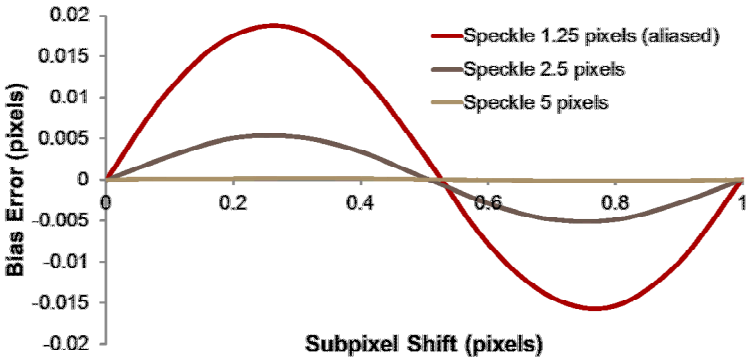
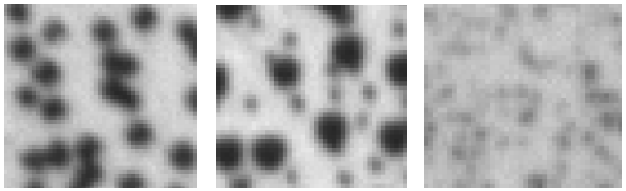
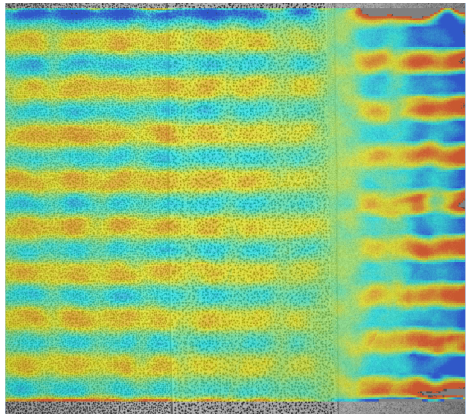
SAND2017-5459C







Using Anti-Aliasing Camera Filters for DIC: Does it Make a Difference?

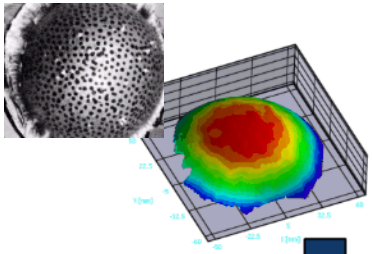
Phillip L. Reu

SEM June 2017 – Indianapolis, Indiana

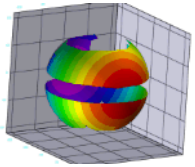
Digital Image Correlation – A revolution in full-field engineering measurements

Sandia National Laboratories

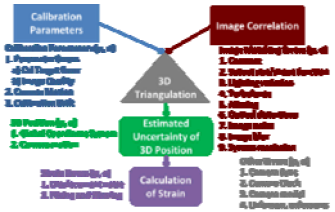
Displacement, velocity and strain



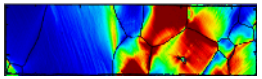
360º coverage



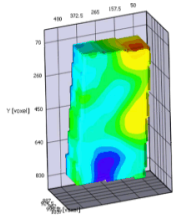
Stereo-DIC Uncertainty Quantification
From colors to metrology.



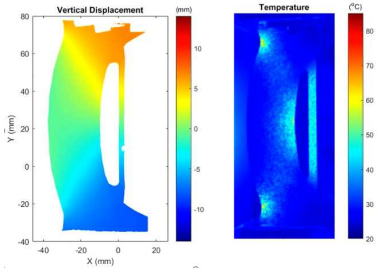
Grain Scale strain



Volumetric DIC

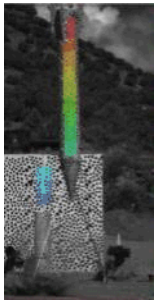


Advanced Material Testing

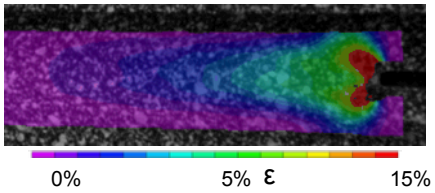


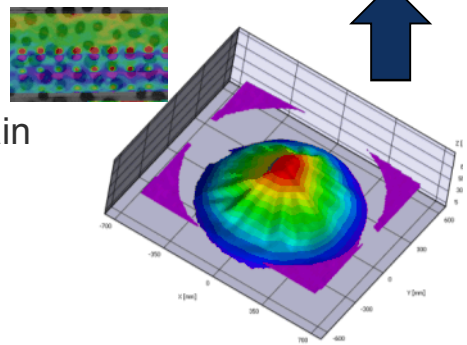
2005 2007 2009 2011 2013 2015 2017

Introduction of DIC to Sandia

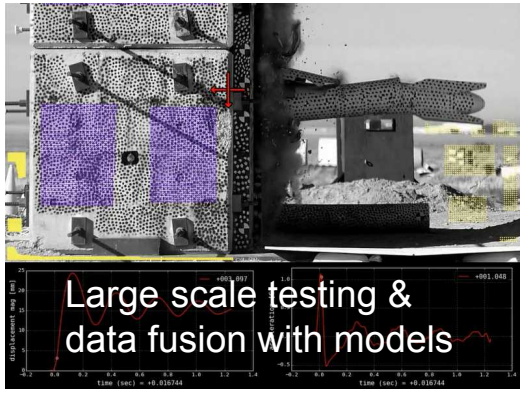


Crack-tip and Fracture Strain





Explosive Panel Deformation



Experimodelment: Inverse techniques for Material Properties

What is spatial aliasing, and how does it effect my DIC measurement?

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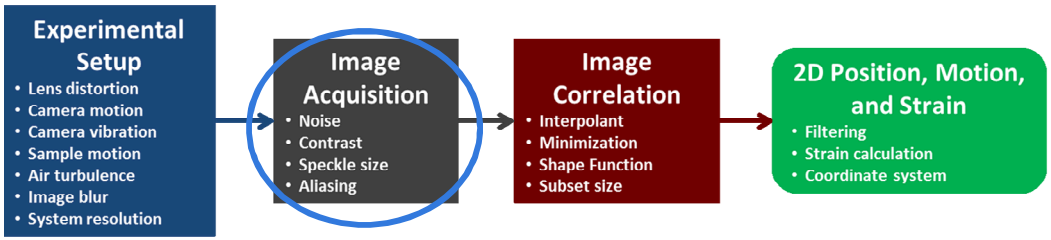
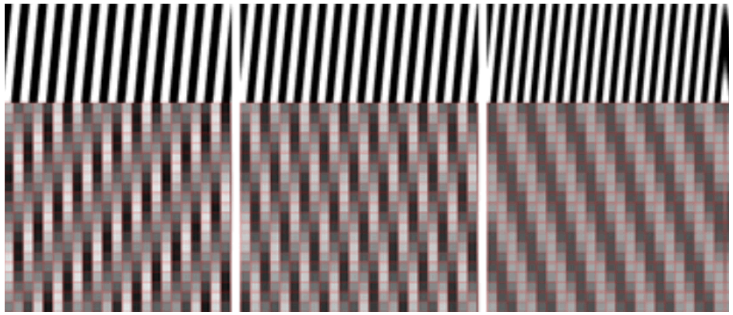
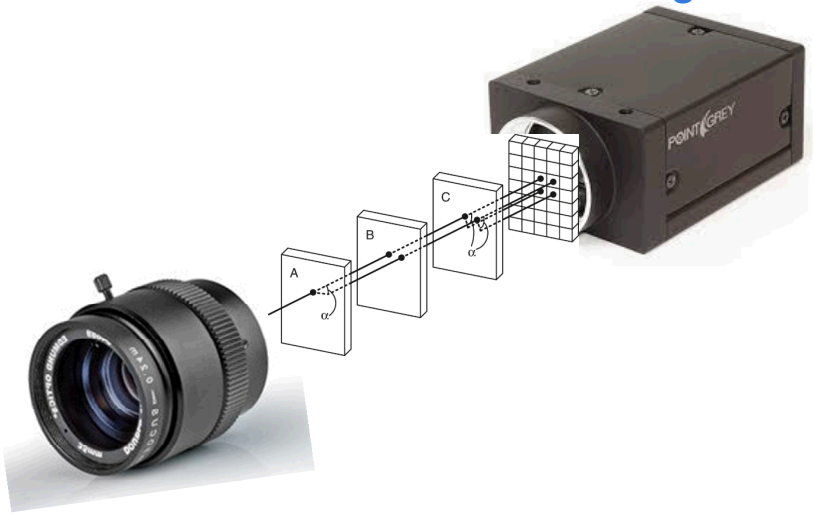
2D – Measurement error flow



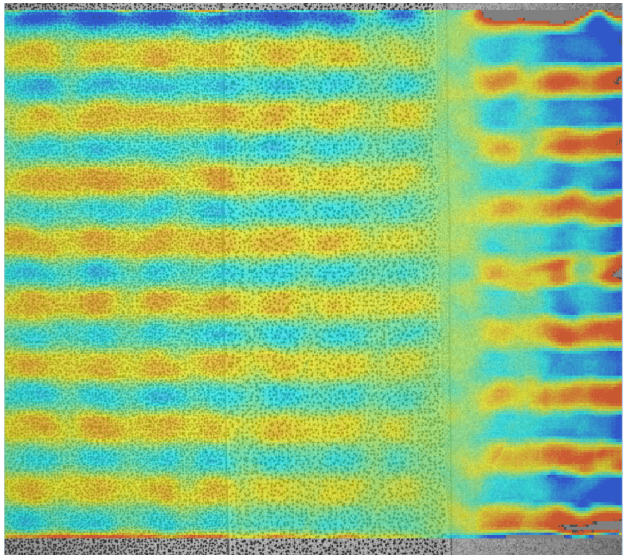
Define spatial aliasing‡



Machine vision anti-aliasing

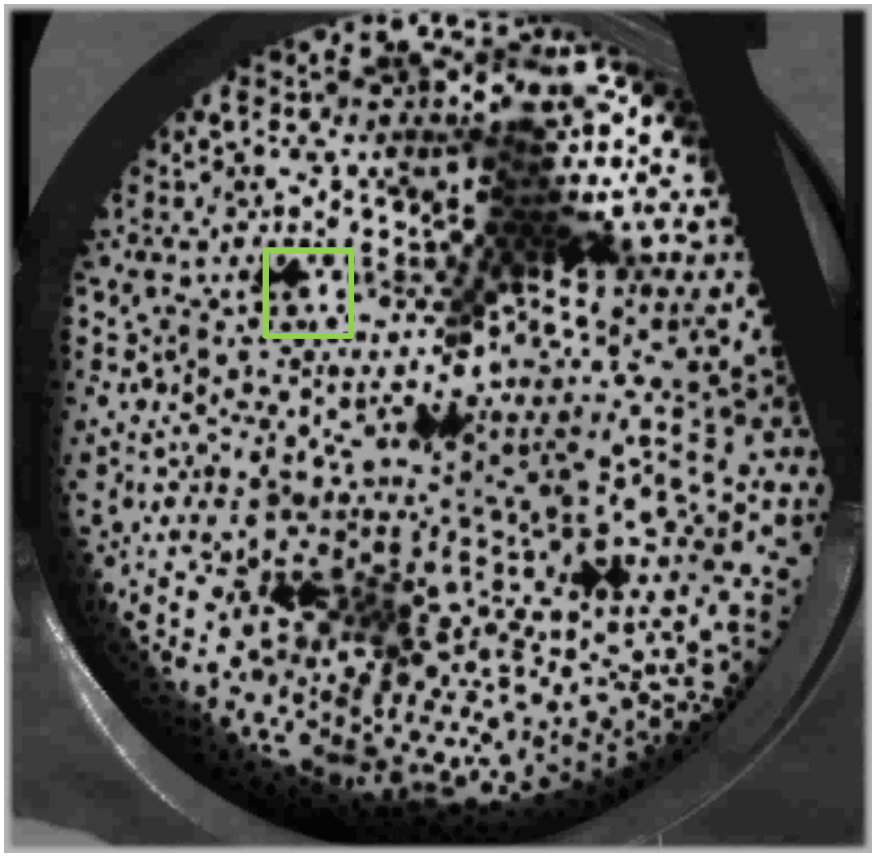


Aliasing influence on 2D-DIC



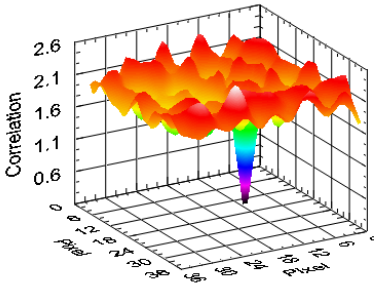
‡http://photoacute.com/

2D-DIC: Keep the dots in the box†

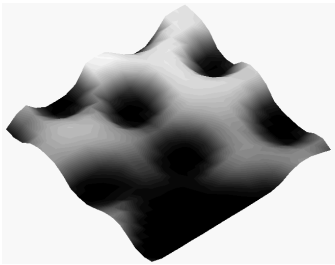


3 Hidden components of DIC‡

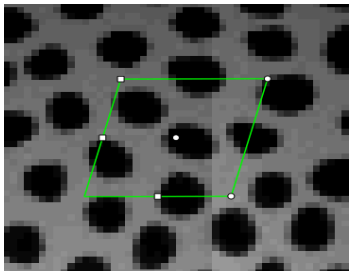
Matching



Interpolation



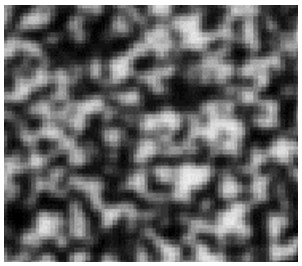
Shape Function



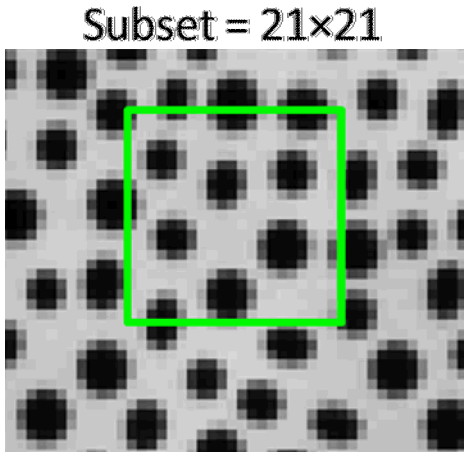
†Samantha Daly

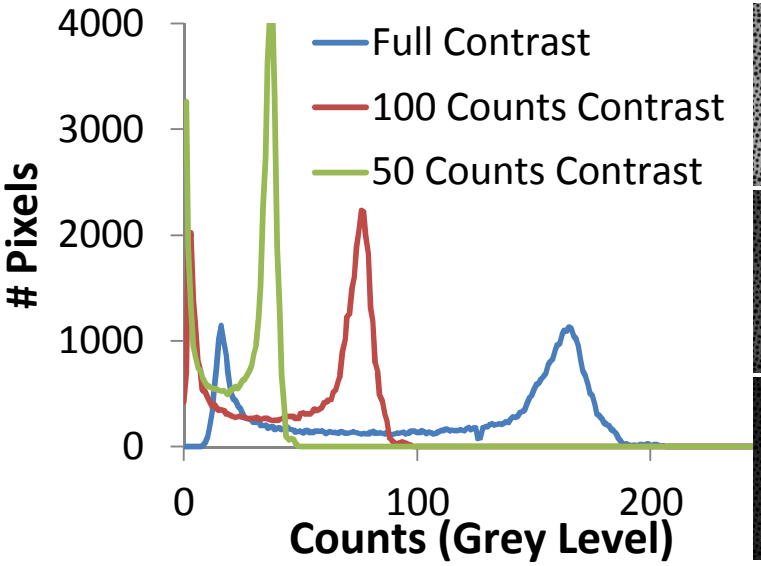
‡Phillip Reu – Experimental Techniques “Art and Application of DIC”

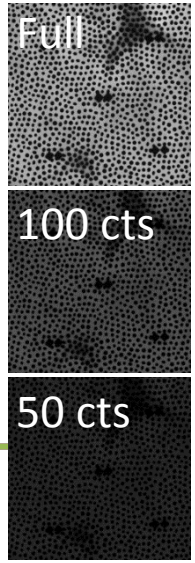
Qualities of a good speckle are: Good contrast, coverage and adequate size.

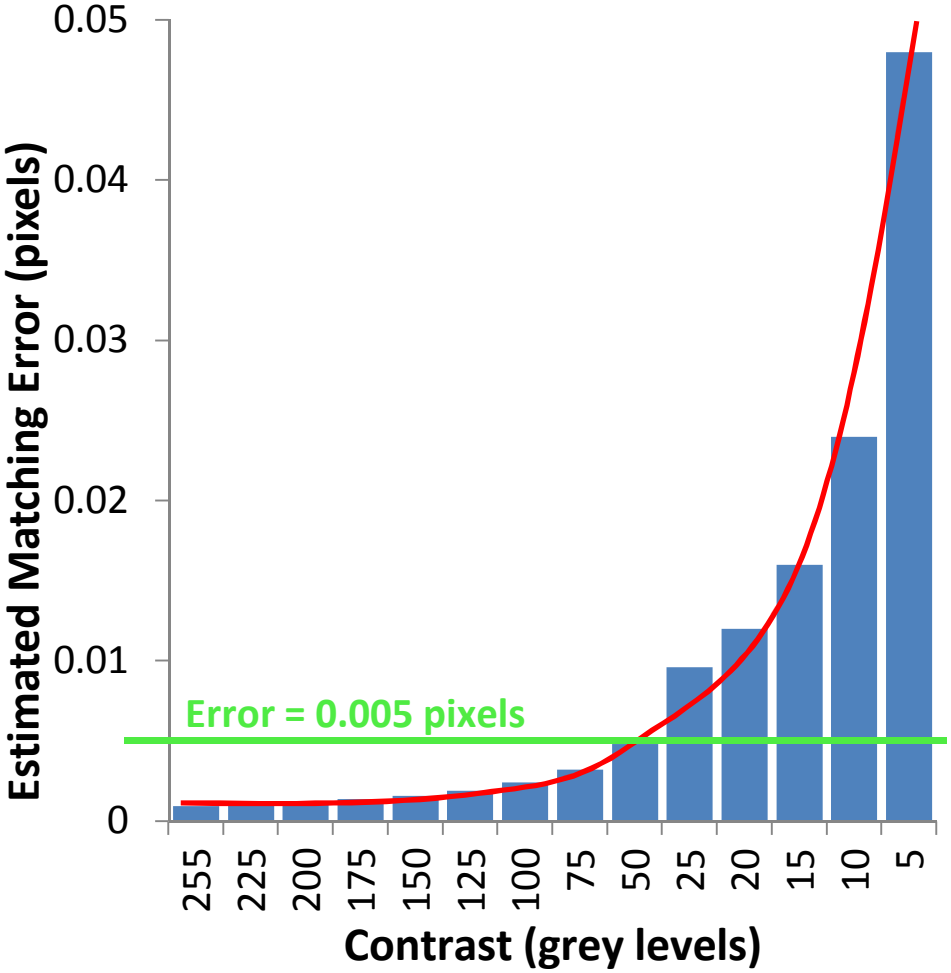


Calculated Size
= 4.3 (autocorrelation)
= 2.9 (autothreshold)
= 3-4(Eyeball)
Coverage = 48%









Matching uncertainty is dictated by the relationship between image contrast and noise.

Systematic Bias

$$\mathrm{E}(t) = \frac{\sum_i \left[h(x_i) \cdot \nabla T(x_i) \right]}{\sum_i \left[\nabla T(x_i) \right]^2} + A \cdot \frac{n\sigma^2}{\sum_i \left[\nabla T(x_i) \right]^2}$$

Interpolation Bias **Noise Bias**

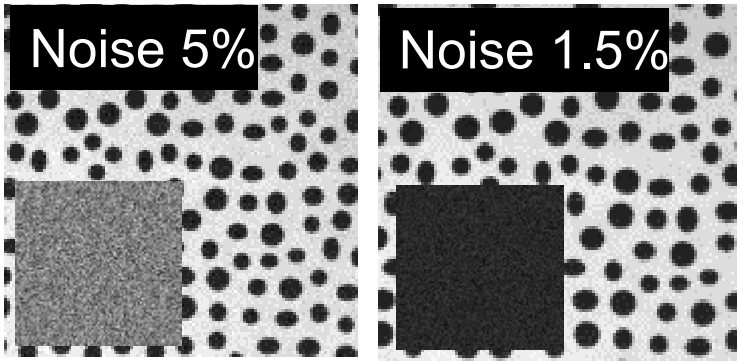
$h(x_i)$ is the interpolant function

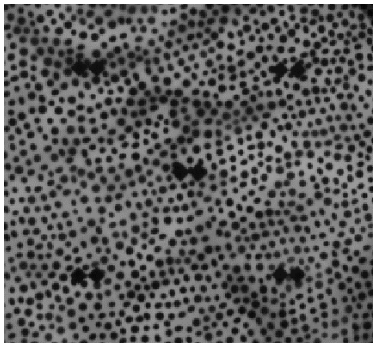
Random Variance

$$\mathrm{Var}(t) \cong \frac{2\sigma^2}{\sum_i \left[\nabla T(x_i) \right]^2}$$

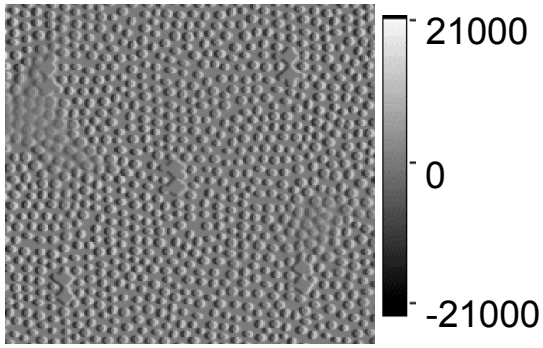
Measurement Variance

$\sigma \propto$



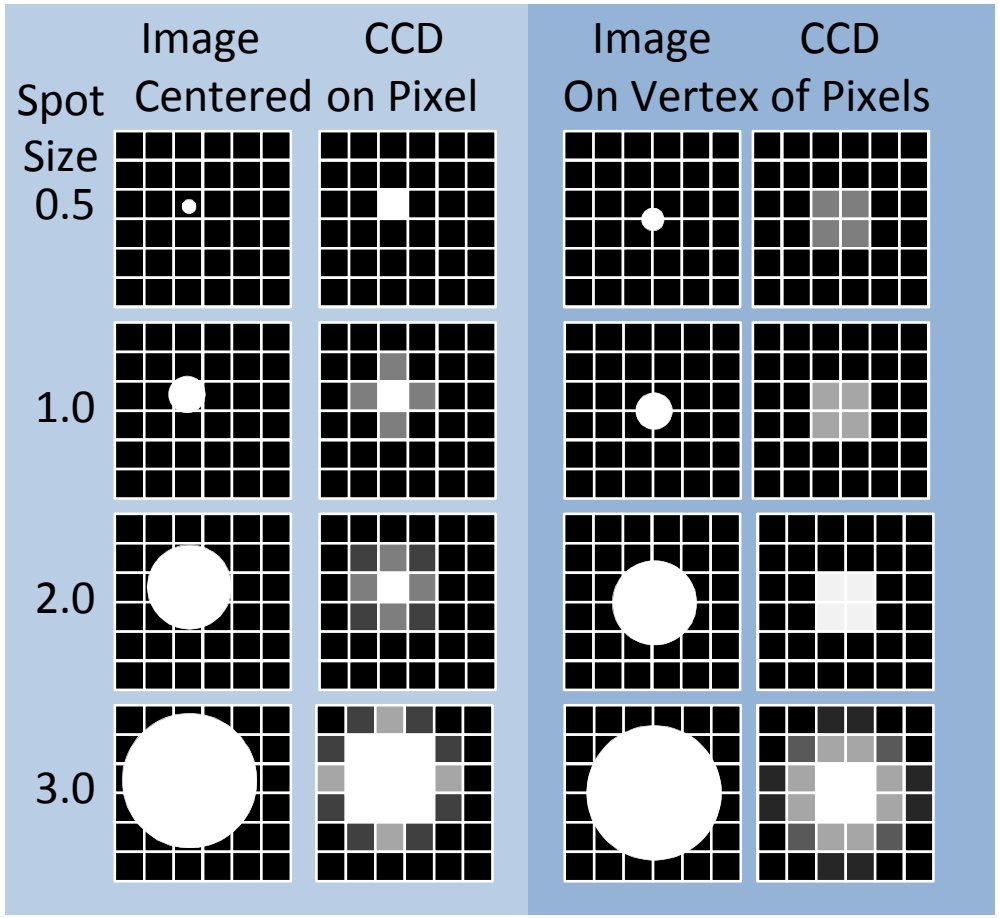


Gradients = $\sum_i \left[\nabla T(x_i) \right]$ **=**



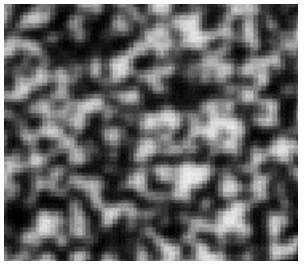
Note: These equations get more complicated with interpolant, and deformation. But the story remains the same.

A physical interpretation of aliasing on the grey values of a pixel.

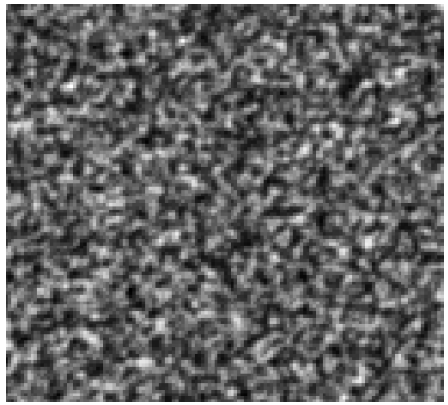


- Represents a single speckle

With an aliased speckle, the imaged spot no longer "localizes" the speckle!



Aliased version



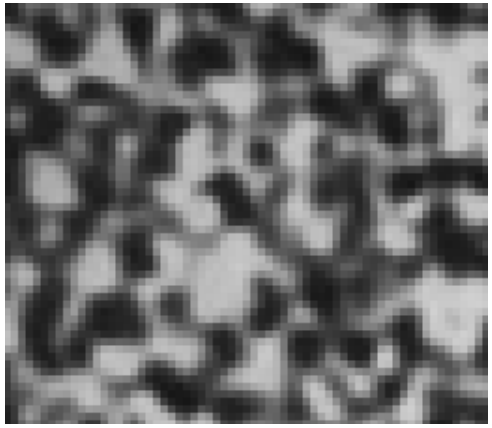
Actual Speckle Size = 1.5 pixels
Calculated Size
= 4.5 (autocorrelation)
= 2.2 (autothreshold)
= 2 to 3 (Eyeball)

$$MTF_{CCD} = \frac{1}{2p}(lp/mm)$$

p = pixel size in mm

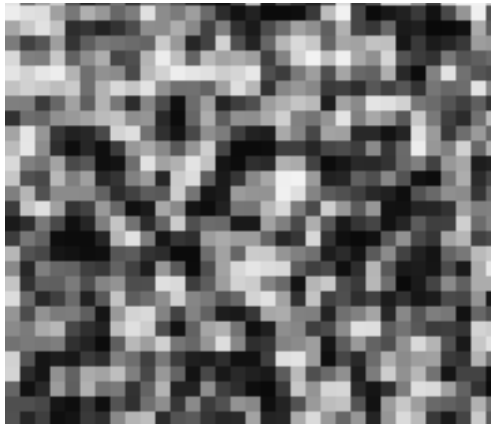
http://www.andor.com/learning/digital_cameras/?docid=319

It is important to quantify your speckle size and optimize for your experiment.



Good Pattern:
Actual Size = 4-5 pixels
Calculated Size

= 4.8 (autocorrelation)
= 3.6 (auto-threshold)
= 3-5(Eyeball)

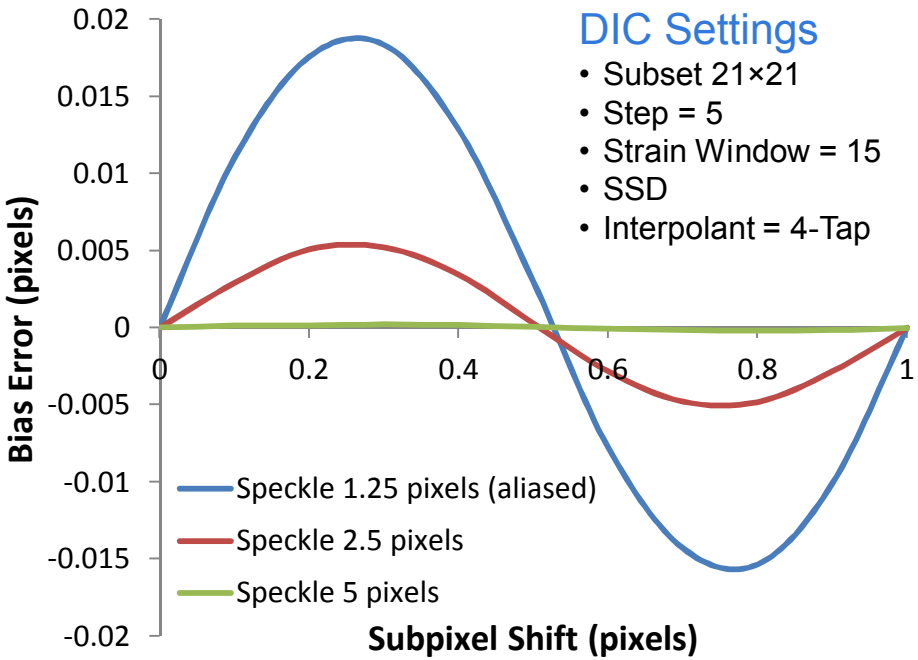


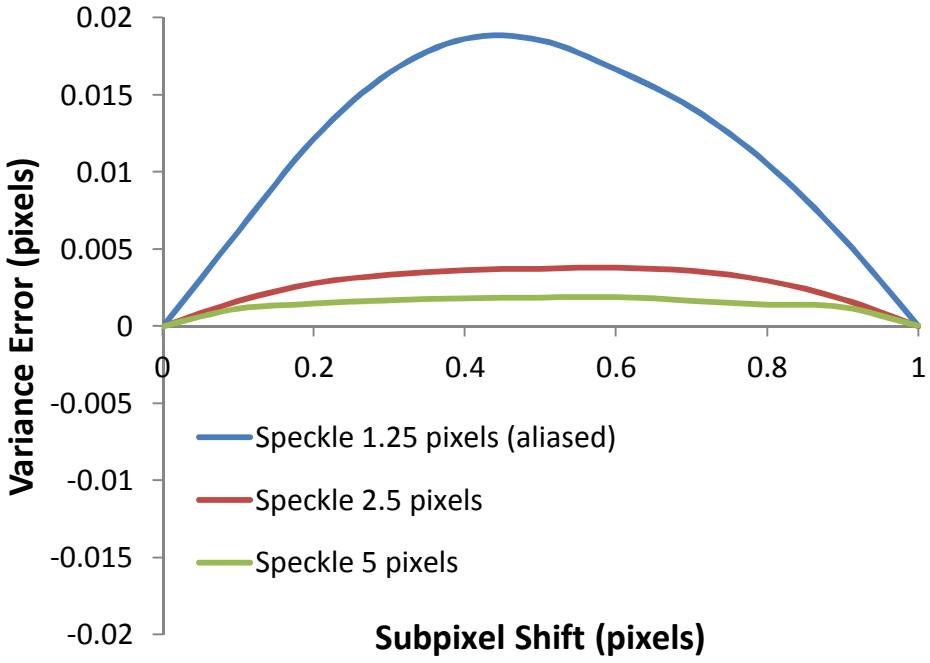
Aliased:
Actual Size = 1.5 pixels
Calculated Size
= 2.1 (autocorrelation)
= 1.6 (auto-threshold)
= 2 to 3 (Eyeball)

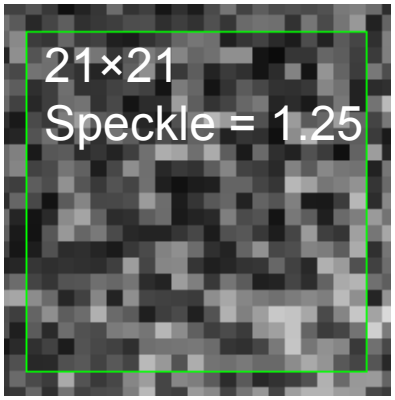
Measure and confirm the speckle size

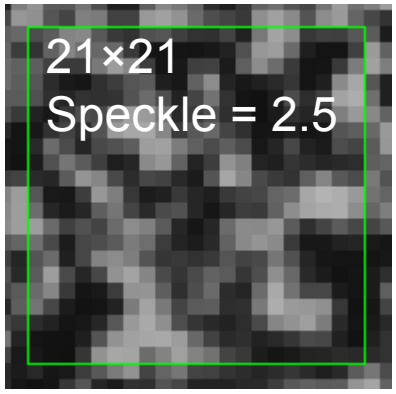
- MatLAB/LabVIEW “blob” analysis (using auto-threshold function)
- Autocorrelation
- By Eye
- Beware of aliasing. No results are correct after an aliased signal is digitized.
- Optimum is 3-5 pixels per speckle.

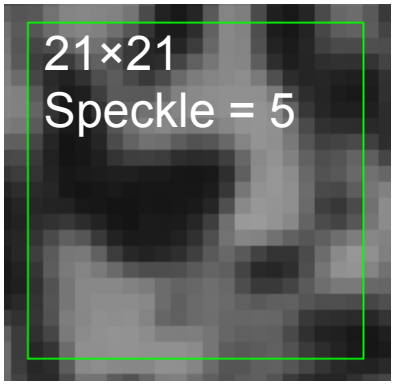
Bias error will increase interpolant bias errors with aliased speckles. Some interpolants more than others…











Maximum strain variance

	ε_{xx} (με)	ε_{yy} (με)
1.25 pixels	434	282
2.5 pixels	78	29
5 pixels	29	25

Spatial anti-aliasing in a camera is an *analog* blur filter.

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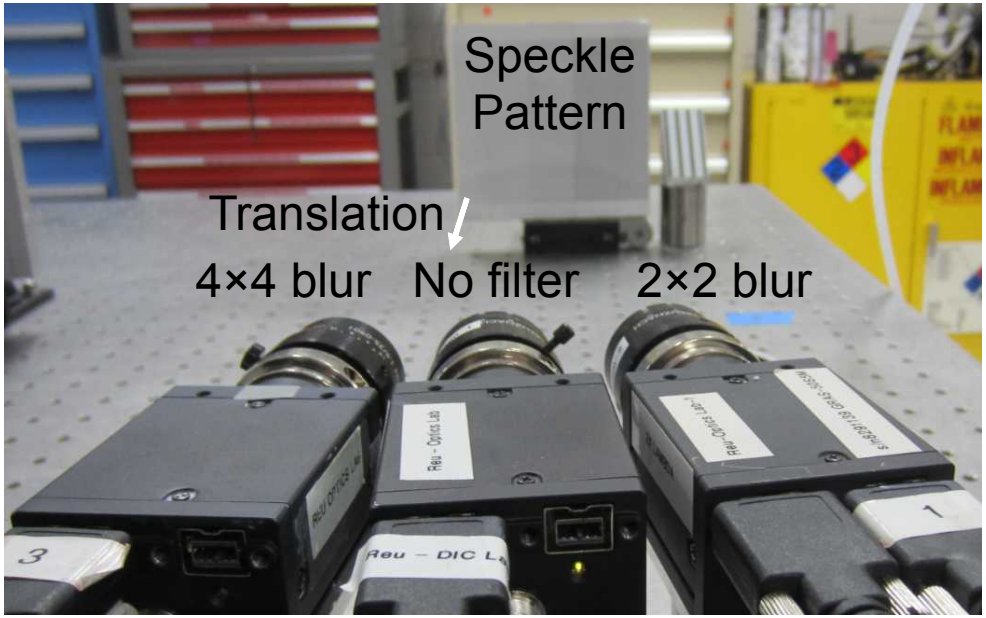
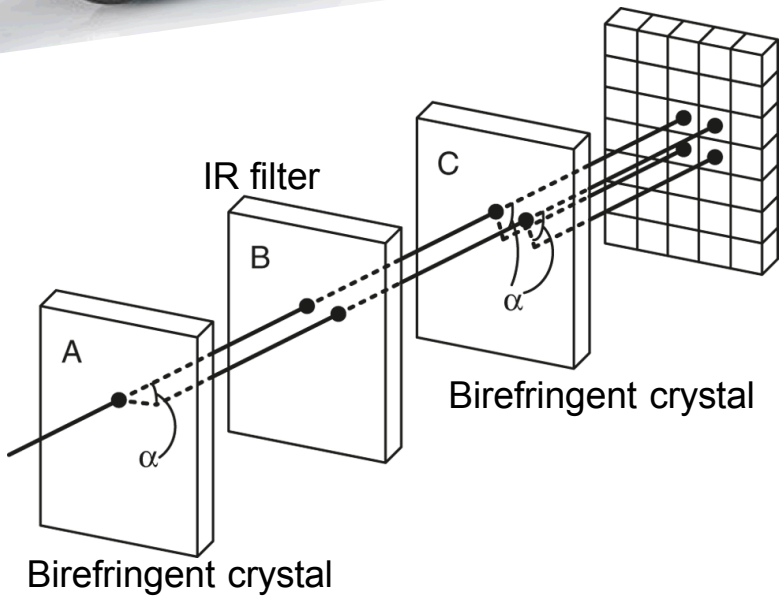
Antialiasing filters in digital cameras

- Most machine vision cameras *do not* have anti-aliasing
- Uses birefringence to crystals (lithium niobate) to blur the image.
- Must be done in analog. Once digitized anti-aliasing is not possible.
- Lens may also help with filtering of the image.

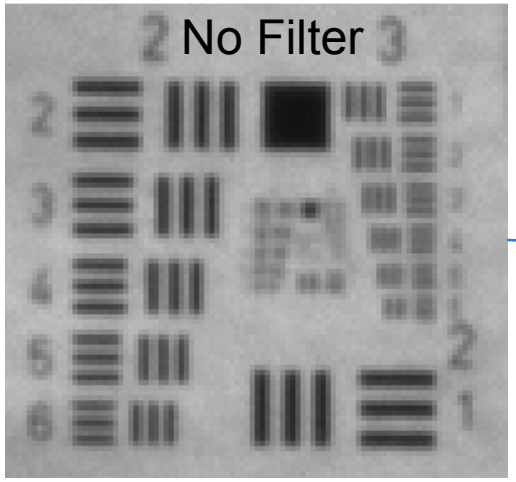


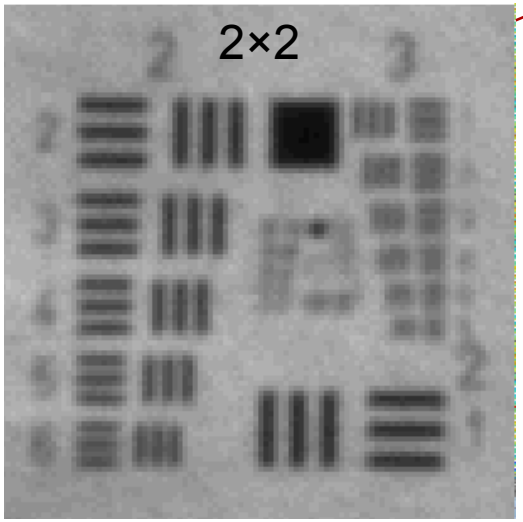
2×2 Pixel Blur

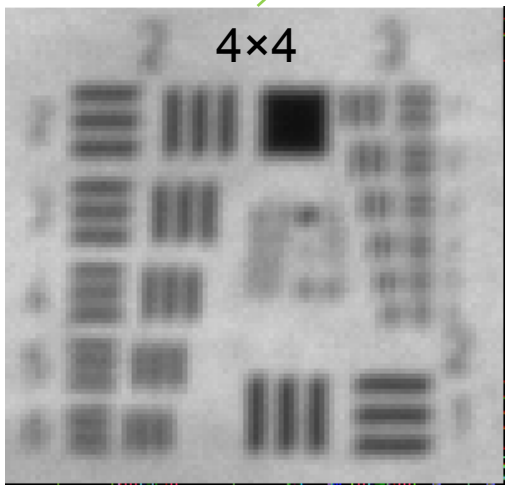


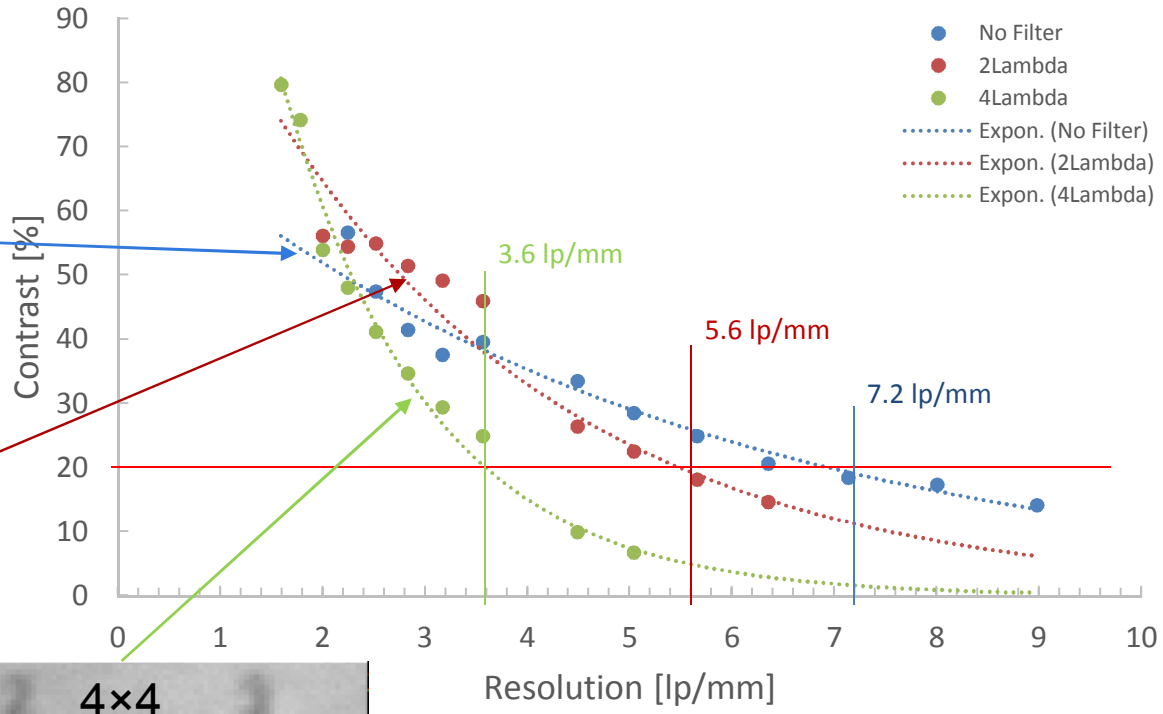
Ma T, Reeves SJ; Adaptive image acquisition by autodefocusing. J. Electron. Imaging. 0001;20(3):033013-033013-10. doi:10.1117/1.3624489.

Modulation transfer function of the three cameras. Blur filter is confirmed.

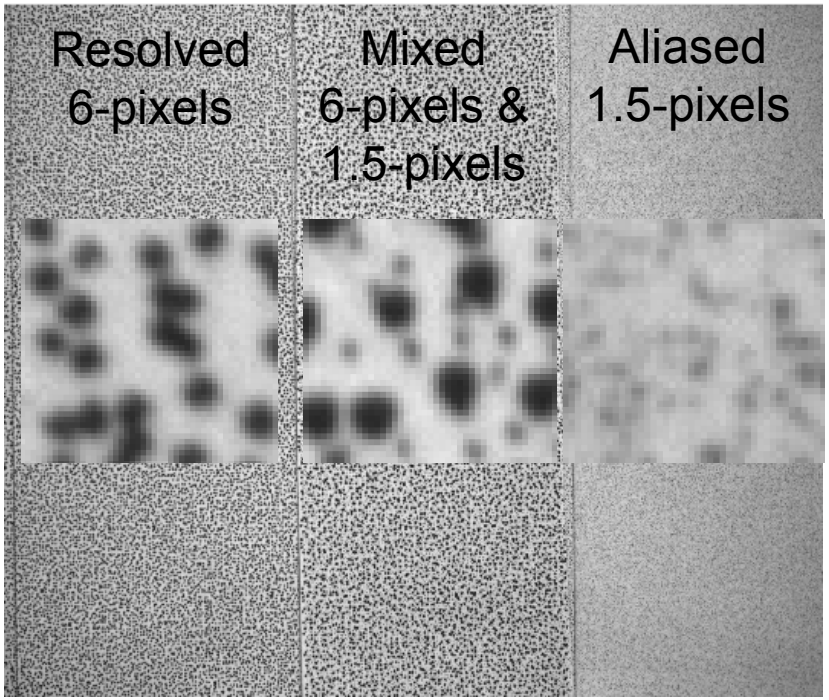




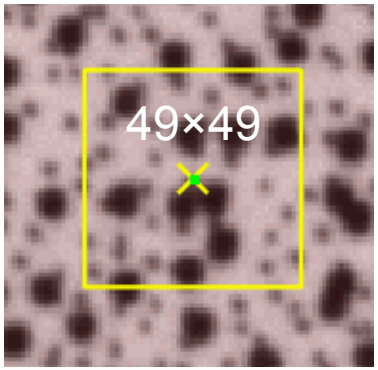




Experimental setup combined 3 cameras with an out-of-plane translation to apply a uniform strain.

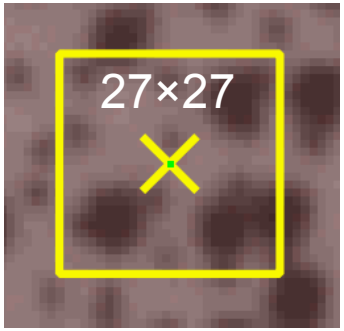


Translation

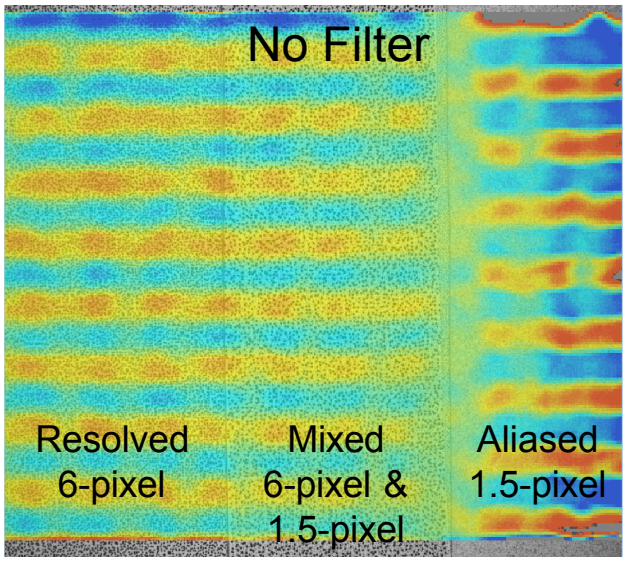


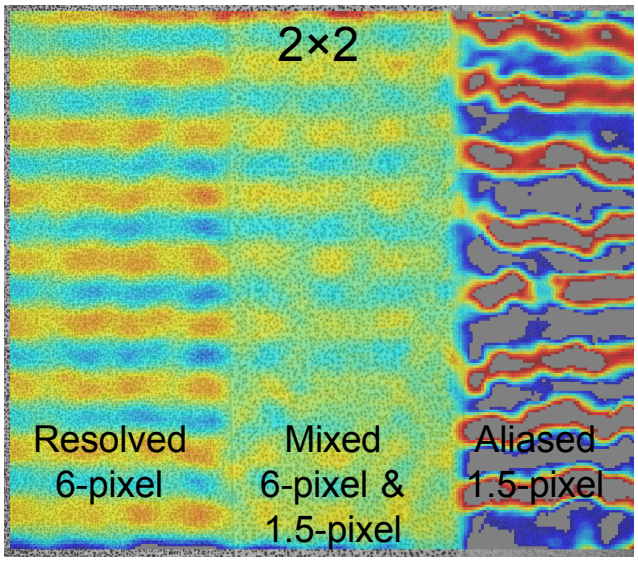
DIC Settings

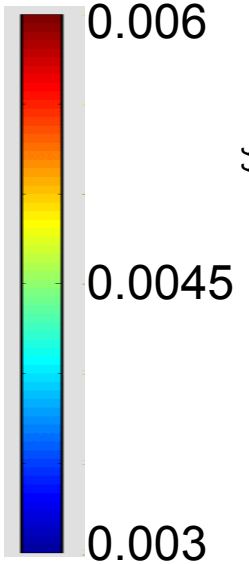
- Subset 49×49
- Step = 10
- Strain Window = 15
- SSD
- Interpolant (varies)



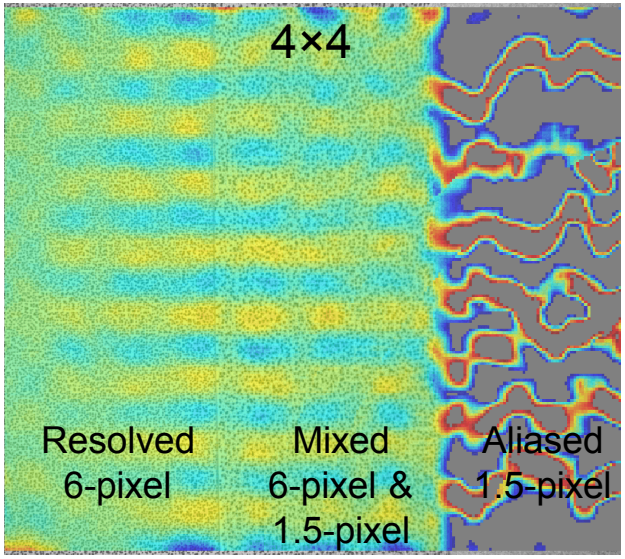
Bilinear interpolant does not perform well with aliased images.

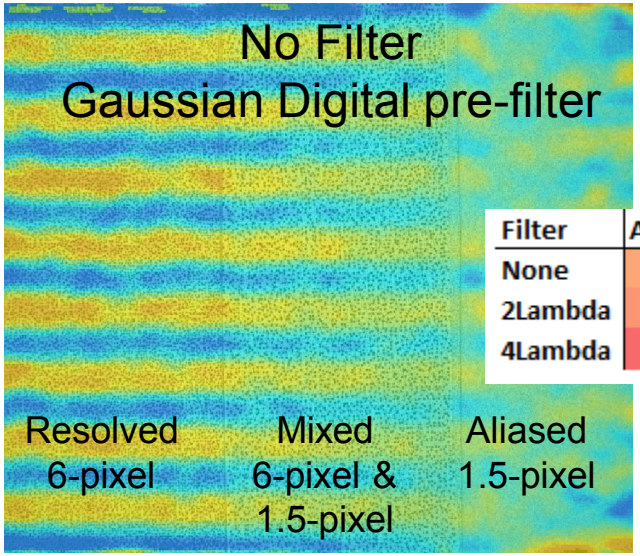






DIC Settings
- Subset 49×49
- Step = 10
- Strain Window = 15
- SSD
- Interpolant: Bi-linear

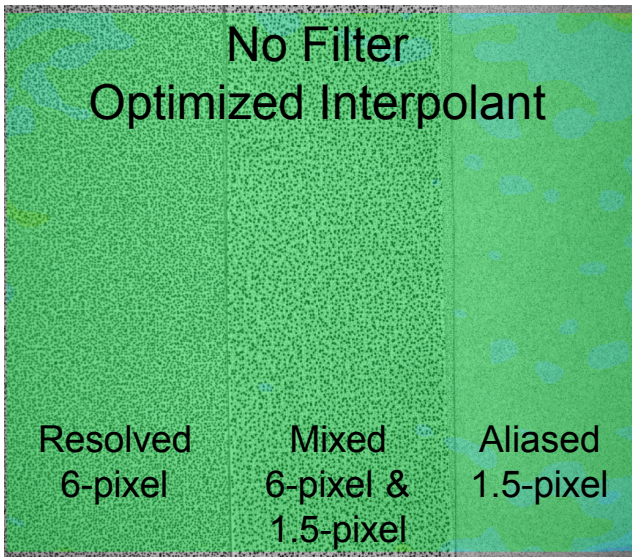


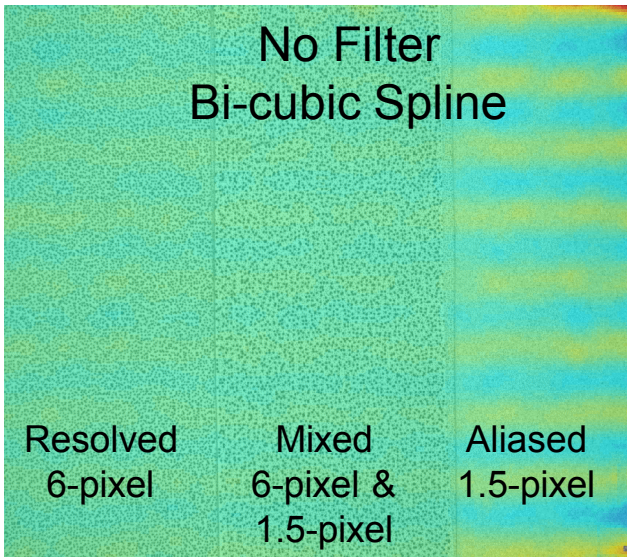


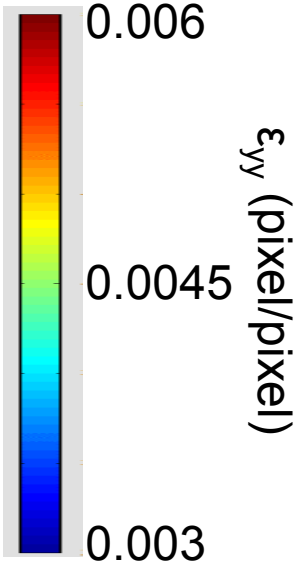
Peak-Valley Strain (με)

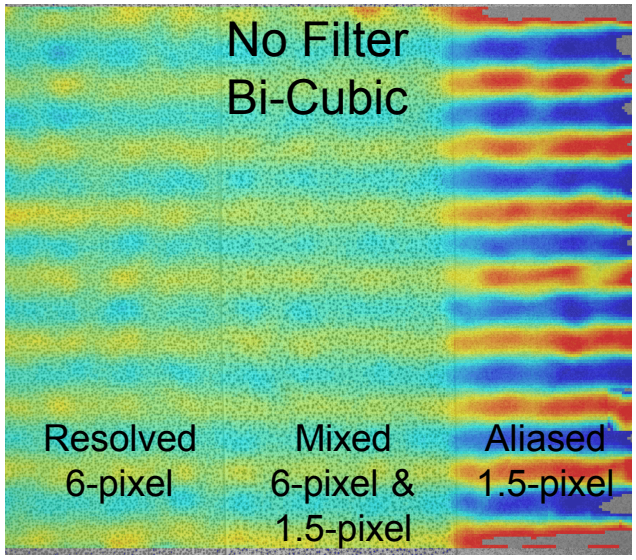
Filter	Aliased Speckle	Good Speckle	Mixed Speckle
None	4520	1309	1388
2Lambda	5393	1182	808
4Lambda	7437	590	589

Optimized interpolants do much better in reducing bias errors.









DIC Settings
- Subset 49×49
- Step = 10
- Strain Window = 15
- SSD
- Interpolant: (Varies)

Aliasing is bad. Anti-aliasing isn't good.

The story with aliasing

- Anti-aliasing filters do not improve aliased patterns.
- They may slightly improve a good speckle pattern.
- There is a competition between loss of contrast in blurring and removal of aliased content.
- Avoid having aliased speckles in the pattern.

Strain – ε_{yy}
Standard Deviation (με)

Subset 49×49

Filter	Aliased Speckle	Good Speckle	Mixed Speckle
None	100	49	33
2Lambda	333	56	85
4Lambda	899	41	43

Subset 27×27

Filter	Aliased Speckle	Good Speckle	Mixed Speckle
None	353	124	126
2Lambda	1103	157	294
4Lambda	203	118	223

Displacement – V
Standard Deviation (pixels)

Filter	Aliased Speckle	Good Speckle	Mixed Speckle
None	0.014	0.006	0.005
2Lambda	0.025	0.007	0.009
4Lambda	0.044	0.007	0.008

Filter	Aliased Speckle	Good Speckle	Mixed Speckle
None	0.028	0.011	0.009
2Lambda	0.050	0.011	0.023
4Lambda	0.085	0.011	0.019

INTERNATIONAL DIGITAL IMAGE CORRELATION SOCIETY

Annual International DIC Society Conference

November 6 – 9, 2017 in Barcelona, Spain

http://idics.org/idics-2017

General Call

The iDICs 2017 Conference and Workshop provides a forum to extend the frontiers of DIC technology, standardize its use, and improve its practice. This meeting brings together leading experts from industry, academia, and laboratories from around the world. Since it's inception in 2015, it has become the centralized nucleus for the state-of-the-art in DIC.

Monday Courses (November 7)

- Put courses here.

Mission: Extend – Improve – Train

Extending the Frontiers: Training the next Generation:
Standardizing for Industry: Improving our Practice

Important Dates

Abstract due July 15, 2016
Paper due Sept. 1, 2016
Early Registration until Sept. 1