First results on a LGSWFS prototype for the ELT

Zibo KE

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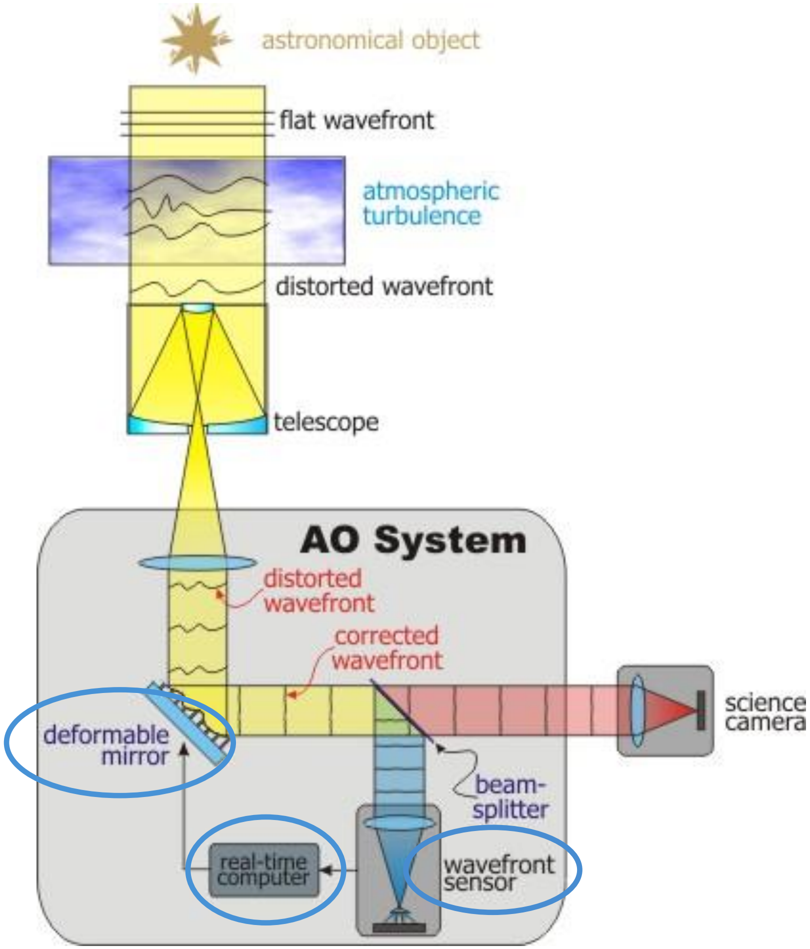
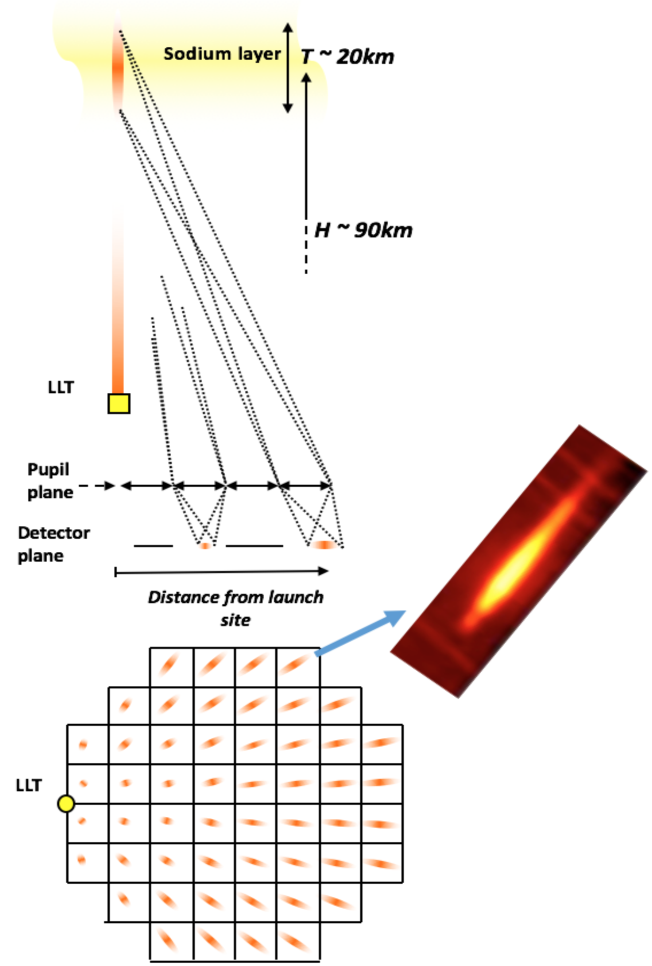
Research background

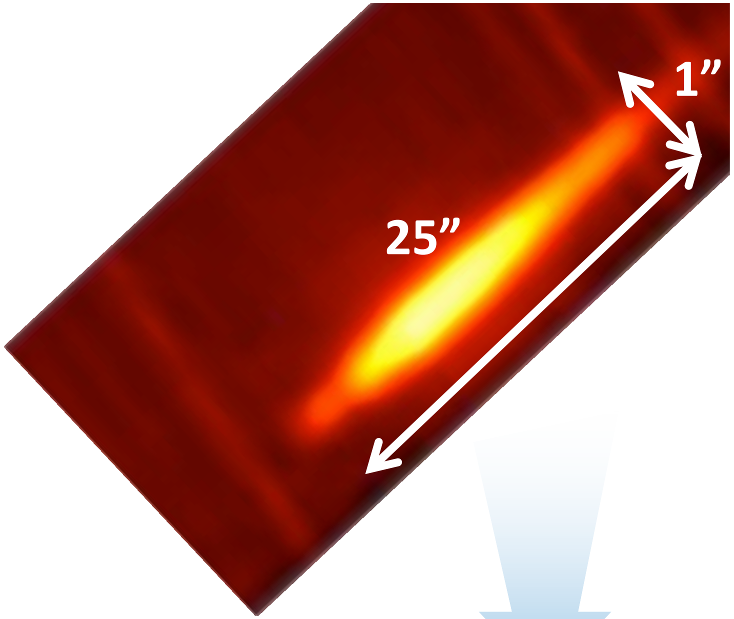


Principle of Adaptive Optics



Elongation on the detector

Research background



Ideally, we need subapertures with 25x25 pixels of ~1” /pixel

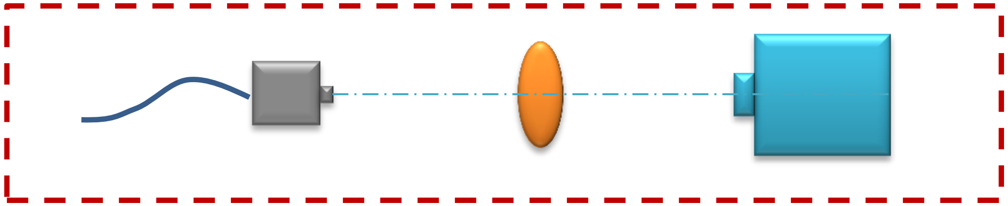
For 80x80 subapertures, we need 2000 x 2000 pixels

2000x2000 pixels detector, running at 500Hz, with RON<3e- does not exist…

In this work we study the possibility to use SONY-CMOS detectors with:
1100x1100pixels
RON<3e-
Fps = 480Hz
Global shutter

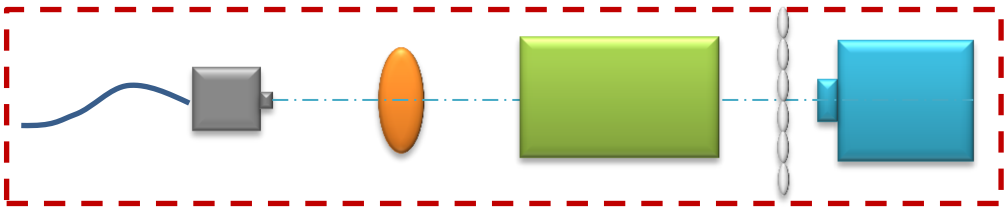
Research objective

Step 1



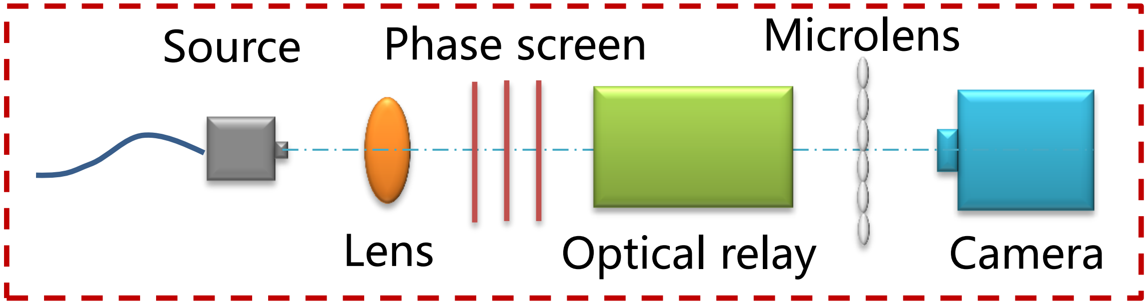
Basic detector + Linearity tests

Step 2



Optical relay + Lenslet tests => Start WFSensing

Step 3

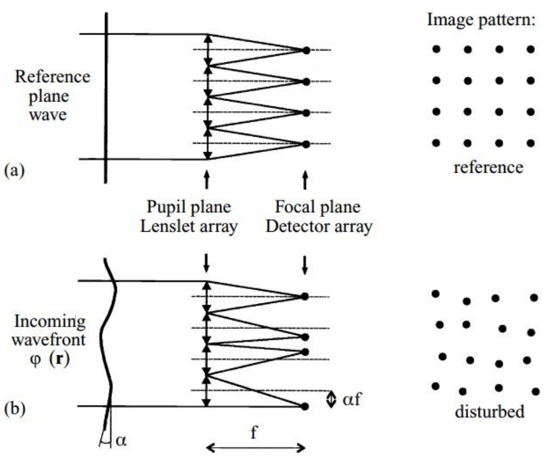


Elongation + Phase screens => Full scale test

This work is to develop a prototype to experimentally validate a full-scale version of a LGSWFS for the ELT

Simulation

First we setup simulation tools



Principle of the SH sensor

Center of gravity

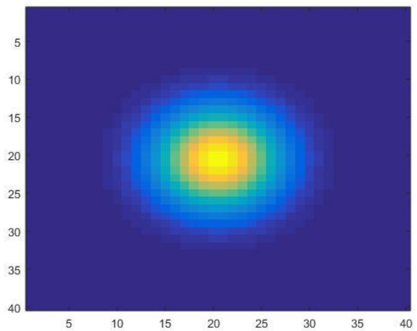
$$c_x = \frac{\sum_{i,j} x_{i,j} I_{i,j}}{\sum_{i,j} I_{i,j}} \text{ and } c_y = \frac{\sum_{i,j} y_{i,j} I_{i,j}}{\sum_{i,j} I_{i,j}},$$

Photon-noise

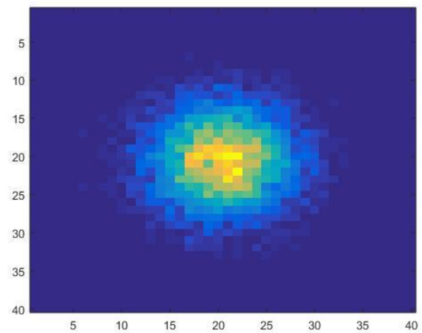
$$(\sigma^2_{\Delta\phi})_{photons} = \frac{\pi^2}{2\ln(2)\ N_{ph}} \left(\frac{N_T}{N_D}\right)^2$$

Read-out noise

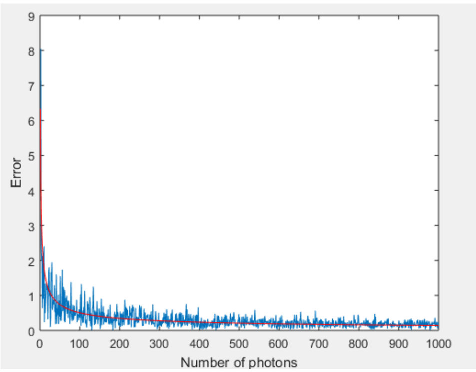
$$(\sigma^2_{\Delta\phi})_{2D} = \frac{\pi^2}{3} \left(\frac{\sigma_{det}}{N_{ph}}\right)^2 \left(\frac{N_S^4}{N_D^2}\right)$$



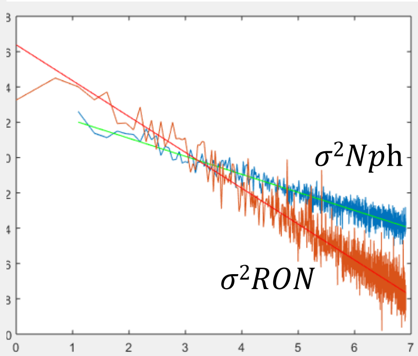
Photon distribution



Photon & read-out noise



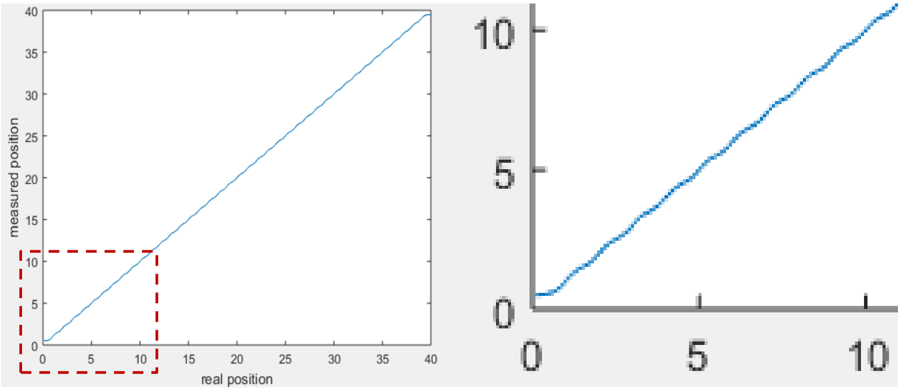
Flux vs. Pixel variance



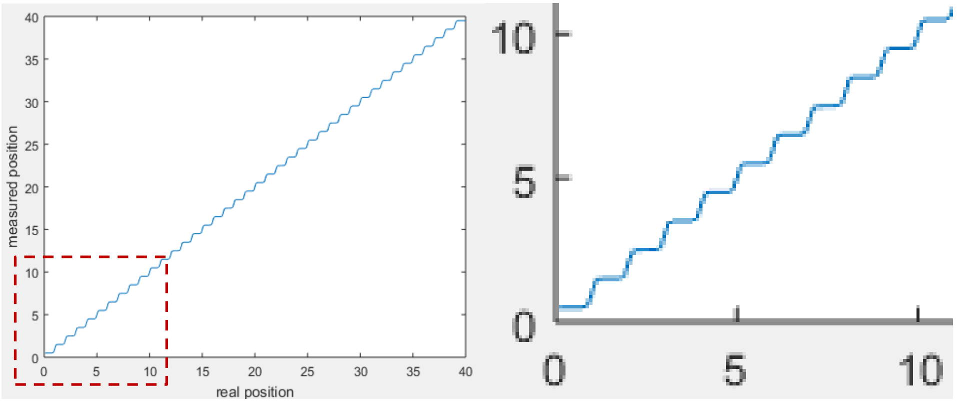
Flux vs. Pixel variance (Logarithmic image)

Simulation

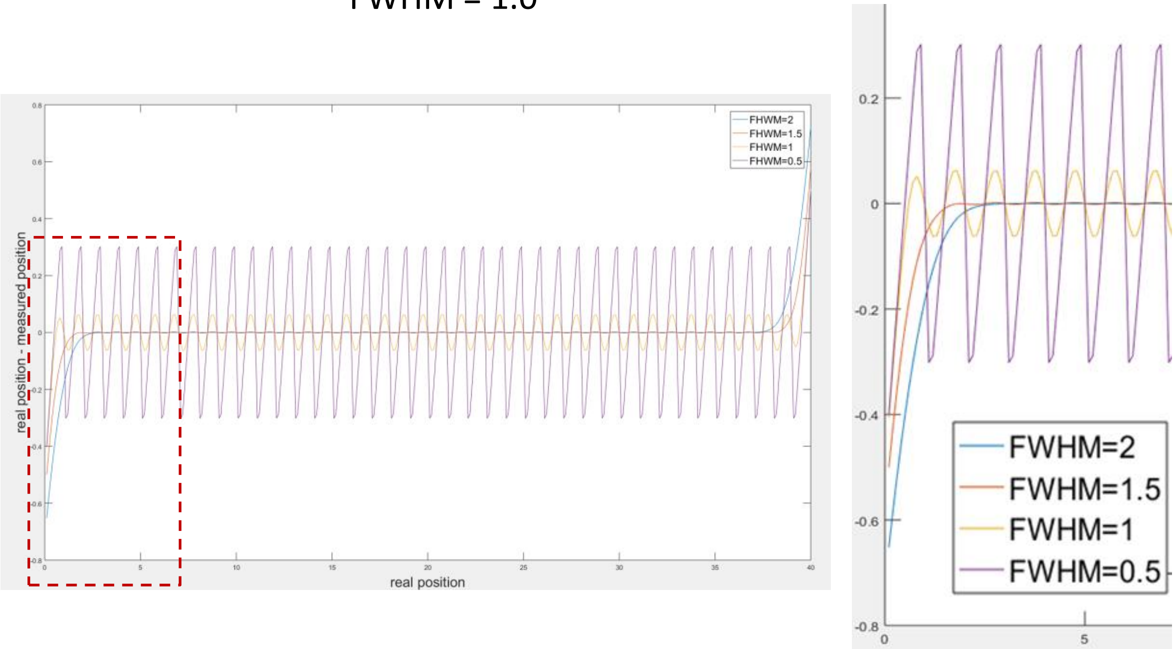
Impact of undersampling



FWHM = 1.0



FWHM = 0.5

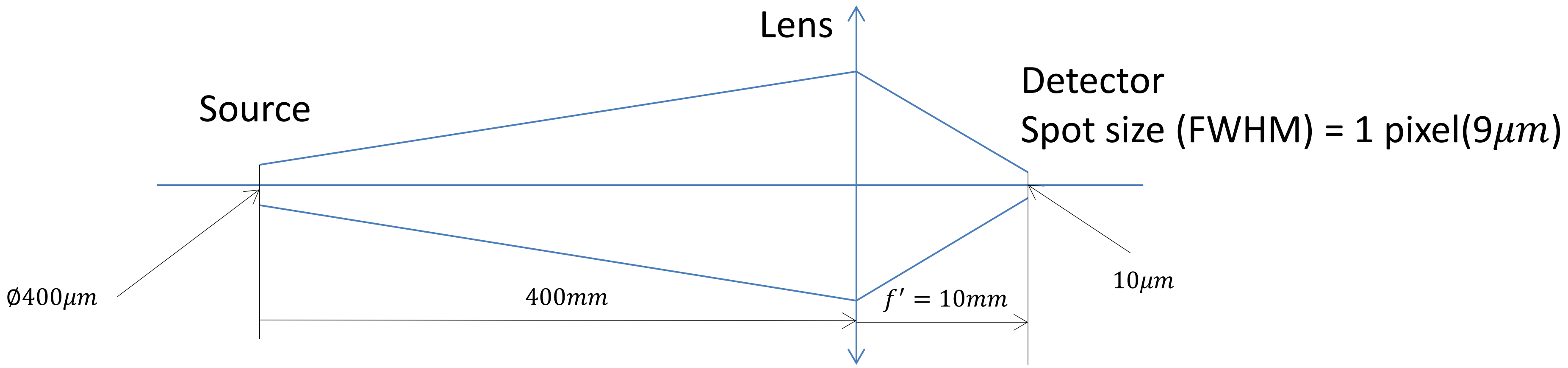


The relationship between real position and measured position

The undersampling of the image introduces a limitation of the accuracy

=> FWHM=1pixel is ok.

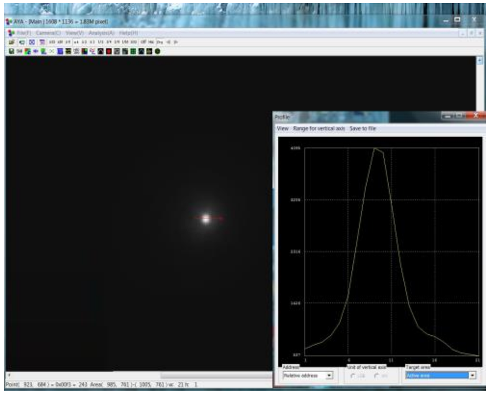
Bench configuration



Schematic of the initial bench

magnification factor: 10/400 = 1/40, the 400 µm source produces a 10µm spot

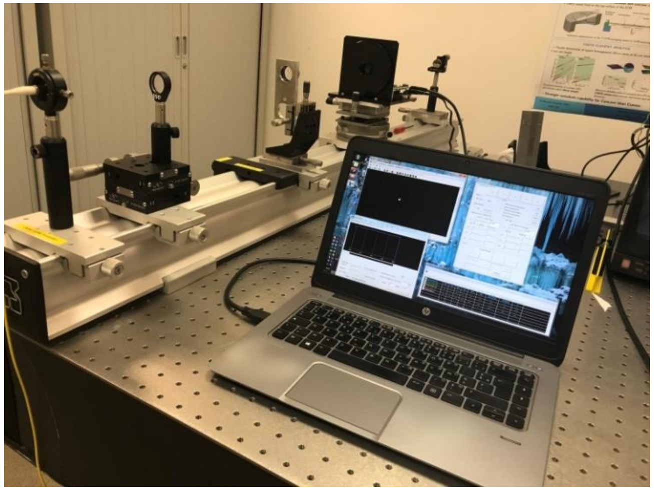
	minimum range	steps
source	72*40=2880µm=2.88mm	0.18*40=7.2µm
image	-4 +4 pixels(8*9=72µm)	<0.02 pixel(0.02*9=0.18µm)



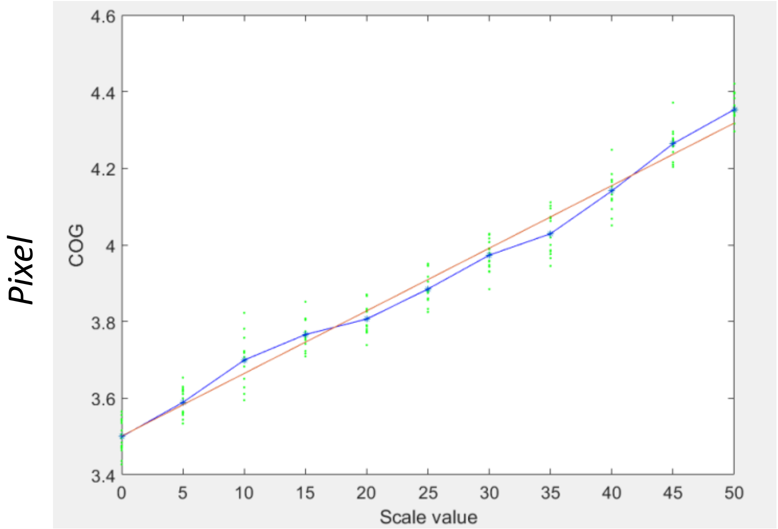
Spot size

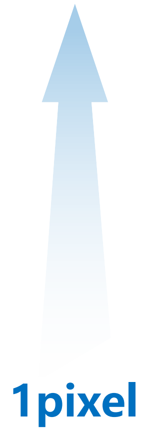
Bench measurements

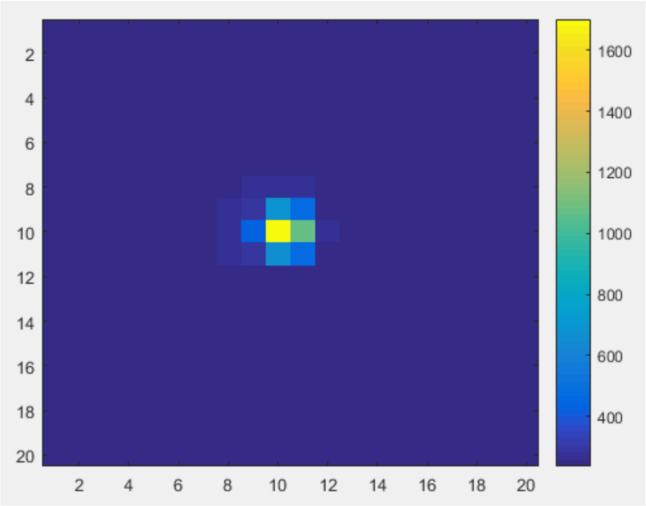
Pixel Linearity



Real bench congifuration







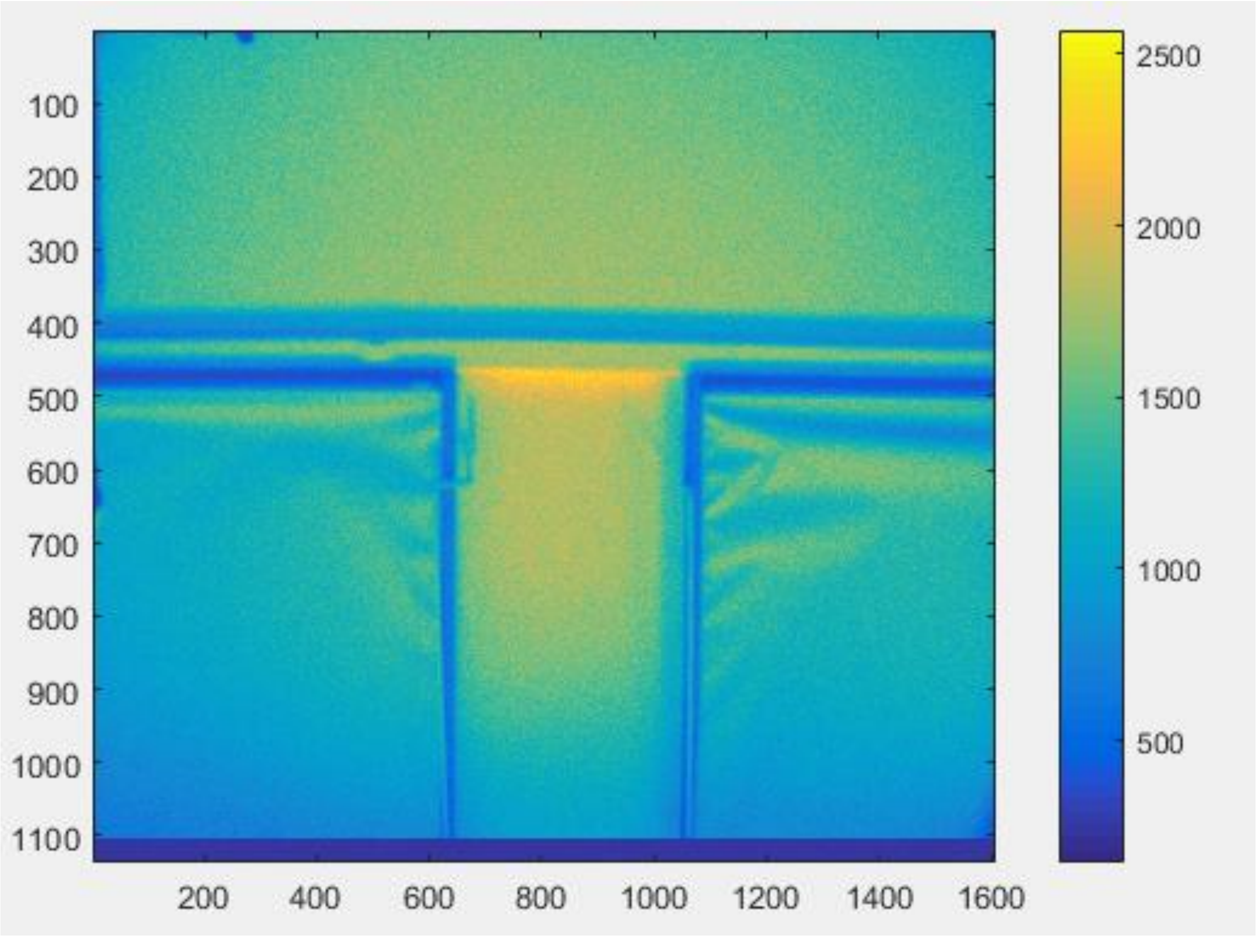
Test spot

Moving the spot by steps of ~0.1 pixel, and measure linearity

Spots are not exactly <1pixel, because the source used so far is not the final one…

Bench measurements

Cosmetic

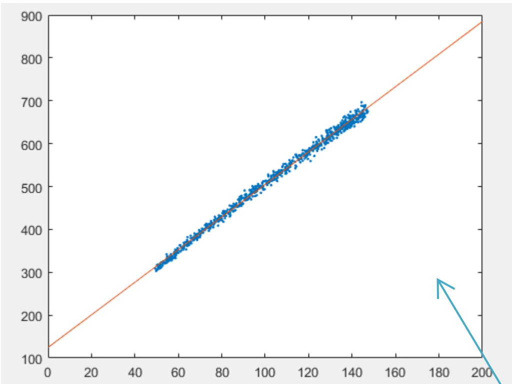


Pefect cosmetic: 0 bad pixels !

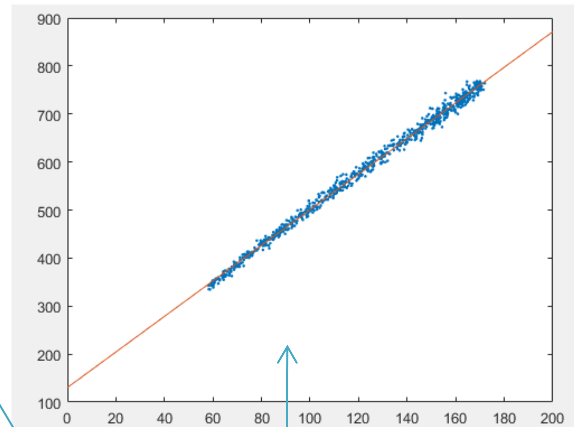
Bench measurements

Read-out noise(RON) and Gain

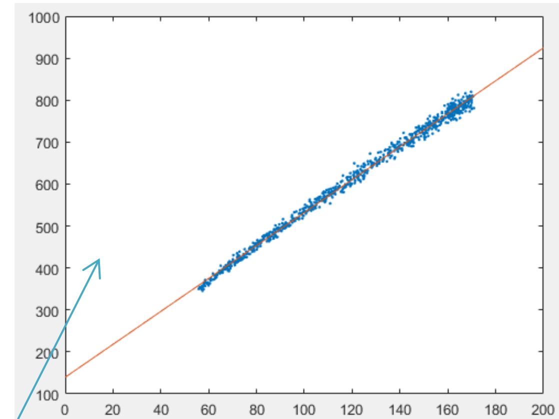
Photon transfer curve



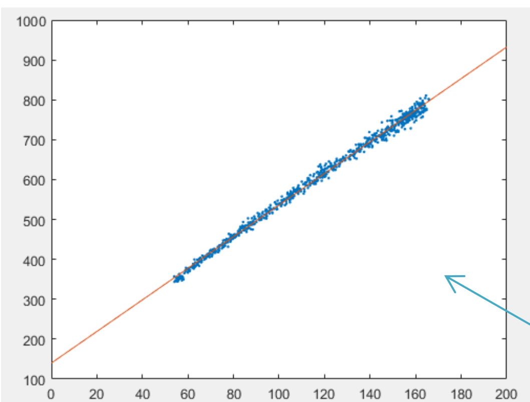
RON=2.9376
Gain=0.2631



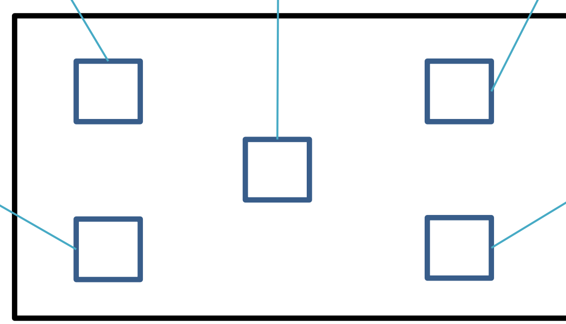
RON=3.0817
Gain=0.2699



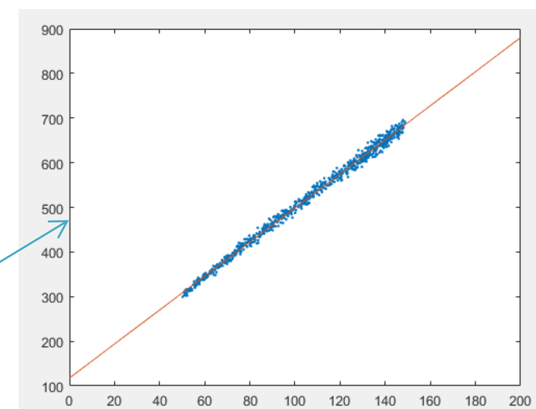
RON=3.0097
Gain=0.2547



RON=2.9868
Gain=0.2524



Different areas on image plane



RON=2.8439
Gain=0.2623

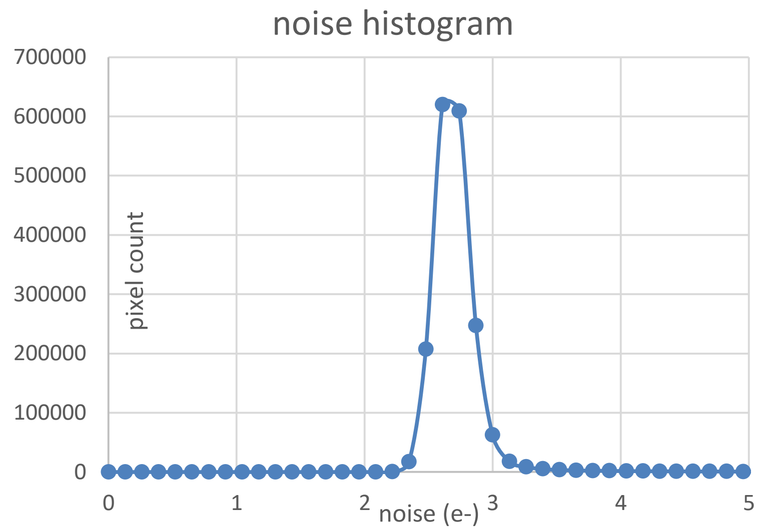
Average RON=2.9719
Average Gain=0.2605

Bench measurements

Read-out noise(RON) and Gain

Tests with different camera setup:

HCG + 24dB = 0.292 e/ADU RON=2,78
HCG + 18dB = 0,568 e/ADU RON=2,84
HCG + 12dB = 1,033 e/ADU RON=2,95
HCG + 8dB = 1,58 e/ADU RON=3,11

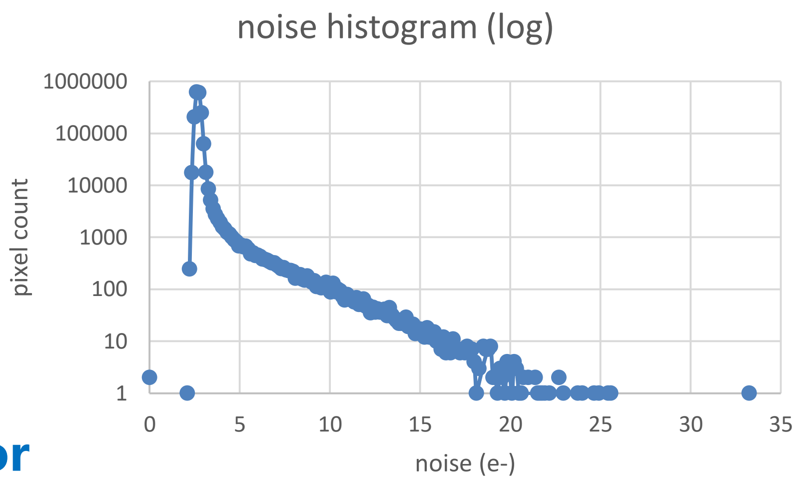


Very consistent with provider spreadsheet

8700 pixels above 2 times mean RON (0.5%)

3100 pixels above 3 RON (0.17%)

noisy pixels evenly distributed on the sensor (no clusters)



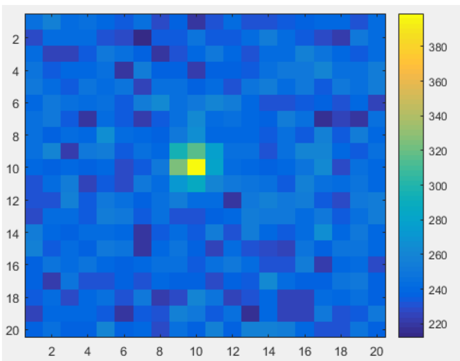
Very consistent from detector to detector (tests done on 10 chips by J.L. Gach).

Bench measurements

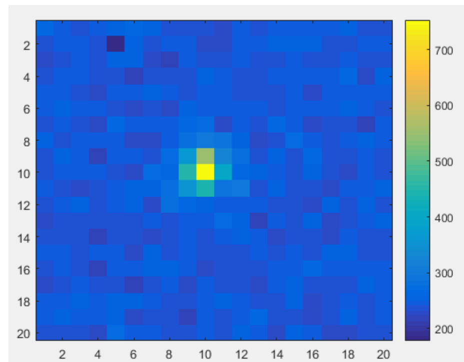
Photon noise(PN)

Testing Centroiding accuracy vs. different level of flux

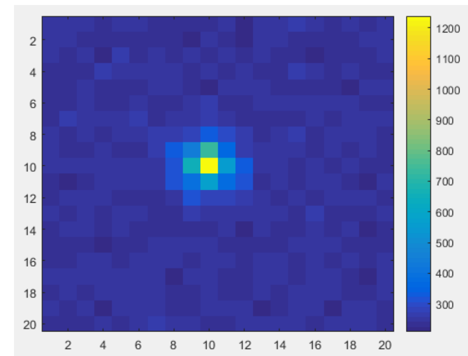
Low Flux



Medium Flux

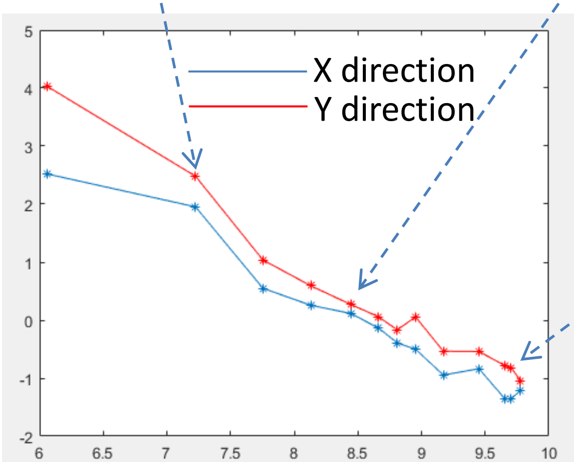


High Flux



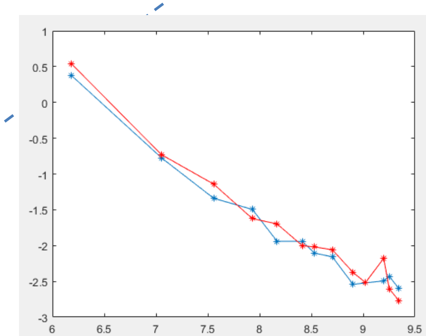
COG

Pixel variance

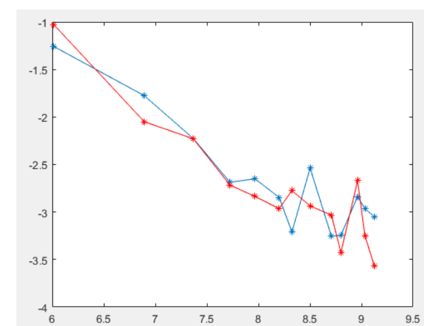


flux

WCOG(r=8)



WCOG(r=4)



Flux vs. Pixel variance (Logarithmic image)

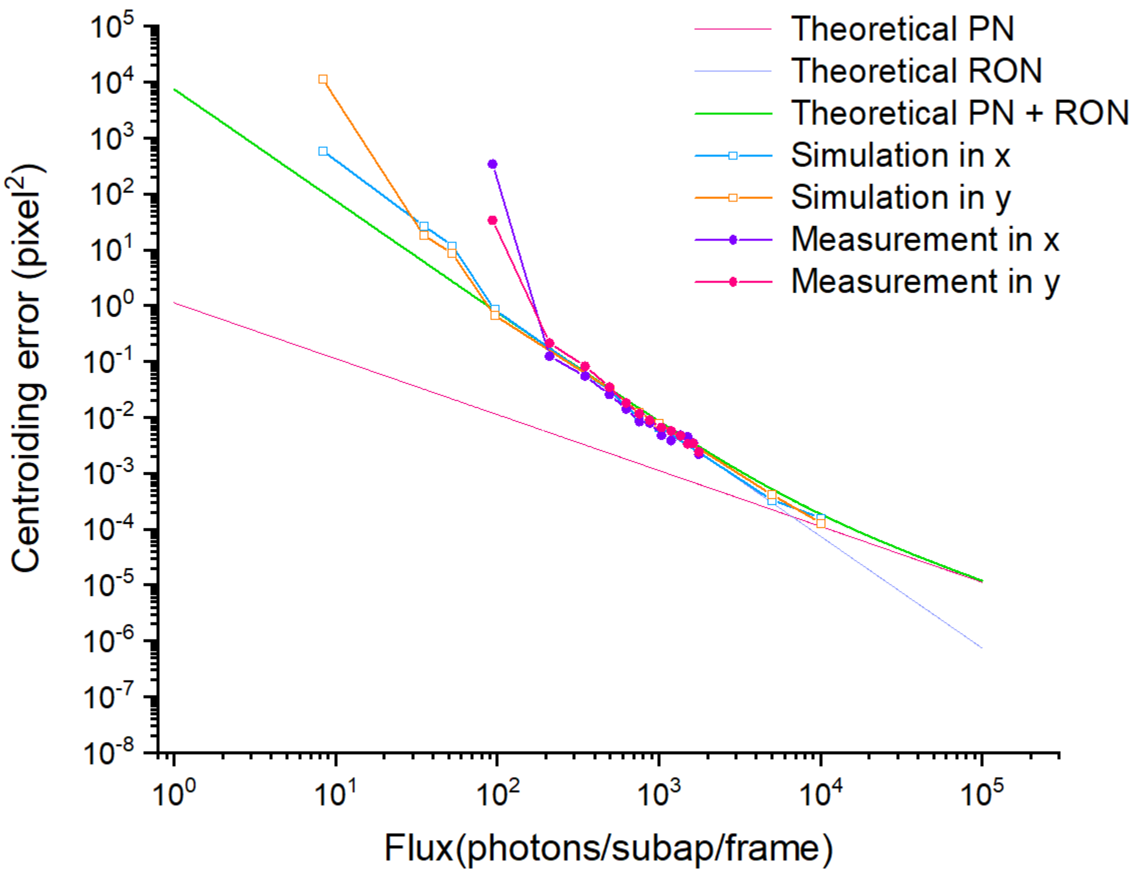
Theory & Simulation & Measurements

Photon + Read-out noise

COG Theory

$$(\sigma^2_{\Delta Cx})^{COG}_{th} = \underbrace{\frac{N_T^2}{8\ ln(2)\ N_{ph}}}_{Photon} + \underbrace{\left(\frac{\sigma_{det}}{N_{ph}}\right)^2 \cdot \left(\frac{N_S^4}{12}\right)}_{Detecteur}$$

$N_T=2.5$, $N_S=10$

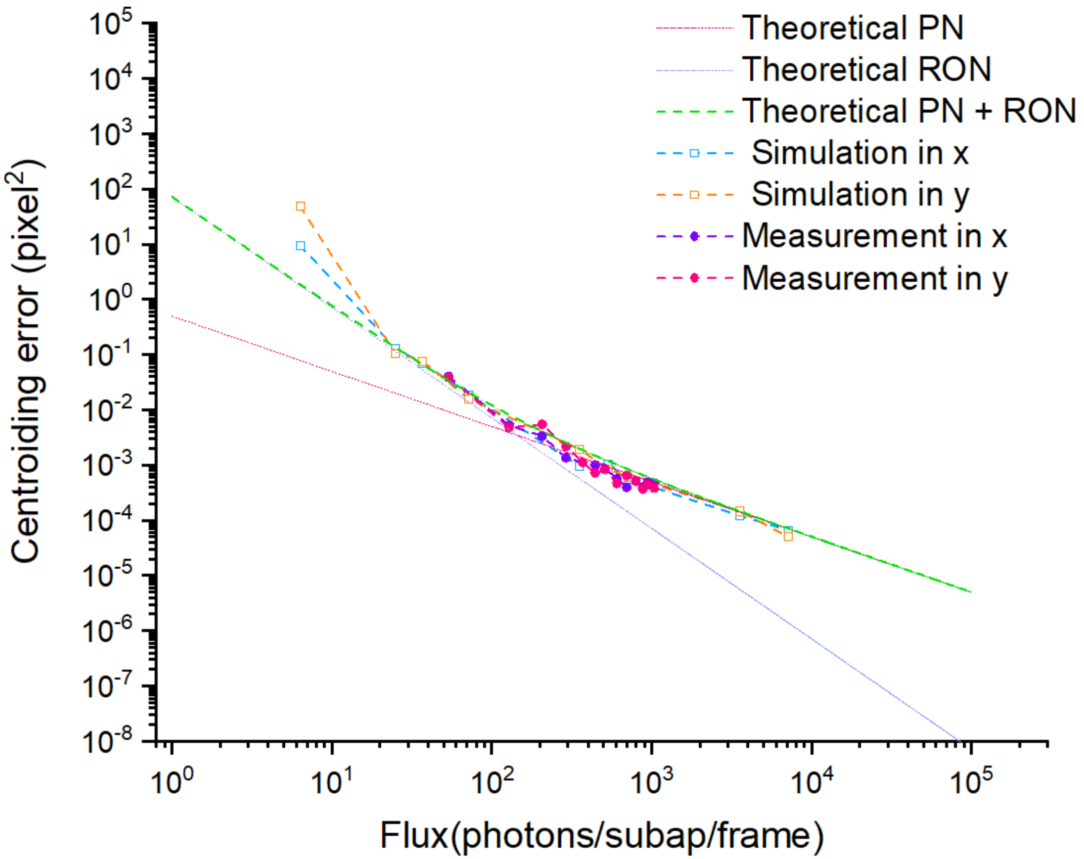


Theory & Simulation & Measurements

Photon + Read-out noise

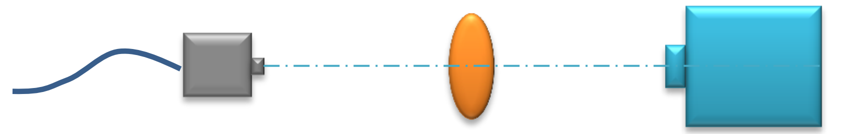
WCOG Theory $$(\sigma^2_{\Delta Cx})^{WCOG}_{th} = \underbrace{\frac{N_T^2}{8\ ln(2) N_{ph}} \cdot \left(\frac{N_T^2 + N_W^2}{2N_T^2 + N_W^2}\right)^2}_{Photon} + \underbrace{\frac{\pi}{128} \frac{(N_T^2 + N_W^2)^2}{(ln(2))^2} \cdot \left(\frac{\sigma_{det}}{N_{ph}}\right)^2}_{Detecteur}$$

N_T=2.5， N_W=2.5



Conclusions

Step 1

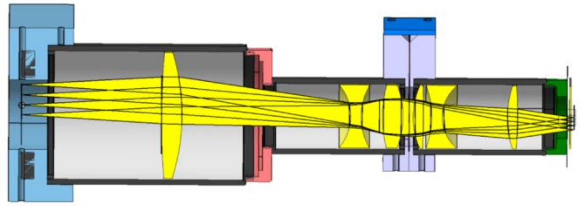


Initial bench configuration | Pixel linerity | Theory & Simulation & Measurements

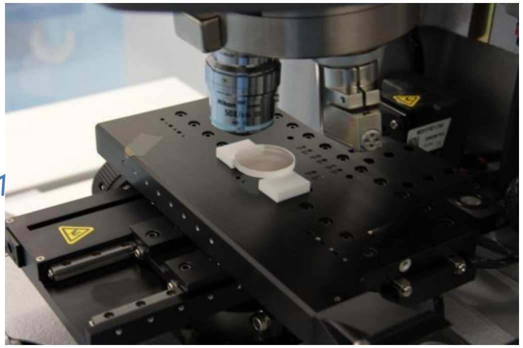
Pixel response - Line spread function measurements

Global shutter vs. Rolling shutter

Next work plan

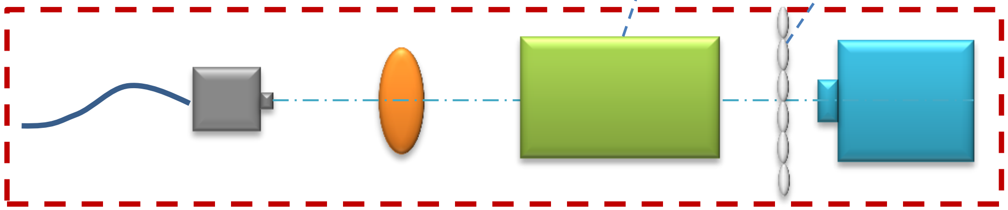


Optical relay



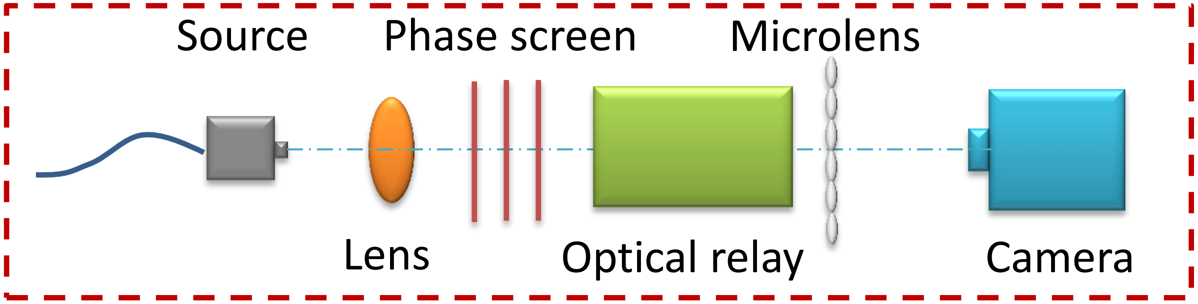
Microlens

Step 2



End in 2019

Step 3



Spring in 2020

Thank you for your attention