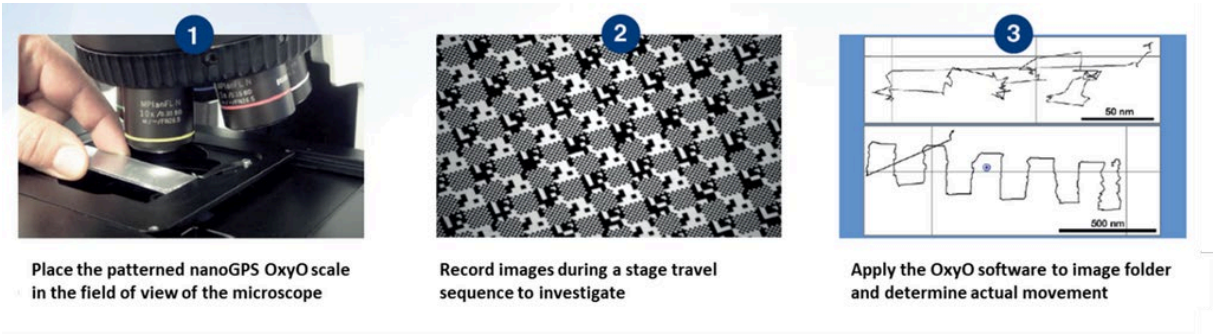
Table of Contents

1 Introduction

A nanoGPS OxyO® kit is a powerful tool to measure the in-plane position and orientation of displacement tool, in the referential of a vision system.
The kit consists in a scale, and a licence of the OxyO software.

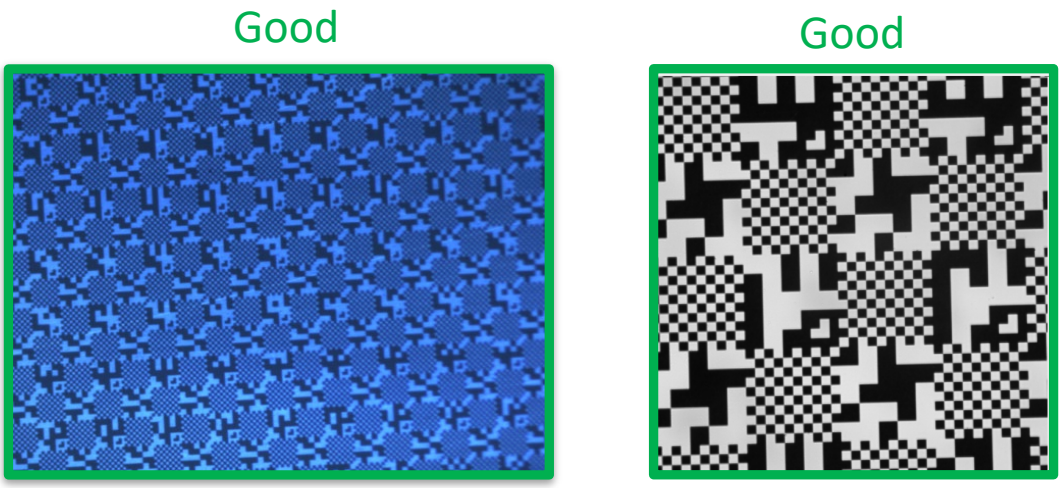


Different scales and associated software licence are available on the online HORIBA Store [Position Sensing (horiba.com)]

2 Getting started

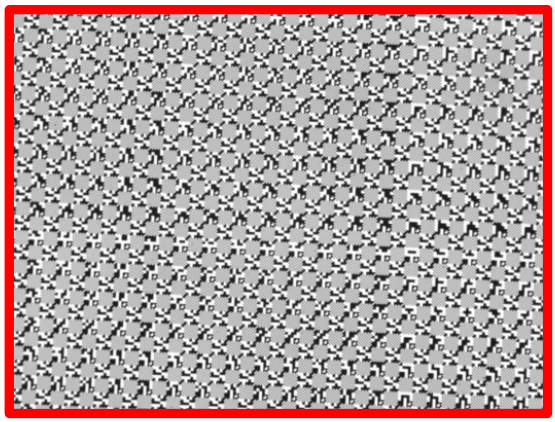
2.1 Recording pictures of the nanoGPS scale with an imaging device

The scales can be read on any vision devices, such as microscopes using either reflection illumination or transmission illumination. The magnification of the imaging device should be large enough so that

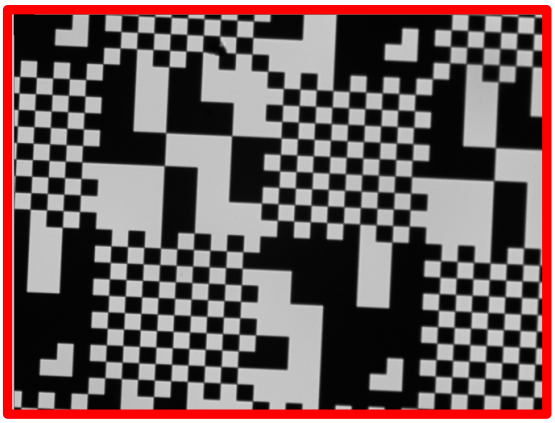


the individual squares of the patterns have a fair resolution (typically, at least 6 pixels per square), but not too large so that the field of view is large enough (typically, at least 5 uncropped chess patterns).

Bad



Bad



2.1.1 Image format

- .Tiff or .BMP (but NOT as .jpeg). Only for monochrome image .PNG is adequate.
- Image dimensions should be even (a **multiple of 2**).

2.1.2 Camera settings

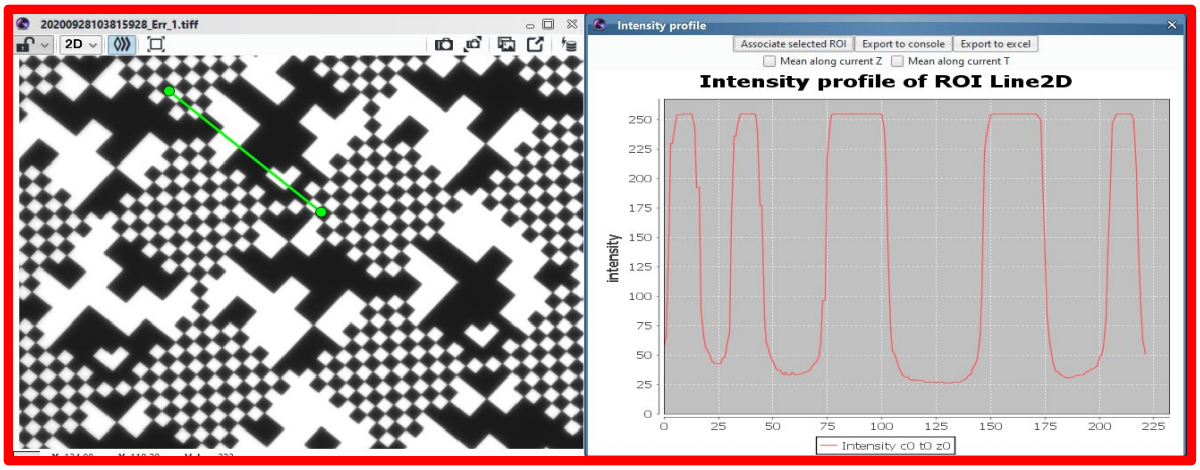
The camera used can be monochrome (preferred), or color.

- **Exposure**

There should be sufficient light so that the black and white patterns appear clearly. Some automatic camera adjustment (auto gain, automatic adjustment of black level, etc..) may be detrimental to image quality and ticked off.

Too much light is also inappropriate, and the exposure settings should be set to avoid saturation.

Bad



- **Cropping**

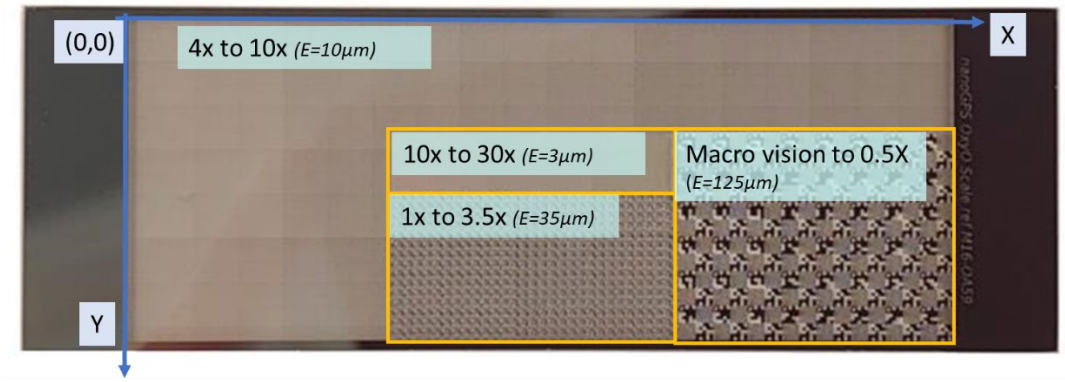
In the case some crop option is used to reduce the field, it is recommended that the cropped zone is centered on the sensor (because of lower optical aberration at the center).

- **Binning and undersampling**

Binning and undersampling can be used to decrease the image size and have faster acquisition and treatment. On some camera, undersampling is more effective in increasing the framerate than binning.

2.1.3 Using a microscope

A nanoGPS OxyO slide can accommodate a range of objectives. While the details depend on the pixel size and pixel number of the camera, tube lens, etc…, it can be mentioned that x10 and x5 objectives are suitable for all nanoGPS scales designed for microscopy.
The evaluation kit can have different zones with different scales, as shown on the figure below. The figure indicates the recommended magnification ranges for each zone, along with the dimension E of the individual squares of the chessboard patterns.



2.1.4 Using another imaging device

Home-made imaging devices can be used with nanoGPS OxyO scales. In the case of diffuse illumination is used, it is recommended to stick a white paper at the back of the scale. The white backing acts as a backside diffuse illumination.

2.2 OxyO Software

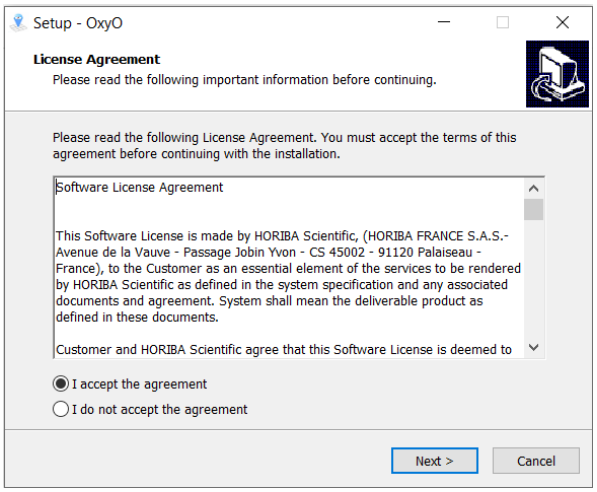
2.2.1 Download

To download the software, click the following link nanoGPS_OxyO Software-1.0.05 , and insert the password ZU428376VAUK to unzip the file.

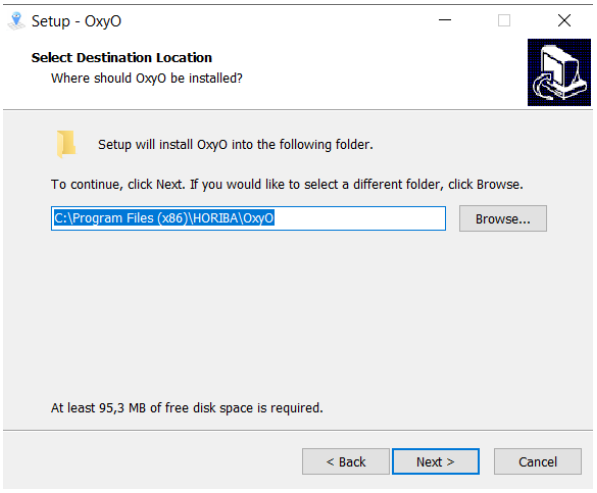
2.2.2 Installation

To install the software, just follow these 4 next steps:

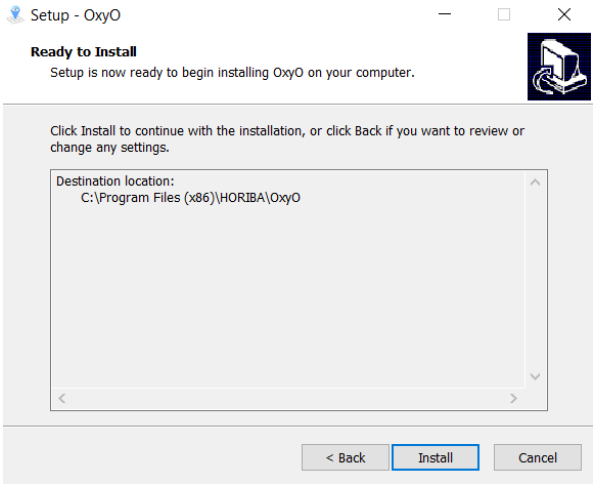
1. After downloading the software, unzip all the files into a desired directory.
2. Next, execute the file ***OxyO-Setup.exe***.
3. Accept the conditions of the license and click ***Next >***.



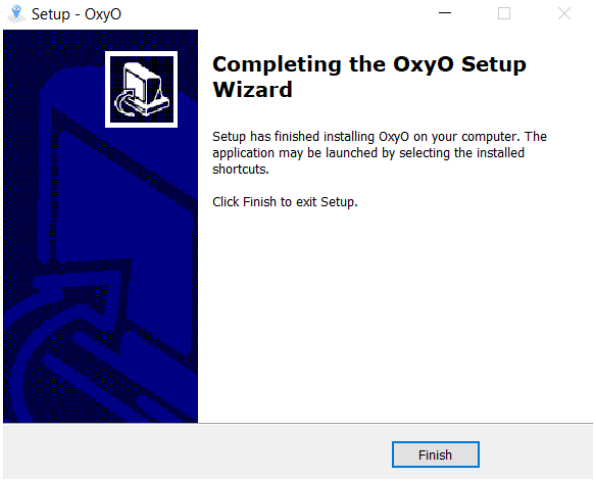
4. Choose the installation folder and click ***Next >***.



5. Confirm the installation by clicking ***Install***.



6. Wait until the installation is concluded and click ***Finish***.

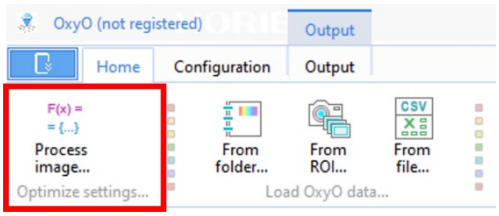


After finishing the installation, the software is ready to be opened and used.

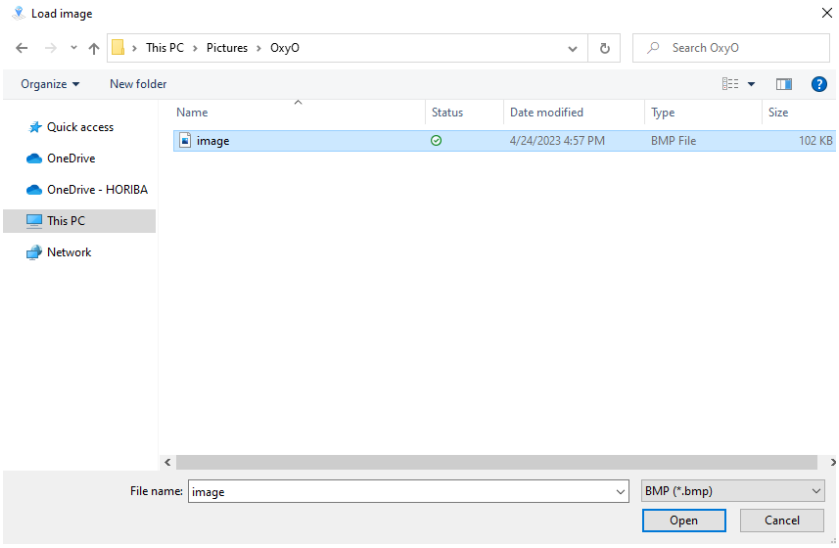
2.2.3 Processing the first image

To process and analyze your first image, just follow the next steps:

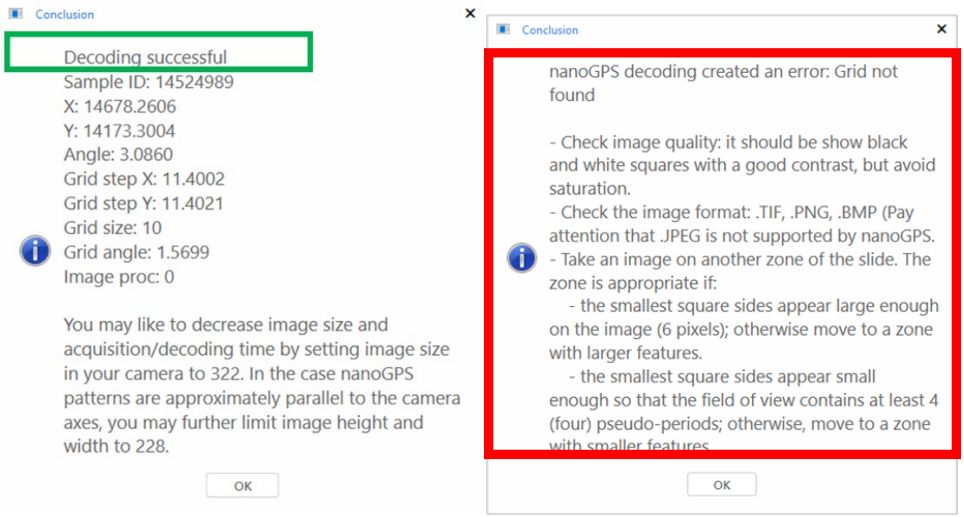
1. In Home tab, click **Process image…**



2. Select the desired image and click ***Open***.



3. If successful, the result below will be shown (left side). Otherwise, an error message will be displayed (right side).



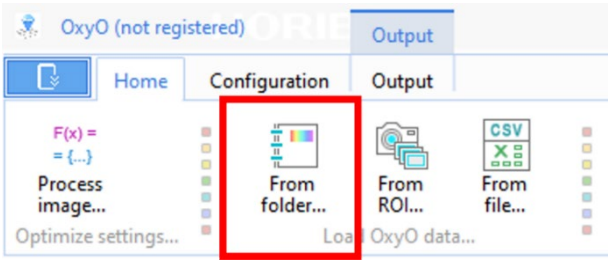
To know how to understand the results, see the section **Handling results**.

3 Position determination strategies

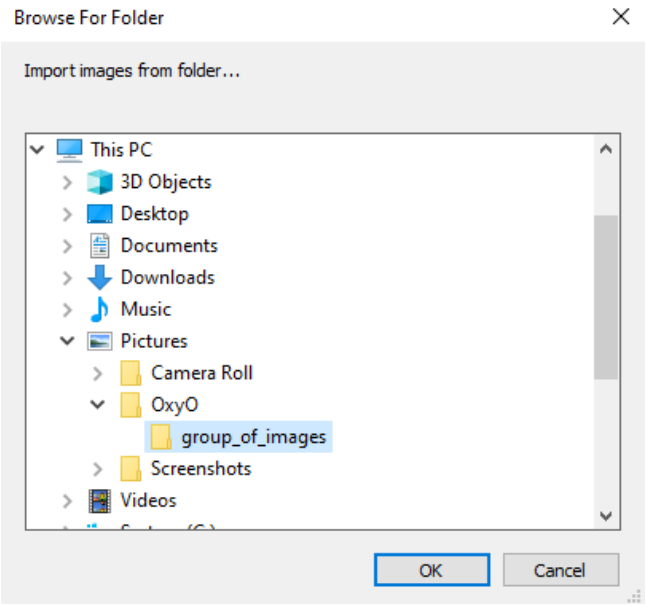
3.1 From folder

With *From folder…* option is possible to process multiple images simultaneously.

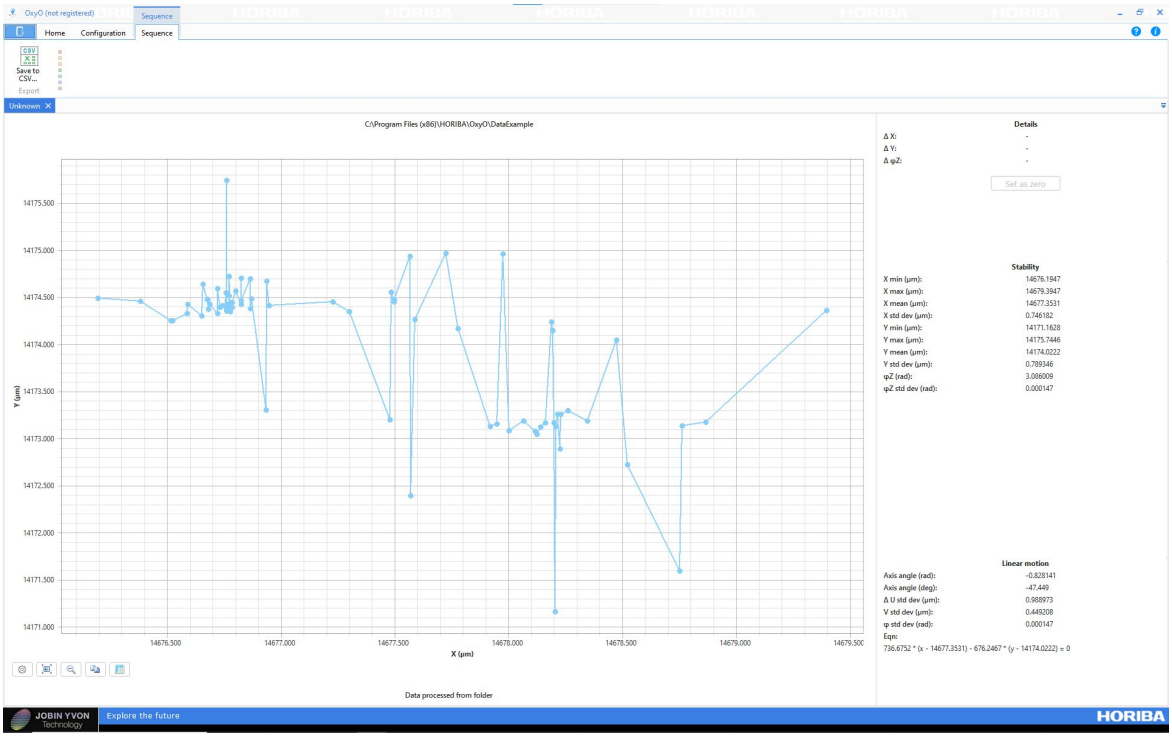
1. In the *Home* tab, click ***From folder***.



2. Select the folder containing the images to be processed and press ***OK***.



3. *Unknown* window result will be open.

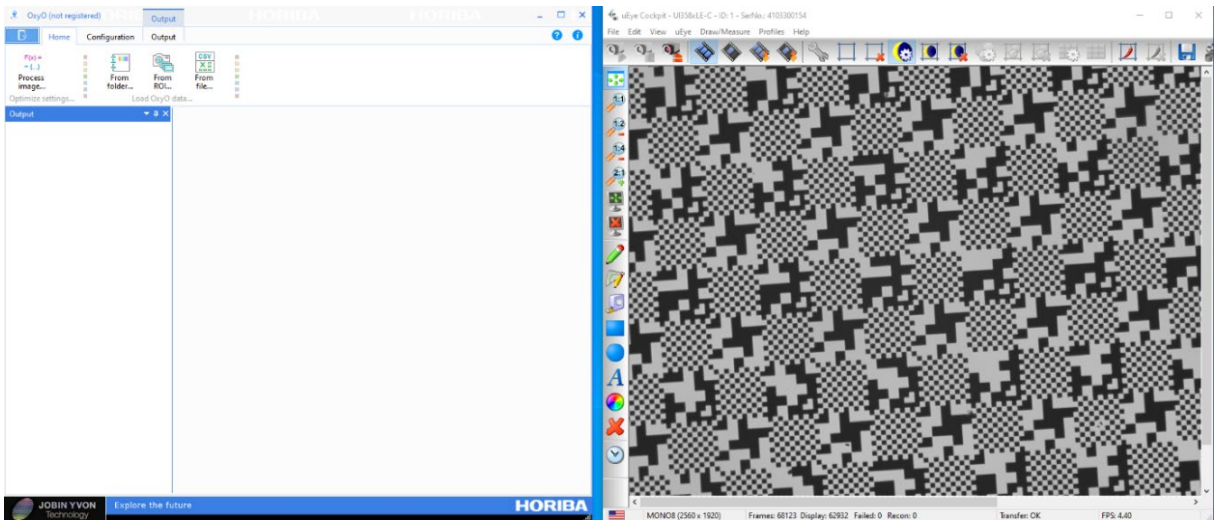


To know how to understand the results, see the section **Handling results**.

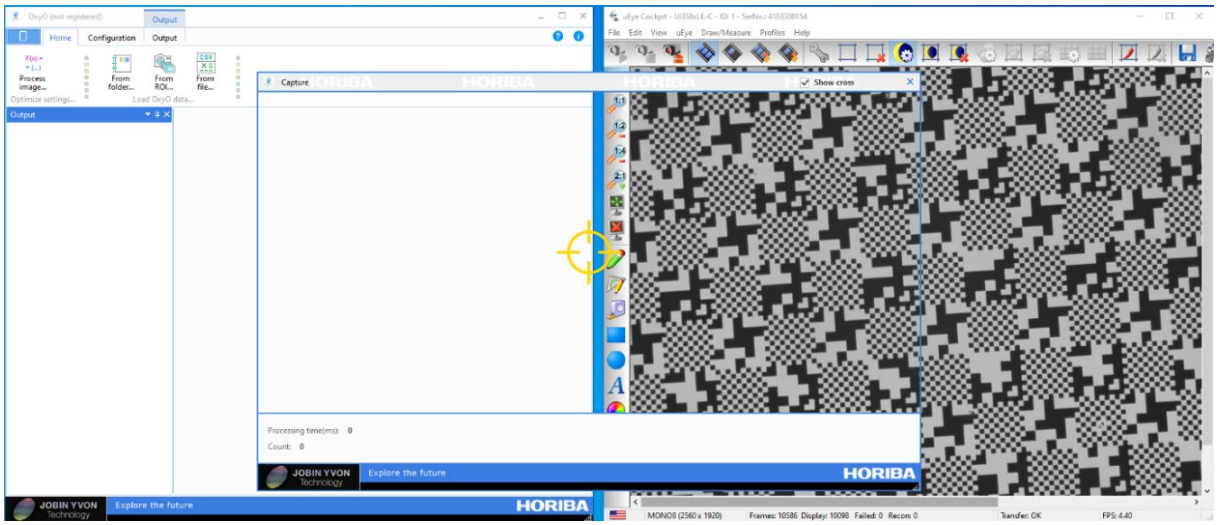
3.2 From ROI

With *From ROI* is possible to collect data directly from the camera video. To do so, follow the next steps:

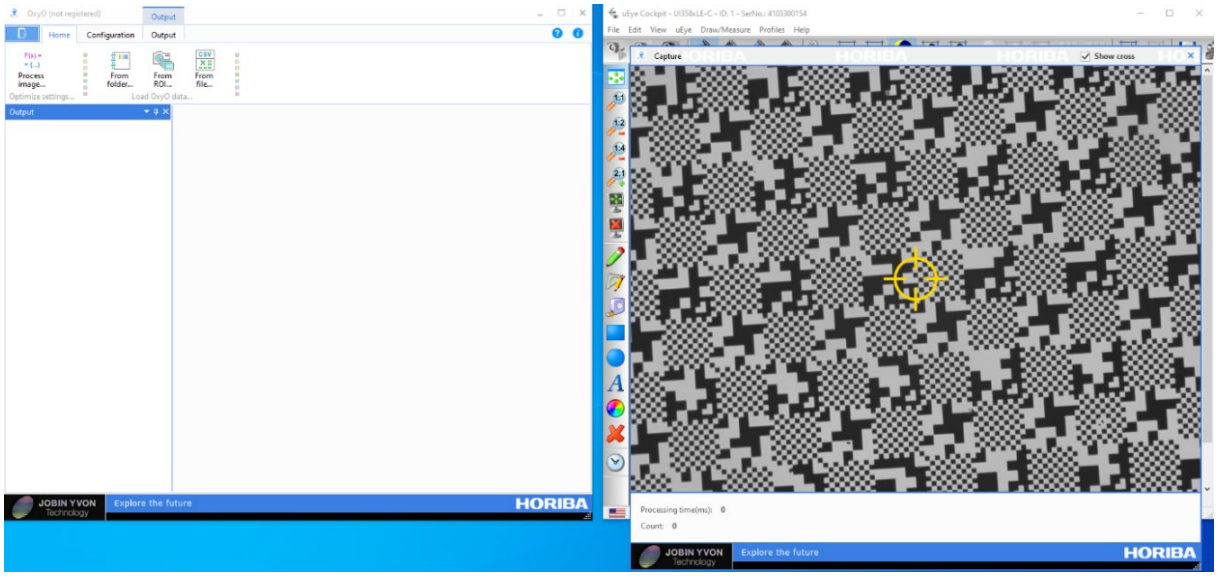
1. Open OxyO and the camera software, side-by-side.



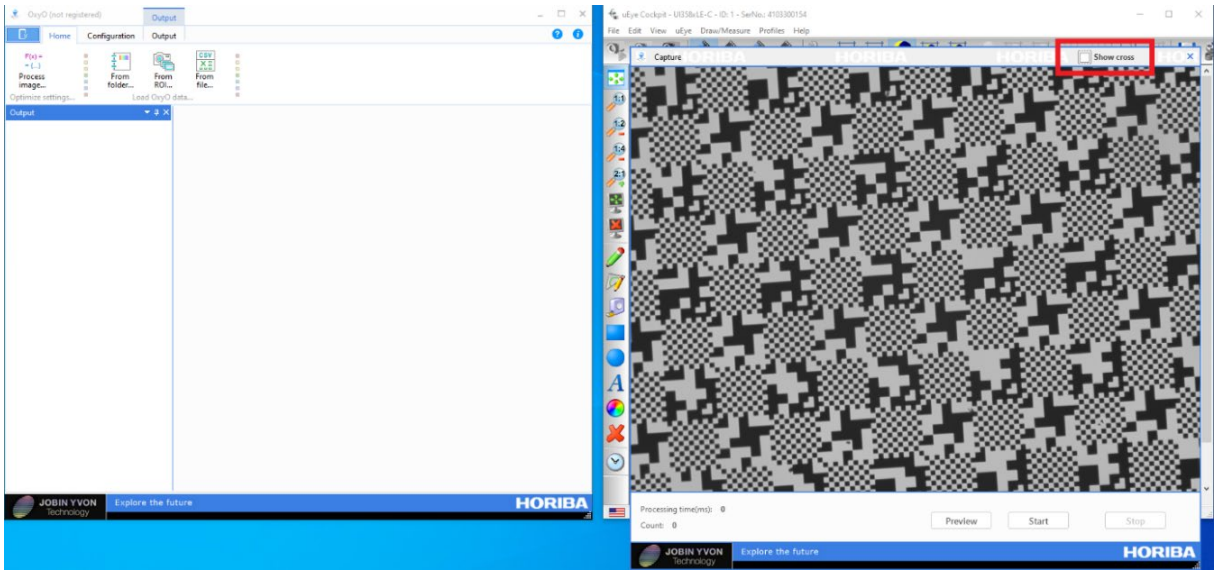
2. In *Home* tab, click ***From ROI***. A *Capture* window will be opened.



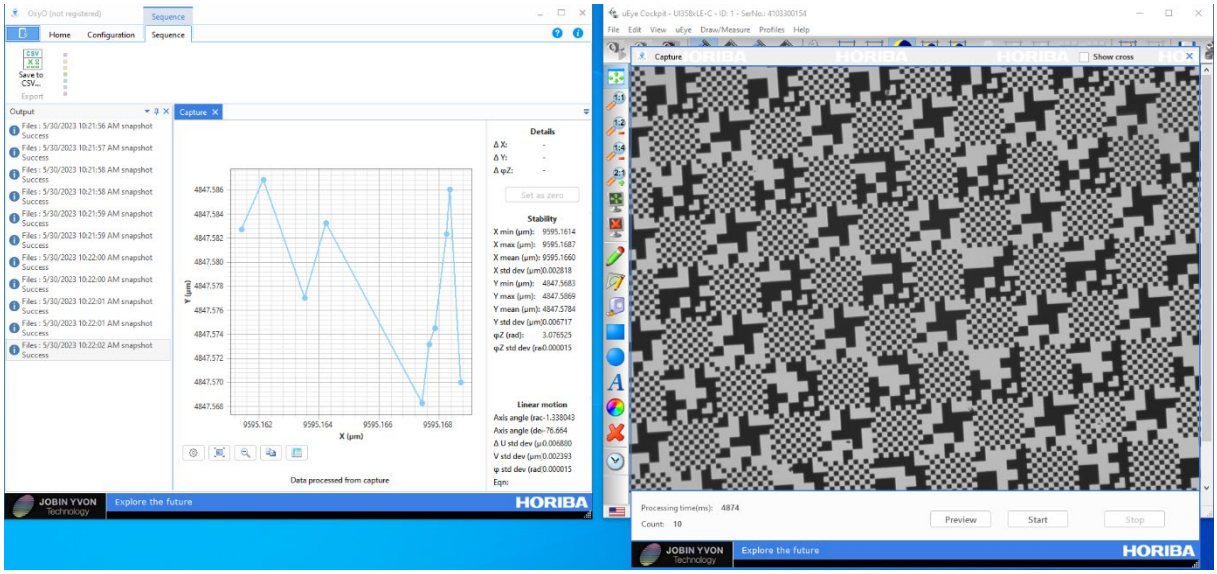
3. Resize the *Capture* window over the camera profile.



4. Unselect the option ***Show Cross*** to see the *Preview, Start* and *Stop* buttons.

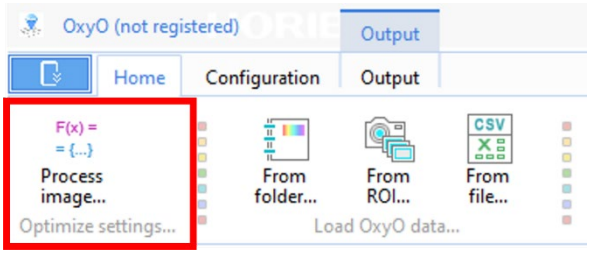


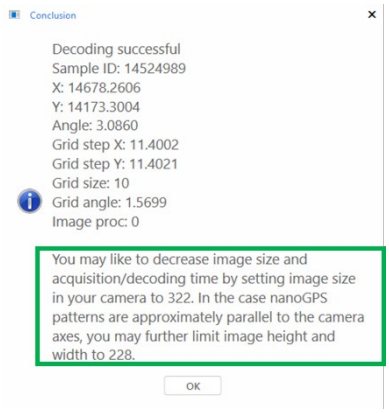
5. Click ***Preview*** to verify the image acquiring. Then, click ***Start***. When the number of data is enough, click ***Stop*** and a graph with be plotted.



3.3 To go faster

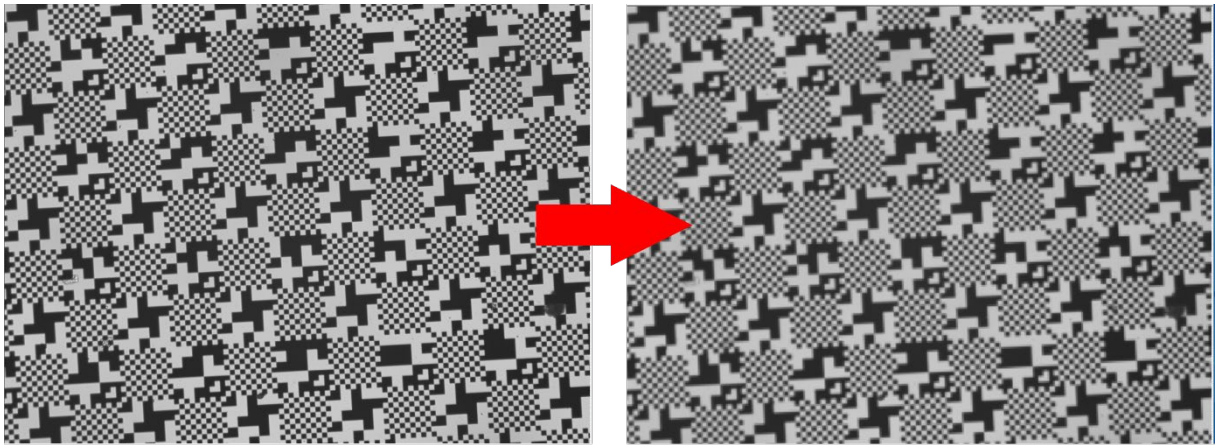
If a faster acquisition and processing is needed, then it is a good idea to perform appropriate binning (or undersampling), and cropping. By applying “Process image” to an image taken without binning or cropping, it is possible to get the recommendation on the binning and cropping parameters.





The process is illustrated by the following example. The first image below is processed using “process image”, which yields suggestion on binning and cropping. The camera settings can be adjusted:

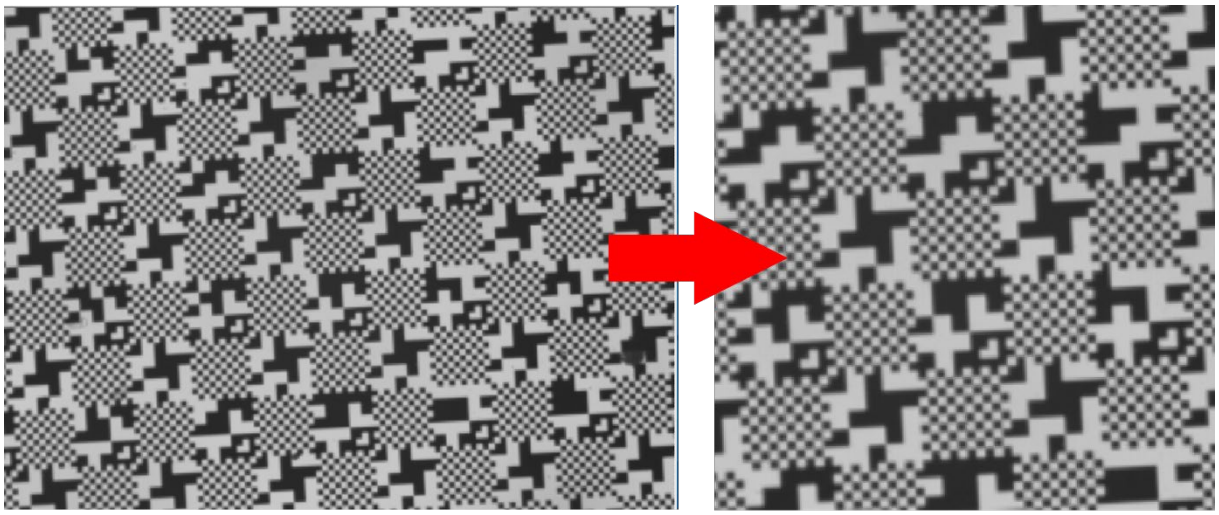
1. Make a binning 4x in the vertical and horizontal axes of the image to reduce its size. At left, we have the original image, and at right, the binned image.



2560 x 1920 px

640 x 480 px

2. Create an area of interest (AOI) with size 322 x 322 at the center of the binning image.



640 x 480 px 322 x 322 px

3. It is also possible to control image gain, gamma factor and time exposure to obtain the best contrast.

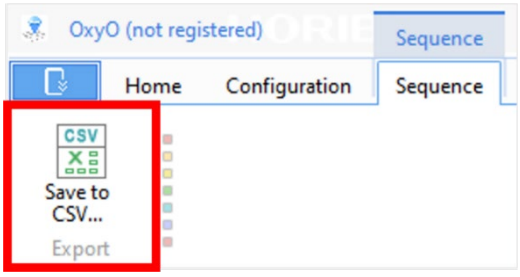
> ***Remark:*** A good strategy to achieve a high contrast is to set a high intensity light source and control the exposure time in camera software to avoid saturation. Also, we set up all the color gains, and gamma factor, to 1.

4 Handling results

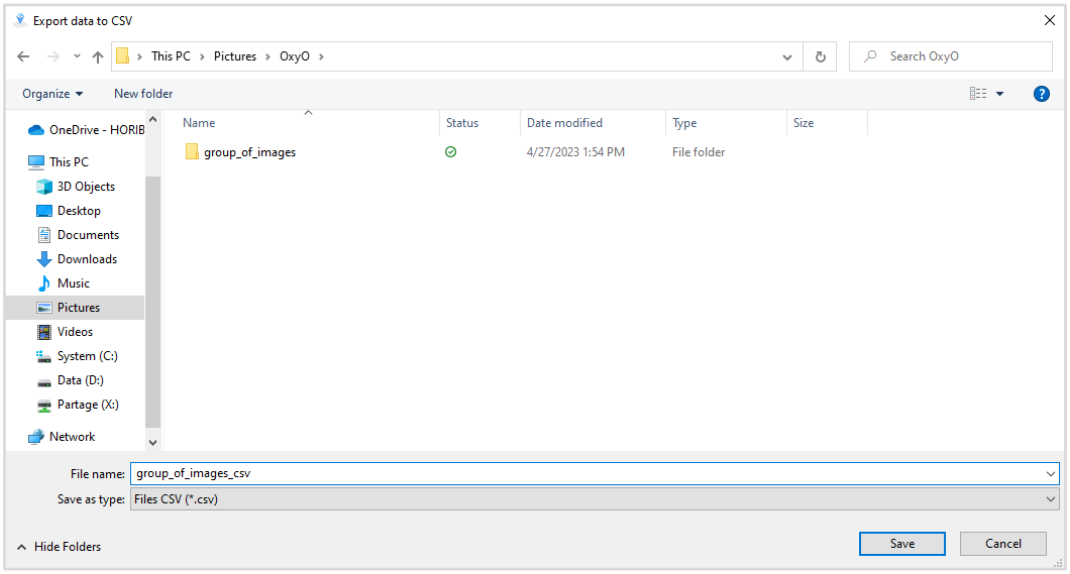
4.1 Saving to a .CSV file

To save the processing as .CSV file, follow the steps below.

1. After generating the graphs from the sections From folder and From ROI, in tab ***Sequence*** click ***Save to CSV***.



2. Choose the destination folder and the file name and click Save.



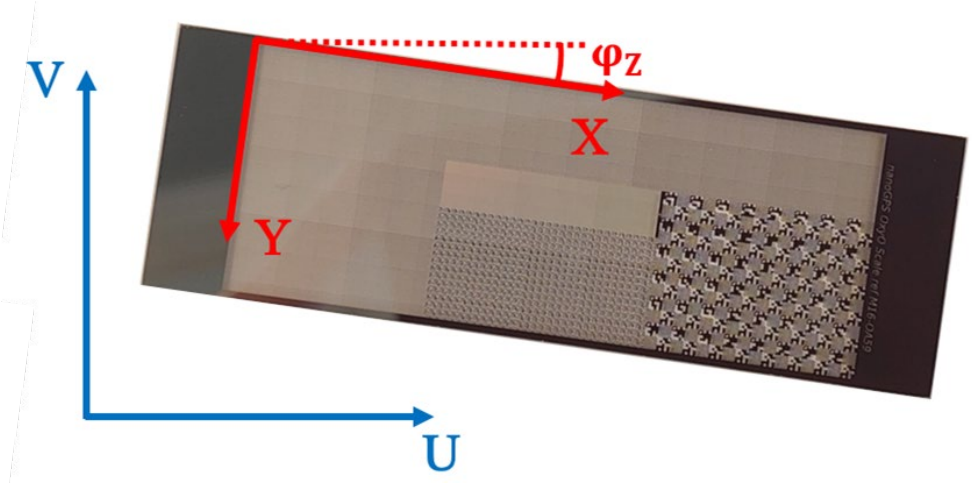
3. The .CSV file has the following structure.

name	timestamp (ms)	date	x (um)	y (um)	phi_z (rad)	pixel size (µm/px)	grid size (µm)	error
st-img_0.bmp	0	23-04-24 16:54:45	14644.691	14818.215	3.086142	1.753888	10	
st-img_1.bmp	1125	23-04-24 16:54:46	14644.682	14818.202	3.086140	1.753794	10	
Filename	Sampling time (useful to plot as a function of time)		Motif position relative the nanoGPS axis		Angle between the nanoGPS and the mouvement axis	Magnification		

It should be noted that the timestamp corresponds to the file creation.

4.2 Referentials

The position that is returned by the nanoGPS software is that of the image center in the referential of the scale. The angle is the angle between the horizontal camera axis (labelled U on the figure below) and the scale axis (labelled X).

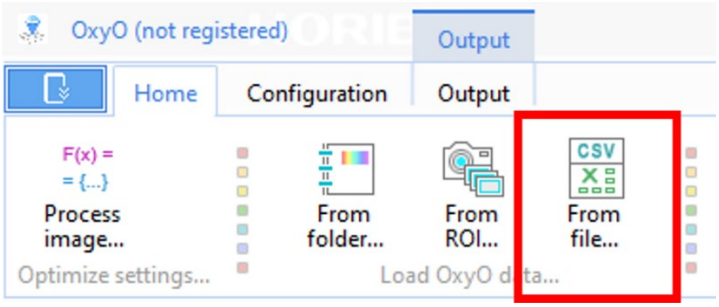


It may be convenient to express the observed movements in the camera coordinates, which is easily done by transforming the observed displacement (ΔX, ΔY) by a rotation with angle φ_z.
The camera and stage are generally fixed so that their axes are nearly parallel, in practice they differ by several mrad. This residual angle can be determined using nanoGPS.

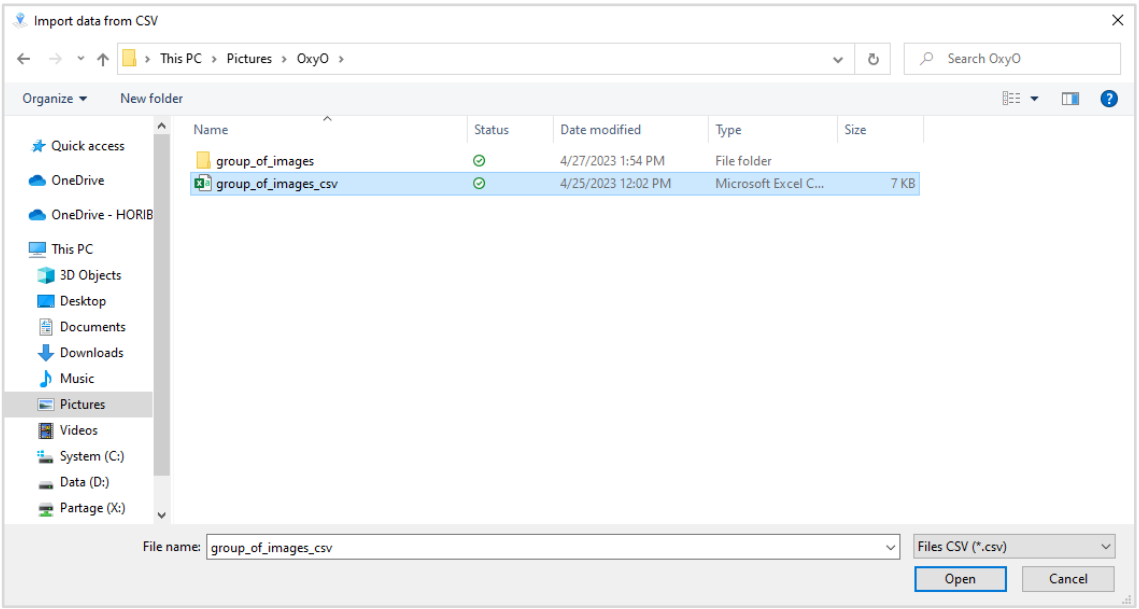
4.3 Plot

To plot a graph directly from a .CSV file saved with help of the section **Saving to a .CSV file**, just do the following steps.

1. In Home tab, click From file.



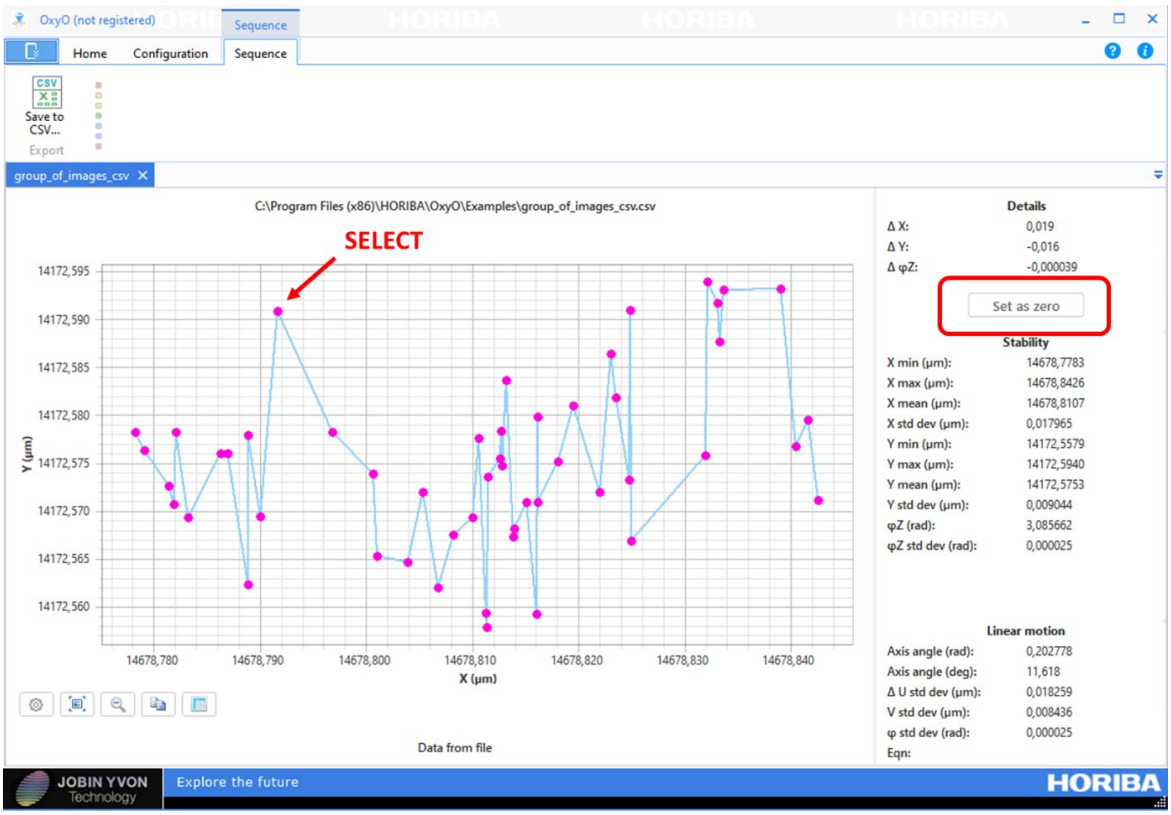
2. Choose the .CSV file and click Open.



4.4 Data analysis displayed on OxyO software

- **Details**

To show the Details, first select one of the discrete data in the graph that is more convenient, then click Set as zero.



- **Stability**

It provides data treatment that is relevant in the case the measurements correspond to position measurements in situations where no intentional displacement has been performed.

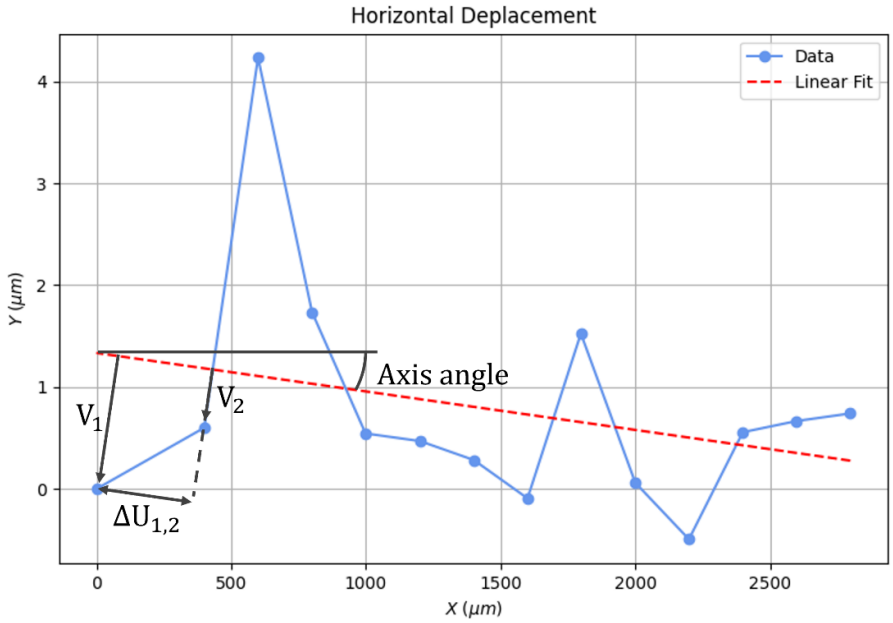
Stability	
X min (µm):	0.0000
X max (µm):	3.2000
X mean (µm):	1.1585
X std dev (µm):	0.746182
Y min (µm):	-3.3315
Y max (µm):	1.2503
Y mean (µm):	-0.4721
Y std dev (µm):	0.789346
φZ (rad):	3.086009
φZ std dev (rad):	0.000147

- **Linear motion**

Consider the following experiment that can be performed with a microscope equipped with a moving stage: take a first picture of the scale, move the stage along one axis (let us call it U) by DU (µm), take a second picture of the scale, move the stage by the same amount DU (µm), repeat a few other times.

Then the "linear motion" treatment based on the least squares approximation method provides useful information on the accuracy of the linear displacement.

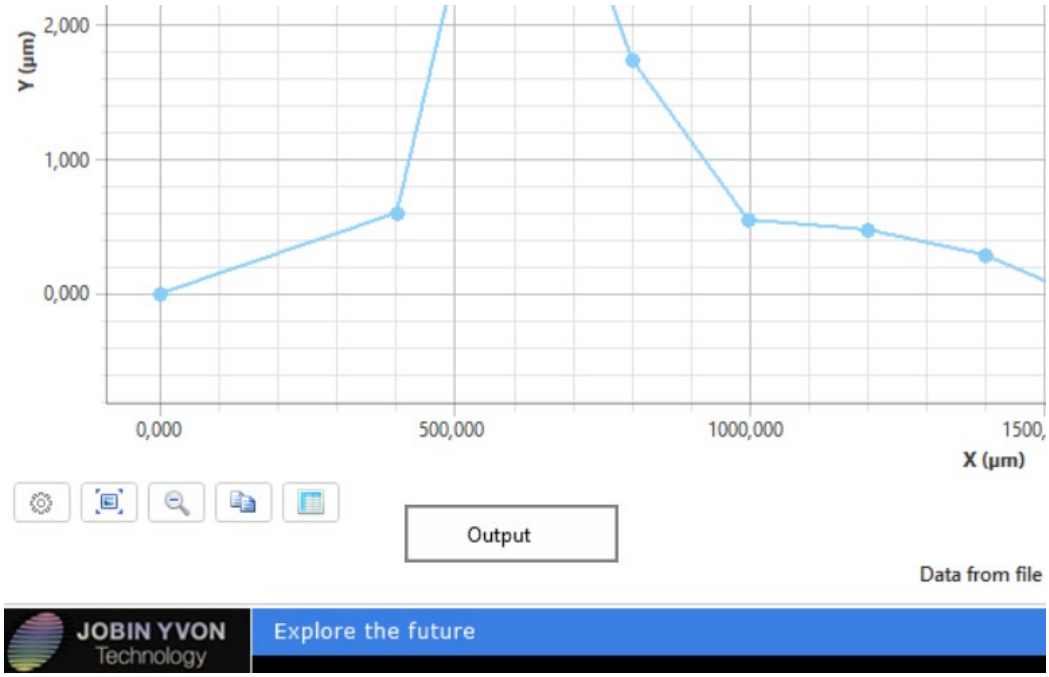
Linear motion	
Axis angle (rad):	-0.828141
Axis angle (deg):	-47.449
Δ U std dev (µm):	0.988973
V std dev (µm):	0.449208
φ std dev (rad):	0.000147
Eqn:	
736.6752 * (x - 1.1585) - 676.2467 * (y + 0.4721) = 0	



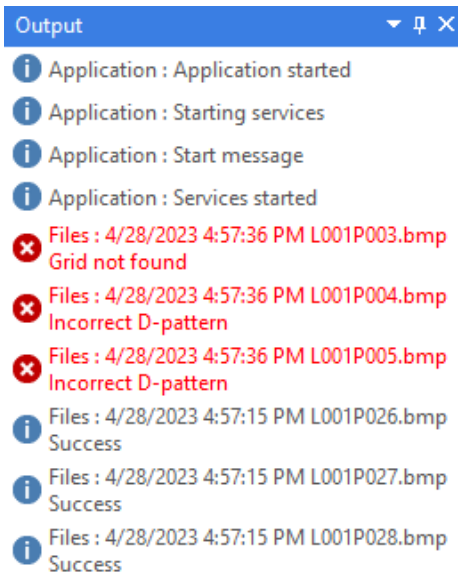
5 Troubleshooting

5.1 Displaying the Output tab

One troubleshooting method recommended is to check the output files window to see which files were well processed and which one has failed. To do so, just right click under the graph and select ***Output***.



The *Output* tab will open at left side showing all successful and failed processing.



6 References

Several peer-reviewed publications feature different uses of nanoGPS OxyO® technology, most of them with earlier versions of software and hardware. The earliest have been presented at the European Society of Precision Engineers (EUSPEN), and at ISOT conference, and probably the easiest way to access them are the following link:

- https://www.researchgate.net/publication/370519951_Olivier-Acher-Postersession-2_ISOT_A4
- https://www.researchgate.net/publication/370490142_Position_control_solution_along_3_degrees_of_freedom_and_with_easy_implementation_for_Laboratory_and_Workshop
- https://www.researchgate.net/publication/370490127_Assessment_of_moving_stage_performances_used_in_scientific_instrumentation
- https://www.researchgate.net/publication/326106509_A_new_absolute_x_y_TH_encoder_with_flexible_implementation_and_standoff_reading_distance
- https://www.researchgate.net/publication/326106509_A_new_absolute_x_y_TH_encoder_with_flexible_implementation_and_standoff_reading_distance

A good synthesis has been presented at a SPIE conference:

- Proceedings Volume 11056, Optical Measurement Systems for Industrial Inspection XI; 110562O (2019) https://doi.org/10.1117/12.2524938

A thorough investigation on the angle precision and accuracy has been performed with the Italian National Metrology Institute, and published in the following open-access journal:

- https://www.mdpi.com/1424-8220/20/12/3462

Another declination of the nanoGPS technology is dedicated to correlative imaging. Though the corresponding products (also to be found on the HORIBA store) differ substantially, the seminal paper on the technology includes a detailed investigation on stage precision and accuracy carried using nanoGPS OxyO scales:

- https://iopscience.iop.org/article/10.1088/1361-6501/abce39/meta

We will make every effort to reference investigations by other groups carried out through nanoGPS technologies on HORIBA website.

7 Contact

Olivier.acher@horiba.com

8 Version History

Version	Date	Modification
A	19/04/2023	First release