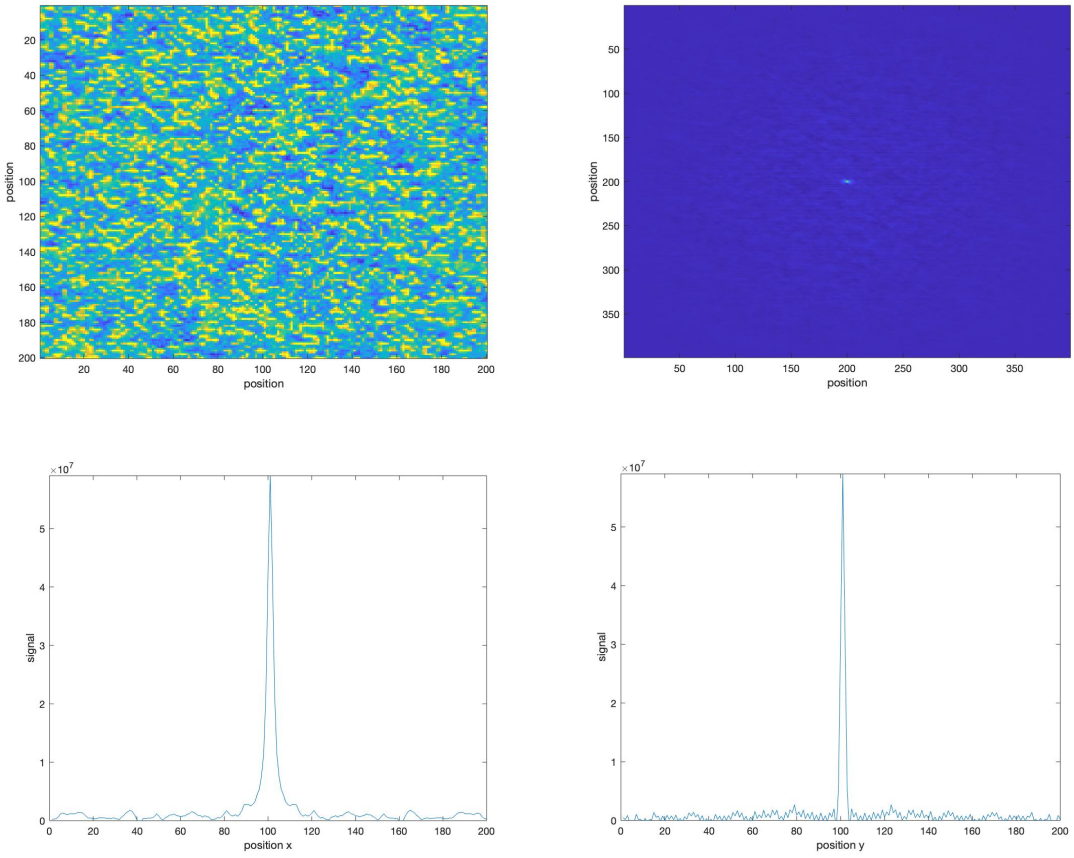
Speckle Sensor

5. Summary of tasks of the experimental work

4.2 Speckle size measurement (40 min)

Present one complete evaluation cycle as in the figure above. (4 graphs).



Set three (3) different speckles size and make a table with spot size and corresponding speckle size and theoretical speckle size. Do not forget to measure the distance between scattering surface and detector as well as the spot size to make the theoretical speckle size calculation. Make error estimation.

No	Spot diameter mm	Distance spot – detector mm	Theoretical speckle size microns $(\Delta x)_s = \frac{4}{\pi}\frac{\lambda d_I}{D_L}$	Speckle size from autocorrelation in px - x direction	Speckle size in from autocorrelation microns - x direction	Speckle size from autocorrelation in px - y direction	Speckle size in from autocorrelation microns - y direction
1	10	58	4.67	4	11.34	2	5.67
2	7	58	6.68	4	11.34	3	8.51
3	4	58	11.69	6	17.01	4	11.34

Error estimation for theoretical speckle size. The error of the spot diameter and distance measurements need to be considered.

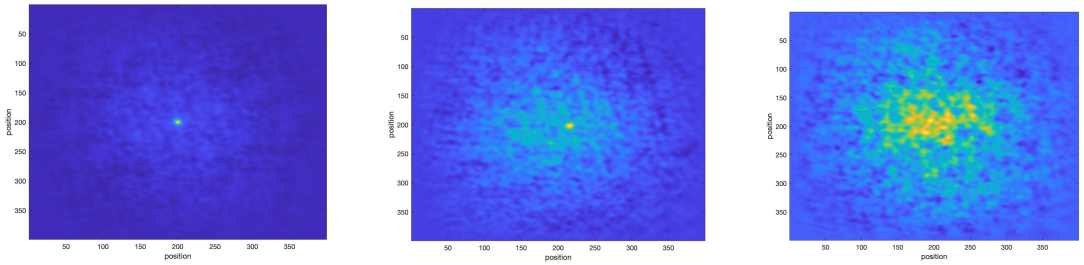
$$\delta(\Delta x)_s = \frac{4}{\pi}\frac{\lambda d_I}{D_L} = \frac{4}{\pi}\lambda\left(\left|\frac{1}{D_L}\delta d_I\right| + \left|\frac{d_I}{D_L^2}\delta D_L\right|\right)$$

The error are (by taking 10% error on DL and dI) for:
DL = 10mm → 0.93 um
DL= 7mm → 1.34 um
DL = 4mm → 2.33um

We see that the smaller is the spot diameter, the better is the precision of measurements. It is because smaller spots create bigger speckles which leads to better precision of measurements. The theoretical speckle size is for a circular speckle, but in reality, speckles are not circular which leads to different sizes in x and y direction. To sum up: the smaller the spot size, the more likely we are to get a precise measurement.

4.3 Speckle motion sensor (60 min)

Find the maximum displacement (no information content) and read the value on the linear stage. Document the de-correlation with three images: Autocorrelation, intermediate value, fully de-correlated.

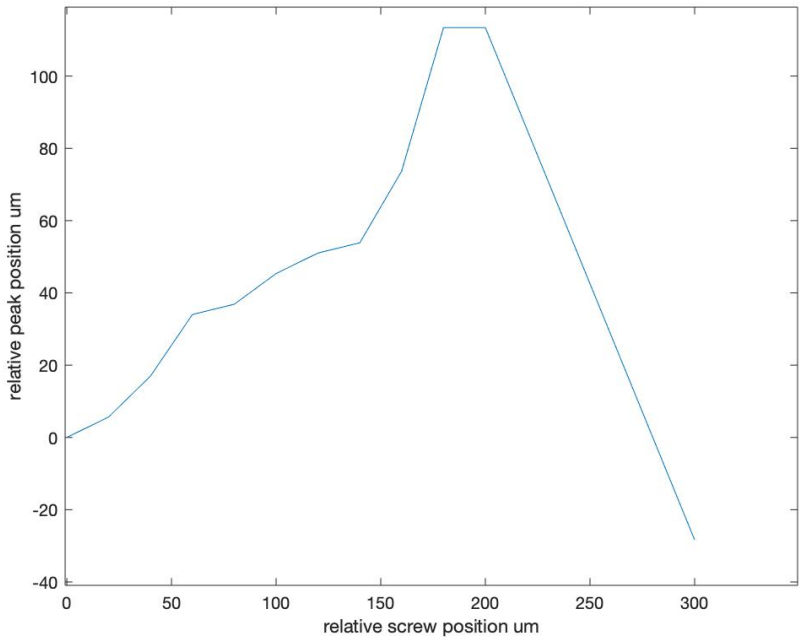


From left to right: Autocorrelation, intermediate value, fully de-correlated.

Measure the displacement within the measurement range by speckle autocorrelation for a minimum of **ten** positions at the linear stage and draw a graph (plot – position of the stage against position evaluated by speckle sensor, print it in the document).

Evaluation is done in the autocorrelation plots and not in the line plots.

No	Absolute position on the micrometer screw in mm	Relative position on the micrometer screw in mm	Relative position from cross-correlation in px	Relative position from cross-correlation in micron
1	10	0	101	286.3350
2	10.02	0.02	103	292.0050
3	10.04	0.04	107	303.3450
4	10.06	0.06	113	320.3550
5	10.08	0.08	114	323.1900
6	10.10	0.10	117	331.6950
7	10.12	0.12	119	337.3650
8	10.14	0.14	120	340.2000
9	10.16	0.16	127	360.0450
10	10.18	0.18	141	399.7350
11	10.20	0.20	141	399.7350
12	10.30	0.30	91	257.9850



The plot should show linear stage position and peak position evaluated by the cross-correlation!!! Both in micron!

Max movement distance:
When taking the initial speckle at center of image: sizeofROI/2 * 2.835um = 200px/2 * 2.835um = **283.5 um** for a displacement in every direction

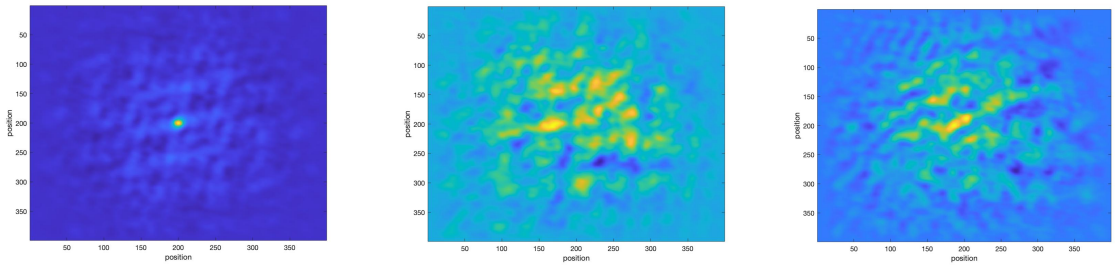
When taking the initial speckle at the border of image: sizeofROI * 2.835um = 200px * 2.835um = **567 um** we can detect double the displacement in the x or y direction. This is the case when we compute the correlation as every pixel is accounted for (and not just one at a specific position).

What determines the maximum movement distance? Find the two factors!
The maximum movement distance is determined by the size of the ROI (here 200px) and by the location of the initial speckle in the image. So, by taking off-center speckles we can increase the maximum movement distance.

In the graph relating screw position to peak position we can see that the last two to three points are fully de-correlated (non-linear relationship) which makes sense as we pass the 200px mark of maximum movement distance.

4.5 Boiling speckles (20 min)

Show **three** (3) correlation images, one in autocorrelation and two for boiling cross-correlation when the movement is in opposite directions. Give the minimal movement distance for the fully de-correlated image.



From left to right: Autocorrelation, cross-correlation left, cross-correlation right.

Minimal movement distance: In our case the cross-correlation occurred with relative distance of 0.03mm and we see fully de-correlated images so we can conclude that the minimal movement distance is less or equal to 0.03mm.

Personal feedback:

Was the amount of work adequate? Yes

What is difficult to understand? More difficult than precedent TP

What did you like about it? Windows crash in online video for TP

How can we do better? By doing real TP ☺