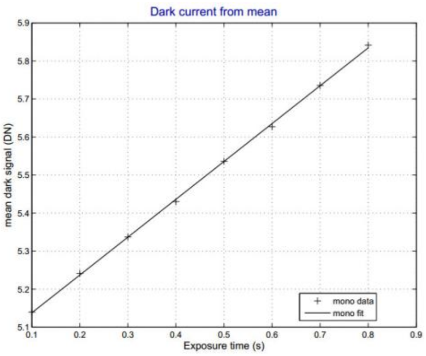
The linearity error is then defined as the the mean of the absolute deviation in the range between 5% and 95% of the saturation capacity.

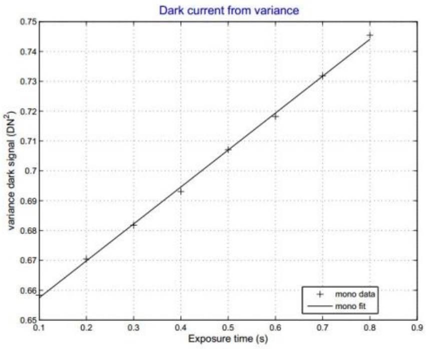
$$\mathrm{LE} = \frac{1}{n}\sum_{i=1}^{n} |\delta_y[i]| \quad . \quad (63)$$

b



9. 暗电流：测出下面的两个图即可。即曝光时间和均值、方差的变化。





空间域：需要采集非常多的图 100-200 张！

1. 空间噪声：测量方差减去时域的方差

For all other evaluation methods of spatial nonuniformities besides variances, such as histograms, profiles, and spectrograms, it is required to suppress the temporal noise well below the spatial variations. This can only be performed by averaging over a sufficiently large number L of images. In this case, spatial variances are computed in the following way. First a mean image averaged over L images $\boldsymbol{y}[l]$ is computed:

$$\langle \boldsymbol{y} \rangle = \frac{1}{L} \sum_{l=0}^{L-1} \boldsymbol{y}[l]. \tag{33}$$

The averaging is performed over all pixels of a sensor array. The mean value of this image is given by:

$$\mu_y = \frac{1}{MN} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} \langle y \rangle [m][n], \tag{34}$$

where M and N are the number of rows and columns of the image and m and n the row and column indices of the array, respectively. Likewise, the *spatial variance* s^2 is

$$s^2_{y.\text{measured}} = \frac{1}{MN} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} (\langle y \rangle [m][n] - \mu_y)^2. \tag{35}$$

All spatial variances are denoted with the symbol s^2 to distinguish them easily from the temporal variances σ^2. The spatial variances computed from L averaged images have to be corrected for the residual variance of the temporal noise. This is why it is required to subtract σ^2_y/L:

$$s^2_{y.\text{stack}} = s^2_{y.\text{measured}} - \sigma^2_y/L. \tag{36}$$

其中 sigma-y 的计算为：

$$\sigma^2_{s[m][n]} = \frac{1}{L-1} \sum_{l=0}^{L-1} \left(y[l][m][n] - \frac{1}{L} \sum_{l=0}^{L-1} y[l][m][n] \right)^2 \quad \text{and} \quad \sigma^2_{y.\text{stack}} = \frac{1}{MN} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} \sigma^2_{s[m][n]}.$$

2. DSNU 和 PRNU：其中 50 表示 50%饱和度，即最中间的曝光时间。

The DSNU_{1288} and PRNU_{1288} values are then given by

$$\text{DSNU}_{1288} = s_{y.\text{dark}}/K \qquad (\text{units } e^-)$$

and

$$\text{PRNU}_{1288} = \frac{\sqrt{s^2_{y.50} - s^2_{y.\text{dark}}}}{\mu_{y.50} - \mu_{y.\text{dark}}} \qquad (\text{units } \%).$$

from highpass-filtered images.

For highpass filtering the following two-step filtering is applied. First the images are smoothed by the following filters, one applied after the other: A 7 × 7 box filter, an 11 × 11 box filter, and a 3 × 3 binomial filter. In a second step this smoothed image is subtracted form the original image, leaving only the high-frequency part of the nonuniformities in the resulting image. Theoretical details for this choice of highpass filtering are detailed in Appendix E.3.

3. 横纹竖纹

数据：暗场图（经过低通滤波）、50%减去这个暗场图。然后按照文章的逻辑去做即可。