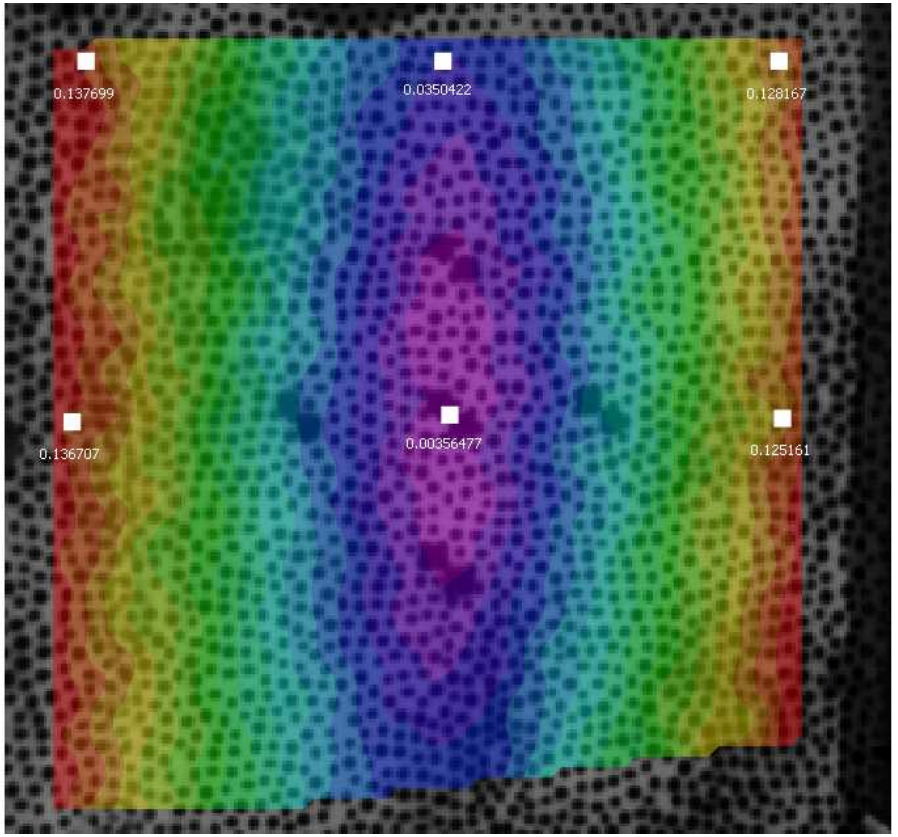
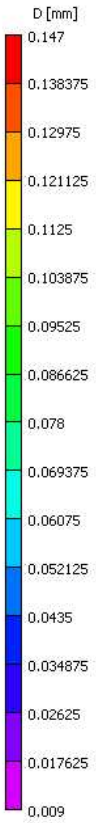
Synchronization Errors in High-Speed Digital Image Correlation

SAND2009-3290C





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Phillip L. Reu and Timothy J. Miller
Senior Member Technical Staff

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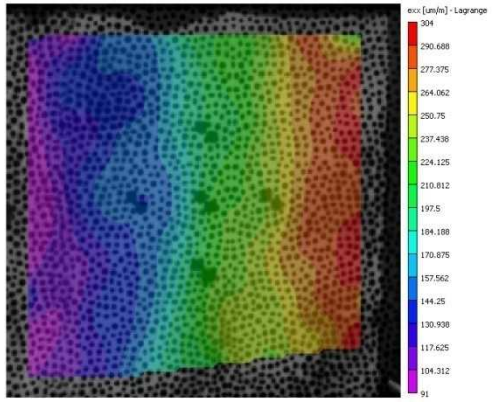
Synchronization errors may corrupt the DIC results

Synchronization Testing of Cameras

Frame Rate (Hz)	Sync Mode	Camera Exposure (µs)	IRIG Error (ns)	Strobe Error (ns)	Corrected Error (ns)
64,000	FSYNC	1	640	28	18
64,000	IRIG	1	10	330	18
66,037	FSYNC	0.3	1150	26	18
175,000	FSYNC	0.3	7400	50	18
175,000	IRIG	0.3	10	356	18
320,000	FSYNC	0.3	82,000	55	18
320,000	IRIG	0.3	10	276	18

Synchronization Results



DIC Error Modeling of Synchronization Errors

Best Practices

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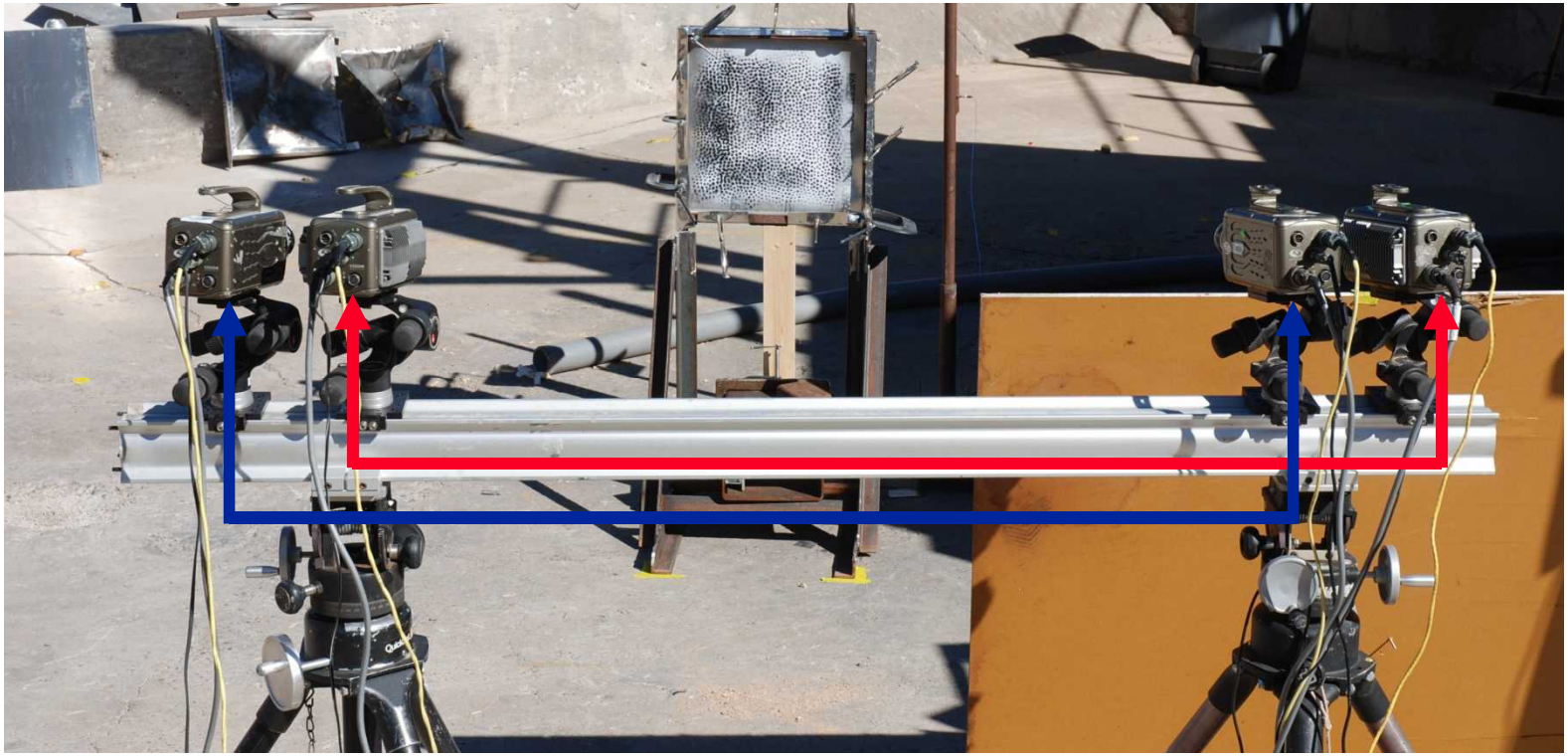
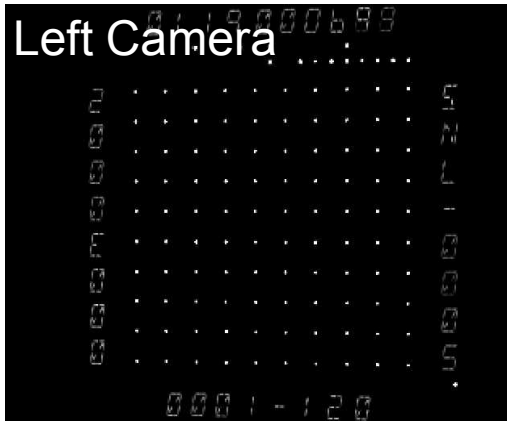
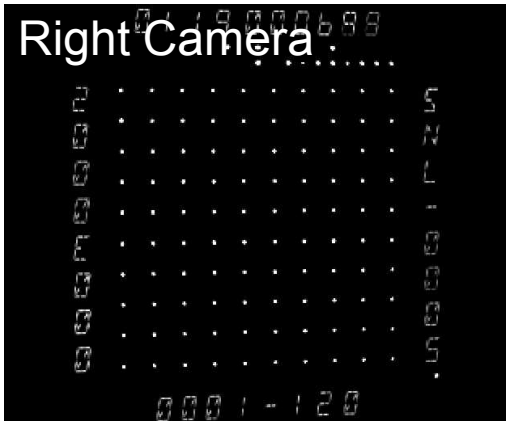
Perfect synchronization can be difficult to achieve with high-speed cameras

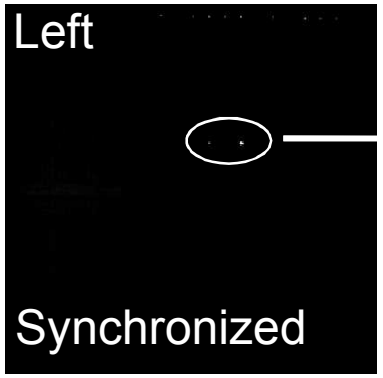


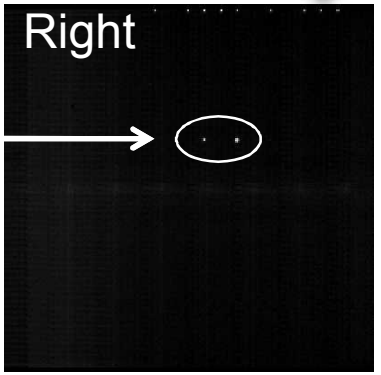
Interlacing of two stereo-rigs was the experiment which prompted the study of the synchronization issue.

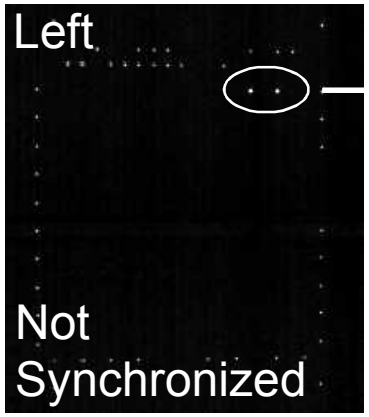
An LED array (LabDITC) was used to optically test synchronization

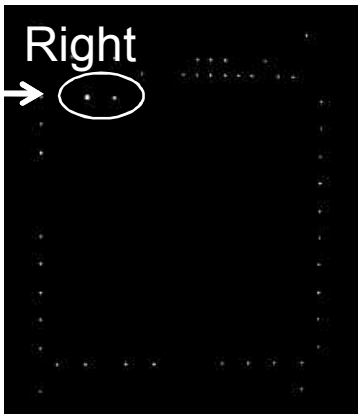












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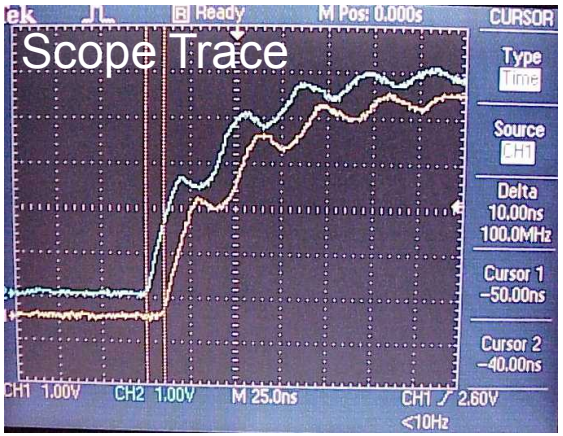
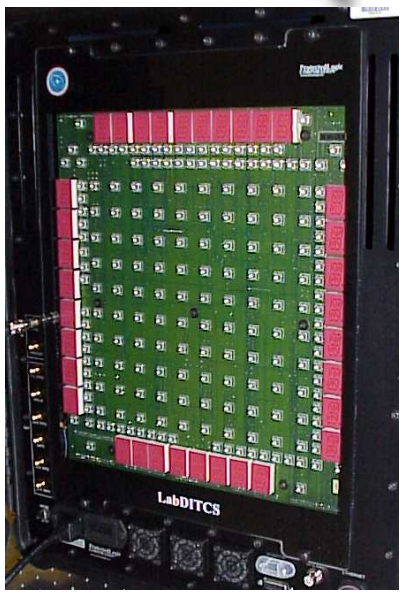
The Strobe or clock output can be used with an oscilloscope to test synchronization





- On the Phantom cameras, the strobe output is not available without creating a breakout box from the large canon plug
- The Shimadzu cameras provide a clock output pulse which indicates the camera framing

Synchronization can be achieved with the Phantom cameras if care is taken

Frame Rate (Hz)	Sync Mode	Camera Exposure (µs)	IRIG Error (ns)	Strobe Error (ns)	Corrected Error (ns)
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64,000	IRIG	1	10	330	18
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320,000	IRIG	0.3	10	276	18

Notes:

- FSYNC mode is always better than IRIG sync when camera separation is less than 30 feet
- IRIG time reported may or may not mean the cameras are not synchronized
- An oscilloscope should always be used to check and set synchronization
- Synchronization errors can be removed in either mode using the “frame delay” parameter

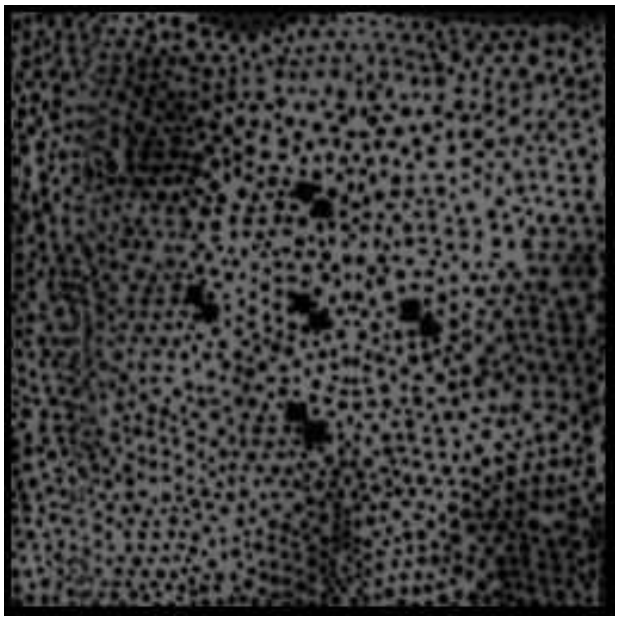
Using realistic experimental velocities, worst case errors are around 0.05 pixels

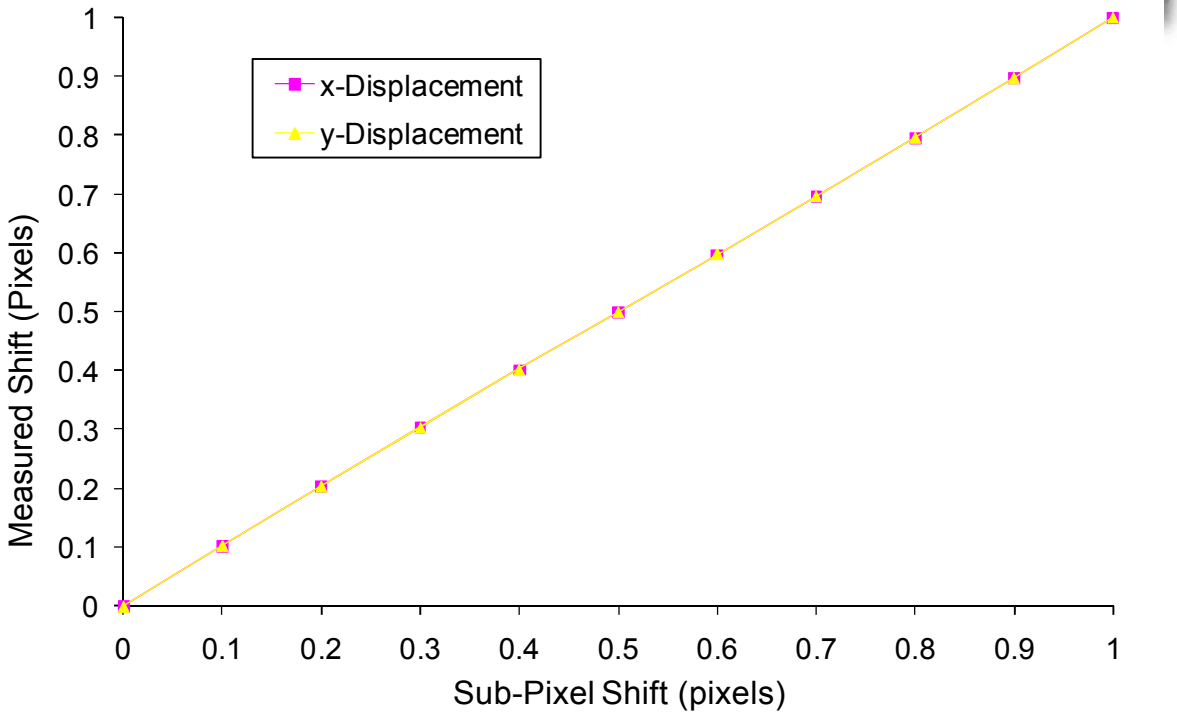
	Experimental Velocities (ft/s)	Assumed Synchronization (ns)	Pixel Scale (in/pixel)	Synchronization Error (pixels)	
IRIG uncorrected	7874	7	0.0125	0.0529	Shimadzu
Worst case →	1351	356	0.12	0.048	Phantom v12
Corrected timing →	1351	18	0.12	0.0024	

Notes:

- All of these parameters will need to be evaluated on a case by case basis
- Experimental velocities are representative of real experiments
- Assumed synchronization taken from laboratory experiments
- Pixel scales are representative of real experimental setups
- Calculated motion of object caused by synchronization error and field-of-view
- Frame rates from 66,000 to 320,000 fps were tested
- Phantom final synchronization value defined by the camera clock rate of 56 MHz – timing granularity of 18 ns
- Shimadzu synchronization determined by cable impedance

To simulate the sync error, the right image was numerically shifted





For *x*- and *y*-shifting the Fourier method was used

For *z*-shifting the image was expanded with a polynomial expansion

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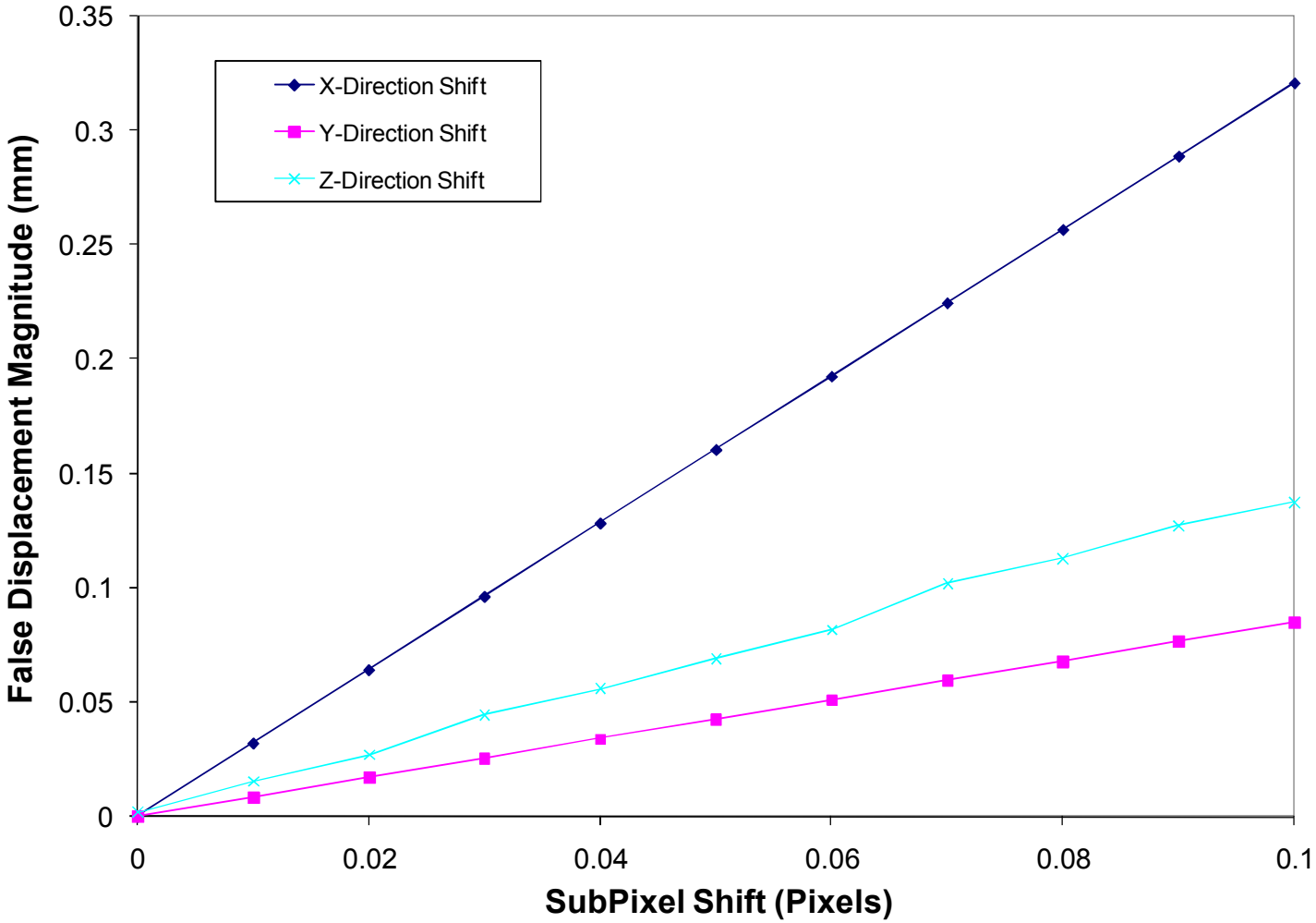
Using Vic3D, the errors caused by a sub-pixel synchronization error were calculated



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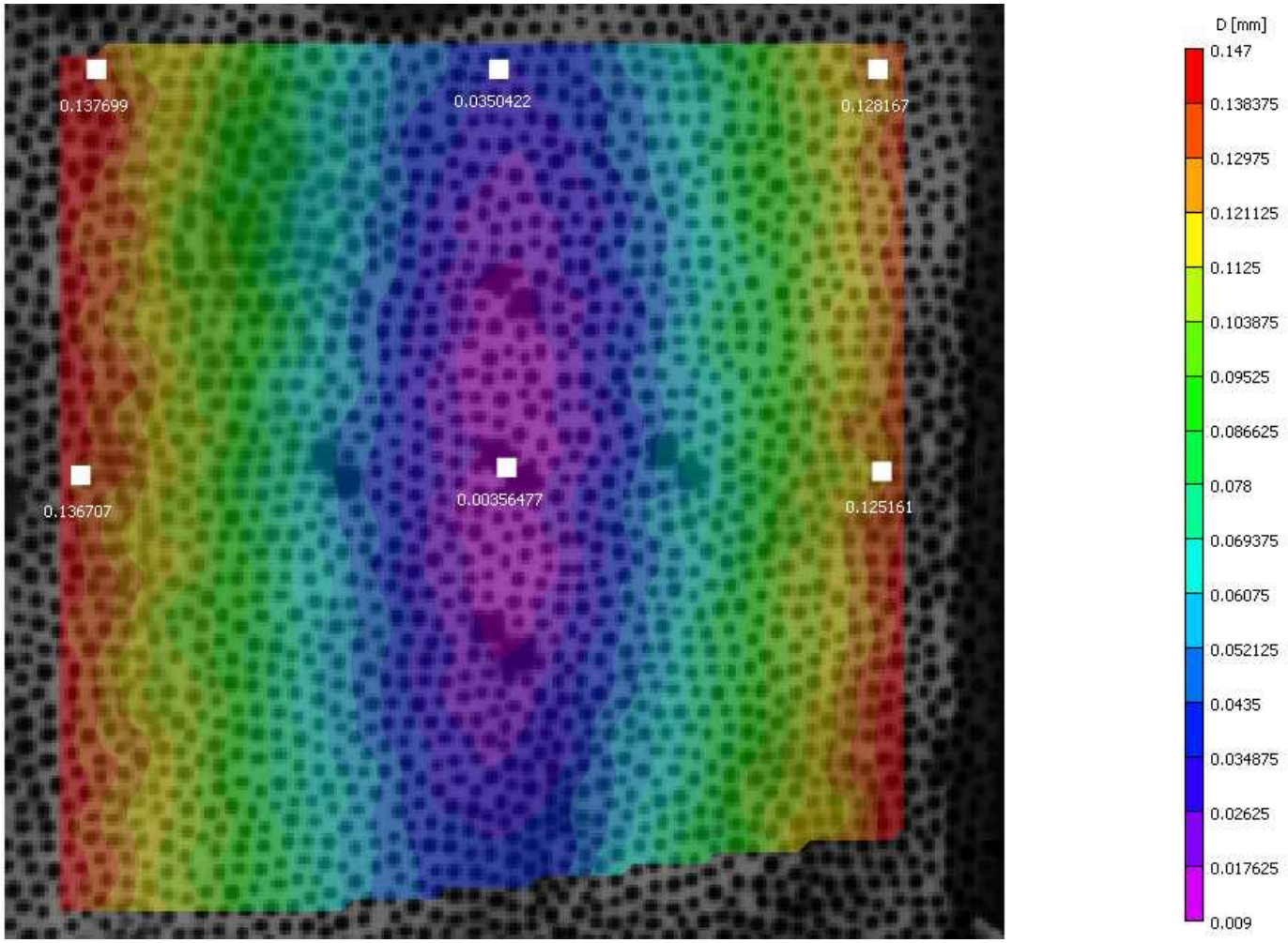
An out-of-plane synchronization translation caused a bowl shaped error



Displacement magnitude for 0.1 pixel out-of-plane translation error

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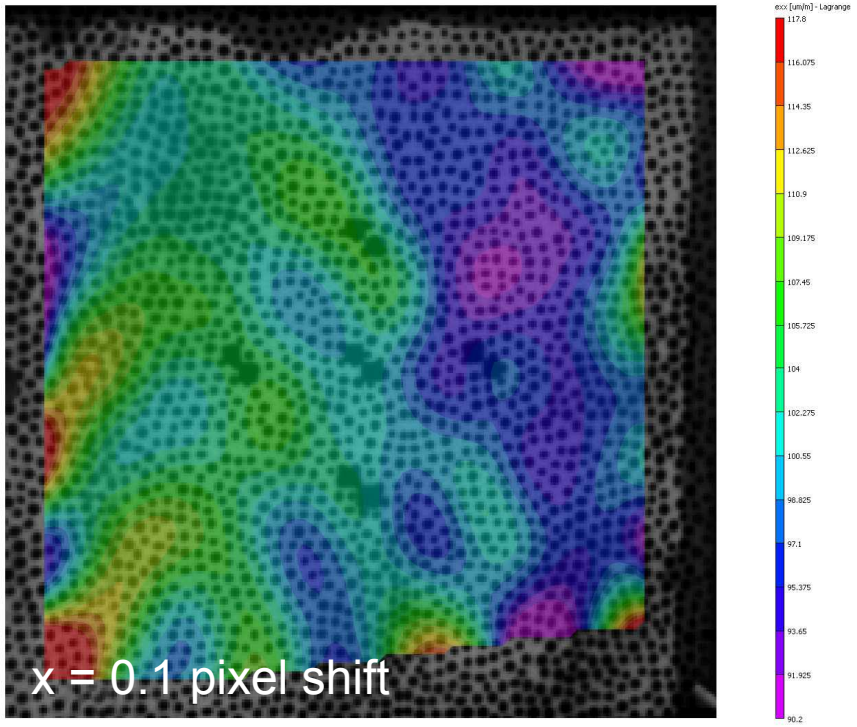
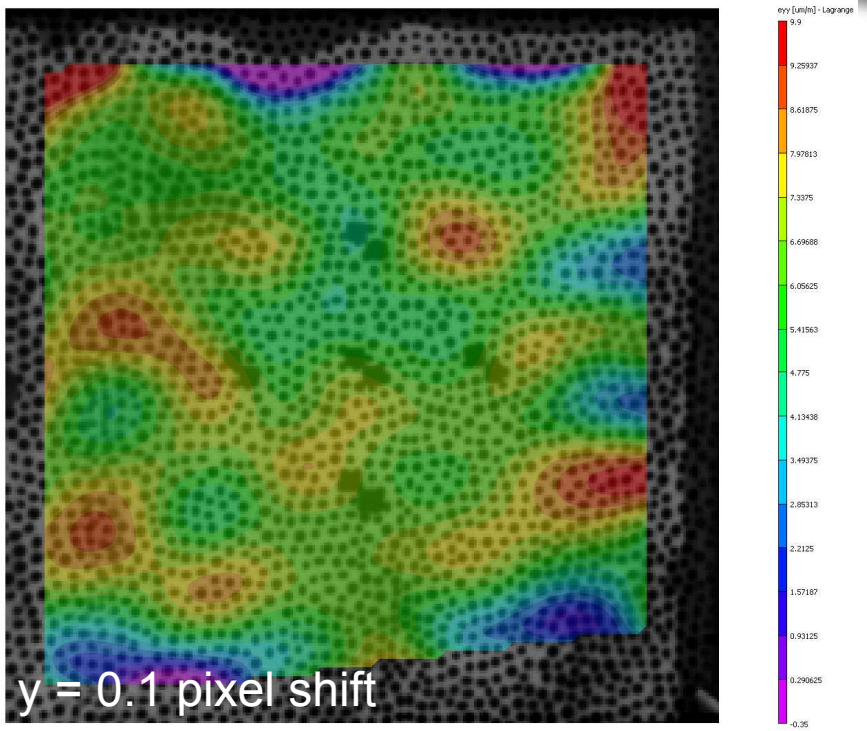
Strain errors for x and y-translations were minimal

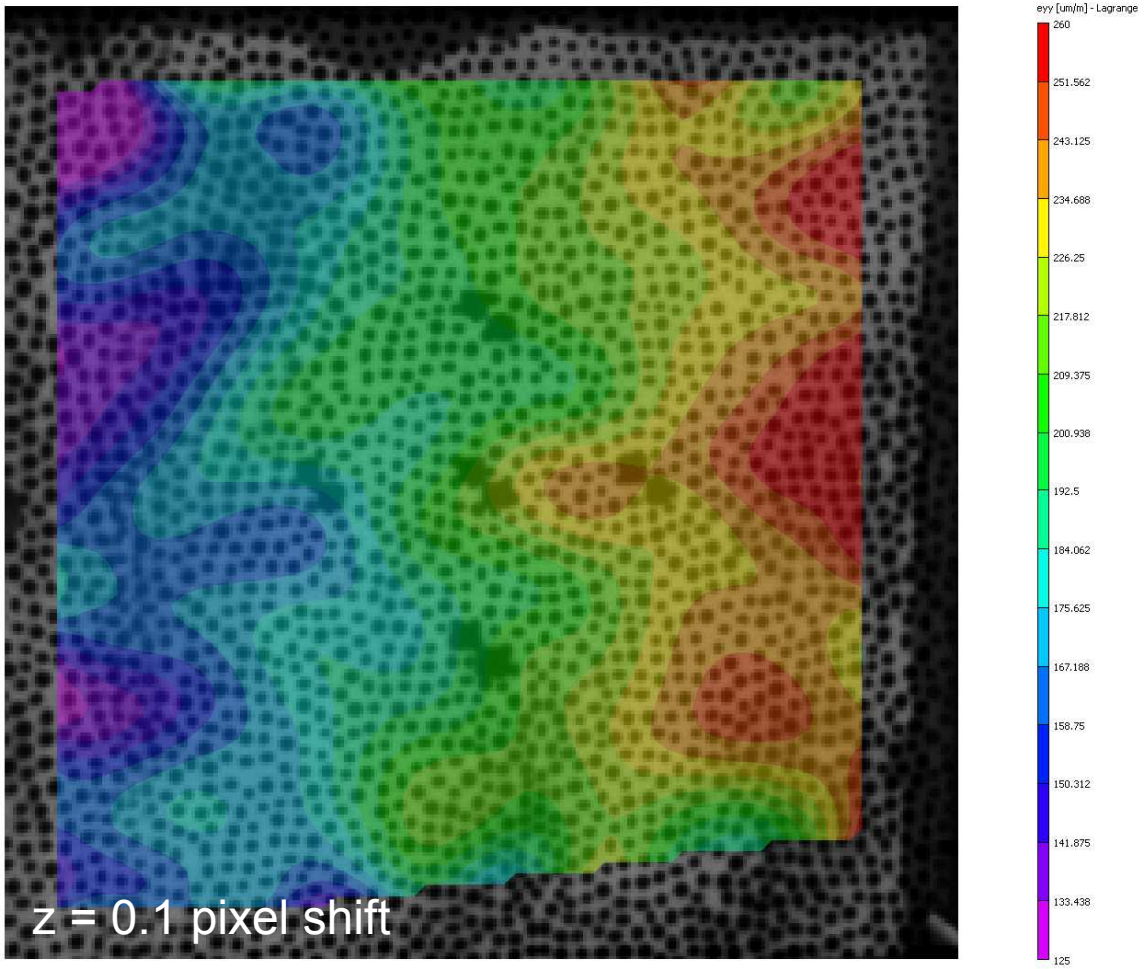


Maximum strain = 120 μm/m



Maximum strain = 10 μm/m

Z-translation errors were significant for strain



Maximum strain = 260 μm/m

Practical notes on camera setup: Check camera synchronization with a scope

Notes:

- For long camera separations, IRIG sync must be used. If this is done check camera synch! The IRIG time is not sufficient.
- FSYNC mode is superior than IRIG for short cable lengths
- The camera reported IRIG time is *not* necessarily correct. Do not trust it for checking synchronization
- Check the camera synchronization with a good oscilloscope!

If camera synchronization is checked and optimized, errors below the resolution of DIC can almost always be obtained