LSST-DESC meeting at Argonne : SAWG
Fringes illuminations to map static distortions

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LPNHE

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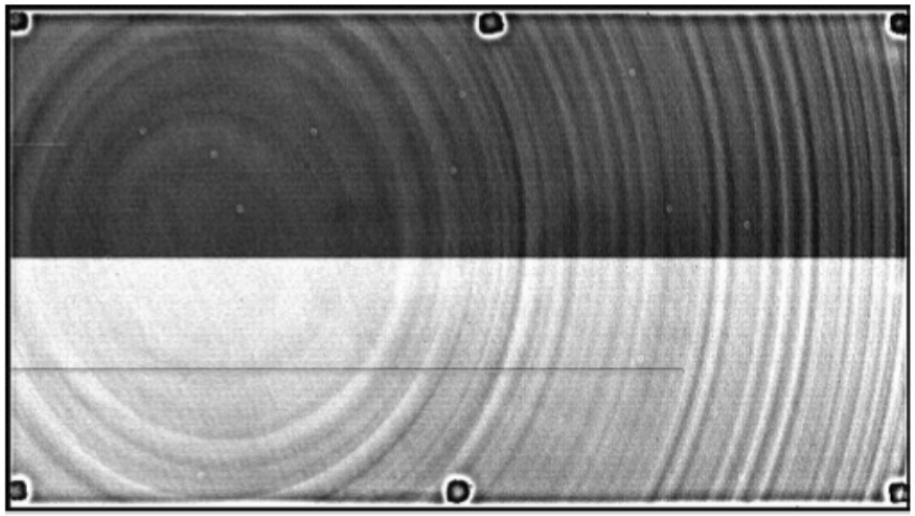
1. Phd advisors

Overview

1. Framework and Method :
   - CCD distortions
   - Mapping static effects
2. Instrumental setup
3. Data
4. Analysis

Framework : CCD distortions

- Inside CCD, there are distortions.
- Two kinds of distortions :
  - Static (flux independent) : tree rings, edges effects.
  - Dynamic (flux dependent) : Brighter Fatter (SAWG session I).
- These distortions have an impact on the astrometry and photometry.
- Need to map and correct these effects in order to make measurements (e.g. weak lensing).
- Apply the method for static effects, then test it for BF.

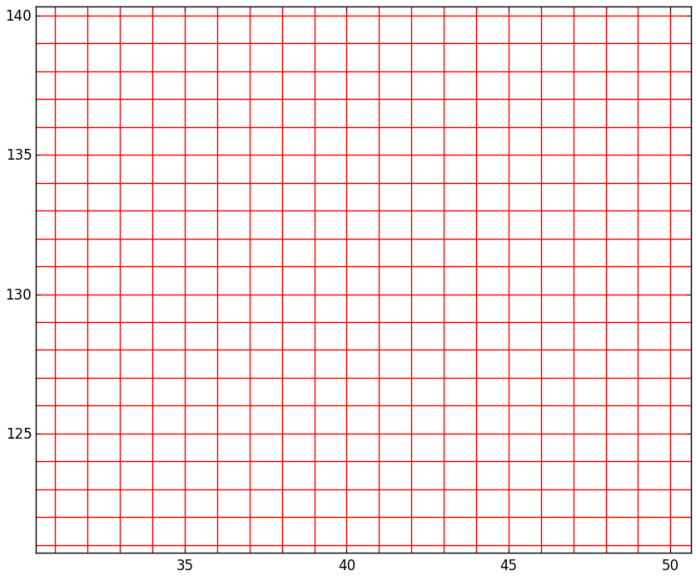


Treerings in DECam master dome flat, g band. arXiv:1403.6127

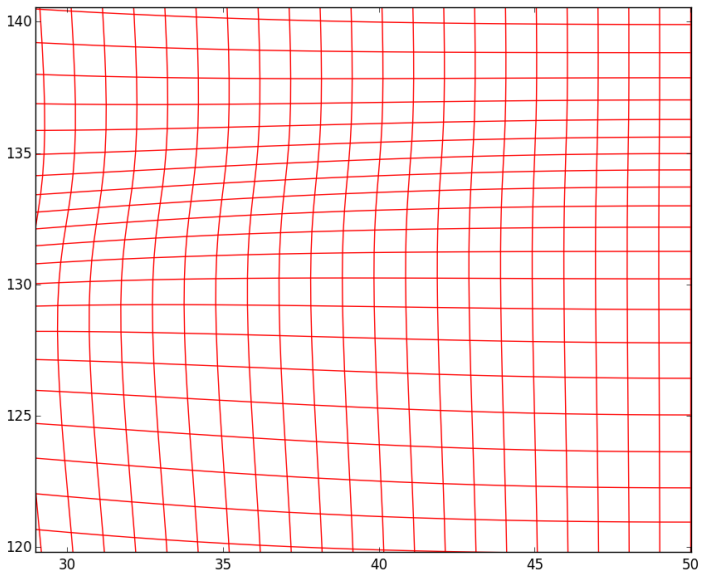
Displacement field

Displacement field $\overrightarrow{\delta}$:

- $\overrightarrow{X'} = \overrightarrow{X} + \overrightarrow{\delta}$



Pixel grid in $\overrightarrow{X}$ (non distorted) coordinate system.



Pixel grid in $\overrightarrow{X'}$ (distorted) coordinate system.

Illumination model

Illumination model :

$$I'(\overrightarrow{X'}) = I(\overrightarrow{X}) \left| \frac{d\overrightarrow{X}}{d\overrightarrow{X'}} \right| \tag{1}$$

If $\overrightarrow{\delta}$ is small, Taylor expansion :

$$I'(\overrightarrow{X}) = I(\overrightarrow{X})(1 - div\,\overrightarrow{\delta}) - \nabla I.\overrightarrow{\delta} \tag{2}$$

Flat fields :

- Constraints on $(1 - div\,\overrightarrow{\delta})$.

Modulated illuminations :

- Constraints on the direction of $\overrightarrow{\delta}$, better if ∇I is important.

Instrumental method :

- **Fringes illuminations**.
- Control of the fringes' orientation.
- Control of the fringes' pixel wavelength.

Displacement field model

- We develop $\overrightarrow{\delta}$ on a (2D) B-splines basis.
- Two models : **A** and **B**

Model "A" :

- General model.

$$\overrightarrow{\delta} = \begin{pmatrix} \sum_p \theta_p^X B_p(\overrightarrow{X}) \\ \sum_q \theta_q^Y B_q(\overrightarrow{X}) \end{pmatrix} \tag{3}$$

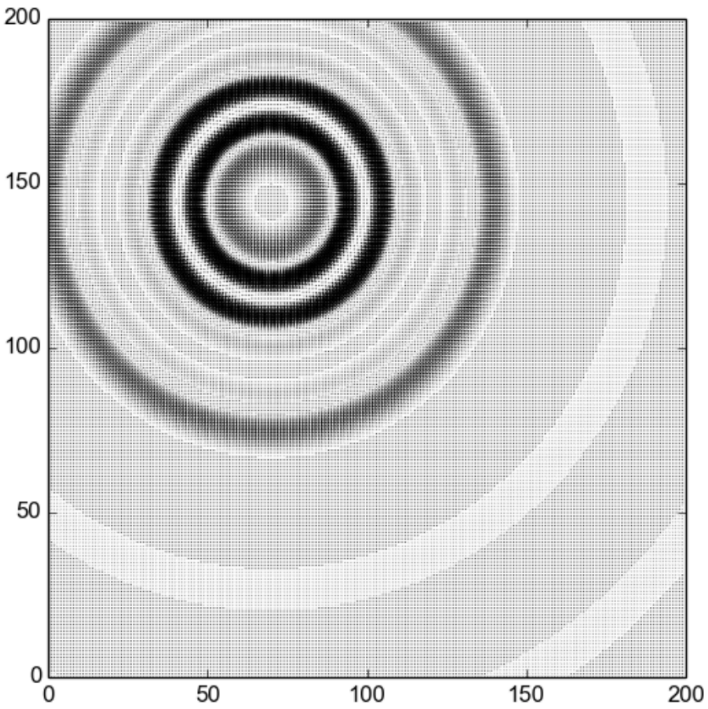
Model "B" :

- $\overrightarrow{\delta}$ derives from a 2D scalar field (potential).
- Two times less parameters.

$$\overrightarrow{\delta} = \overrightarrow{\nabla} \sum_p \theta_p^X B_p(\overrightarrow{X}) \tag{4}$$

Fit details and time consumption

Displacement field example :



Models are fit with :

- Least square method.
- Flat fields and fringes at various angle.

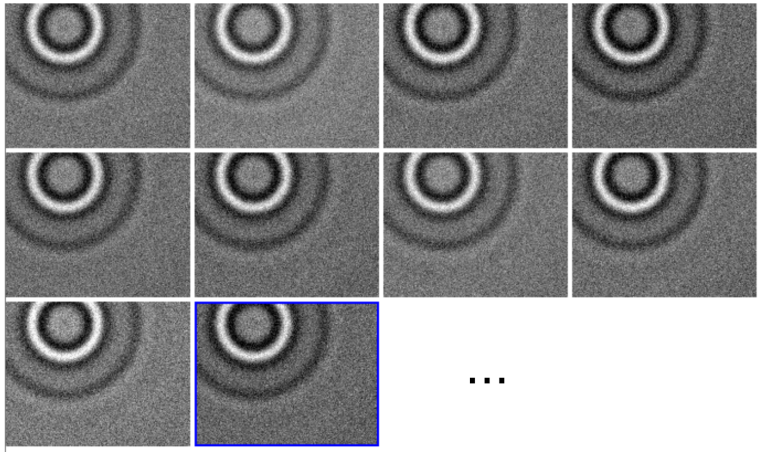
Large fit :

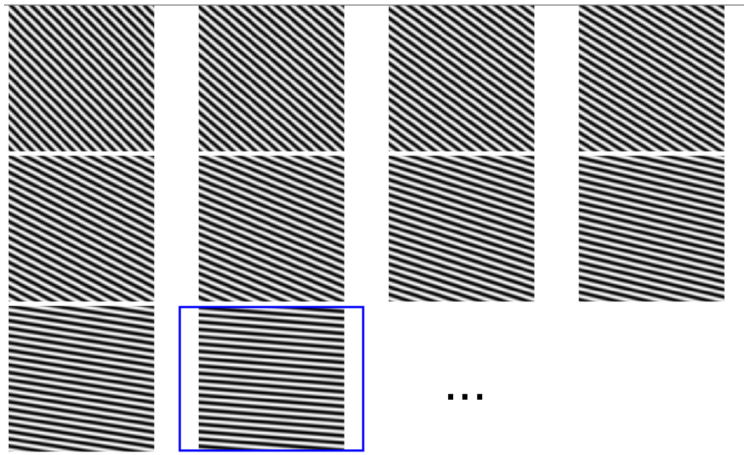
- For whole sensor, 1 spline node every 5 - 10 pixels (160,000 - 640,000 parameters).
- But minimization in minutes (500x500 exposure).
- $\backsim$ 30 minutes for 2000x2000 exposure.

Simulated displacement field :

- $\| \vec{\delta} \| =$ 0.01 pixel.

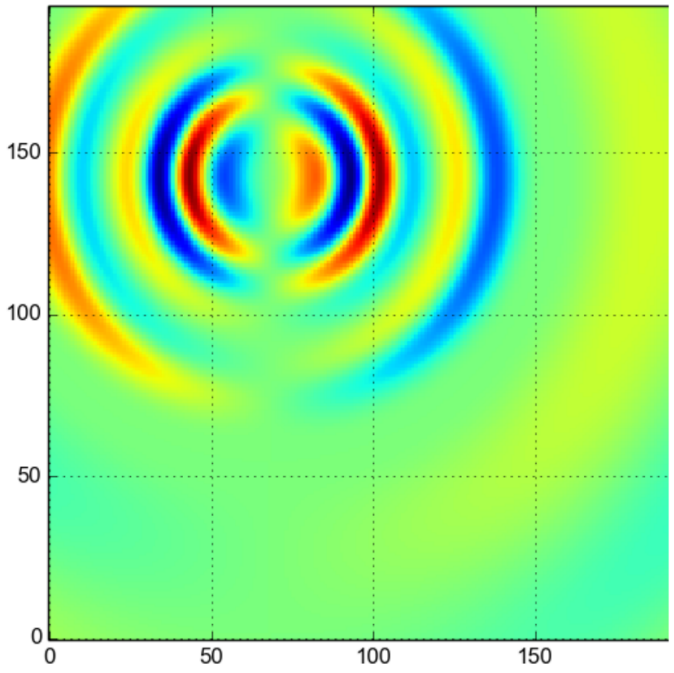
Simulation data



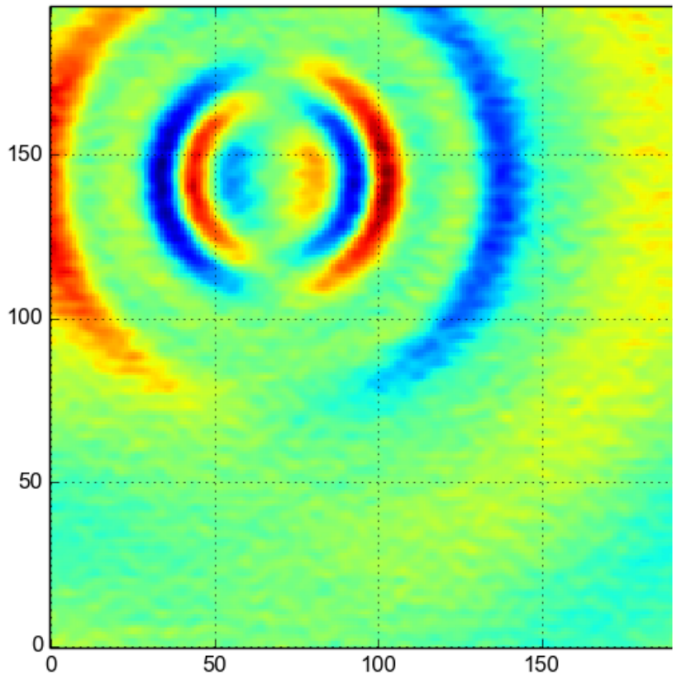


- 20 flats.
- Poisson noise.
- Mean level 7000 $e-$.
- 20 fringes with different orientations.

Simulation validation : results



x component of the true $\overrightarrow{\delta}$

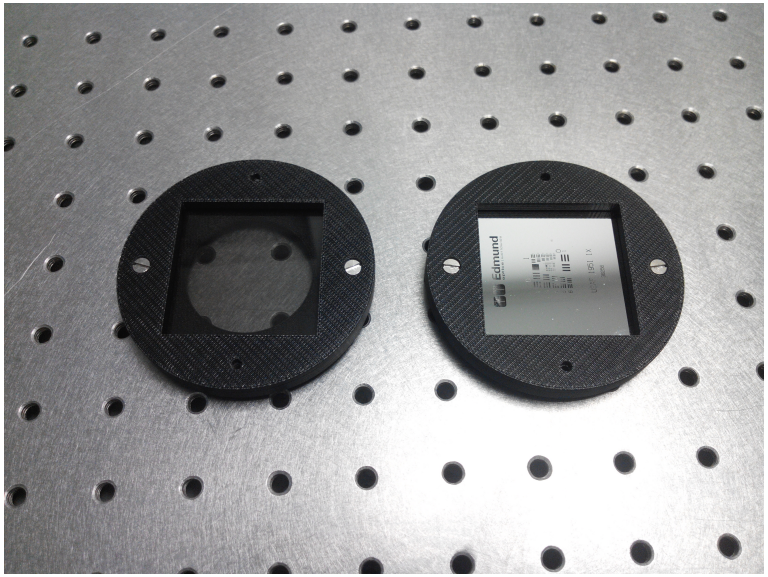


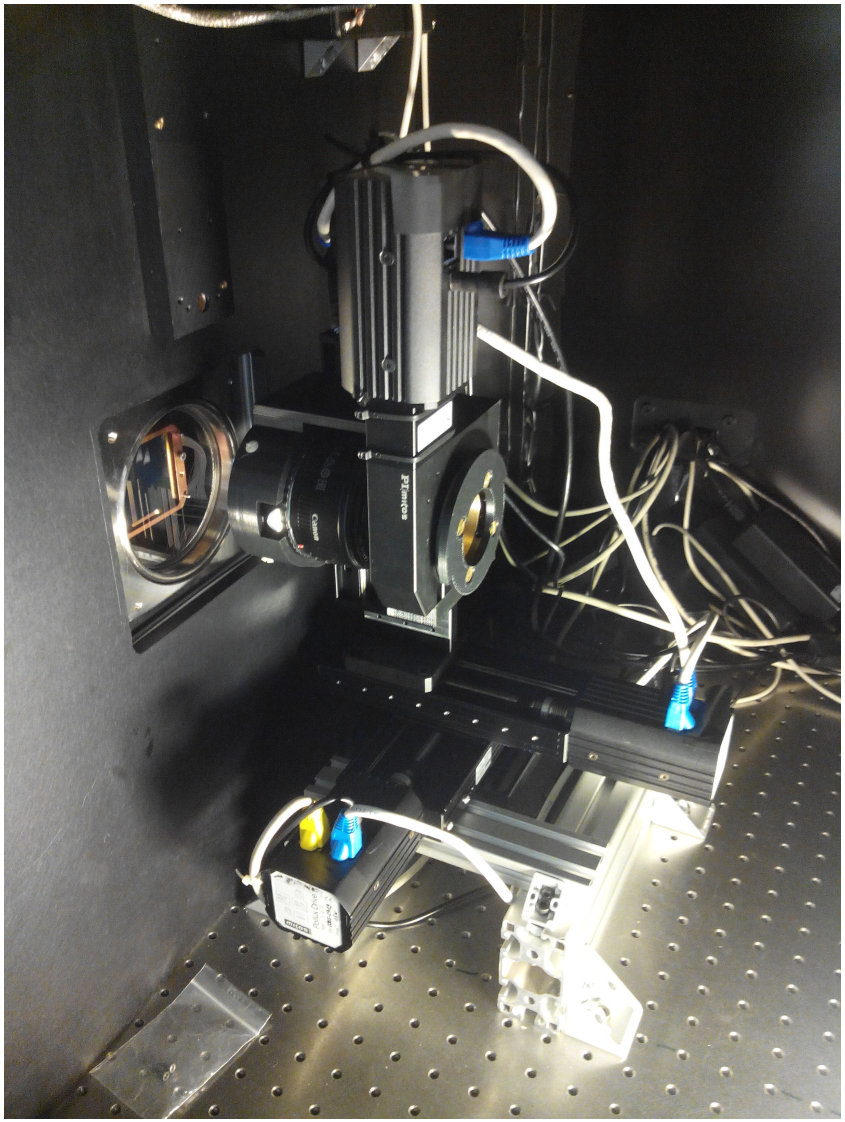
x component of the fitted $\overrightarrow{\delta}$

- Good final χ^2.
- Validation of the method : we can map static distortions.

Instrumental setup

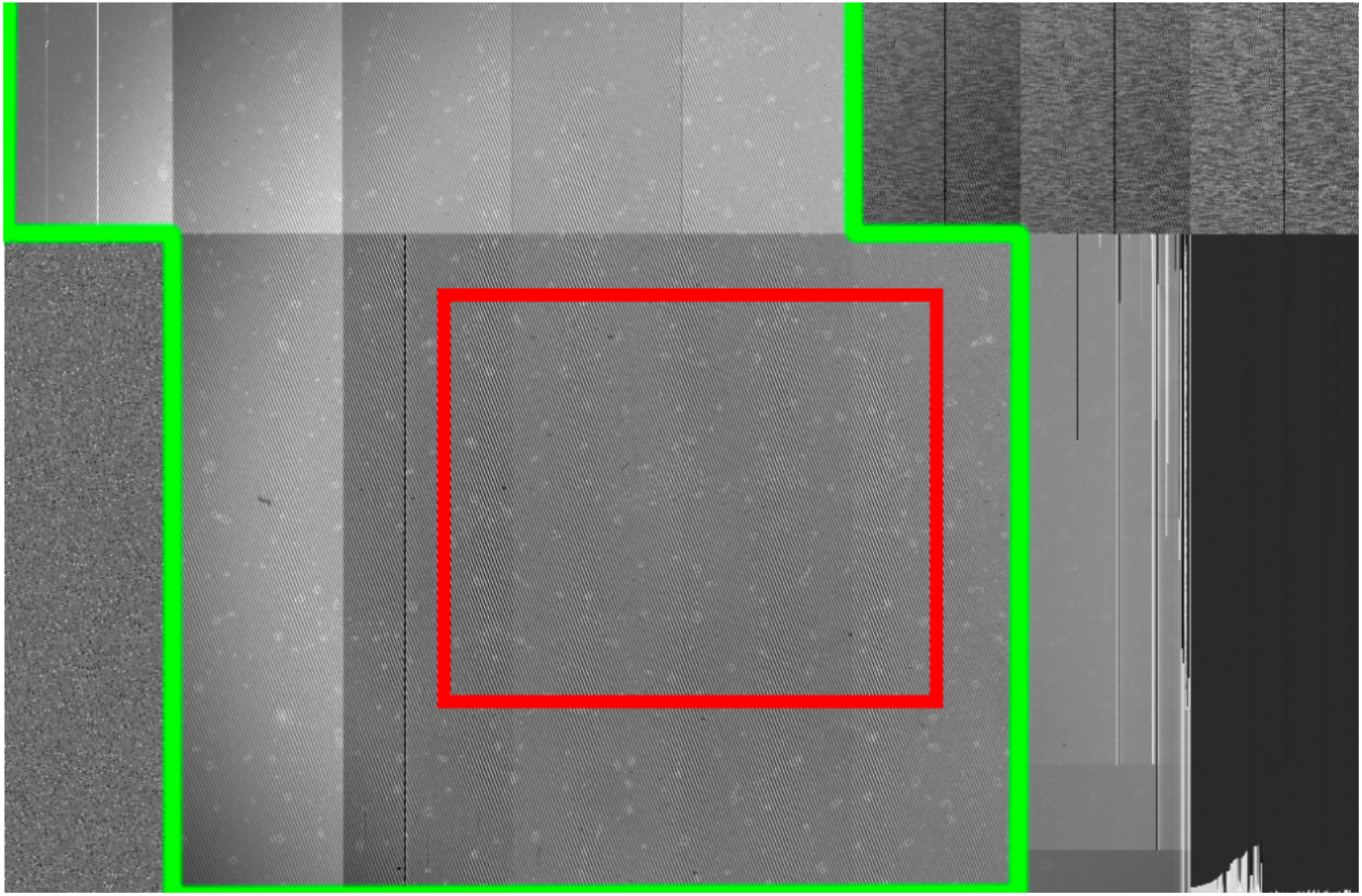
- Experiments done in clean room.
- Setup inside a black box.
- XYZ and rotating motor.
- Pixel period of fringes 5 to 13 px.
- Using test target. (transmission sinusoïdal pattern)
- Canon lens + integrating sphere.





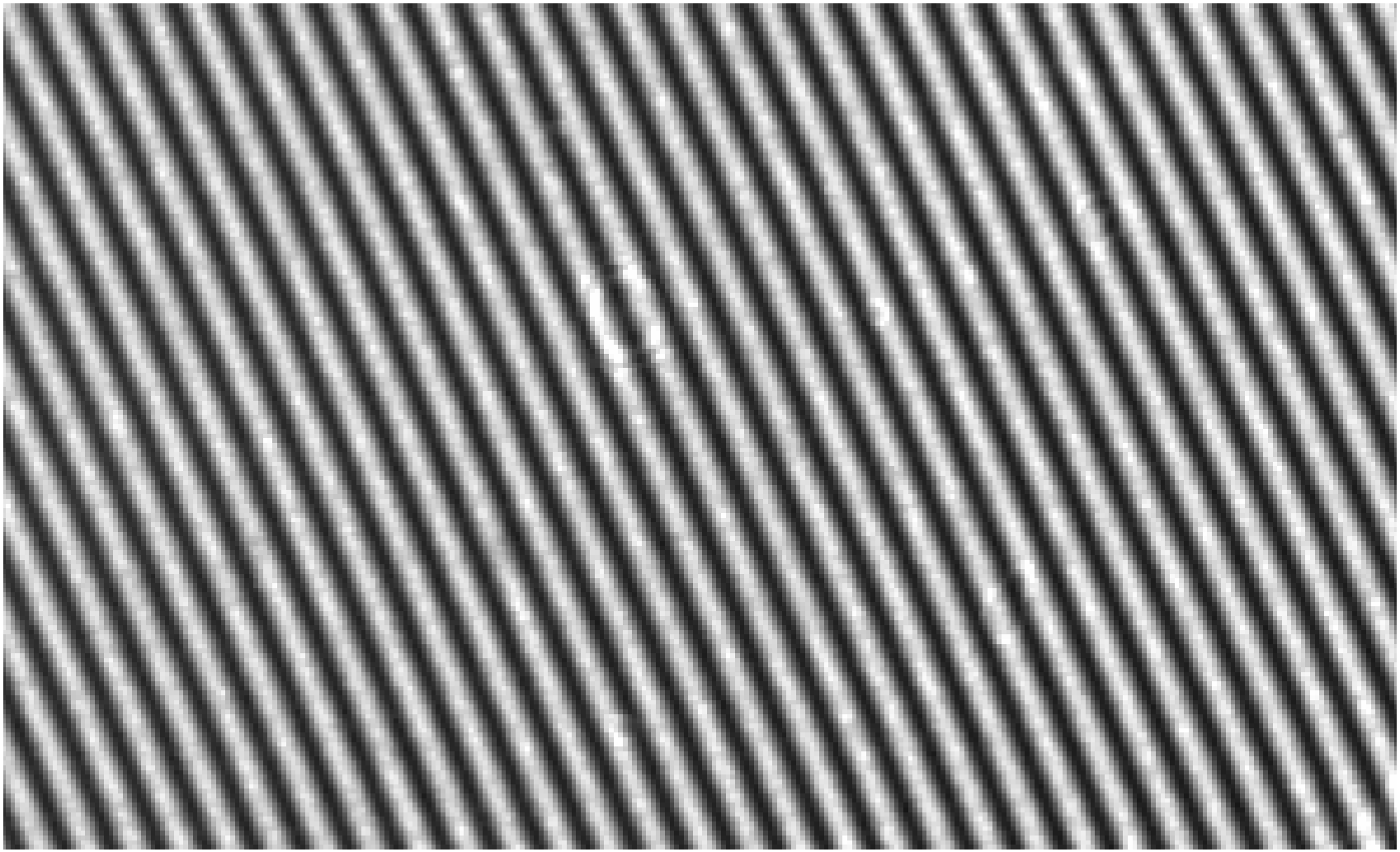
Raw image, fringe wavelength of $\backsim$ 9 px

- Ingeneering device CCD E2V-250-100-00.
- Not entirely working, but there are treerings.

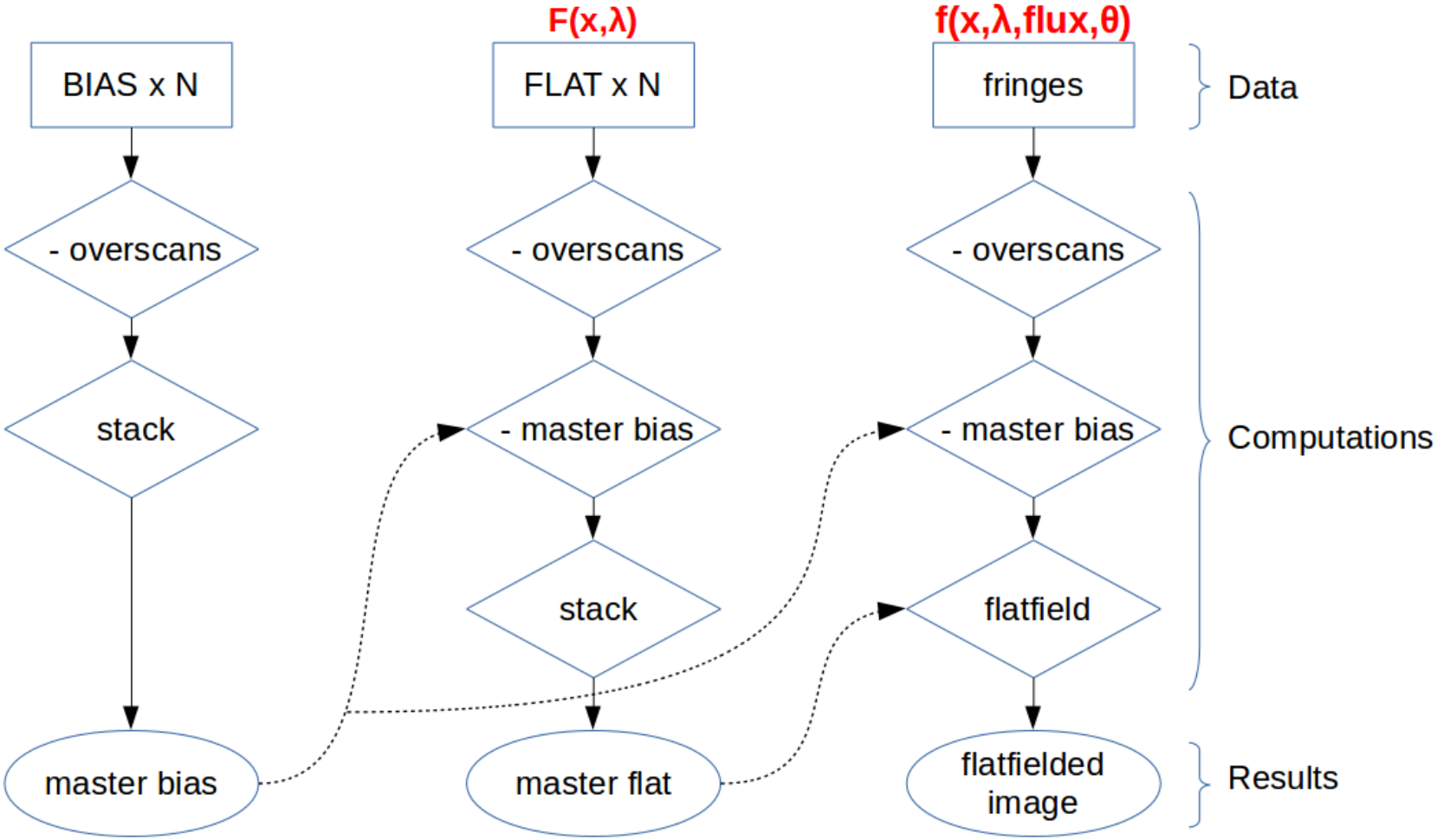


Zoom on previous image

- Achieved contrast : $MAX - MIN = 30,000$ ADU

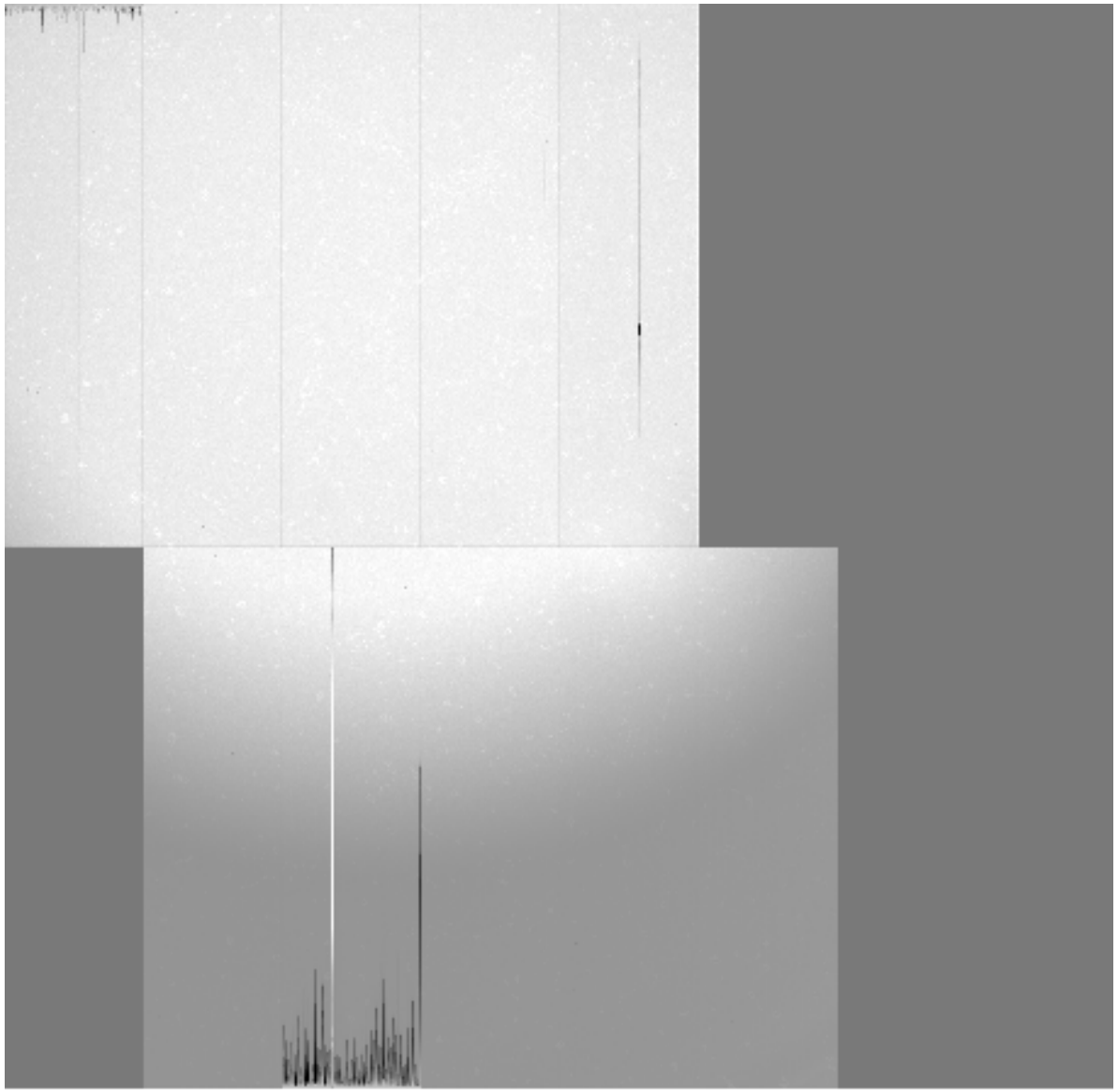


Pipeline prototype

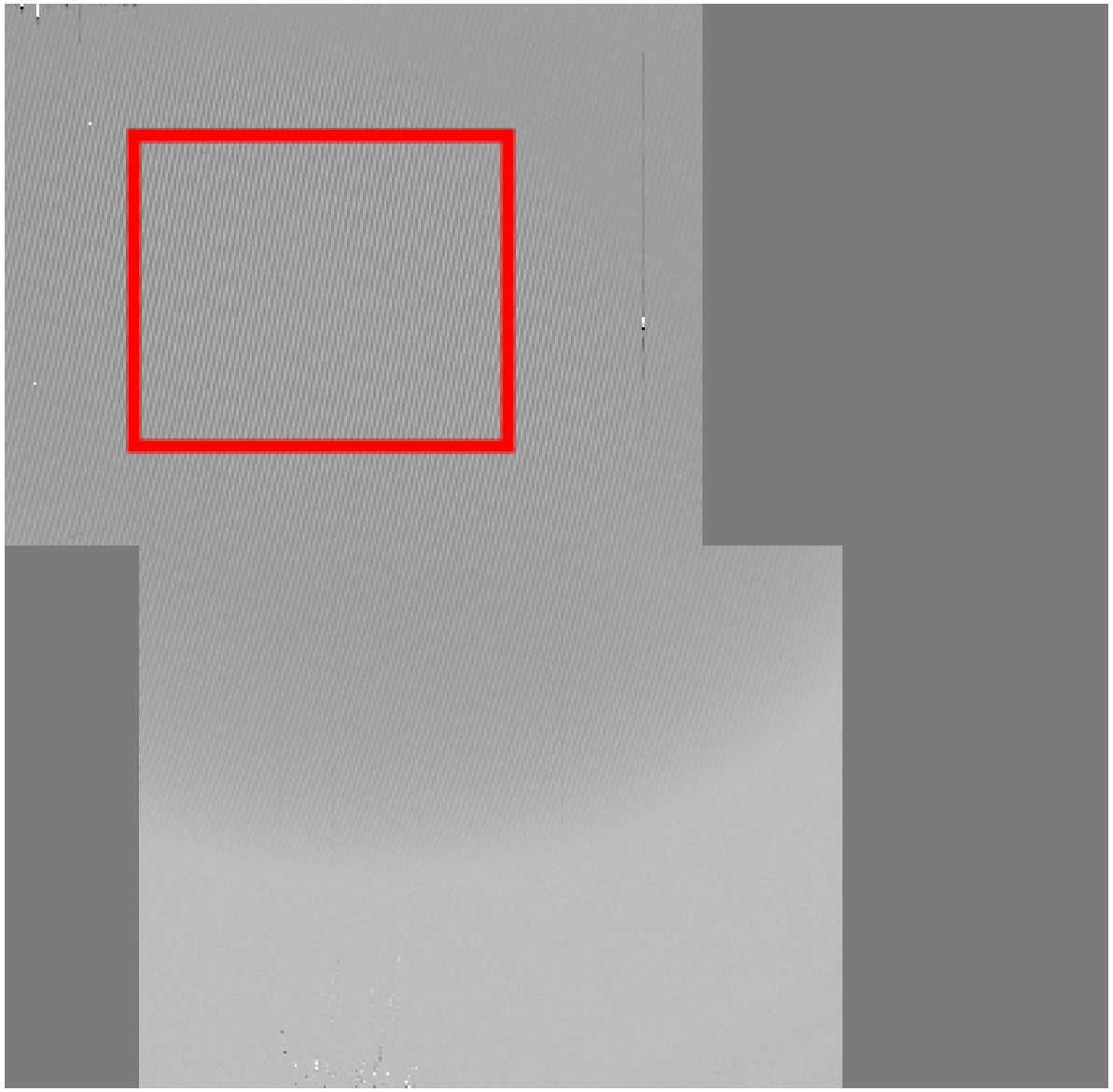


+ Creating a mask for each position

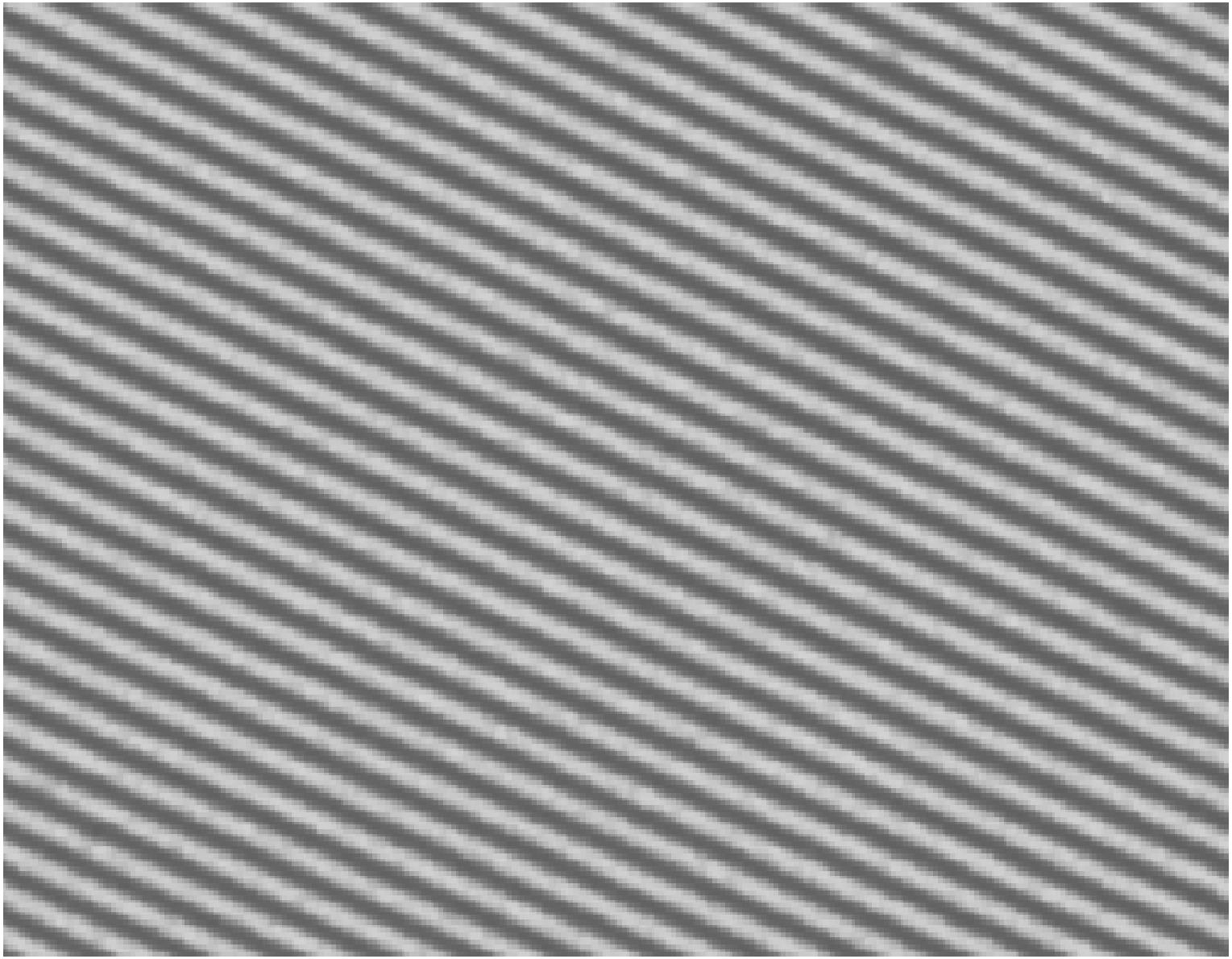
Masterflat



Flatfielded image



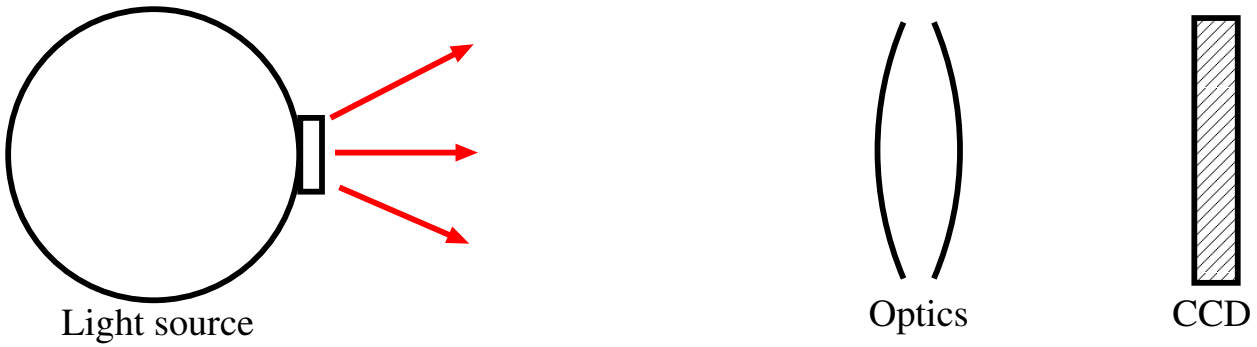
Flatfielded image



Disentangling Quantum Efficiency ε : flatfield the images

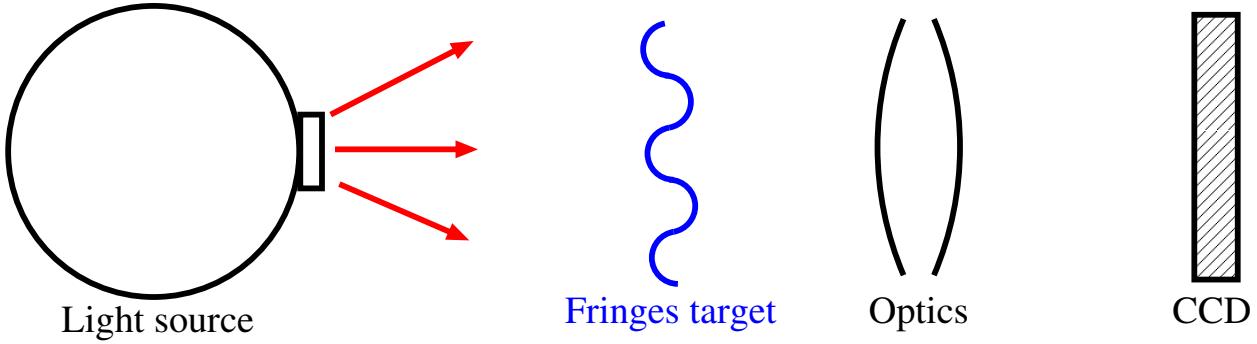
Flatfield illumination :

$$I_p^{[f]} = \varepsilon(x_p) J(x_p) \times F(x_p) \tag{5}$$



Modulated illumination :

$$I_p^{[m]} = \varepsilon(x_p) J(x_p) \times F(x_p) \times M(x_p + \vec{\delta}) \tag{6}$$



Displacement field from the flatfielded illumination

After flatfield :

$$\frac{I_p^{[m]}}{I_p^{[f]}} = M(x_p + \overrightarrow{\delta}) \tag{7}$$

Model :

$$I'(\overrightarrow{X}) = I(\overrightarrow{X})(1 - div\,\overrightarrow{\delta}) - \nabla I.\overrightarrow{\delta} \tag{8}$$

- In the simulation, $I(\overrightarrow{X})$ is supposed perfectly known.
- So if I is known, $\overrightarrow{\delta}$ is also known.
- But it is not the case : need to fit the illumination.

Illumination model

Illumination : Integration of a sin^2 over the surface of one pixel :

Equation :

$$A.sin^2(\overrightarrow{k}.\overrightarrow{x} + \varphi) + B \tag{9}$$

Integrated equation :

$$I = \int_i^{i+1} \int_j^{j+1} S.dxdy \tag{10}$$

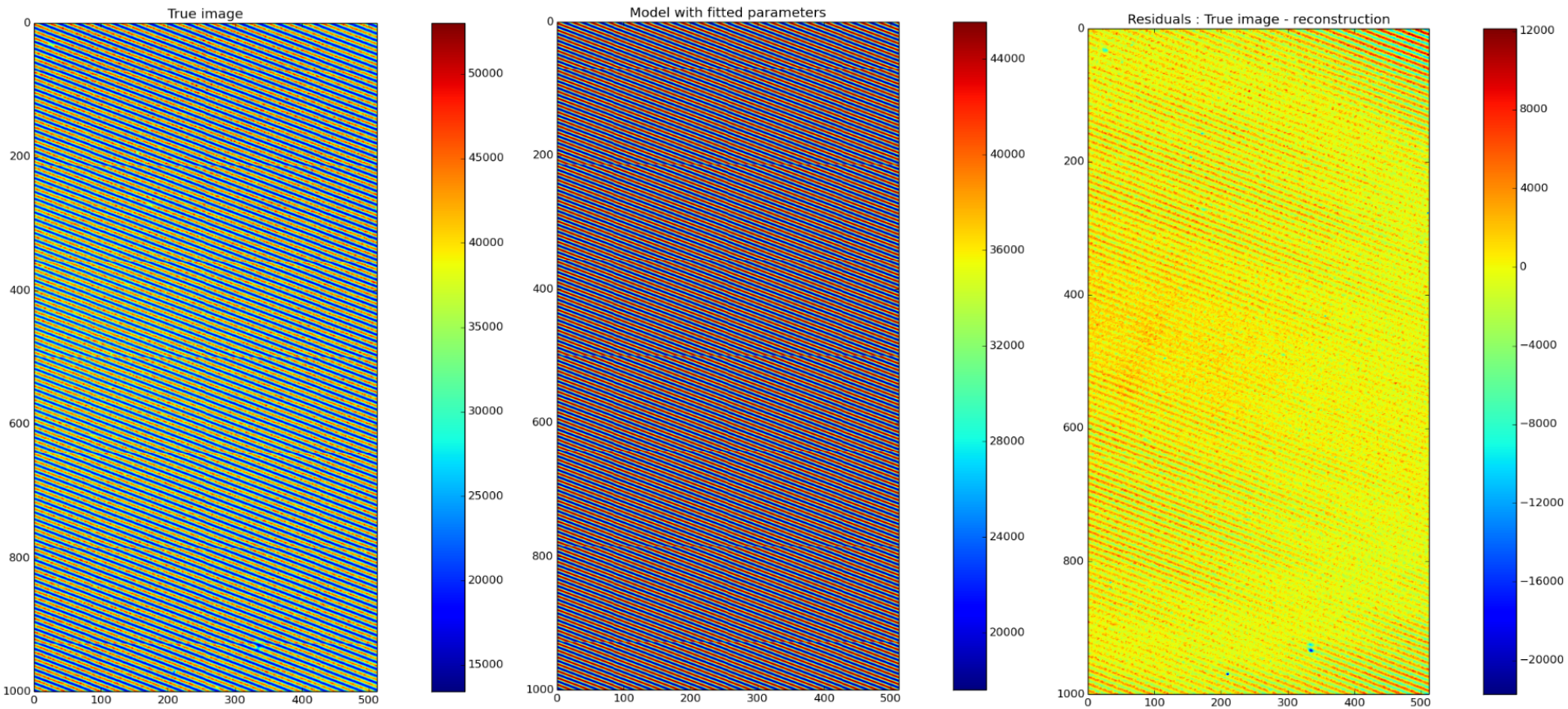
$$= \frac{-A}{2k_x k_y} sin(k_x) sin(k_y) cos(k_x + k_y + 2\varphi + 2\overrightarrow{k}.\overrightarrow{ij}) + \frac{A}{2} + B \tag{11}$$

Initial parameters for the fit

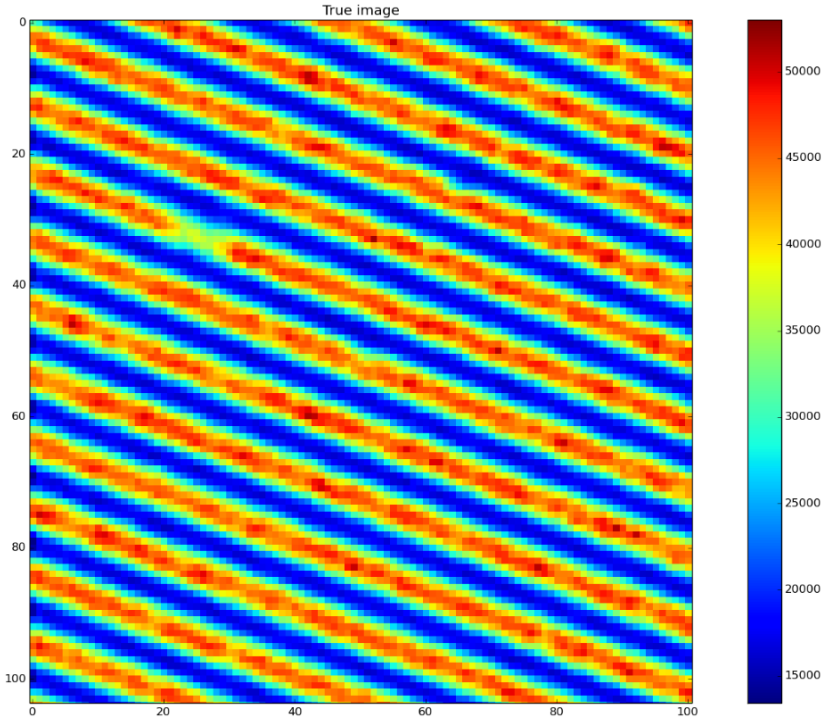
- $\overrightarrow{k}$ with the FFT.
- A et B with an histogram of the image.
- φ by χ^2 scanning.

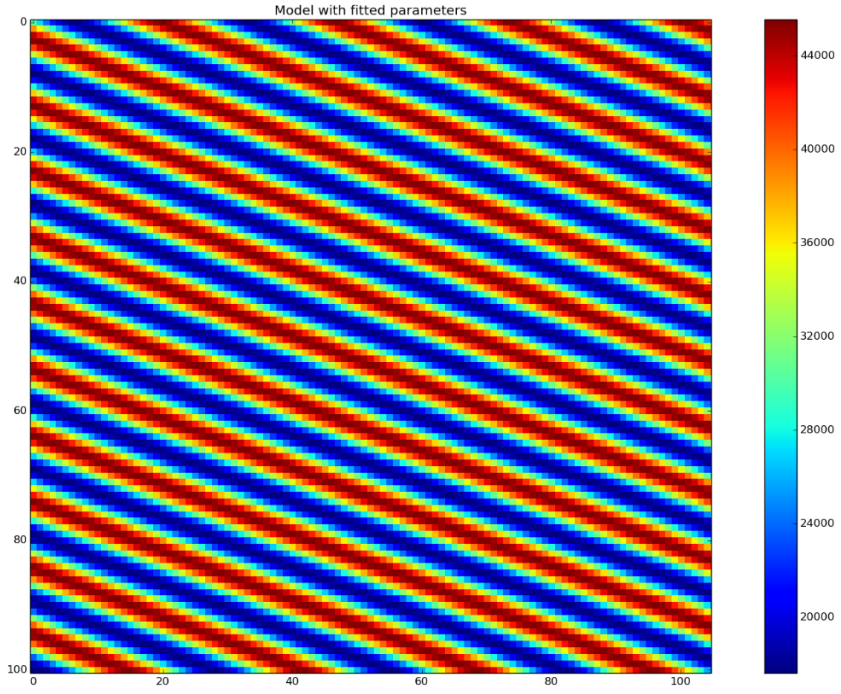
Some results

- Non linear fit over 1/2 channel.

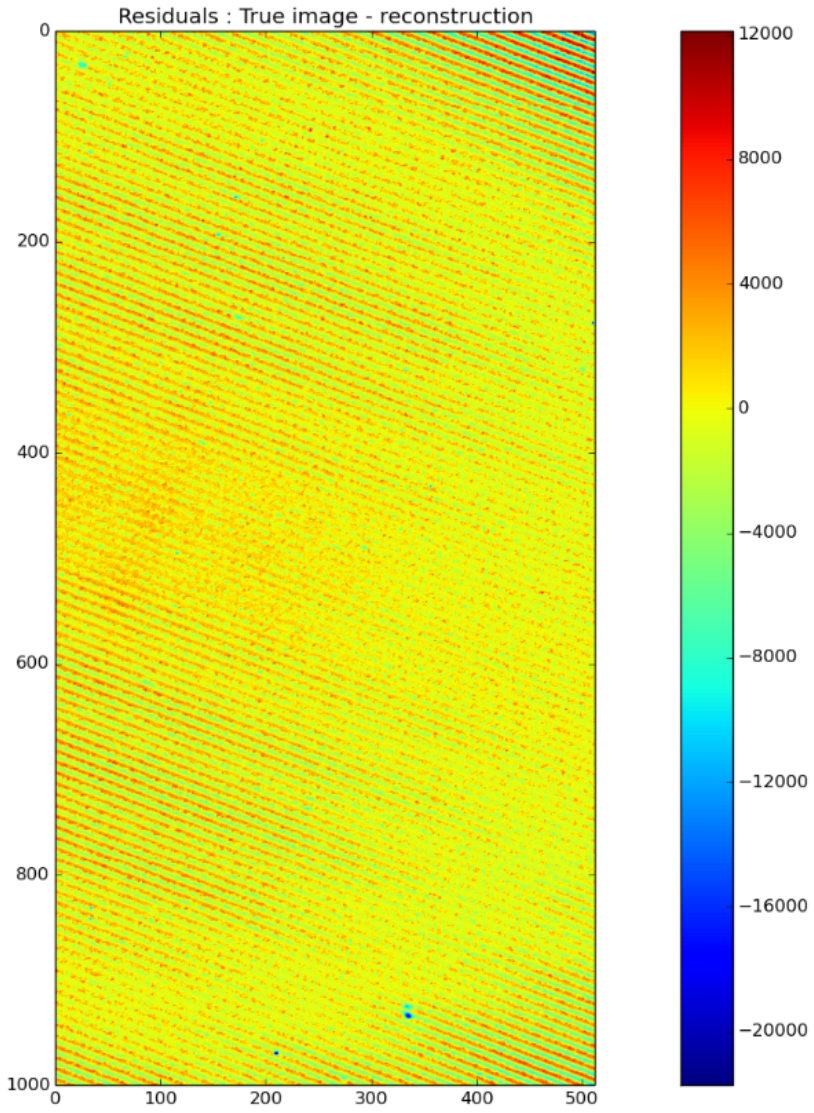


Zoom on the results





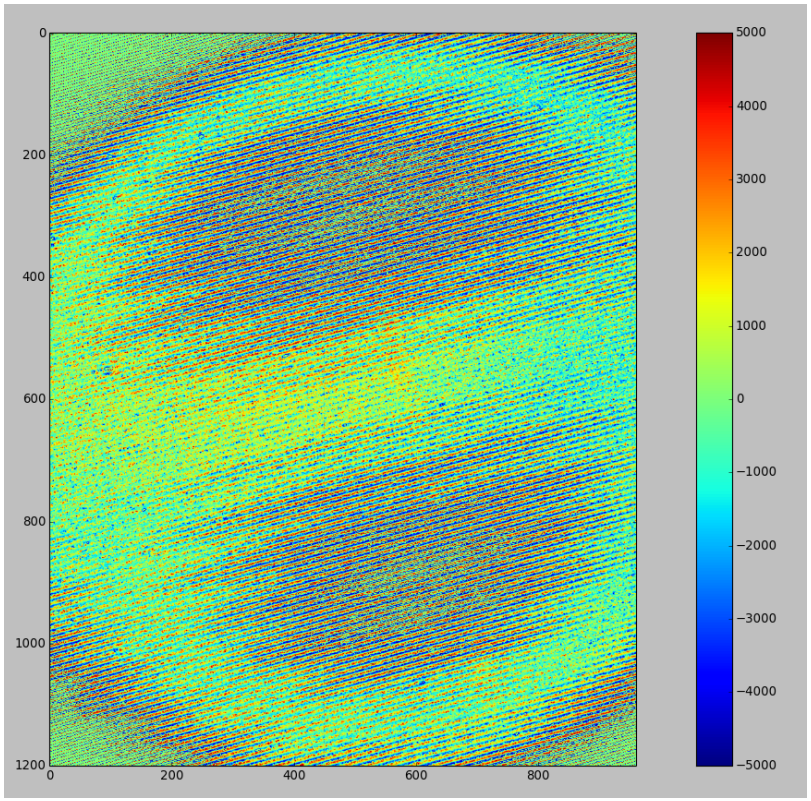
Looking back at the residuals

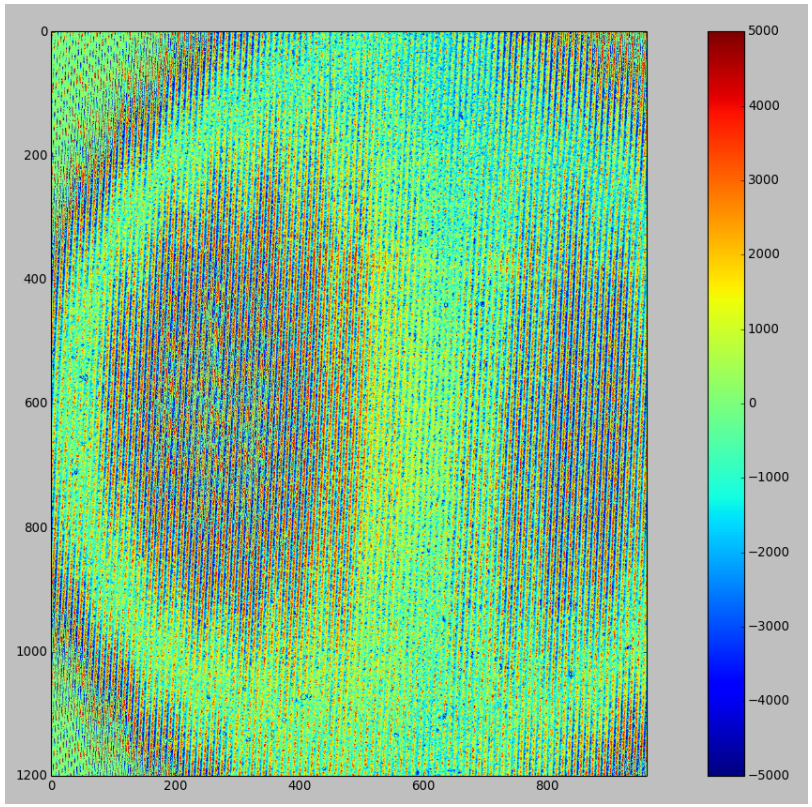


- The residuals are structured.
- It was expected : the test target is not perfect.

The residuals are structured

- When we rotate the test target, the residuals also rotate :





Ongoing work

- Better test targets would be easier to model : test new ones (sinusoïdal target, Ronchi target).
- Make more complex models.
- Once the illumination is understood : fit static distortions.

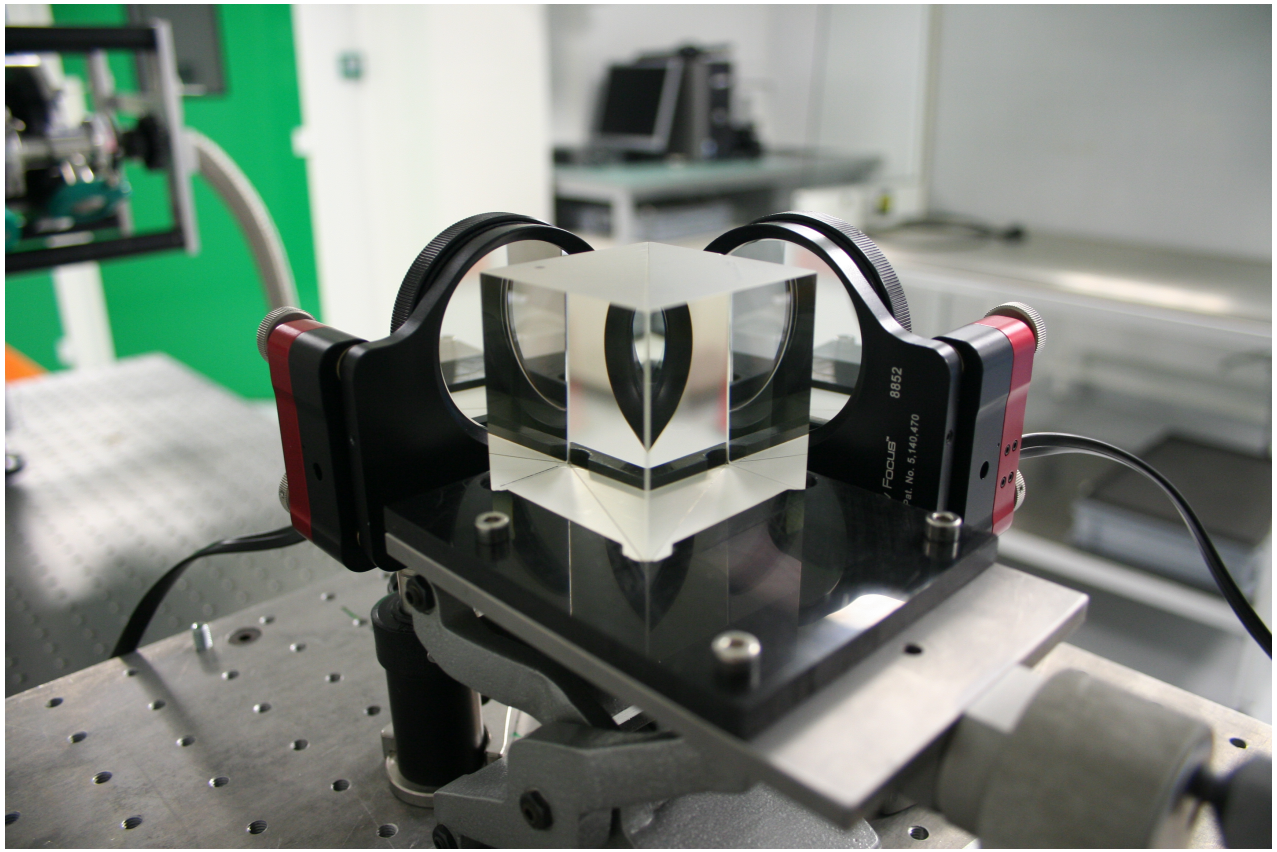
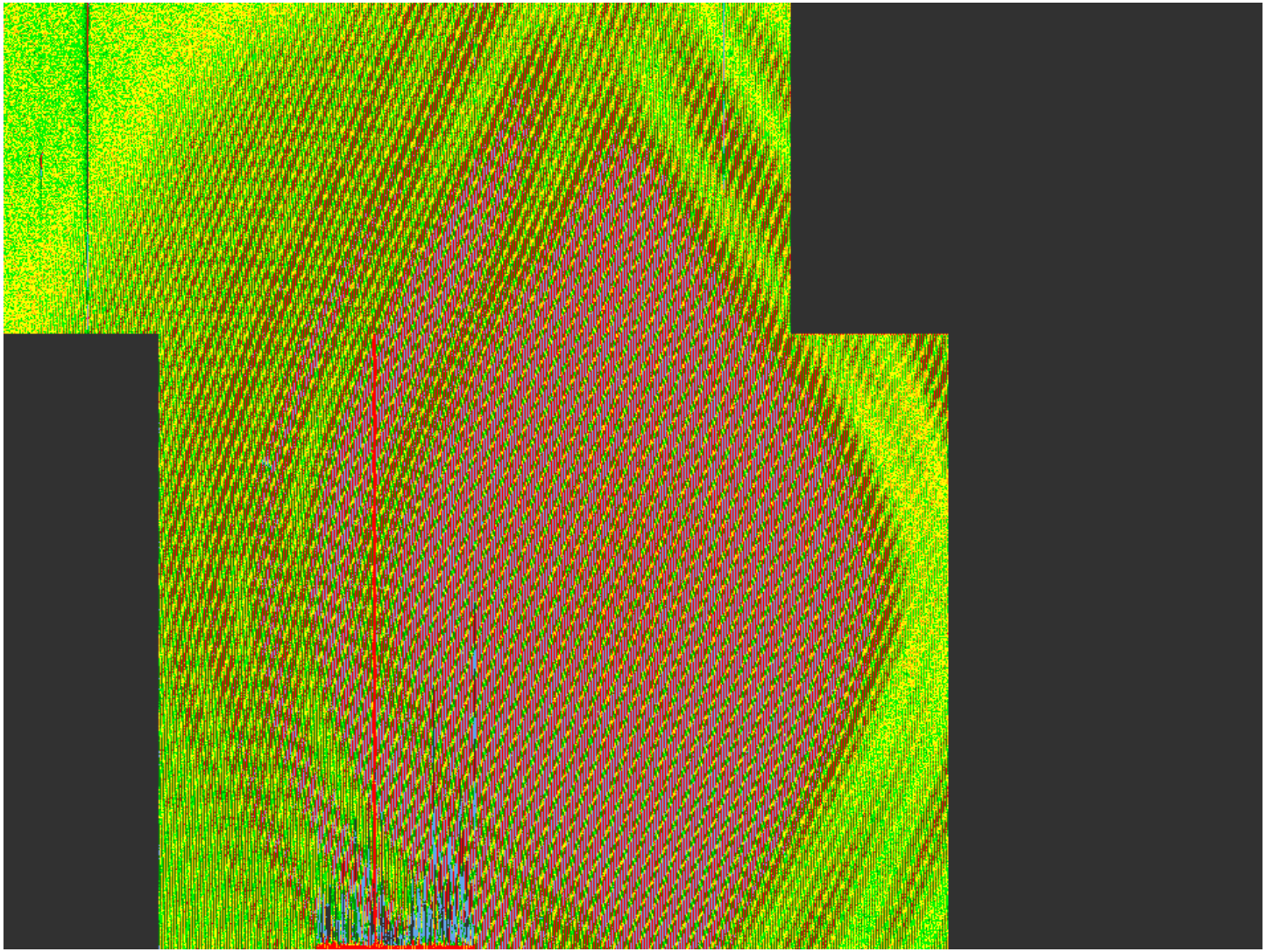
Backup slides

Backup slides

Backup slides

Michelson interferometer is being tested :

- Too much vibrations in the room.
- Very difficult to image the fringes.
- Sismograph data have been taken for several weeks.
- Vibration are being studied.



Flatfielded image with baffling