A new technique of characterization of the intrapixel response dedicated to astronomical large focal plane arrays

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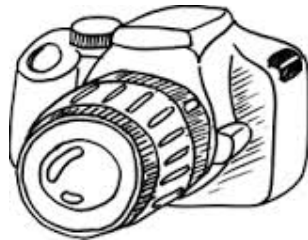[b]ONERA, The French Aerospace Lab, F-91761, Palaiseau, France

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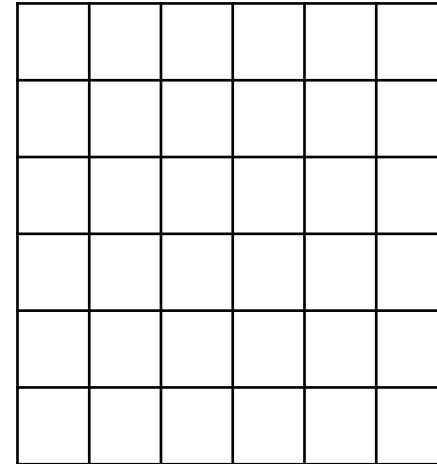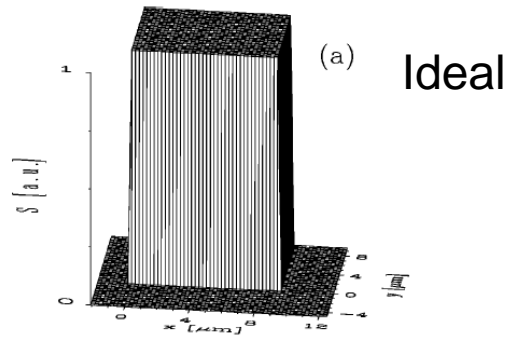NDIP, *30 June -4 July 2014 Tours (France)*

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Camera

Focal plane array

(a) Ideal
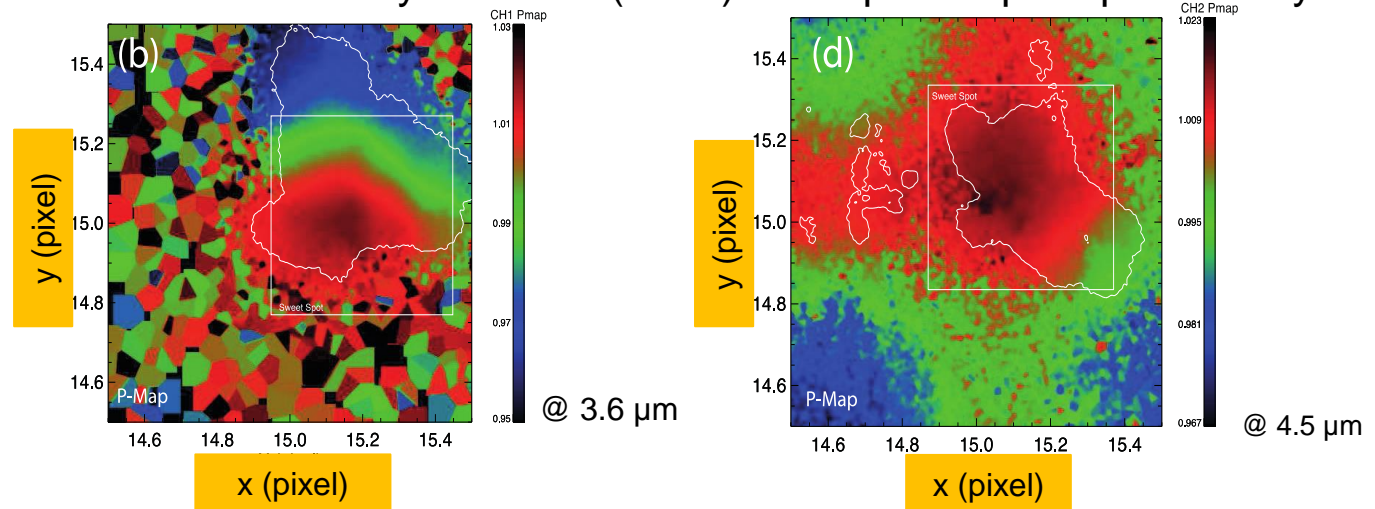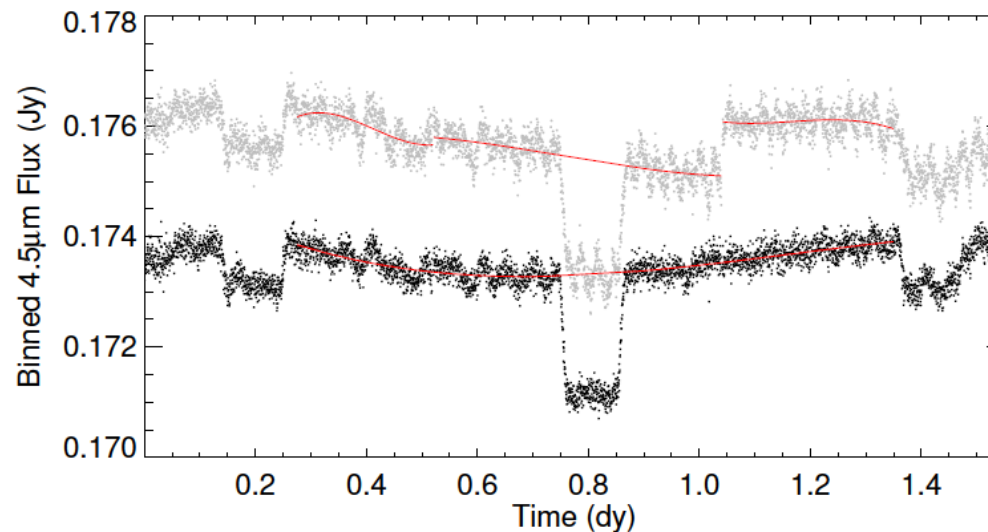
(b)
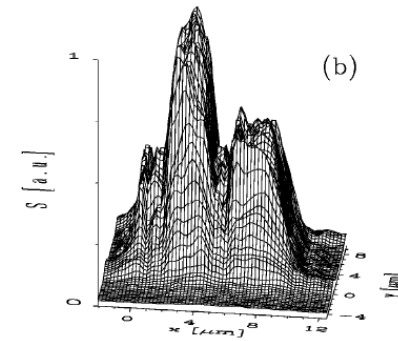
FI-9x9 µm² CCD pixel sensitivity map. (a) Ideal, (b) Real (images from Kavaldjev 2001)

- Influence of detector effects in photometry (IRAC SPITZER)
  - **I**ntra**P**ixel **S**ensitivity **V**ariation (**IPSV**): examples of pixel photometry maps

@ 3.6 μm

@ 4.5 μm

  - Influence of the IPSV in the measurement

- ## Euclid VIS : Shape measurements
  - ### Illustration of WL measurement processes

Illustration of the processes that affect galaxy shapes
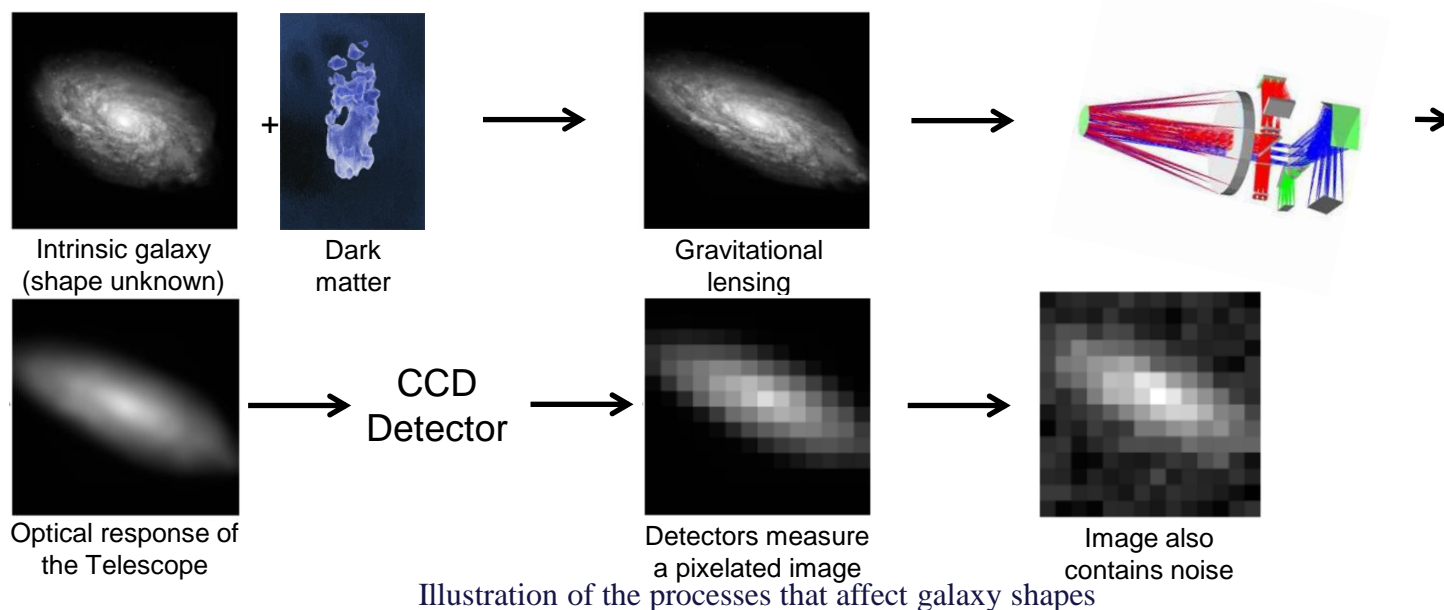
- ### The resulting image depends on the detector effects

- ### We have to know the contribution of the detector:
  →Evaluation of the scientific performances of the detectors

- Idea: to measure the pixel response as a function of the position (x,y) on the whole sensitive area.

- Common use approach: the direct method

  – Scan an optical probe (spot light or a line light)
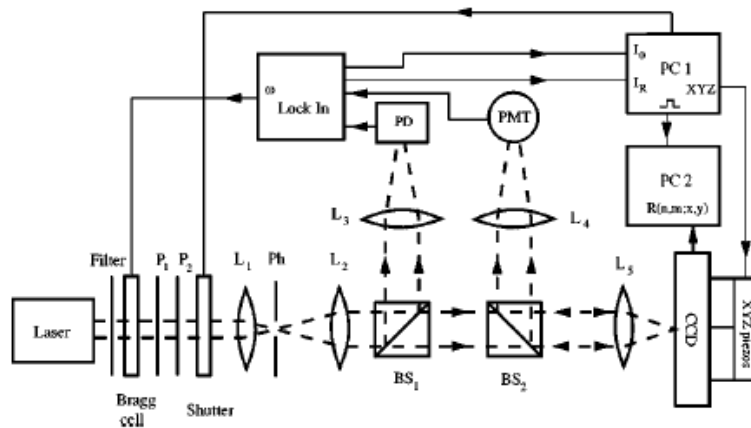
Kalvadjiev and Ninkov, Opt. Eng, 37, 3
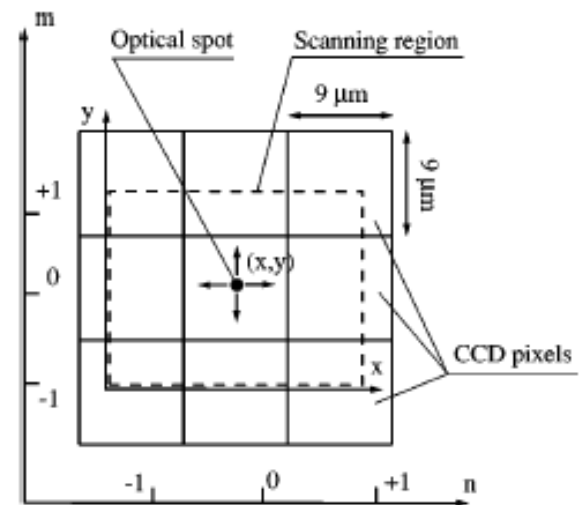
Kalvadjiev and Ninkov, Opt. Eng, 37, 3

- Advantages and inconvenient
☺ Simple to realize and analyze (direct approach)
☹ Requires excellent optics: stability, precision
☹ Requires high aperture optics
☹ Time consuming

Measurement technique

- ## Our approach: indirect method

It consists to project discrete spatial frequencies onto the sensors **without classic optics** but using a self imaging property of the Continuously Self Imaging Grating (CSIG) and compute the output distribution of the spatial frequencies attenuated by the transfer function of the detector.
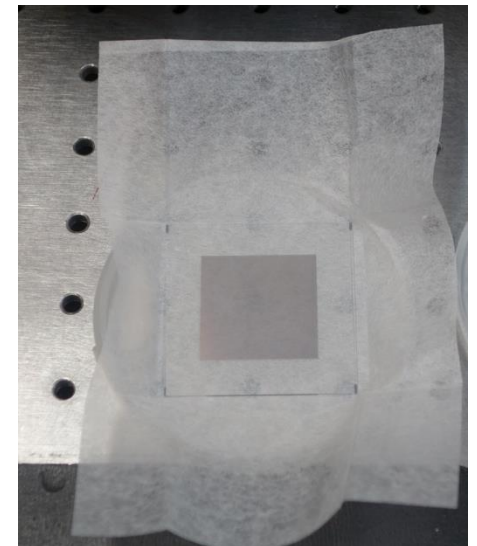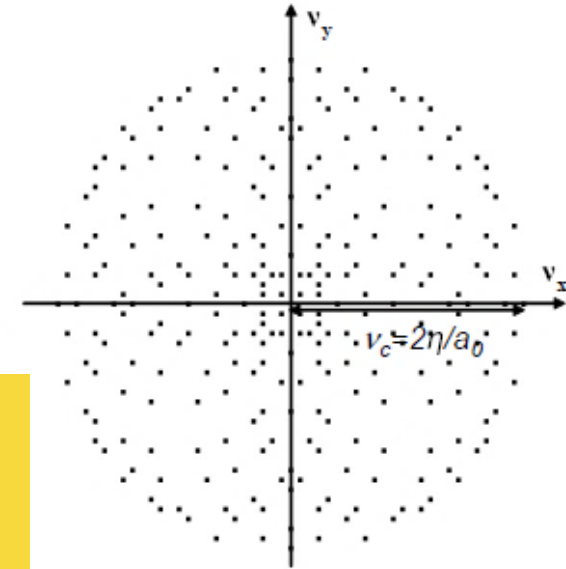
- ## Advantages an inconvenient
  - ☺ Simplified optical setup
  - ☺ Time duration: only one acquisition can be enough
  - ☹ Aliasing effects
 - ☹ Requires advanced data processing

- ## SAp Objectives
  - – Develop a new test bench
  - – To characterize the IPSV with a resolution of pix/10
  - – Band: VIS, NIR, LIR

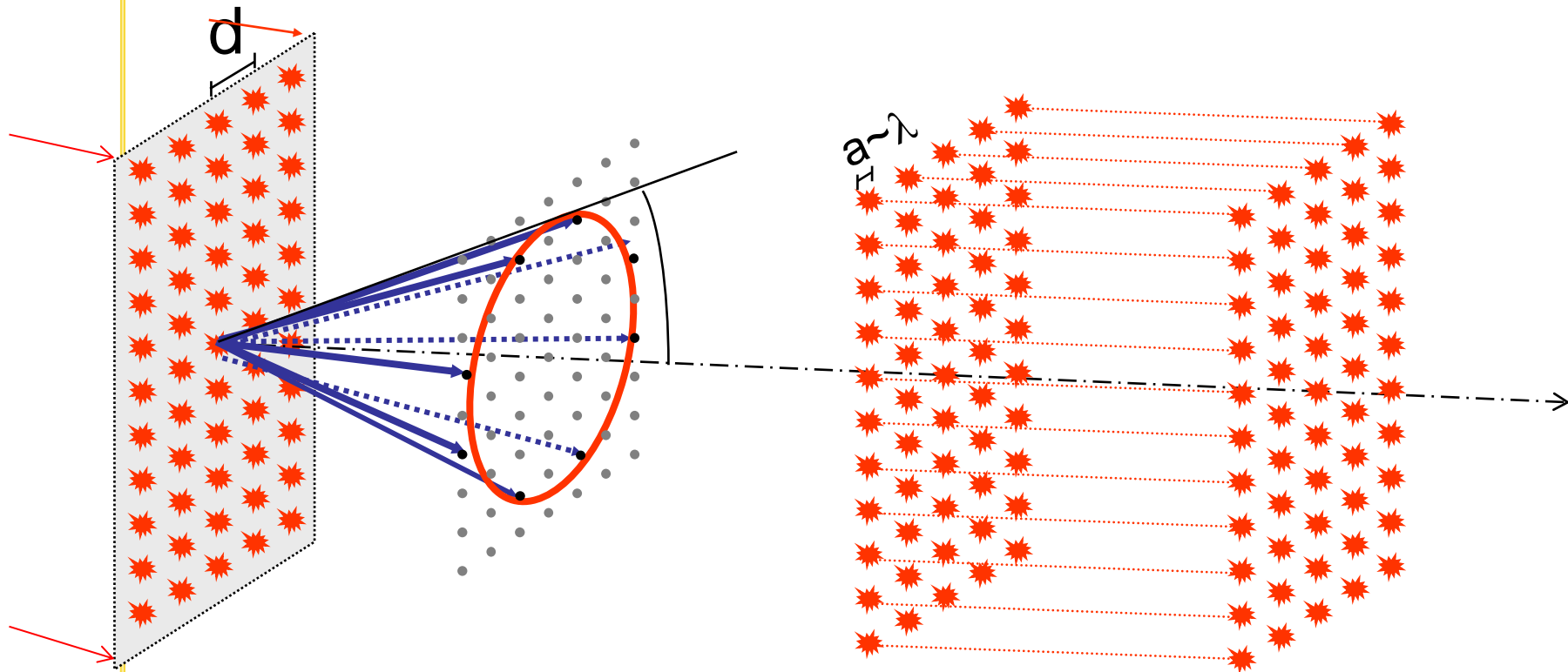 *(First tests to carry with the Euclid VIS detector)*

- The talbot effect explanation

1. Diffraction and interferences: basic Young Slits experience

2. The Talbot effect explanation: many holes and displacement of the screen
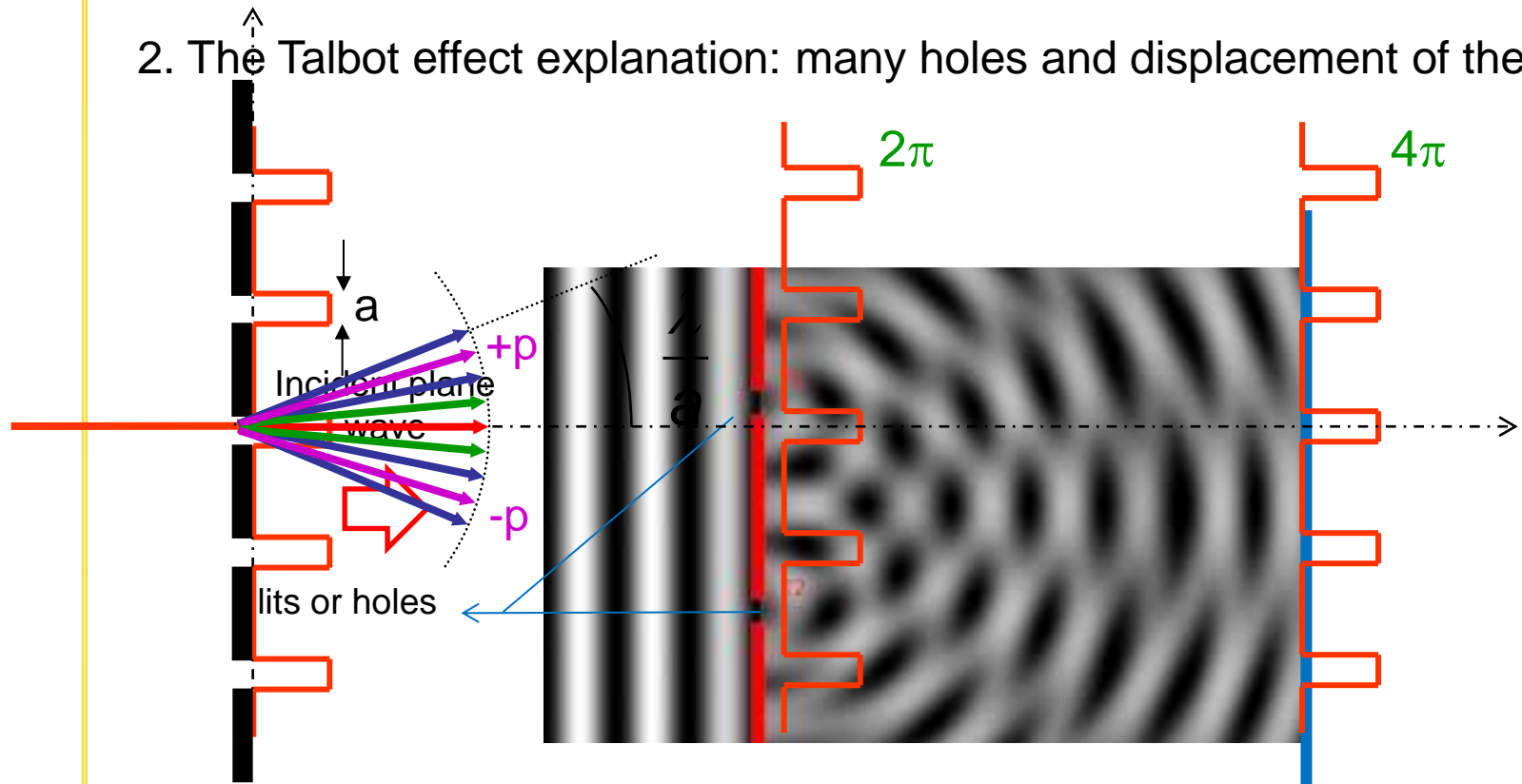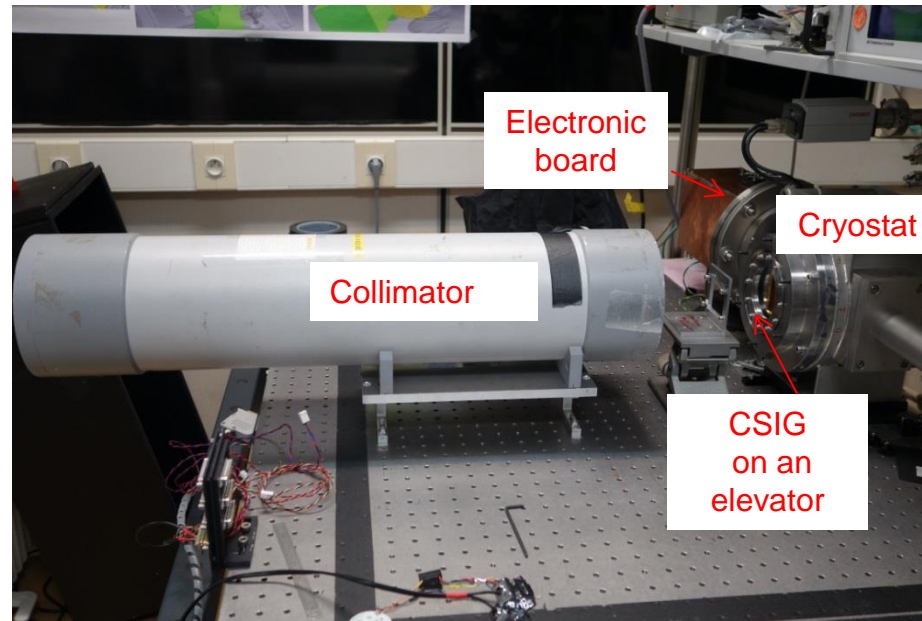

The initial Talbot experience

- The continuously Self-Imaging Grating: 2D generalization of the talbot effect
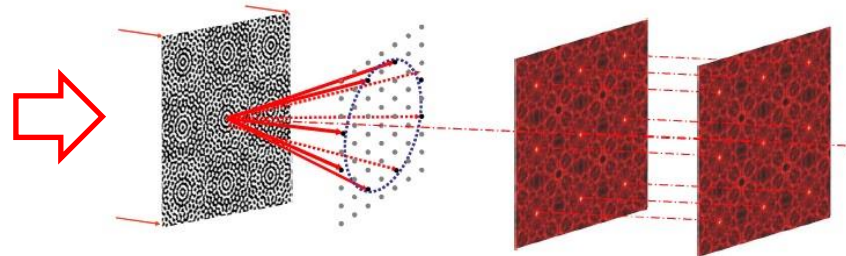
Optics et source

- Source: LED, polychromatic, Band: 0,12 μm, central wavelength: 530 nm
- Collimator: off-axis parabolic mirror (f=760 mm)
- …

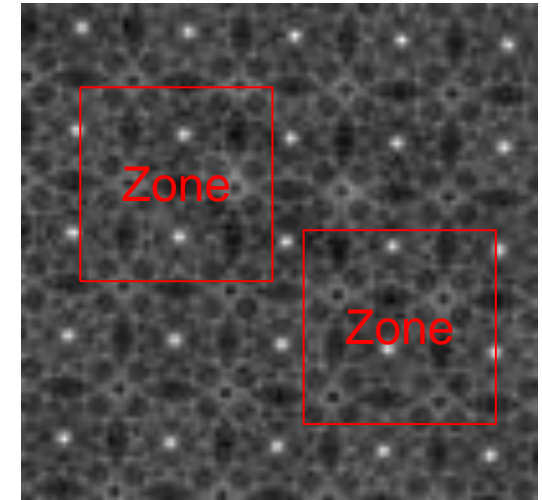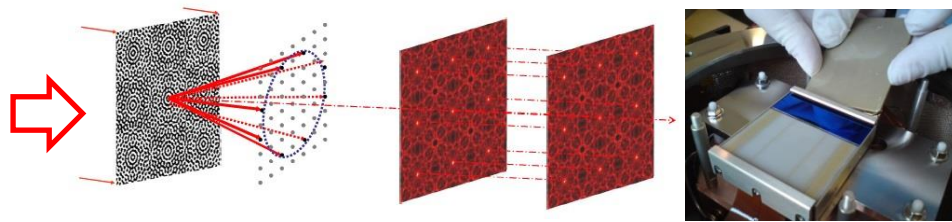Incident plane wave from the collimator

CSIG

- 24-order/ 48-order
- High frequency value: 511 mm^{-1}
- Distance to the detector: 31,4 mm

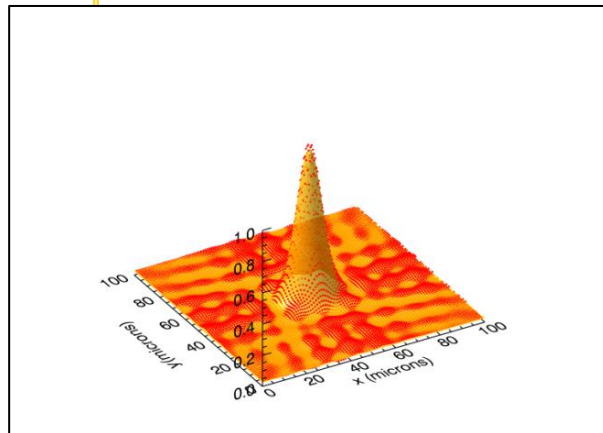**The detector**: CCD e2v 204 (Euclid-VIS evaluation version)

- Pixel pitch: 12 µm
- size: 1k x 4k pix, 12mmx48mm
- Operation: Full frame
- Wavelength: 550-900 nm
- QE > 90%, T=153 K

- Global procedure

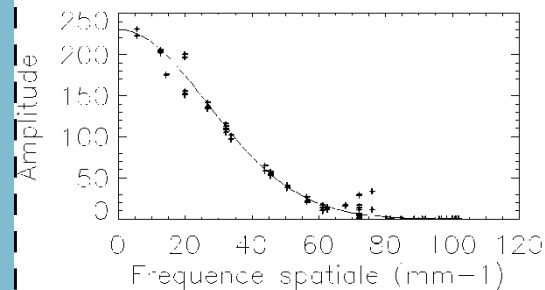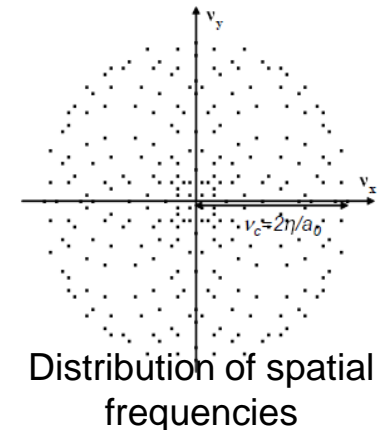Incident plane wave from the collimator

Zone

Zone

FT^{-1}

Fourier Domain

Pixel MTF sampling

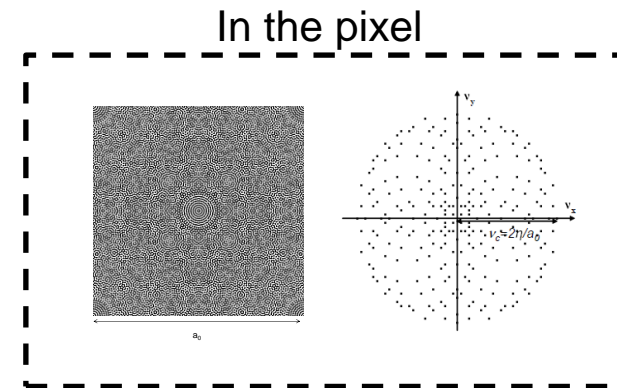Distribution of spatial frequencies

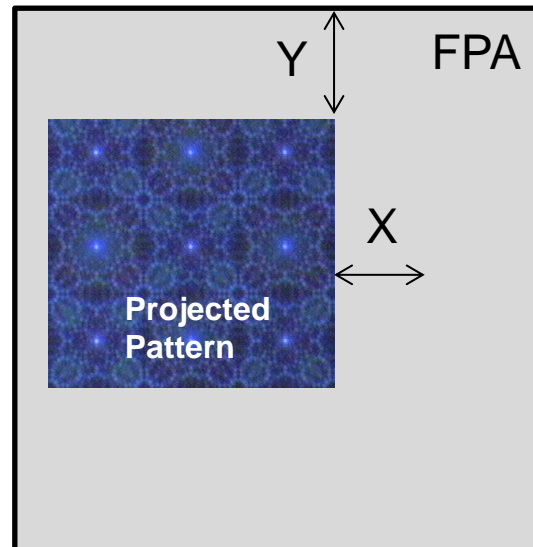**Mean Pixel response function**

Modulation transfer function (256x256 pixels)

• Local procedure

- Implementation of the multiplexing pixel MTF measurement
- Idea: scan the pattern through the FPA
- Result: reconstruction of response of each pixel

- Status: at the moment, the procedure has been validated by simulations
- Application on the CCD-273: deplacement amplitude 380 μm, deplacement pitch: 1 μm for 1/10 resolution. Then 144400 acquisitions and data storage of 2 TeraOctet are required !

- Improvement of the test procedures and the acquisition

- Improvement of the data processing techniques

- Implementation of the multiplexing pixel MTF measurement

- Development of the final test bench

- Thank U for your attention
- Questions ?

- IPSV can be a source of errors
  - Undersampled instruments
  - High-quality imagery
  - Precise and accurate photometry
  - Precise astrometry

- For measurements with high constraints
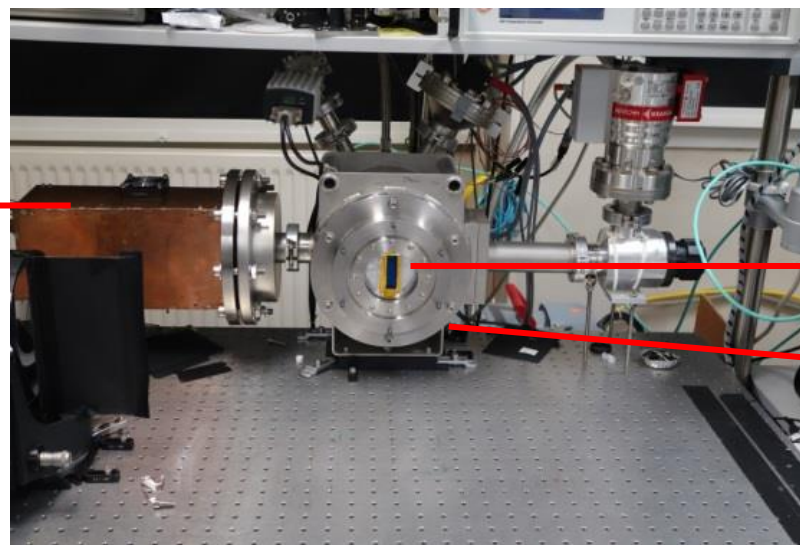 → Evaluation of the IPSV is necessary

- Euclid CCD evaluation-version
  - Pixel pitch: 12 µm
  - Number of pixels: 1k x 4k
  - Image area: 12mmx48mm
  - Operation: Full frame
  - 2 Outputs
  - Wavelength: 550-900 nm
  - Quantum efficiency: > 90%
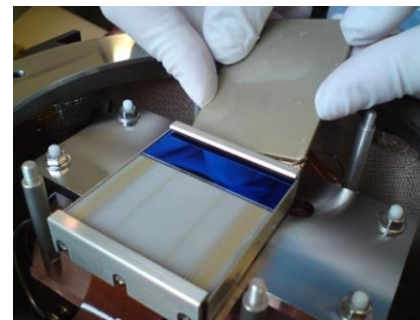
Euclid e2v CCD-204

- The CCD is cooled at 153 K in the cryostat

Electronics Box

Window

Cryostat

- ## The optical setup
  - Projection of a periodic intensity pattern onto the detector
  - Self-imaging properties (The talbot effect)
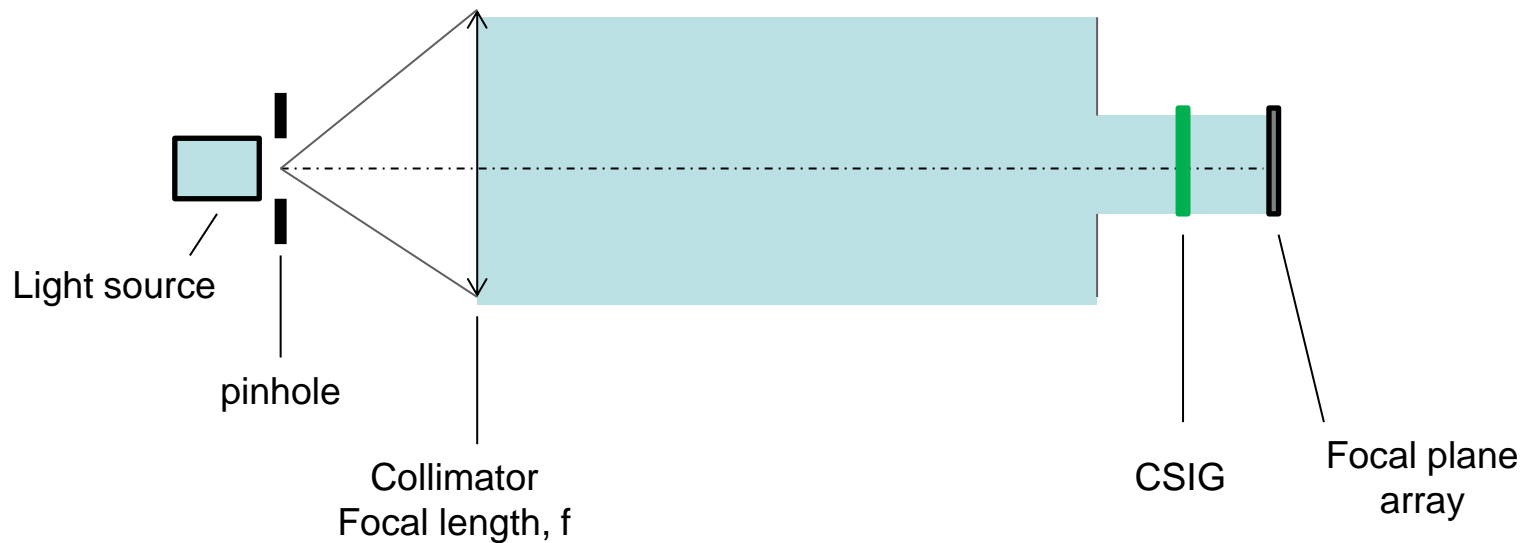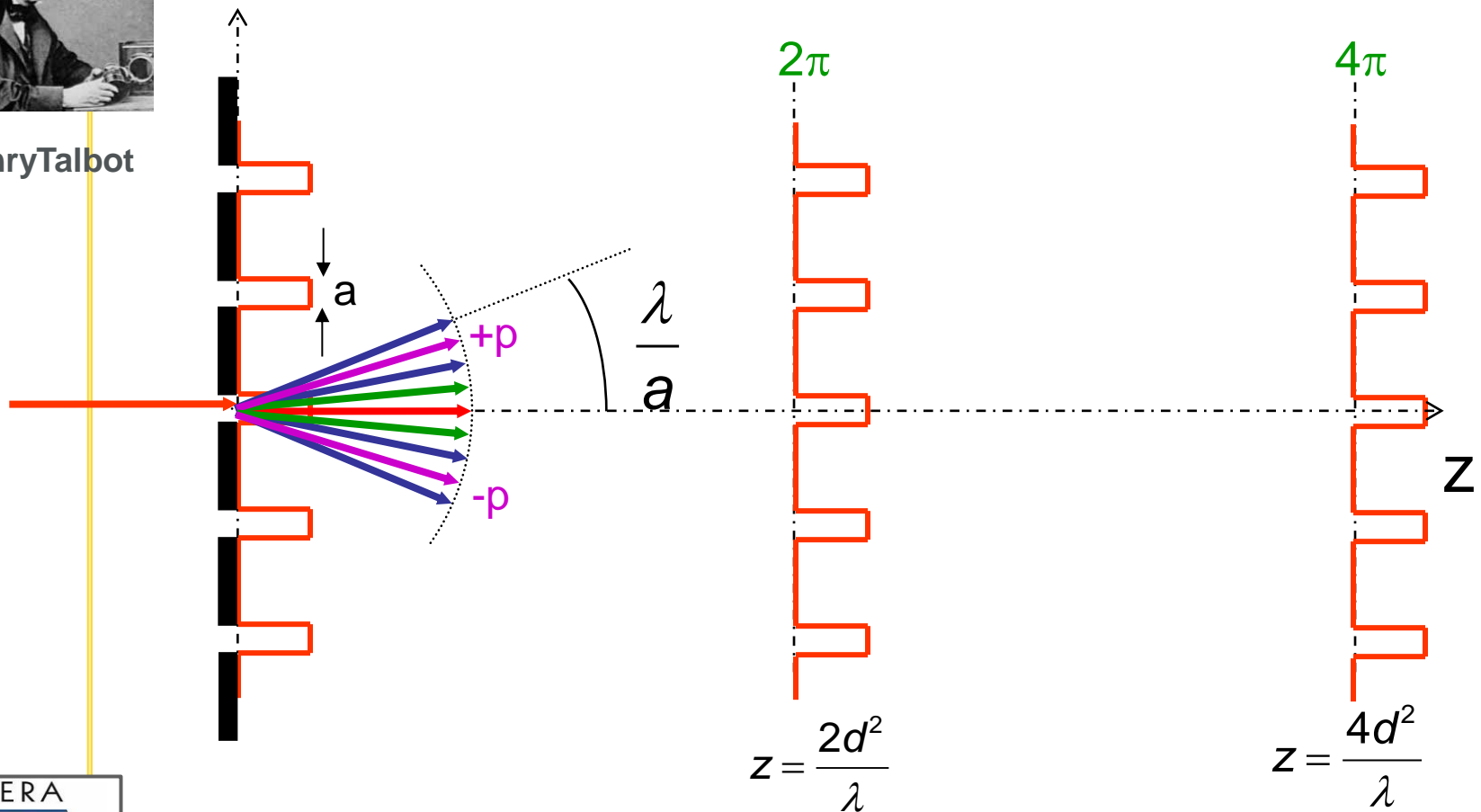 - Continuously-Self Imaging Grating (CSIG)

Light source

pinhole

Collimator
Focal length, f

CSIG

Focal plane
array

Fig. Schematic representation of the test bench

- The Talbot effect explanation

HenryTalbot

$$\frac{\lambda}{a}$$

2π

4π

a

+p

-p

z

$$z = \frac{2d^2}{\lambda}$$

$$z = \frac{4d^2}{\lambda}$$

- # The talbot effect explanation
  - ## Many holes, displacement of the screen

Image from Guerineau. ONERA

Initial interference status