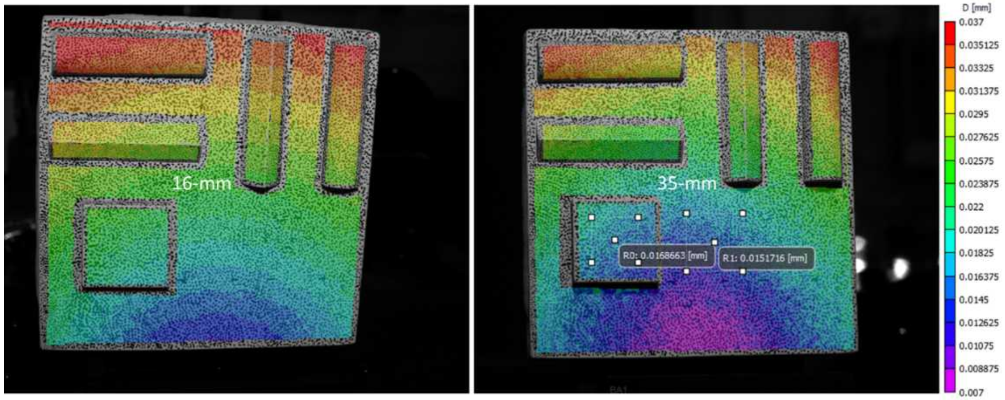
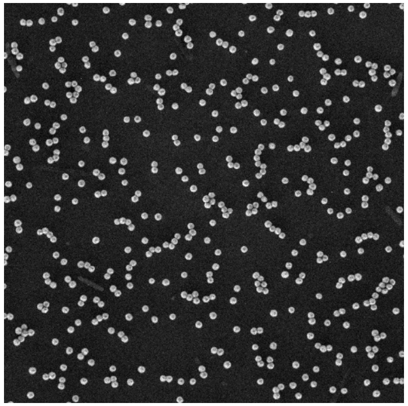
www.dic-challenge.org

SAND2017-12017C





Digital Image Correlation DIC – Challenge Meeting

International DIC Society
November, 2017

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

DIC Challenge Charter

The DIC Challenge seeks to:

- Provide sample images for code verification and development.
- Benchmarked results for the sample images – published and peer-reviewed.
- A forum for the discussion and improvement of DIC.
- Provide image sets for all DIC modalities: Stereo-DIC (3D), Digital Volume Correlation (DVC), Scanning electron microscope (SEM-DIC)

The official charter is available at the website:
www.dic-challenge.org

Current Board Members

- Phillip Reu – Chairman (US – FFT Shifting)
- Mark Iadicola (NIST) – co-chair
- Will LePage (Univ. Mich.) – SEM challenge Lead
- Helena Jin (Sandia) – DVC challenge Lead
- Elizabeth Jones (Sandia) – Results analysis
- Evelyne Toussaint (University Clermont Auvergne, France) – Results analysis
- Ruben Balcaen (PhD Student KU Leuven) – Stereo-DIC synthetic image generation
- Hugh Bruck (University of Maryland) – Advisor at large
- In memoriam – Laurent Robert

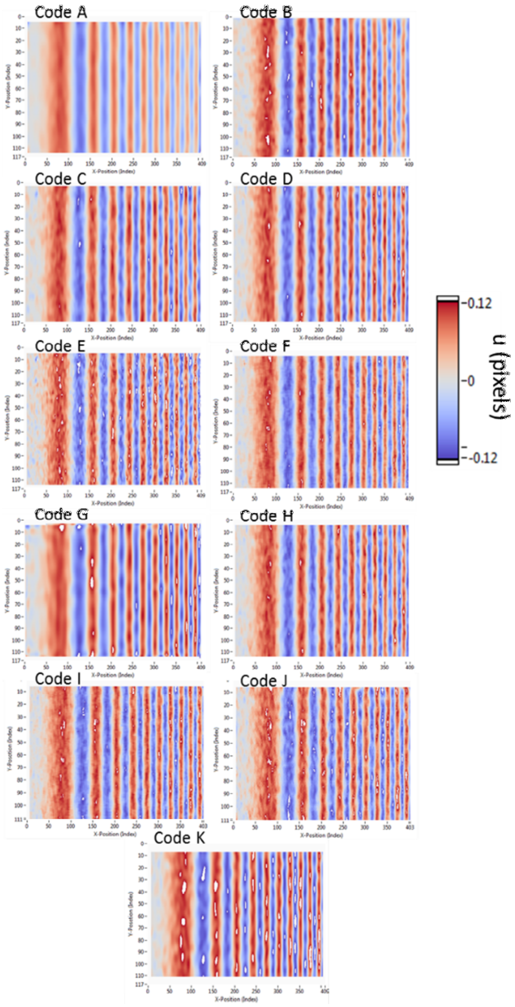
Looking for volunteers

The DIC challenge is important because it is an independent organization

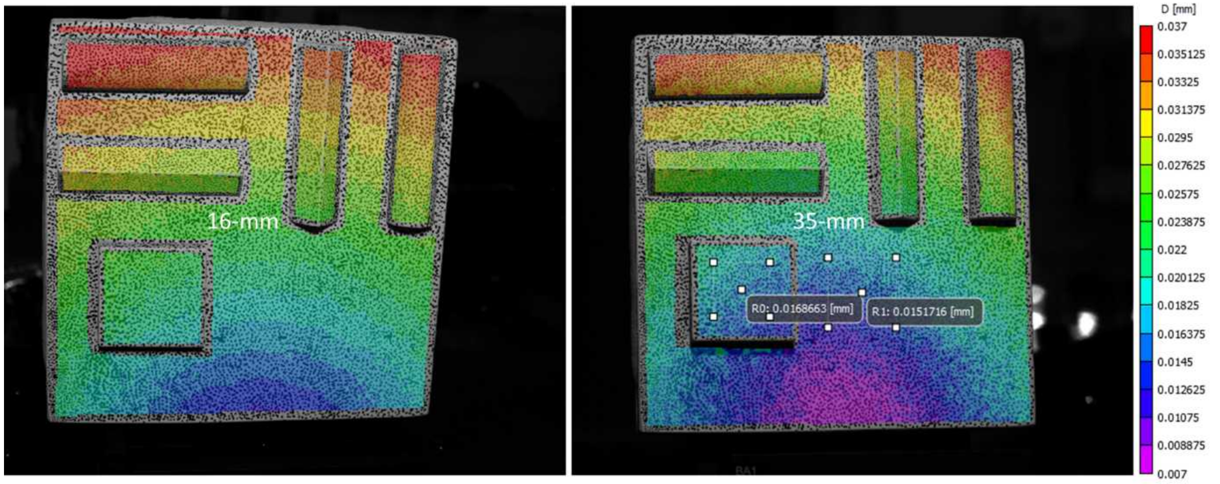
- No ties to any commercial or university codes
- Open and free to participate
- Code developers will run their own code ensuring “optimum” parameter selection
- Validated image sets will be available tested by many groups for testing software
    - Simpler image shifting results are important!
- Benchmark results will be presented for all participants

Current state of the challenge

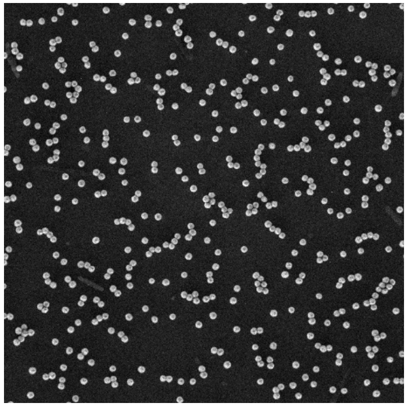
2D Results and Paper Discussion



Stereo-DIC Image Set Description



SEM-DIC Challenge



DVC-DIC Challenge

Description	Set Name	Method‡	Contrast	Subset Size*	Noise σ (GL)	Shift (pixels)	# Images
TexGen Shift X,Y	Sample1	TexGen	Varying	Specify	1.5	X=Y=0.05	20
TexGen Shift X,Y	Sample2	TexGen	0 to 50	Specify	8	X=Y=0.05	20
FFT Shift X,Y	Sample3	FFT Shift	0 to 200	Specify	1.5	X=Y=0.1	10
FFT Step Shift	Sample3b	FFT Shift	0 to 200	User	1.5	0.05 to 0.5	5
FFT Shift x and y	Sample4	FFT Shift	0 to 50	Specify	8	X=Y=0.1	10
FFT Shift x and y	Sample5	FFT Shift	Varying	Specify	1.5	X=Y=0.1	10
Prosilica Bin	Sample6	Binning	0 to 200	21	Low	X=Y=0.1	10
Prosilica Bin	Sample7	Binning	0 to 50	Specify	High	X=Y=0.1	10
Rotation TexGen	Sample8	TexGen	0 to 100	Specify	2	Θ by 1	10
Rotation FFT	Sample9	FFT	0 to 100	Specify	2	Θ by 1	10
Strain Gradient	Sample10	TexGen	0 to 200	User	2	Sinusoid	10
Strain Gradient	Sample11	TexGen	60 to 130	User	2	Sinusoid	10
Strain Gradient	Sample11b	FFT	0 to 200	User	1.5	Tri. .01 to 1	6
Ex1 – Plate Hole	Sample12	Exper.	Good	User	Low	N/A	12
Ex2 – Weld	Sample13	Exper.	Poor	User	Low	N/A	52
Varying Strain	Sample14	FFT	0 to 200	User	5	N/A	4
Varying Strain	Sample15	TexGen	80 to 180	User	2	N/A	9
Rigid Motion	Sample16	Exper.	0 to 254	User	0.26	≈ 0.1	11
Interpolant Check	Sample17	Exper.	0 to 255	User	?	N/A	6

State of the 2D challenge

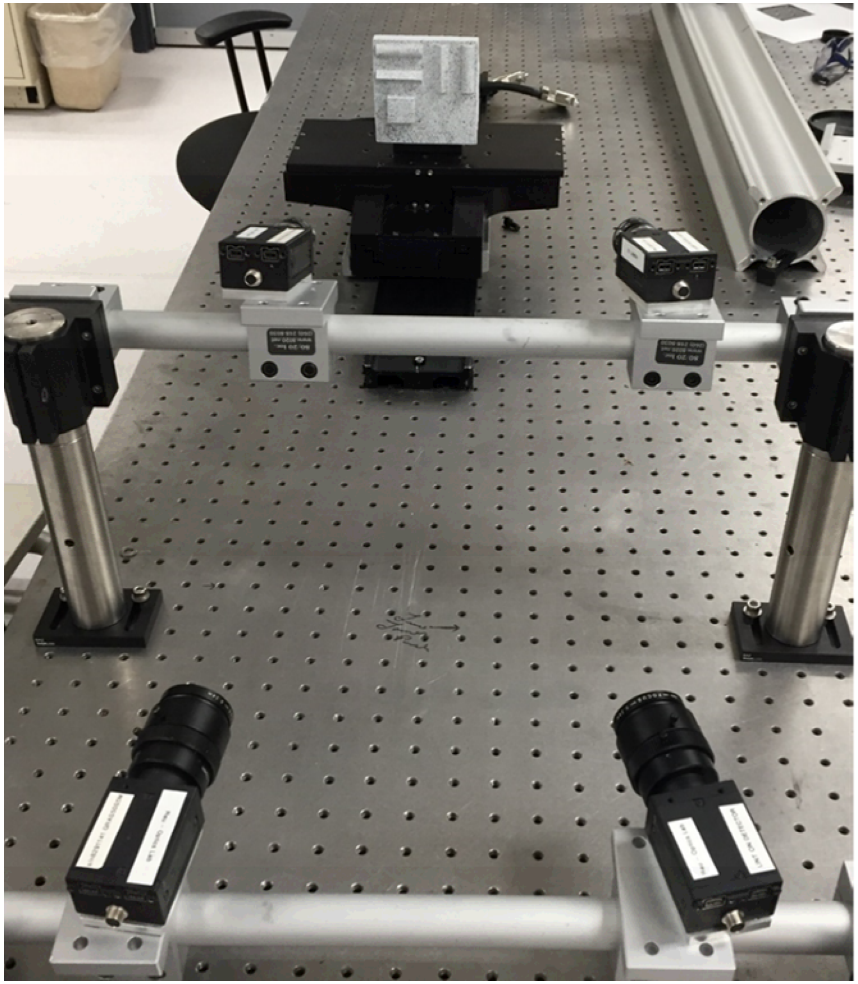
- The paper contains a description of all the image sets and details on the analysis of Sample 14 and Sample 15.
- The paper is in proof stage.
- Analysis software is being completed for release to the DIC challenge website in both MatLAB and LabVIEW versions.
- For Reviewers: Strongly encourage people making “better” claims to use the DIC images.
- We need another 2D simulation code (or someone who can run TexGen) to redo the study in Sample14 and Sample 15. We need higher frequencies. Does someone want to lead that?

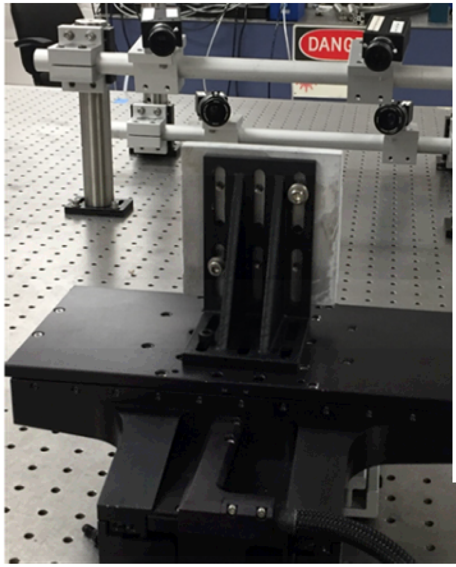
Stereo-DIC Challenge

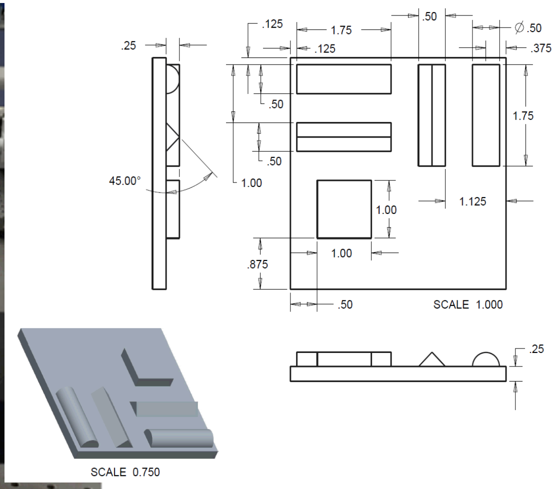
Challenge Set Name	Description	Method of Creation
StereoSample1 – Experiment **StereoSample1&2 – Sim Cal**	Translation of sample with known dimension. Includes calibration and translation images for a 16-mm and 35-mm stereo-system. Calibration 14×10-10mm	Experimental
StereoSample2 – Simulated **StereoSample1&2 – Sim Cal**	Simulated translation of plate with known dimensions. Includes calibration and translation images for a 16-mm and 35-mm stereo-system.	Balcaen Simulator
StereoSample3 – Experiment **StereoSample3&4 – Sim Cal**	D-Specimen tensile test. Calibration 14x10-7mm	Experimental
StereoSample4 – Simulated **StereoSample3&4 – Sim Cal**	D-Specimen simulated from FE displacement field	Balcaen Simulator
StereoSample5 – Experiment	Tensile specimen with “dummy” region. Calibration 12×9-3.5mm	Experimental
TelecentricSample6 - Experiment	Tensile specimen with telecentric lens. Opposite side to StereoSample5 results.	Experimental

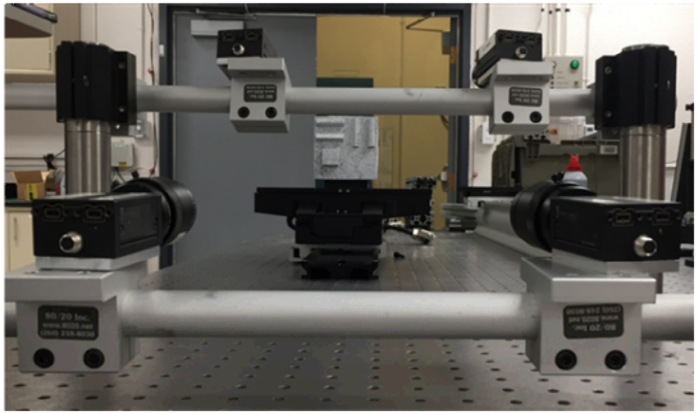
1. Balcaen R, Wittevrongel L, Reu PL, Lava P, Debruyne D (2017) Stereo-DIC Calibration and Speckle Image Generator Based on FE Formulations. Exp Mech 57 (5):703-718. doi:10.1007/s11340-017-0259-1

STEREO-Rigid body motion

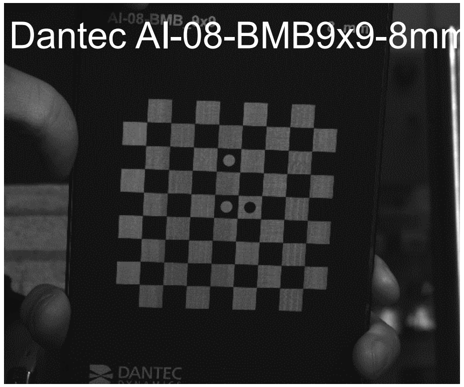


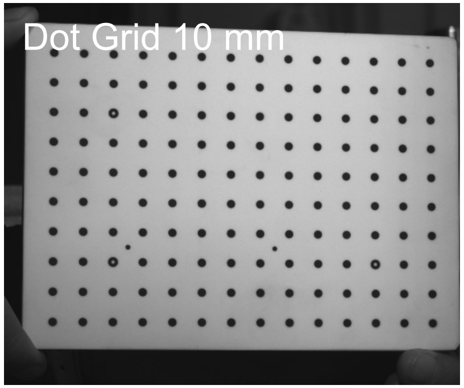


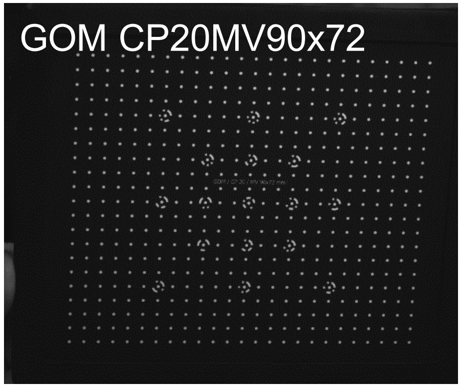


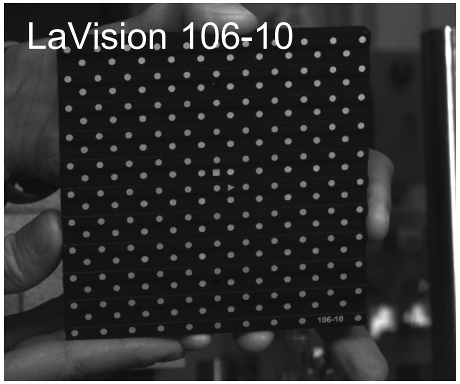


Calibration images are supplied for all target types


Dantec AI-08-BMB9x9-8mm


Dot Grid 10 mm


GOM CP20MV90x72


LaVision 106-10

Übercal images are available for the dot grid if desired for research. Show some statistics for this that are completed. Approximately 1600 images.

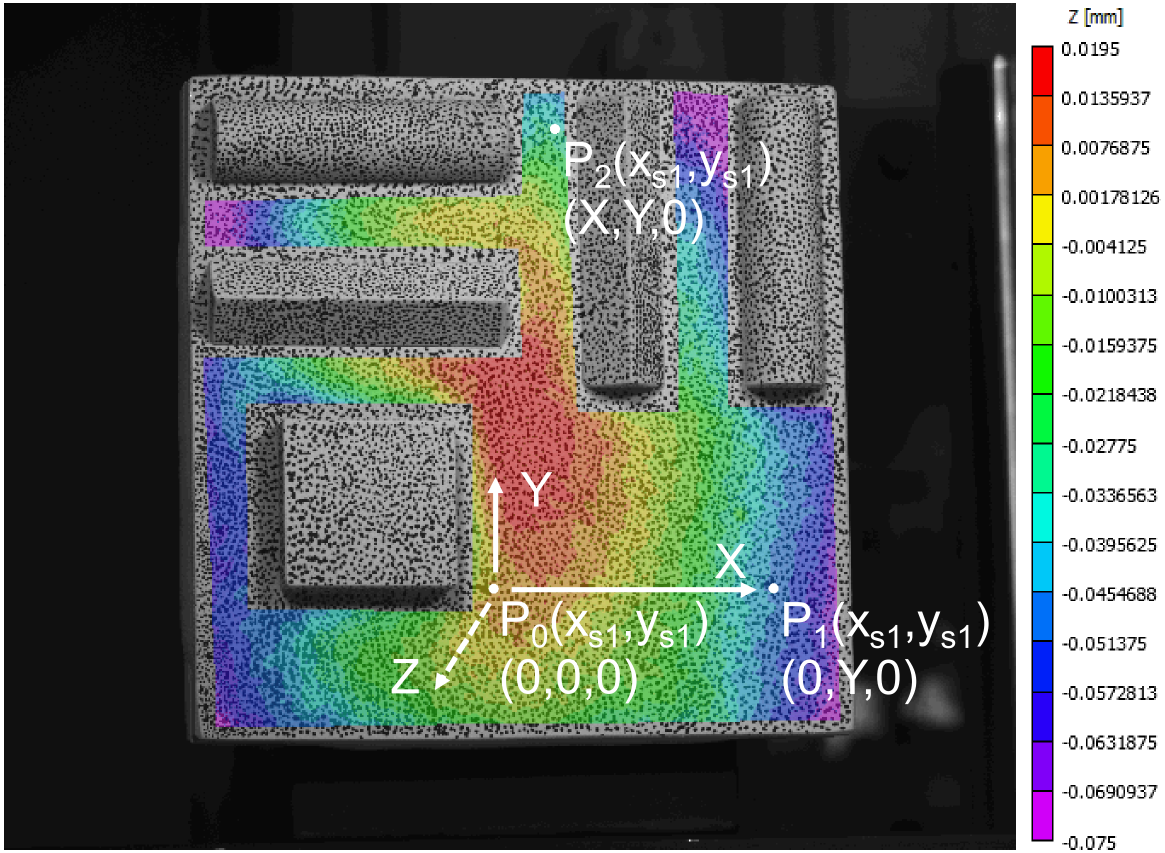
Calibration Zip files:
https://connect.sandia.gov/sites/DIC_Challenge/Documents/LaVision106-10.zip
https://connect.sandia.gov/sites/DIC_Challenge/Documents/GOMCP20MV90x72.zip
https://connect.sandia.gov/sites/DIC_Challenge/Documents/DotGrid10-mm.zip
https://connect.sandia.gov/sites/DIC_Challenge/Documents/DantecAI-08-BMB9x9-8mm.zip

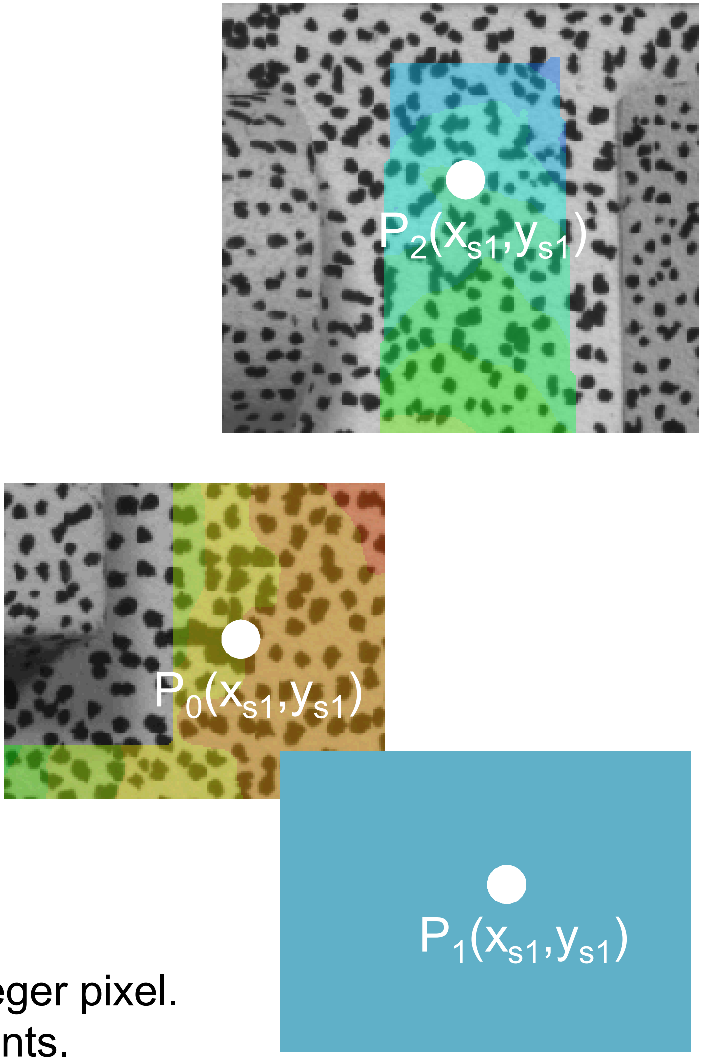
New Translated Plate Data:
https://connect.sandia.gov/sites/DIC_Challenge/Documents/Translate.zip

Translation images

- We have 18 translated images with 5 stationary images at each step.
- We have optical encoder position readings with sub-micron precision and accuracy. (Specs from stage available)
- We have a CMM measured shape (after painting) for comparison.

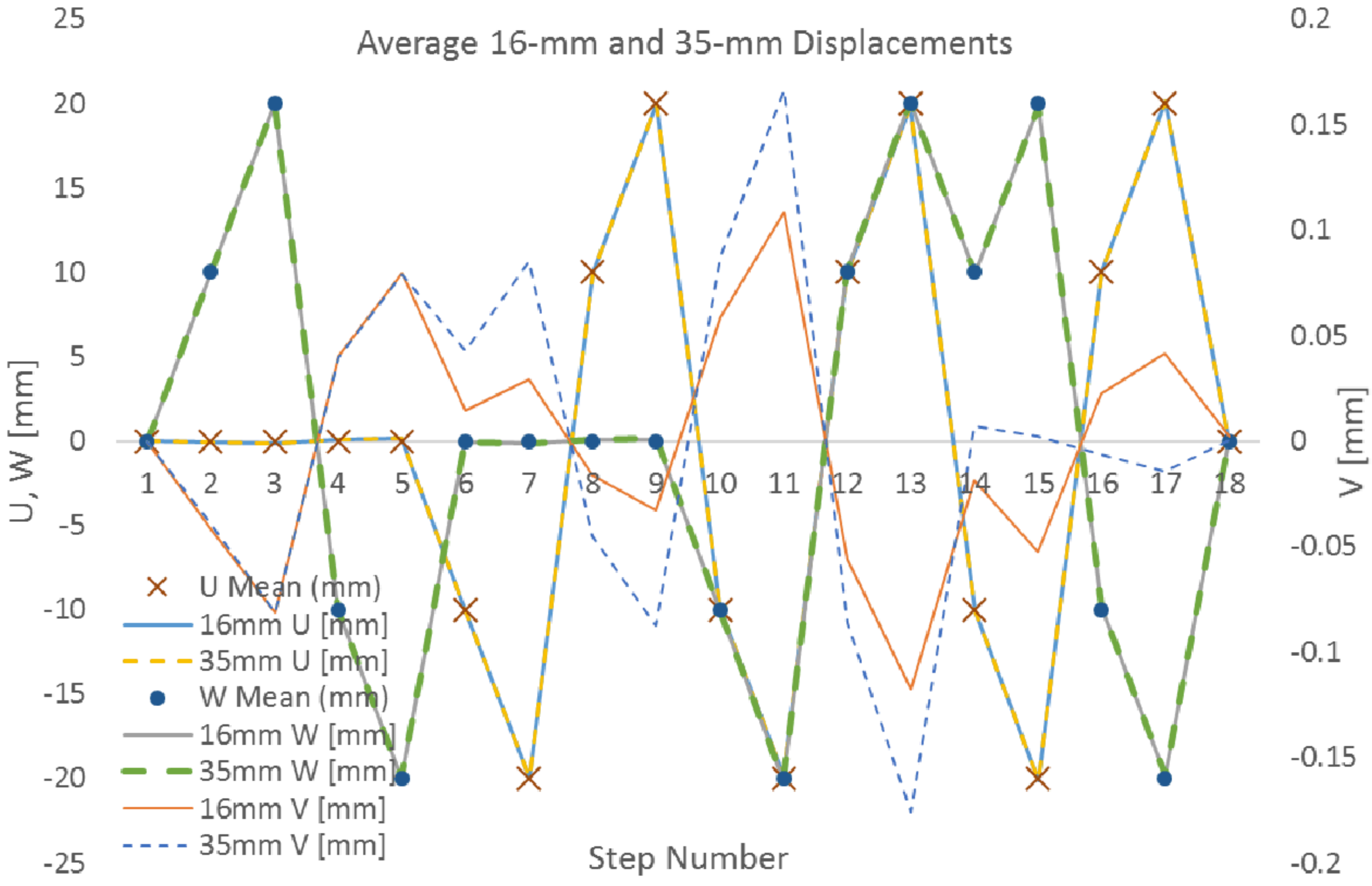
Common coordinate system is needed for comparison



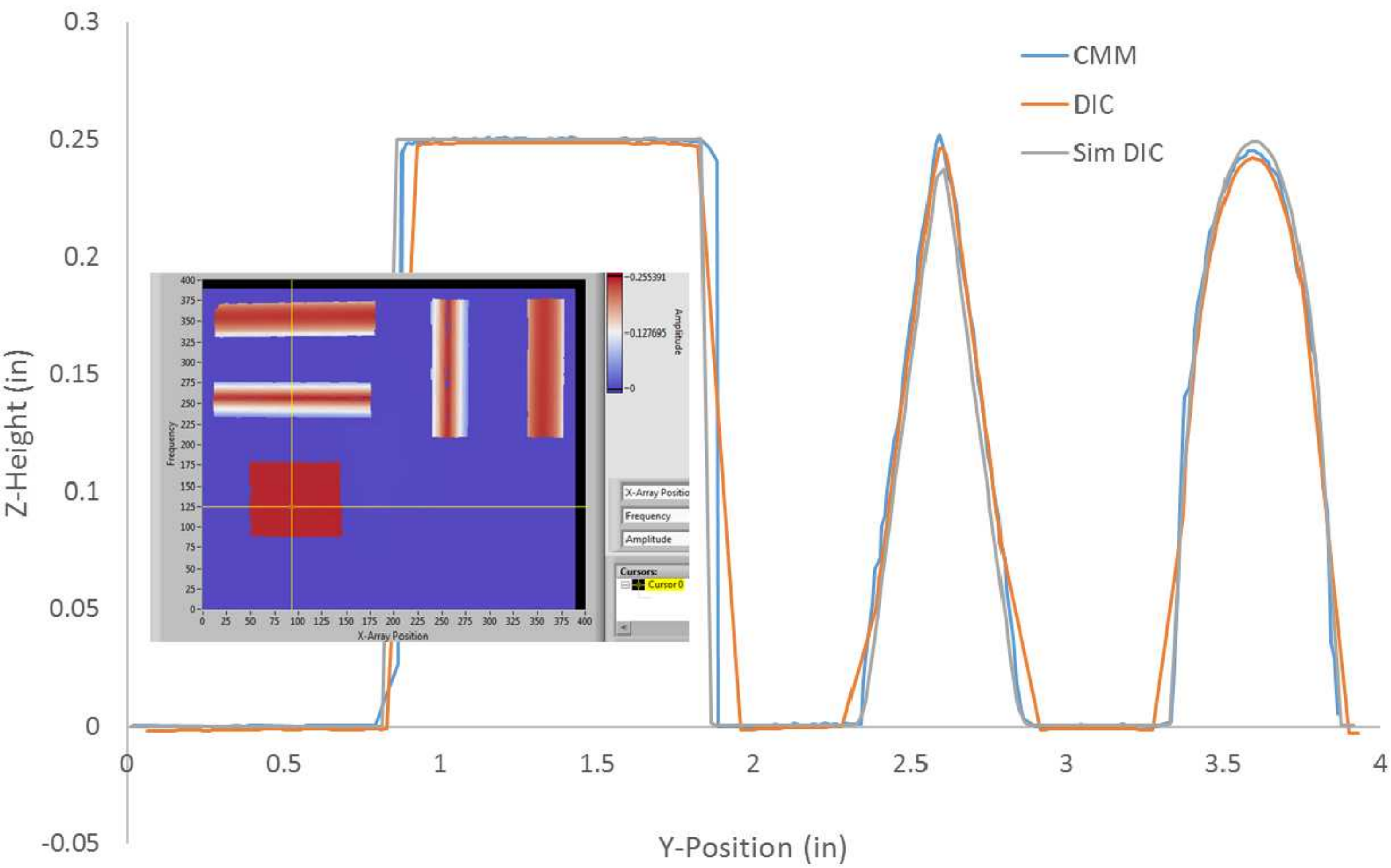


- Reference image (x_{s1}, y_{s1}) will be provided for 3-points. Integer pixel.
- Best fit plane will be found with x-axis along bottom two points.
- This will be done on the averaged reference images from Step01 at 0,0,0.
- This transformation will be used for all steps after.

Sample 1 Translation results

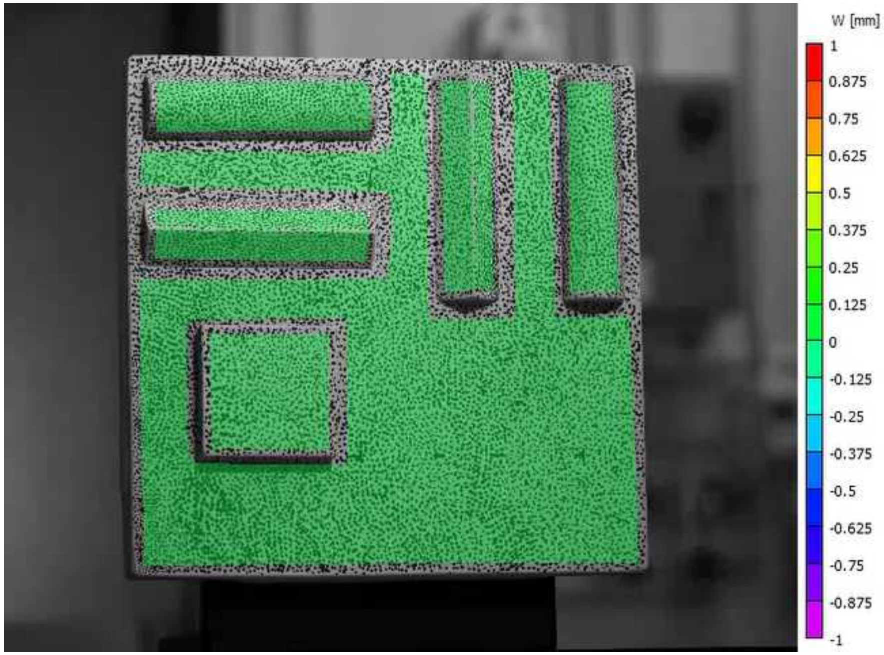


Shape measurement

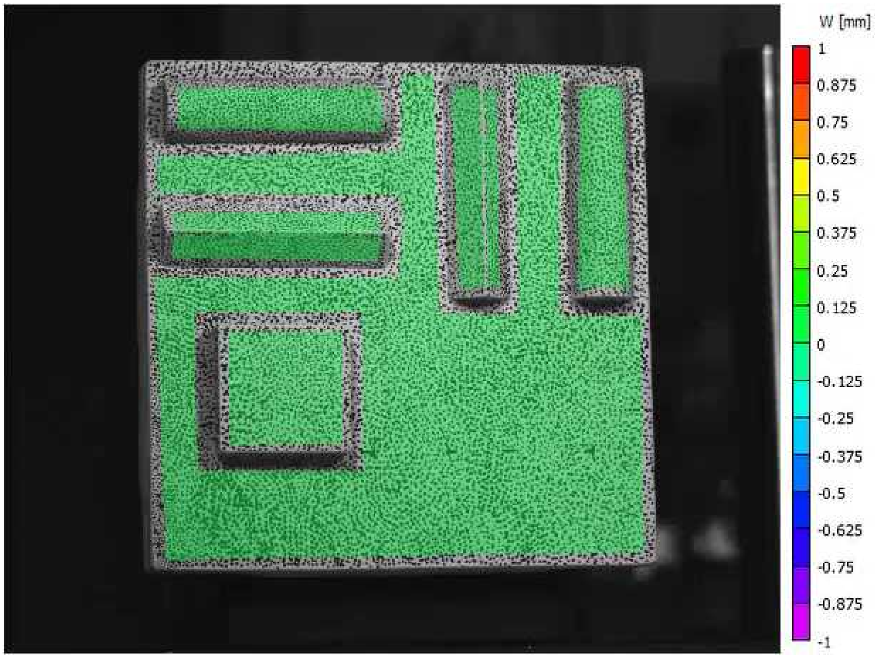


Issues with the first data sets

Old Image Set Firewire 5-MPixel



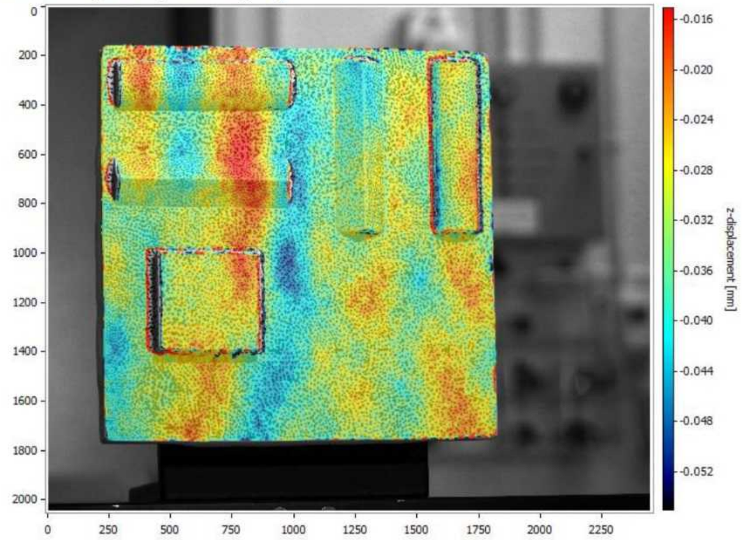
New Image Set Sony 5-MPixel

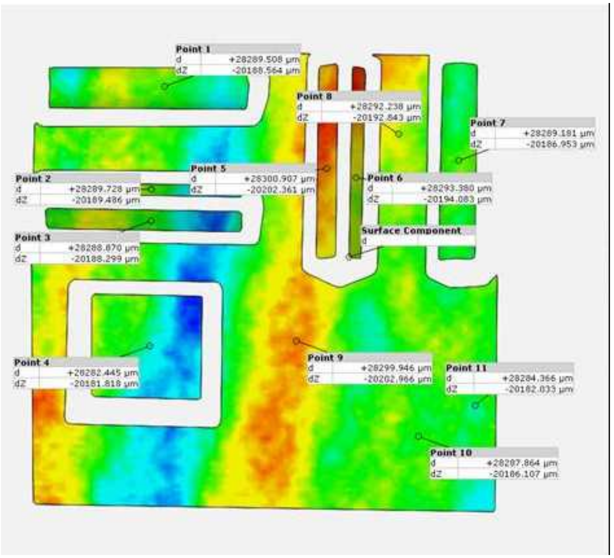


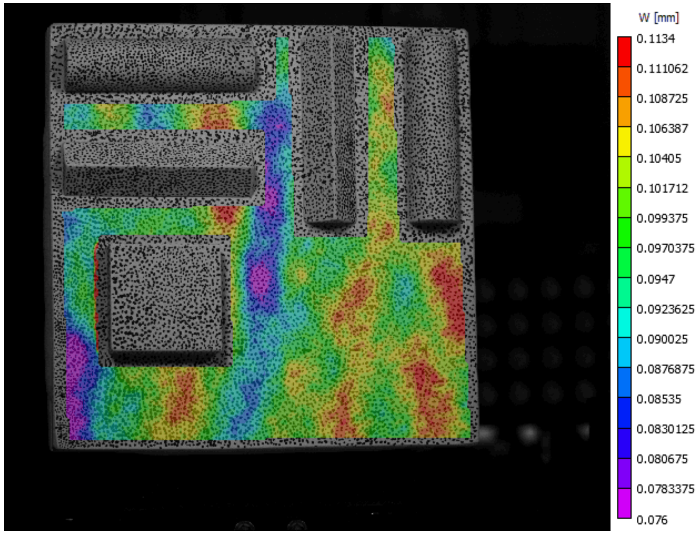
Relax and watch the moving plate…

Results from the codes

35mm – Step 8 z-displacement [mm]:





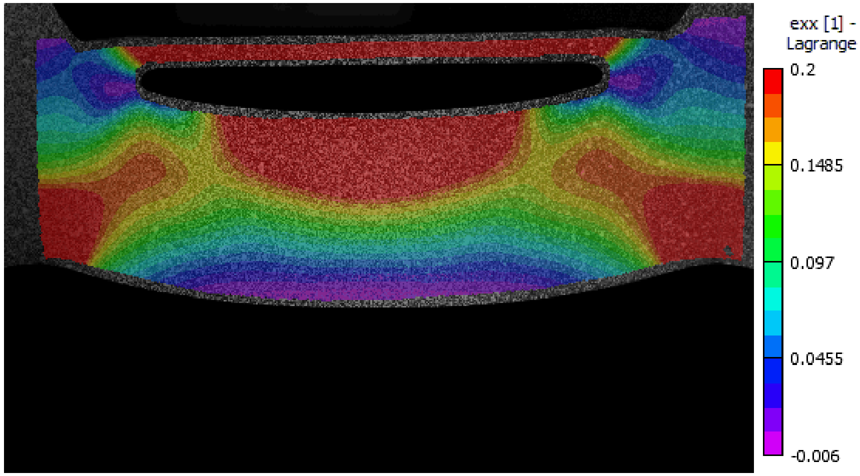


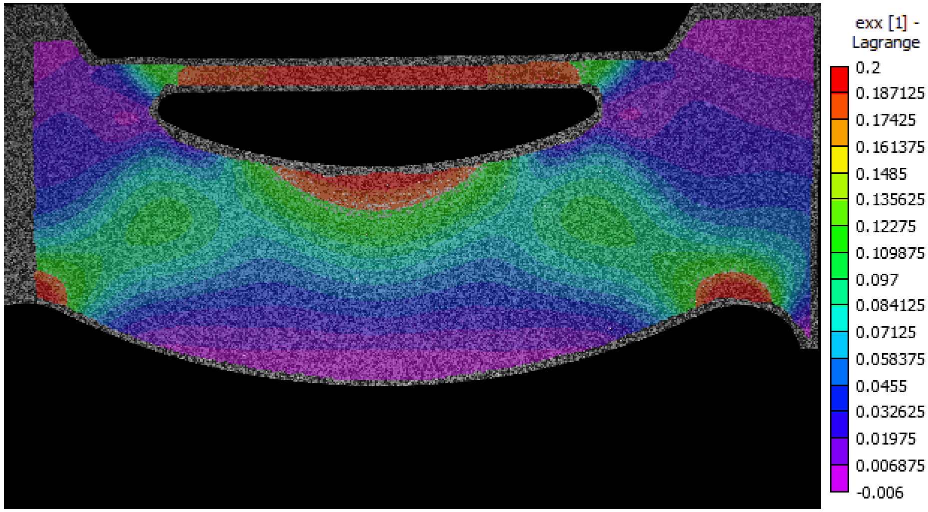
- Banding showed up in all codes and was stationary
- Is this a warped sensor? How would we prove that?

Goal: Accept sample image sets and move on to blind image sets

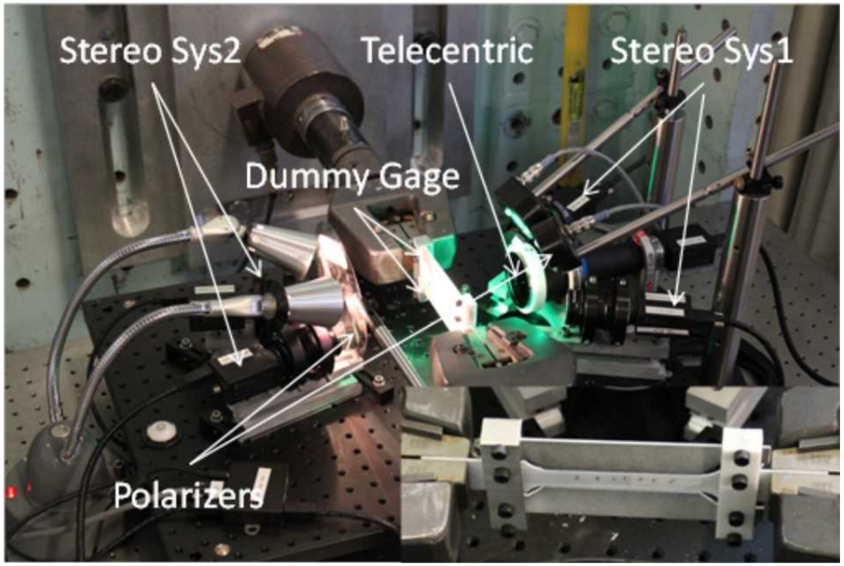
- We need to ratify the sample image sets including:
  - Determine best method of analyzing the image sets we have.
  - I could redo the D-Specimen and can have other calibration images taken.
  - Do we do blind Stereo-DIC translation images?
    - I could redo the experiment one more time…
    - Do both the standard set above and unknown translations.
    - Ideas?

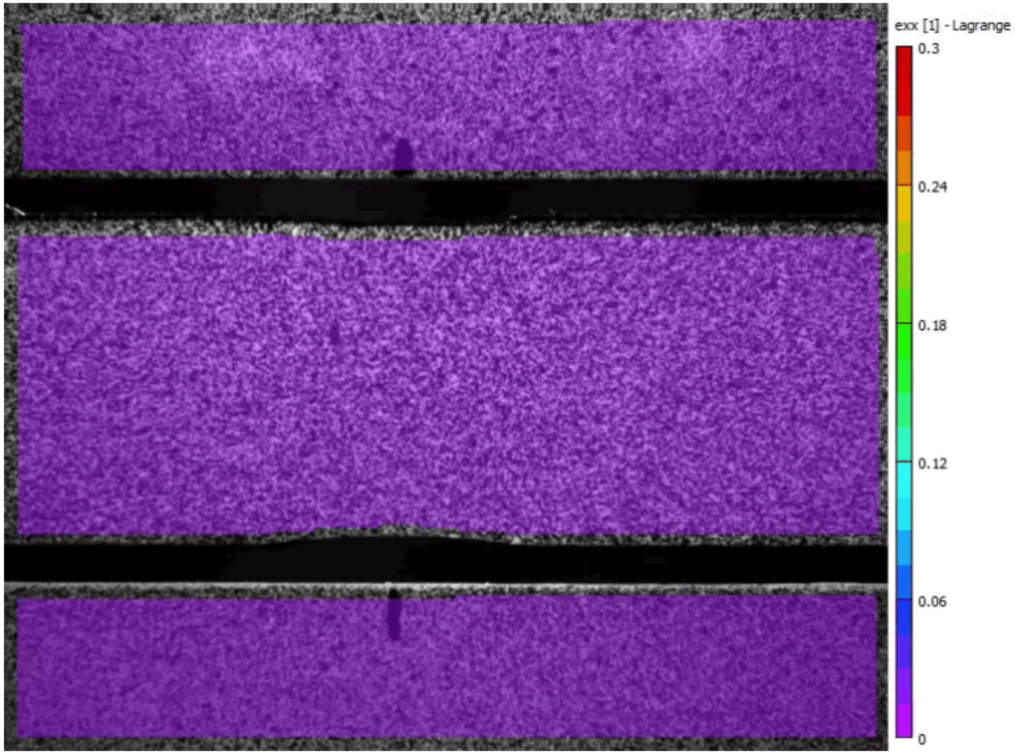
D-Specimen – Experimental and Simulation





DIC experiment

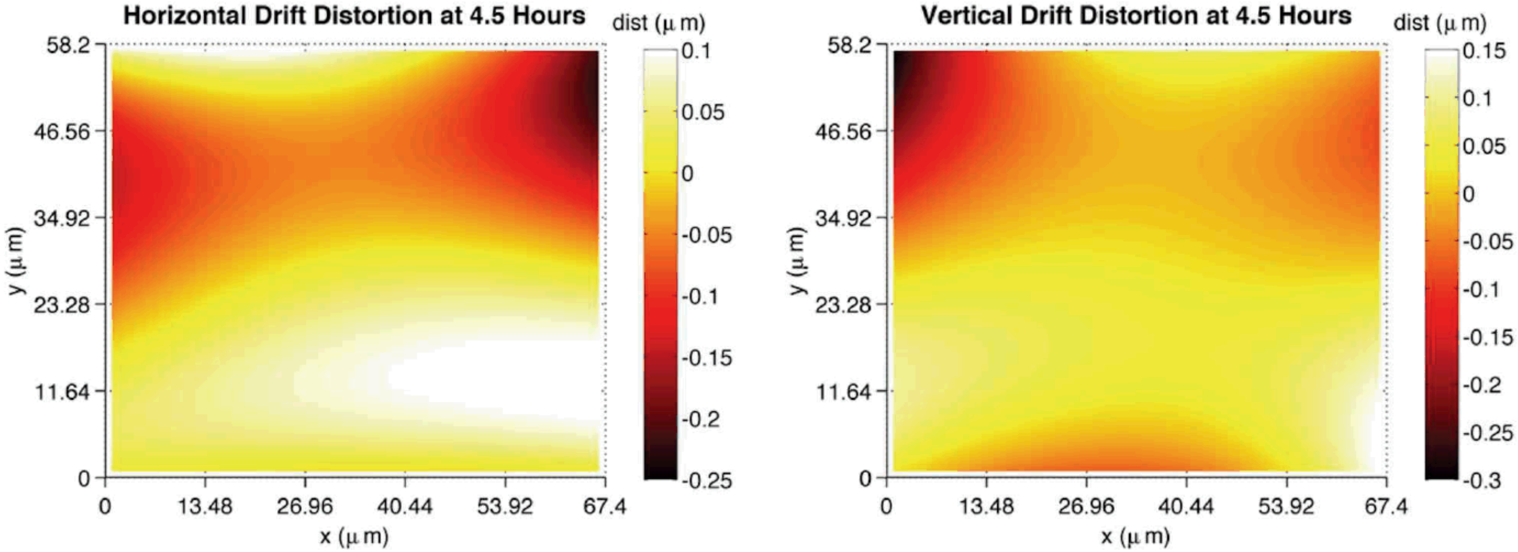




The error sources for SEM-DIC images are poorly understood compared to those from optical DIC.

Chair: William LePage (University of Michigan) wlepage@umich.edu

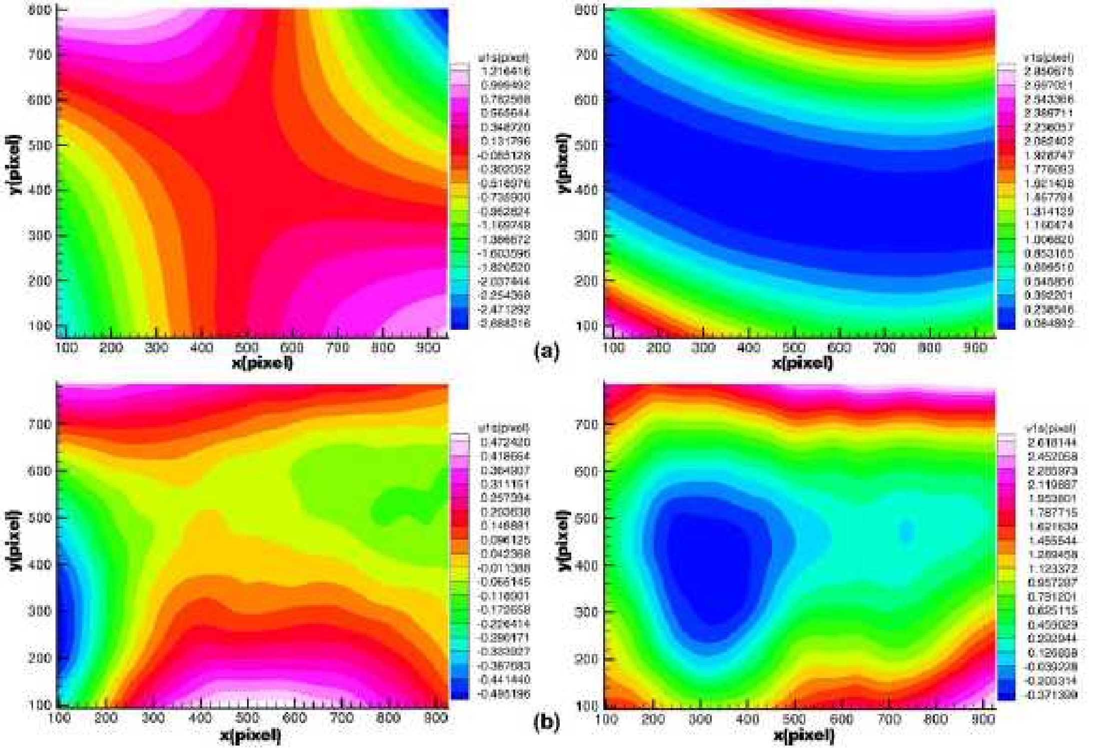
Drift distortions



Kammers, Adam D., and Samantha Daly. "Digital image correlation under scanning electron microscopy: methodology and validation." *Experimental Mechanics* 53.9 (2013): 1743-1761.

The error sources for SEM-DIC images are poorly understood compared to those from optical DIC.

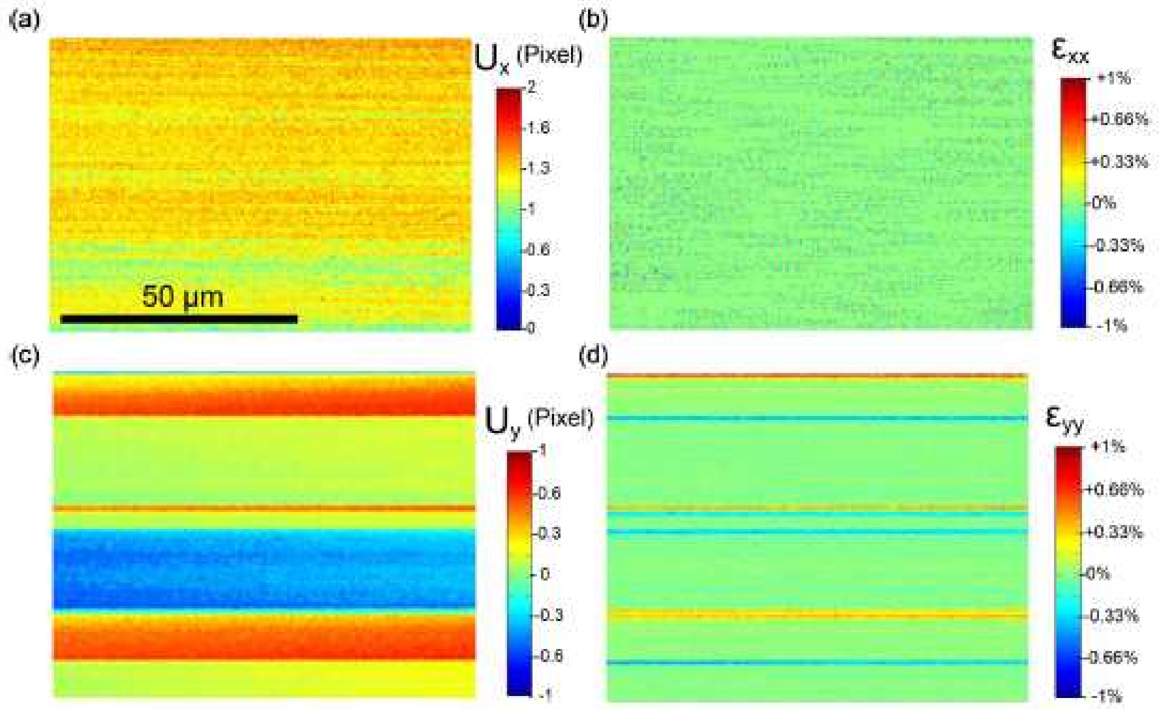
Spatial distortions



Sutton, Michael A., et al. "Scanning electron microscopy for quantitative small and large deformation measurements part II." *Experimental Mechanics* 47.6 (2007): 789-804.

The error sources for SEM-DIC images are poorly understood compared to those from optical DIC.

Line scan errors (also known as jumps or shifts)



Stinville, J. C., et al. "Sub-grain scale digital image correlation by electron microscopy for polycrystalline materials during elastic and plastic deformation." *Experimental Mechanics* 56.2 (2016): 197-216.

There are many variables for SEM-DIC (a few listed below). The relative contributions to error from these variables are not understood.

Scanning conditions

- magnification or field of view
- beam voltage
- beam current
- dwell time
- line or frame averaging
- working distance

Hardware configurations

- electrostatic and electromagnetic columns
- various detector technologies and positions, such as Everhart-Thornley for secondary and backscattered electrons, in-lens directional, through the lens, etc.

The proposed SEM-DIC challenge begins with the goal of understanding hardware and scan settings for optimizing DIC quality (without image post-processing).

- Set of SEM-DIC images would build understanding of error sources, as well as enable groups to develop new distortion correction and post-processing methods on the same platform of images.
- This collection of SEM-DIC images could come from just one group (and I'd be happy to lead this effort), or we could crowdsource the collection of SEM images and make that the crux of an SEM-DIC challenge.

The proposed SEM-DIC challenge begins with the goal of understanding hardware and scan settings for optimizing DIC quality (without image post-processing).

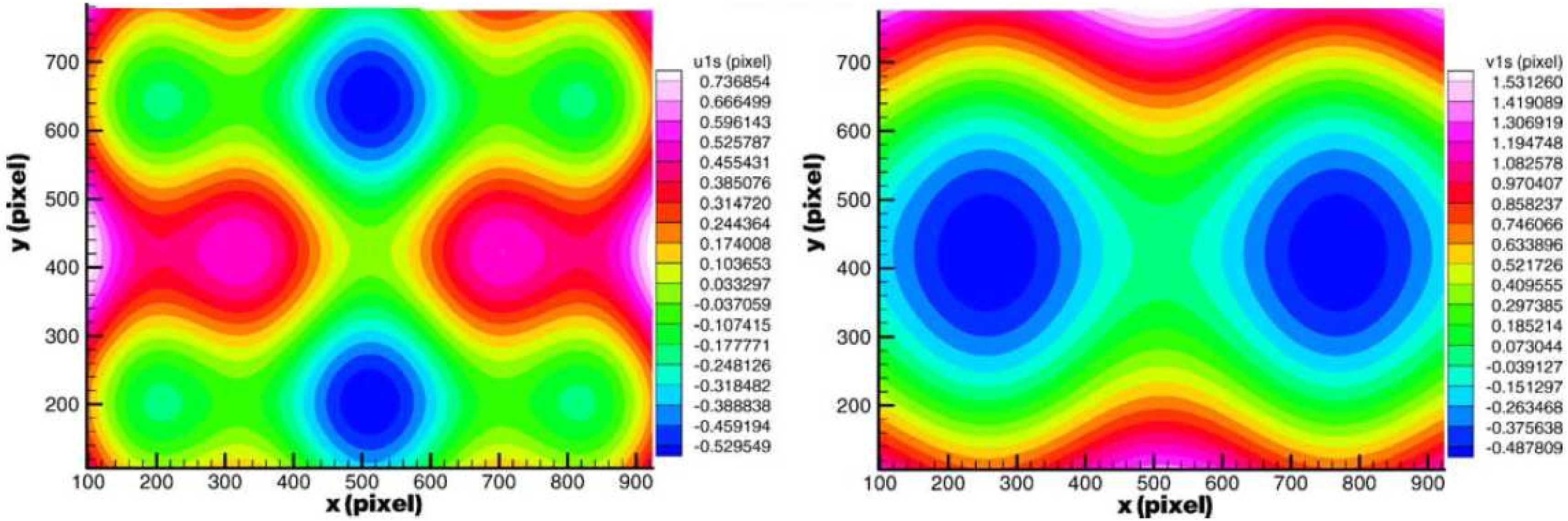
- Instead of having groups analyze the same predefined set of images (as the 2D and 3D DIC Challenges have done), the SEM-DIC challenge would ask groups to submit candidate image sets that seek to minimize error (before post-processing) and then we could analyze them all on the same 2-D DIC code to assess error.
- This structure of the SEM-DIC challenge would have a similar hurdle as the DVC Challenge, that we'd need a uniform sample set for all the teams to use. I have created 7 samples that should be suitable, and 3 of them will be at the iDICs conference (thank you to Dr. Reu).

Future phases of the SEM-DIC Challenge would assess post-processing methods for identifying and correcting SEM scanning errors.

- The results from the initial phase of the SEM-DIC Challenge would build a collection of high-quality SEM-DIC images and make them available to the community for understanding and correcting these errors in future phases.
- Some SEM-DIC error correction codes require a set of calibration images (typically pairs of images with several rigid body translations). Similar to the 3D DIC Challenge, then, there will be some difficulty with obtaining a consistent baseline of images for the calibration procedure.

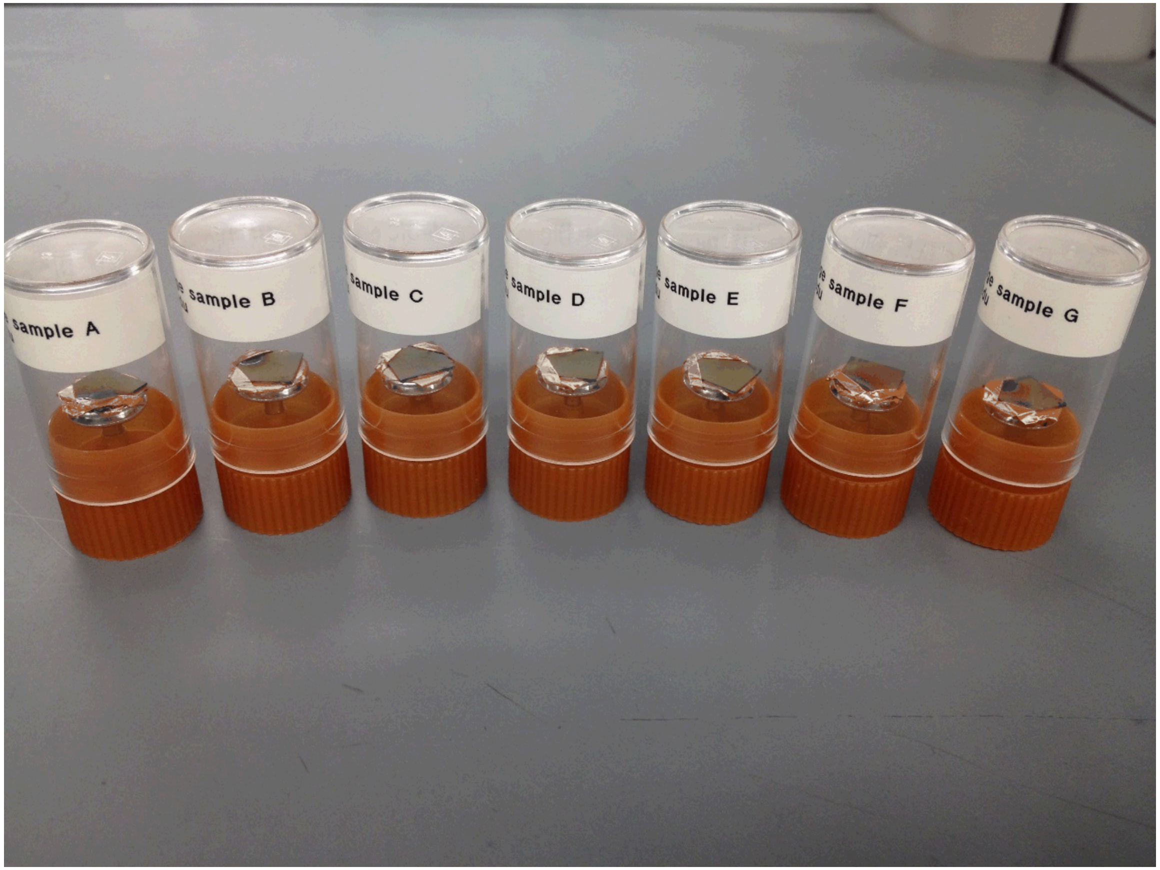
Synthetically-generated SEM errors would also be helpful for the assessment of error correction codes.

Drift distortion and spatial distortion components for computer simulations

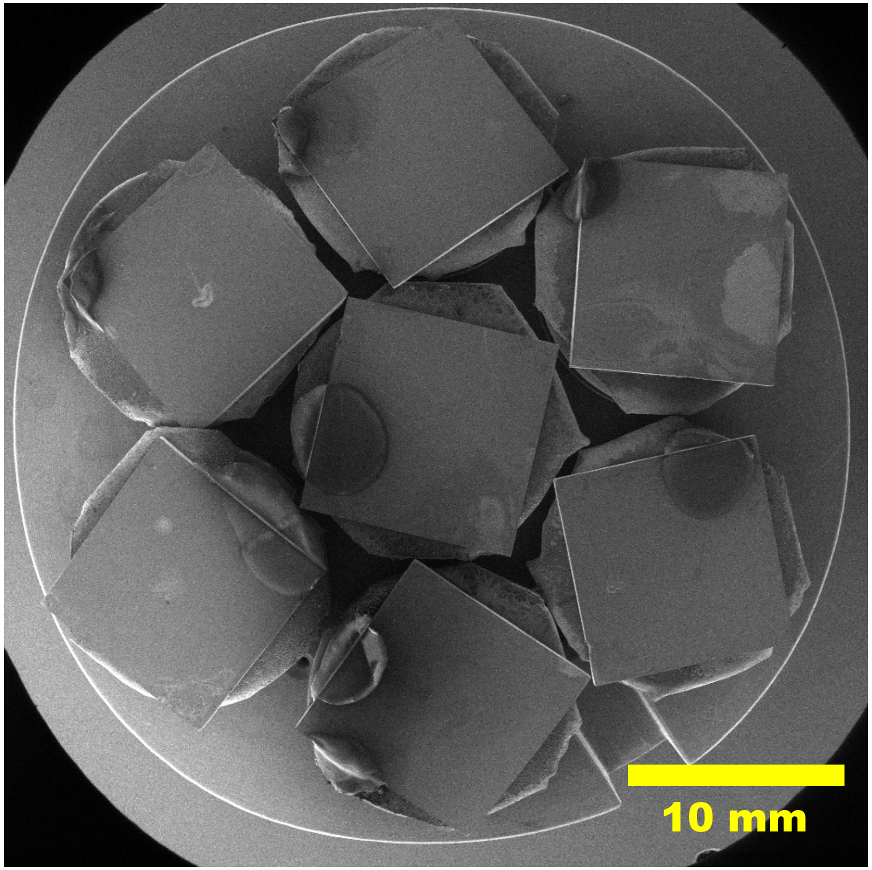


Sutton, Michael A., et al. "Scanning electron microscopy for quantitative small and large deformation measurements part II: experimental validation for magnifications from 200 to 10,000." *Experimental Mechanics* 47.6 (2007): 789-804.

Seven matching samples have been prepared for the SEM-DIC Challenge.



Seven matching samples (10 x 10 mm Si chips) have been prepared for the SEM-DIC Challenge.



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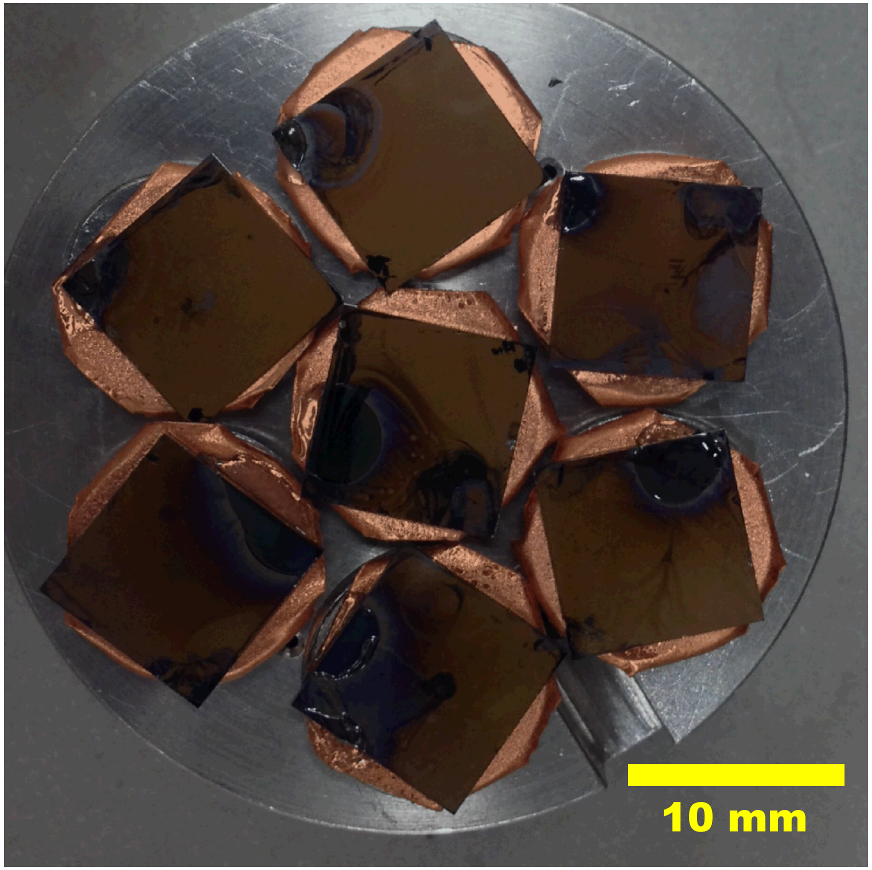
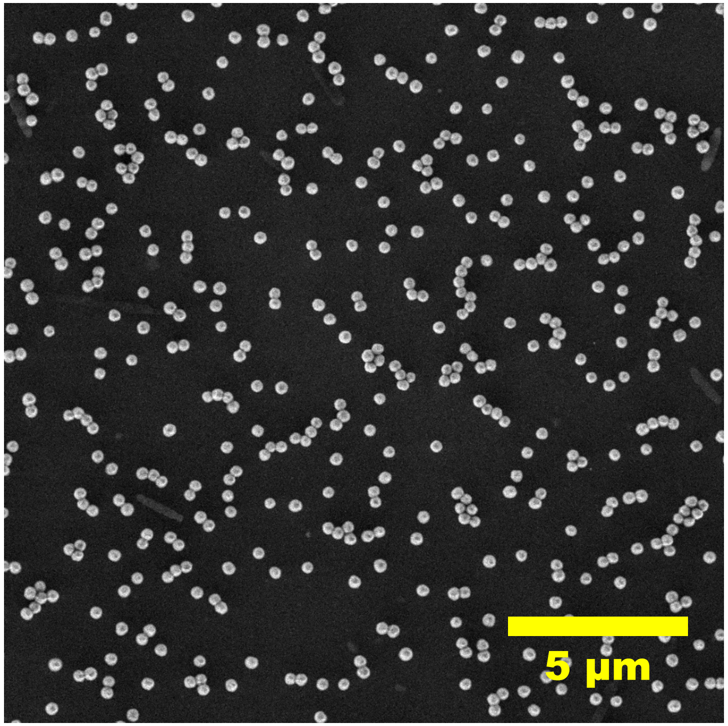
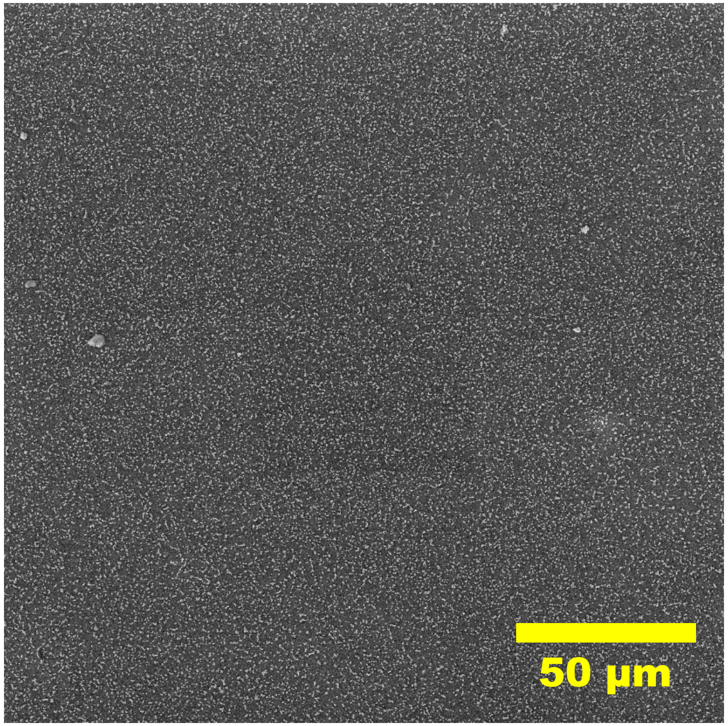


The samples have a speckle pattern made with a self-assembled layer of 300 nm Au nanoparticles.
The following slides show 200 µm FOVs from each sample.

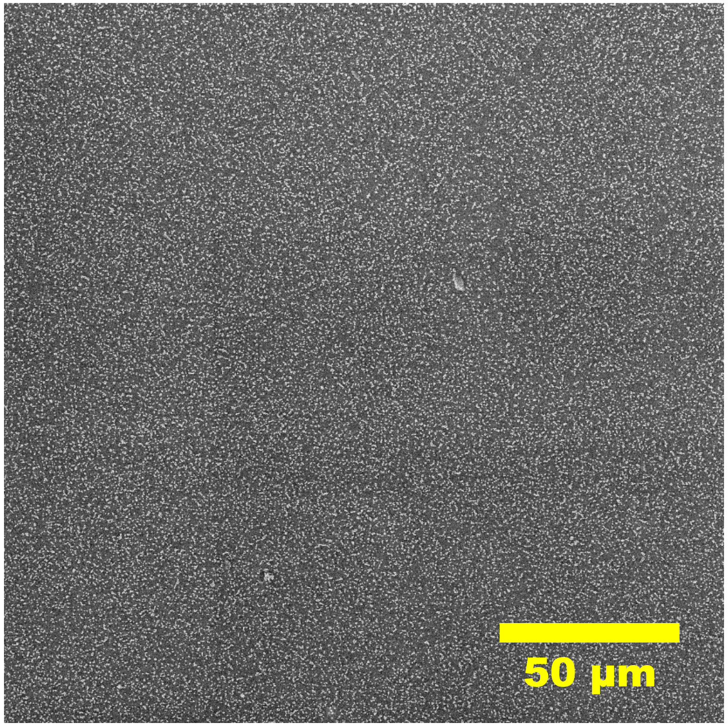


Kammers, Adam D., and Samantha Daly. "Self-assembled nanoparticle surface patterning for improved digital image correlation in a scanning electron microscope." *Experimental Mechanics* 53.8 (2013): 1333-1341.

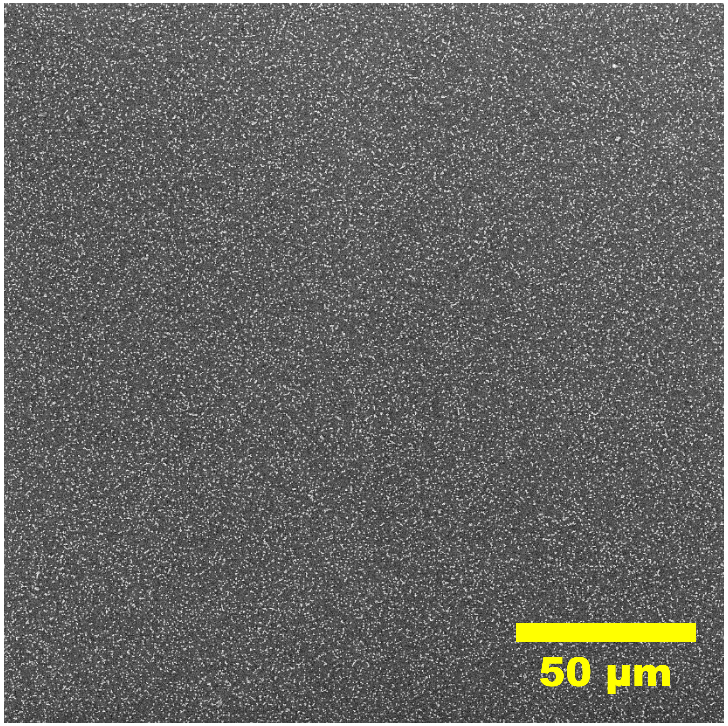
Sample A



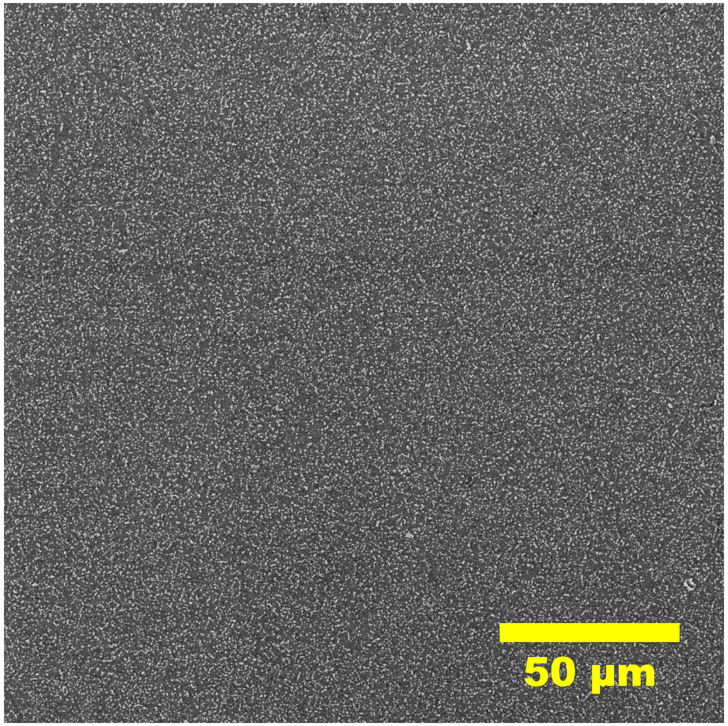
Sample B



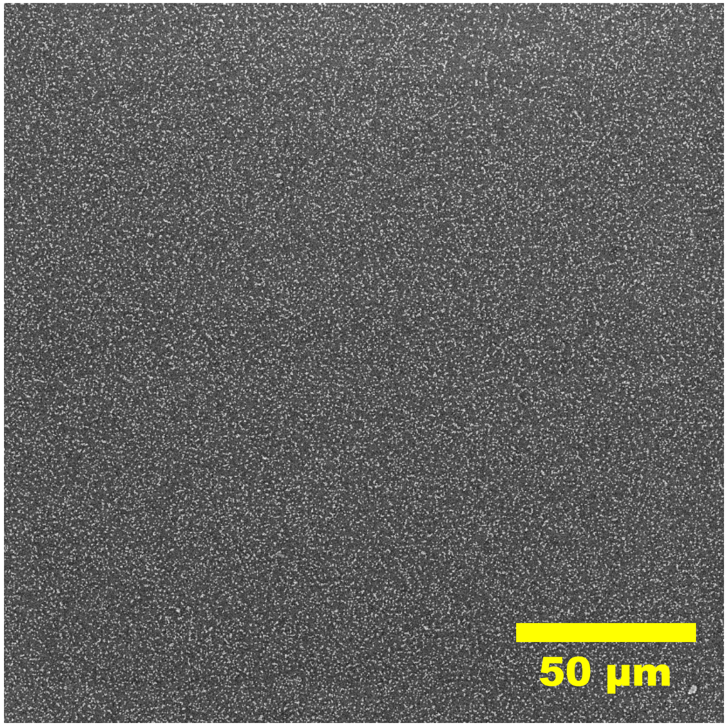
Sample C



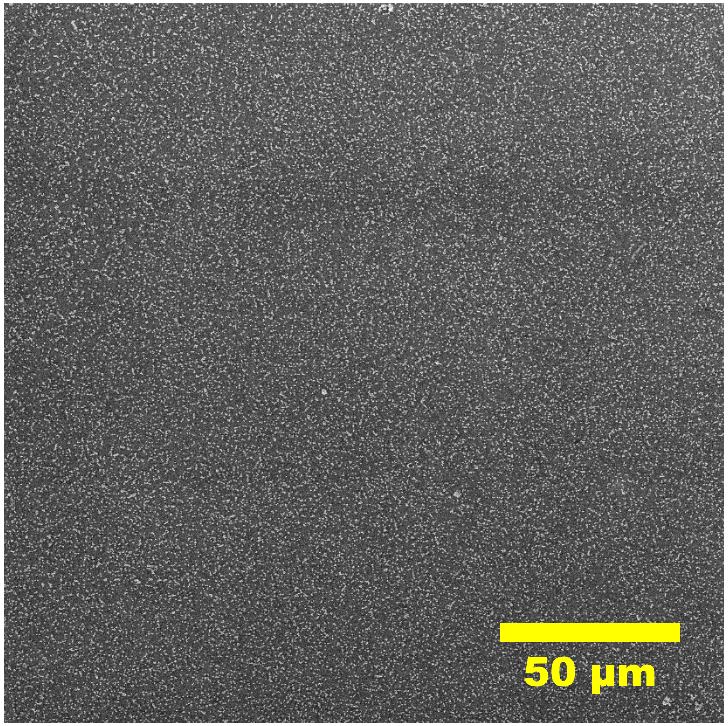
Sample D



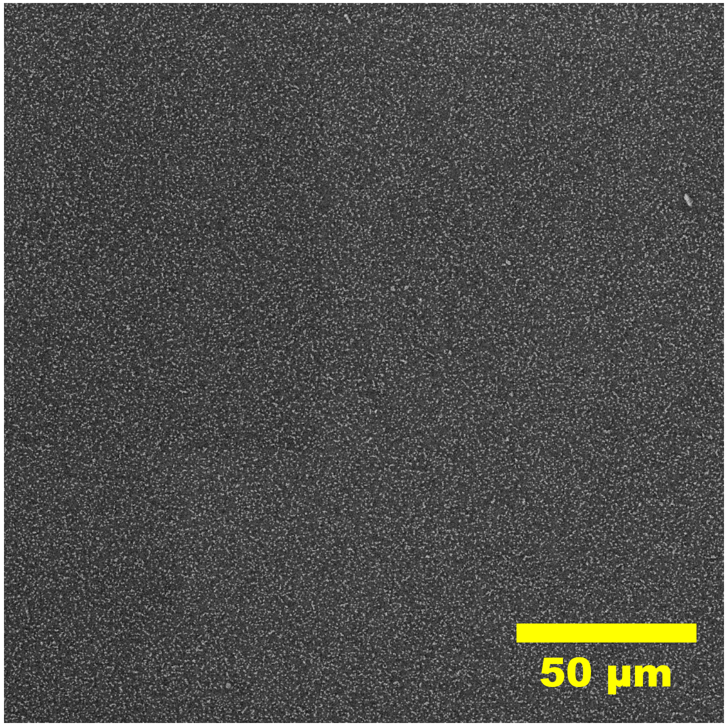
Sample E



Sample F



Sample G



Would you like to help with the SEM-DIC Challenge?

Participant requirements

- No prior experience with SEM-DIC required
- Only novice experience with an SEM needed
- Access to an SEM for tentatively about 20 non-consecutive hours of imaging will be required; exactly how many images/hours the Challenge will include is up for discussion.

Steps to get involved

1. Obtain one of the three SEM-DIC Challenge samples from Phil Reu at iDICs. In doing so, you make an in-kind commitment to follow through with your set of images.
2. Challenge participants will coordinate experiments via email with Will (wlepage@umich.edu).

Timeline

- October-November: Si wafer chips patterned with Au nanoparticles for a range of length scales and distributed to contributors
- December-January: initial image sets gathered by contributors; tentatively the design of experiments will include 20 images at 4 length scales, 3 dwell times, 3 beam voltages per detector (total of 720 images per detector, and contributors may submit images for multiple detectors, e.g. SE and BSE)
- February: initial data set analyzed
- March-May: possible follow-up images based on results from first image set
- June: present results at DIC Challenge meeting at SEM Annual Conference in Greenville, SC