

# LABORATORY CHARACTERISATION BENCH FOR HIGH PRECISION ASTROMETRY

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## THEIA scientific objectives

- Explore planetary systems in the Sun's vicinity by astrometry
- Discovery of Earth like planets orbiting Sun like stars
- Investigate the nature of dark matter.

## High precision relative astrometry

Evaluation of the position, distances and movements of celestial objects in relation to the stars present in the field of view

**Constraints:** high spatial resolution:  $0.3\mu\text{as}$ . Field of view:  $0.5^\circ$

## Detector characterization for THEIA

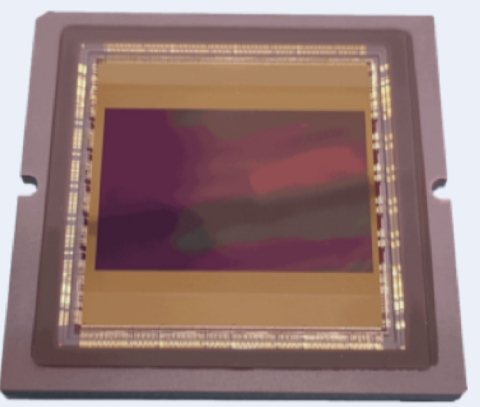
### Calibration of the detector and correction of the field distortion using stars in the field of view

The focal plane of the THEIA space telescope must be calibrated with an extreme precision down to the level of  $1e-5$  pixel. Need for total field of view coverage: 1 Gpixel

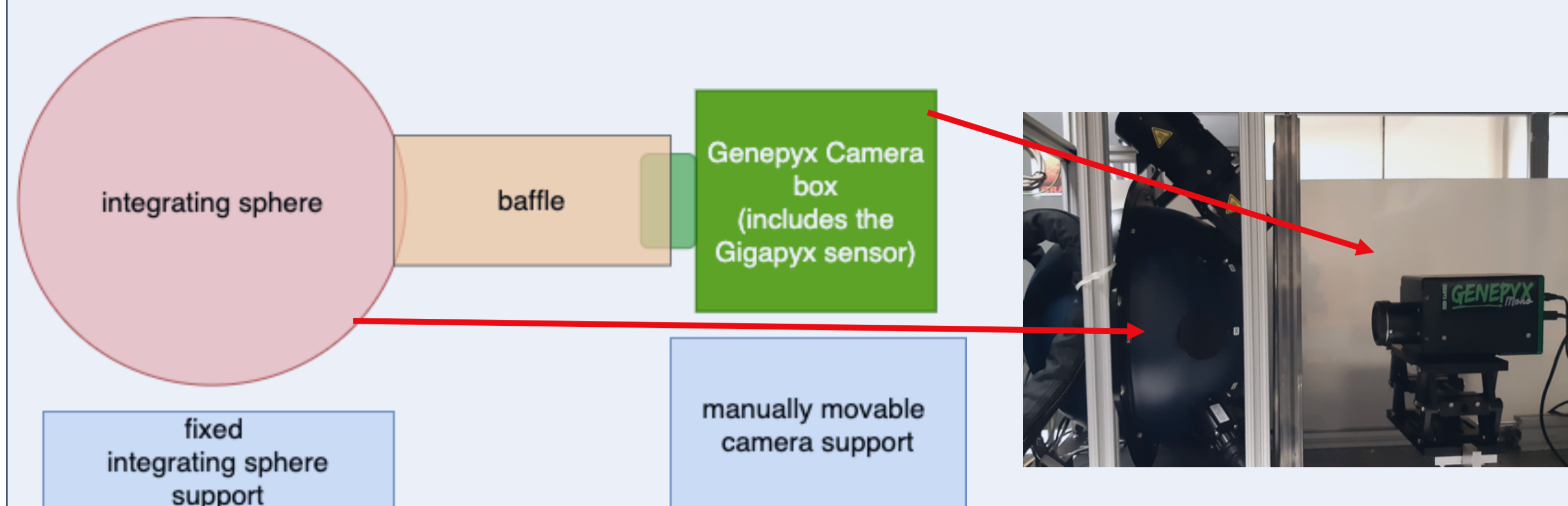
**Laboratory experiment with new large visible detector**  
PYXALIS Gigapix4600 (CMOS 46 MPixels) (planned: 200)

Pixel size:  $4.4\mu\text{m}$ . Sensor size:  $24 \times 36\text{mm}$

See poster by Lizzana et al.: "Experimental tests of the calibration of high precision differential astrometry for exoplanets and dark matter"



## Standard Detector Calibration

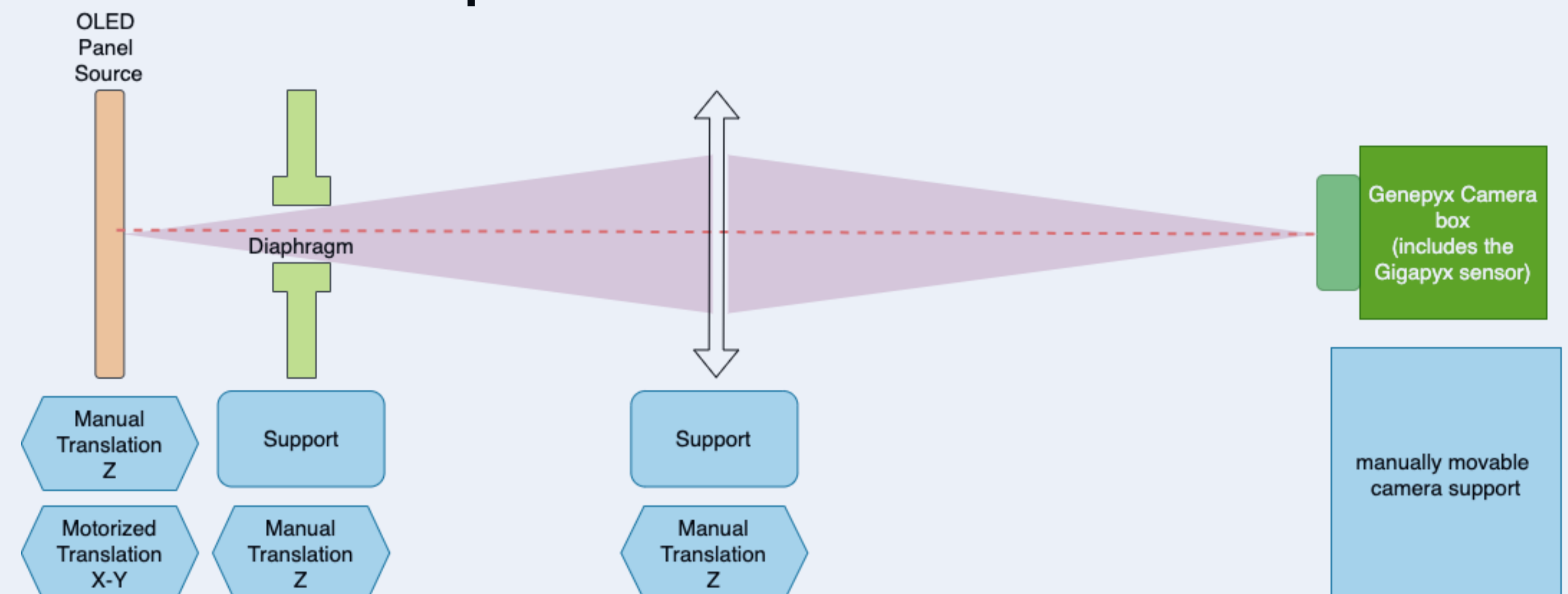


**Parameters of interest:** linearity, dark current, readout noise, gain, defective pixels...

**Integrating sphere:** Source that uniformly diffuses light.

Luminous flux intensity is configurable. Integrated light sensors enable precise luminosity adjustment. Scripts are developed for the automation of the characterization tests while varying the luminous flux intensity and sensor parameters

## Optical distortion calibration



**Goal:** investigate the evolution of the pixel geometry in response to environment fluctuations.

**Source:** 5 megapixels OLED monochrome panel ( $0.61''$  sub-pixel pitch:  $4.7 \times 4.7\mu\text{m}$ , luminance:  $1000\text{cd/m}^2$  max)

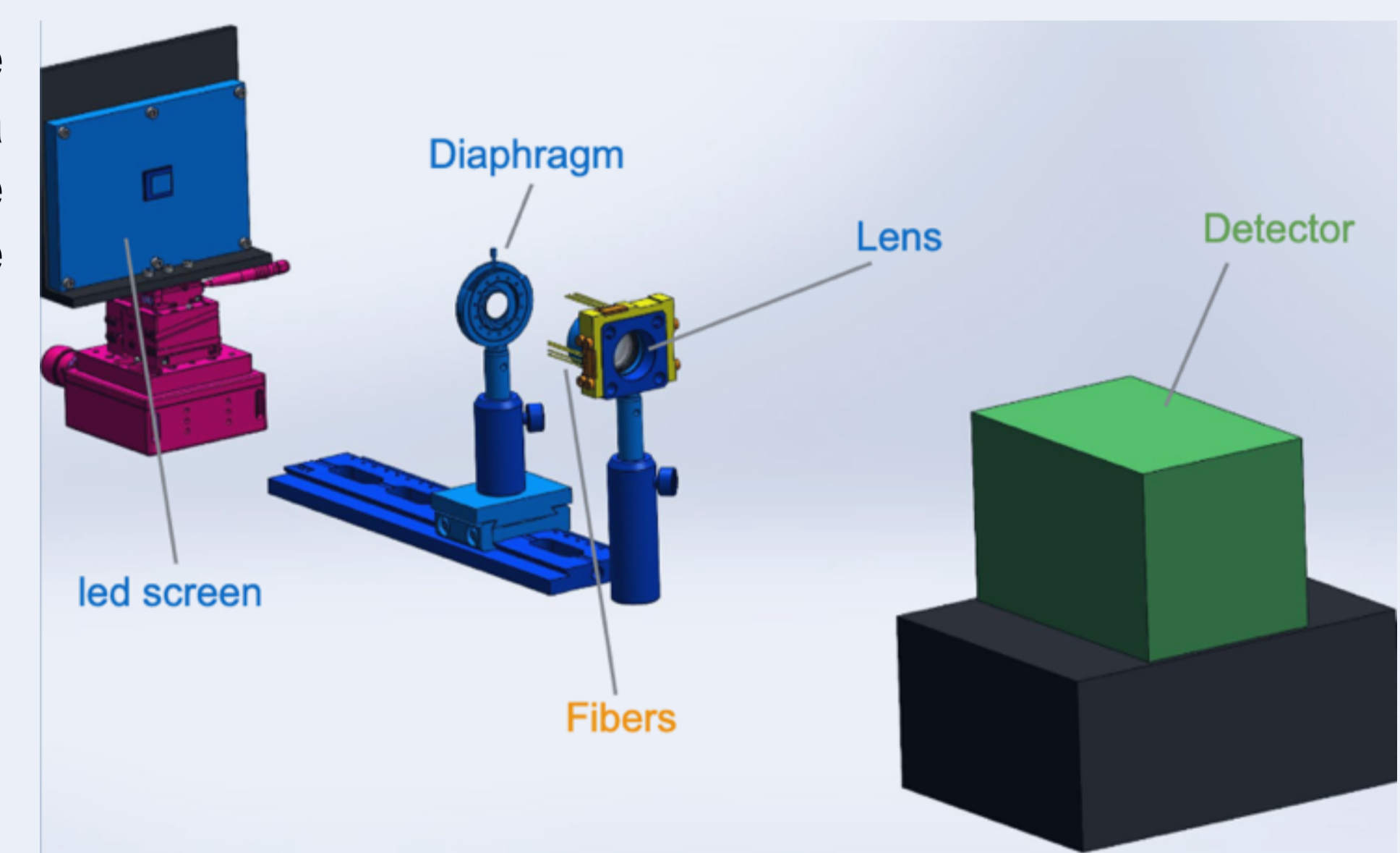
Custom patterns direct the light to selected groups of pixels. Reproduce pseudo stars.

**Doublet:** At the middle of the optical path ensures that a single pixel from the source will reach at least one or more pixels of the sensor.

**Diaphragm:** Induce distortion

**Motorized translations:** piezoelectric inertia drives

**Detector:** Records distorted star images

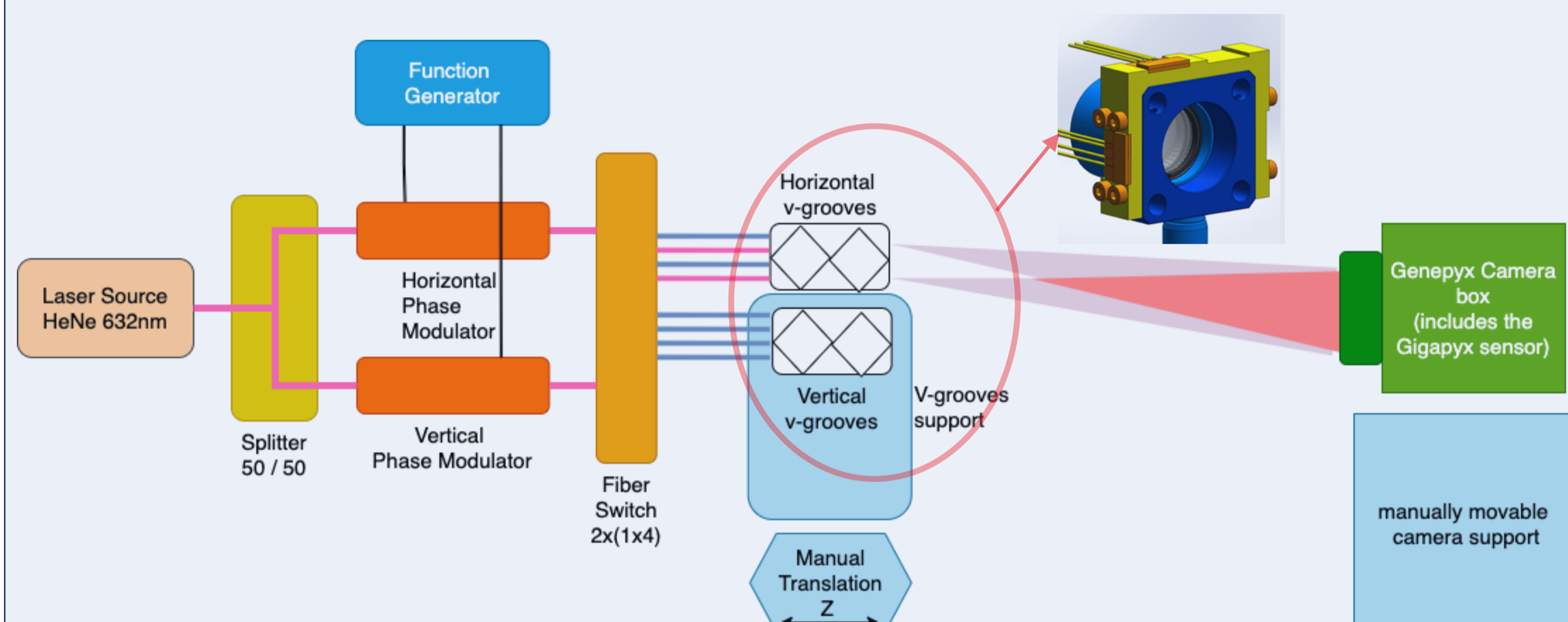


## Interferometric calibration of the pixels centroid position

*Ideal detector: rows and columns are well aligned*

*Real detector: pixels are misaligned at scale smaller than the millipixel level*

**Need of calibration: Use fibers that illuminates the detector with Young's fringes**

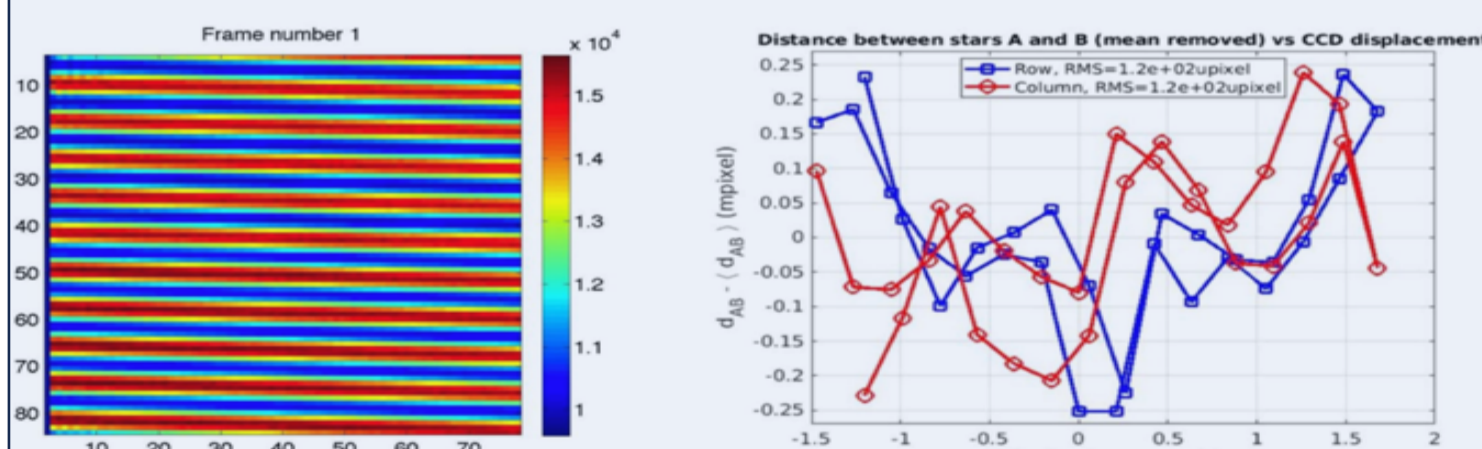


**Phase modulators** (Jenoptics PM-635): make the fringes scroll. The modulation observed by each pixel provides the position of the centroids.

**Voltage generator** (Agilent 33522A): drive phase modulators

**Fibers Switch** (Leoni EOL 2x(1x4)): allow the selection of fibers combinations. 2 input and 2 groups of 4 fibers outputs. Free to select any output combination

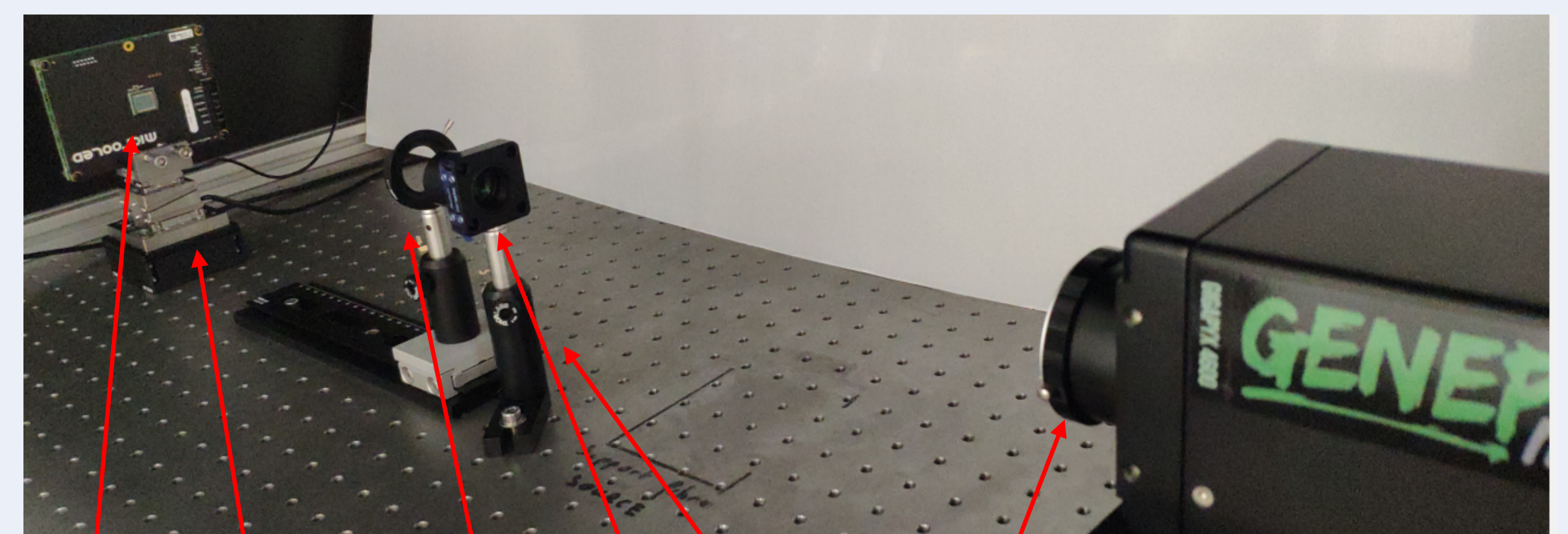
**V-grooves:** fibers are fixed on a doublet support (used for distortion). Distance between fibers is fixed.



Each pixel sees a modulation of the light  
**This allows precise positions of pixels centroids to be calculated**

Illustration of interferometric calibration with Young fringes (Crouzier et al. 2016, Shao et al. 2023))

## Initial tests with OLED screen and image sensor



Sensor: Pyxalis Gigapix4600 (46 MPixels. Pixel pitch:  $4.4\mu\text{m}$ )

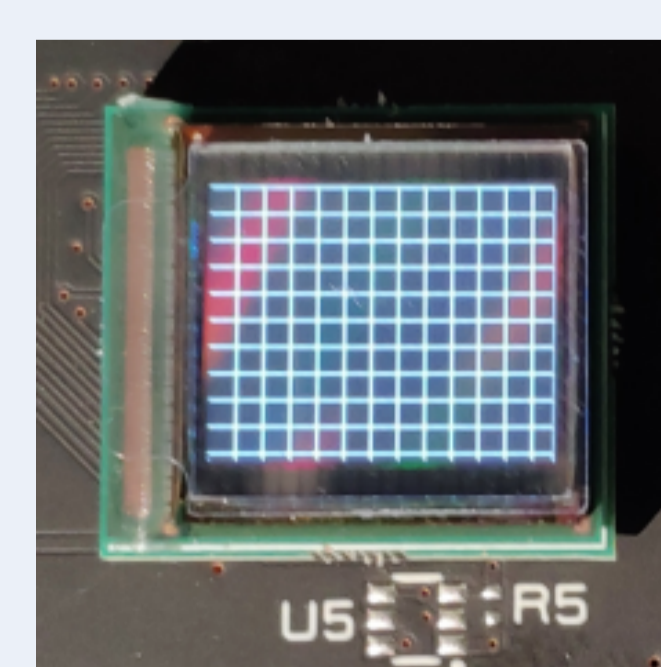
Doublet and V-grooves support

Doublet: Thorlabs ACA254-200

Iris: Thorlabs ID25

Translations: Thorlabs PD1 - PDXZ1 - NFL5D

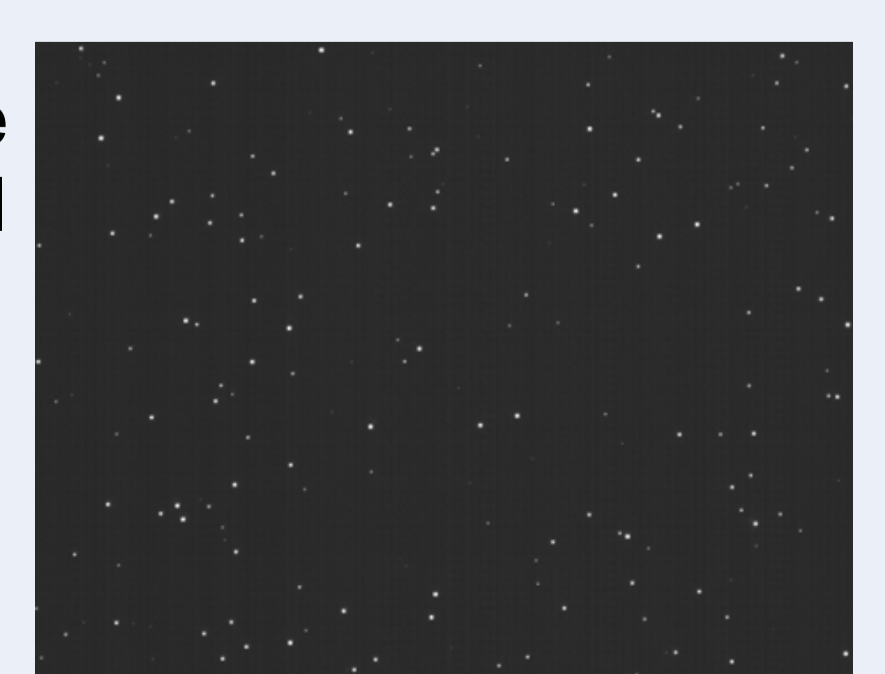
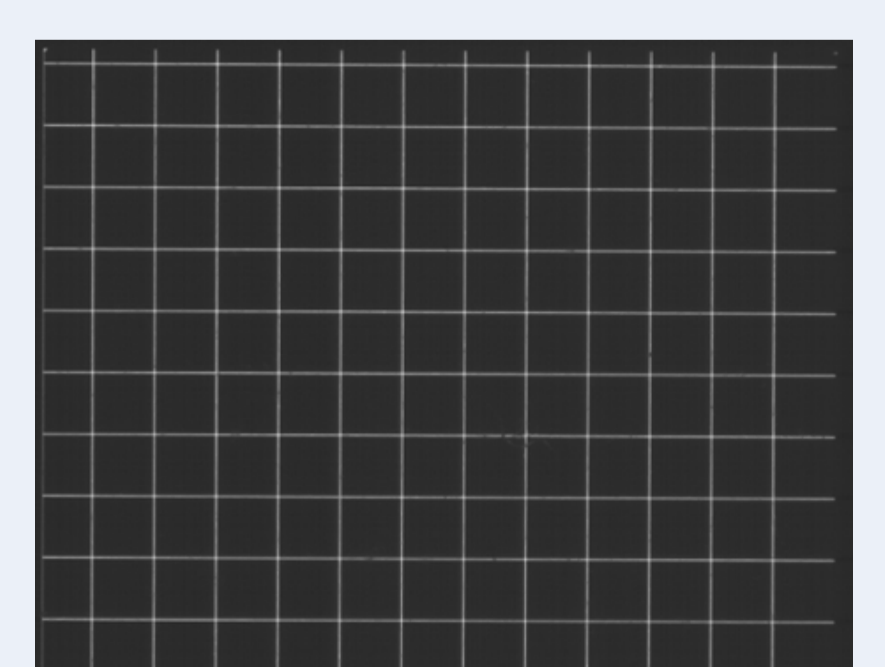
Source: Microoled MDP04B (5MPixels - size:  $0.61''$  - pixel pitch:  $4.7 \times 4.7\mu\text{m}$ )



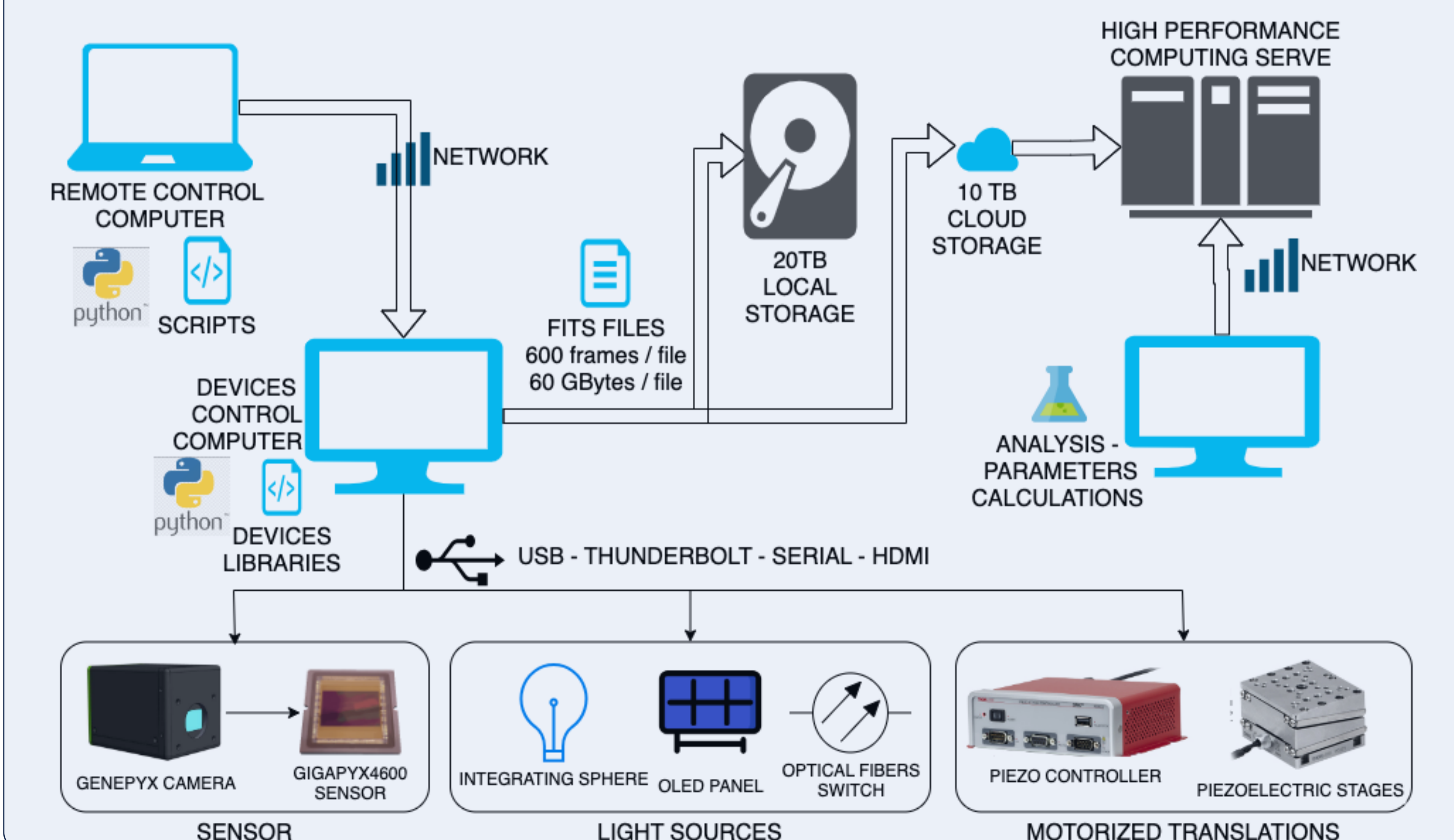
**Left:** pictures of the OLED screen with patterns generated by Python scripts (grid and stars)



**Right:** images captured by the GIGAPYX4600 sensor (ROI crop)



## Control Architecture



1 : Institut de Planétologie et d'Astrophysique de Grenoble, observatoire des sciences de l'univers de Grenoble, Université Grenoble Alpes, Centre National de la Recherche Scientifique  
2 : Centre National d'Études Spatiales (France)  
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