Introduction to PIV

Part 1

Collecting Good PIV Data

TSI Webinar Training Series

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Topics Covered

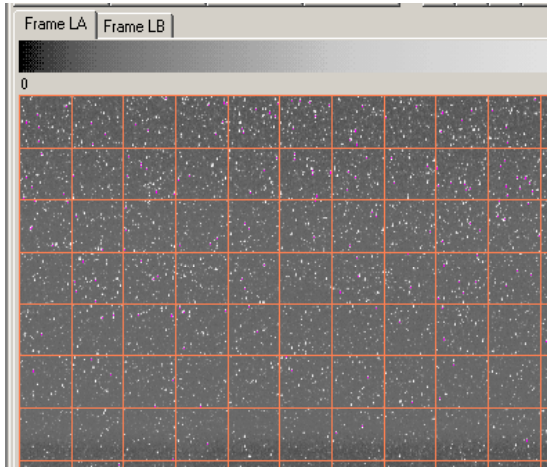
- PIV Fundamentals (2D PIV)
  - Cross Correlation
  - Rules of Thumb
- Experimental Considerations
- Measurement Setup
  - Calibration
  - Seed Density
  - Optimizing Δt
- Introduction to Insight 3G

PIV Fundamentals

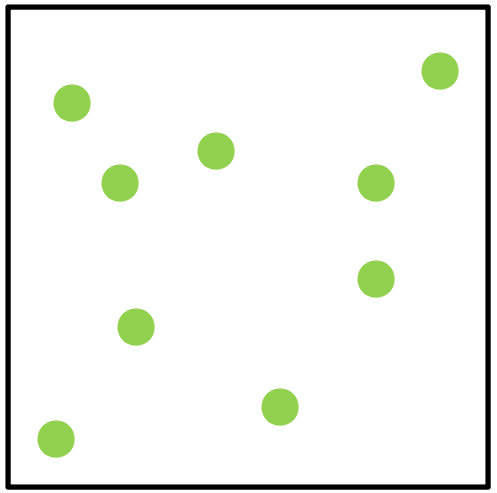
- PIV measures the displacement of tracer seed particles in a flowfield to determine the 2D velocity field
  - At time t_1
    - Pulsed laser sheet illuminates a planar region of the flow
    - Particles are imaged on the camera (Frame A)
  - At time $t_1 + \Delta t$
    - A second image (Frame B) is taken of a second light sheet
  - Statistical (Cross-Correlation) methods are used to determine the particle displacement over the time Δt, and thus the local velocity

Cross Correlation

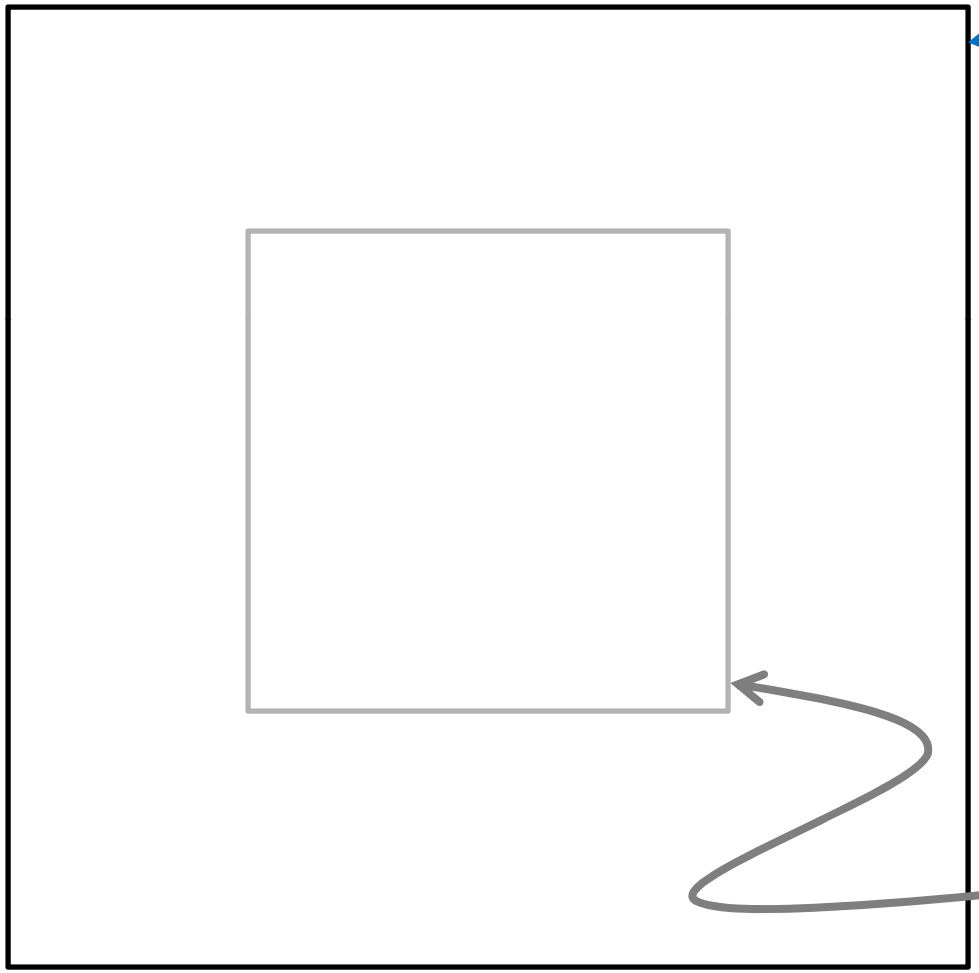
- All particles look alike, so it is hard to find the ‘same’ particle in both Frame A and B (PTV)
- Instead, PIV uses a statistical approach to find the most likely displacement of a group of particles
- Frame A is broken up into a grid of ‘interrogation regions’



- The group of particles in the interrogation region creates a fairly unique ‘fingerprint’ that we can look for in both frames (PIV)



Cross Correlation

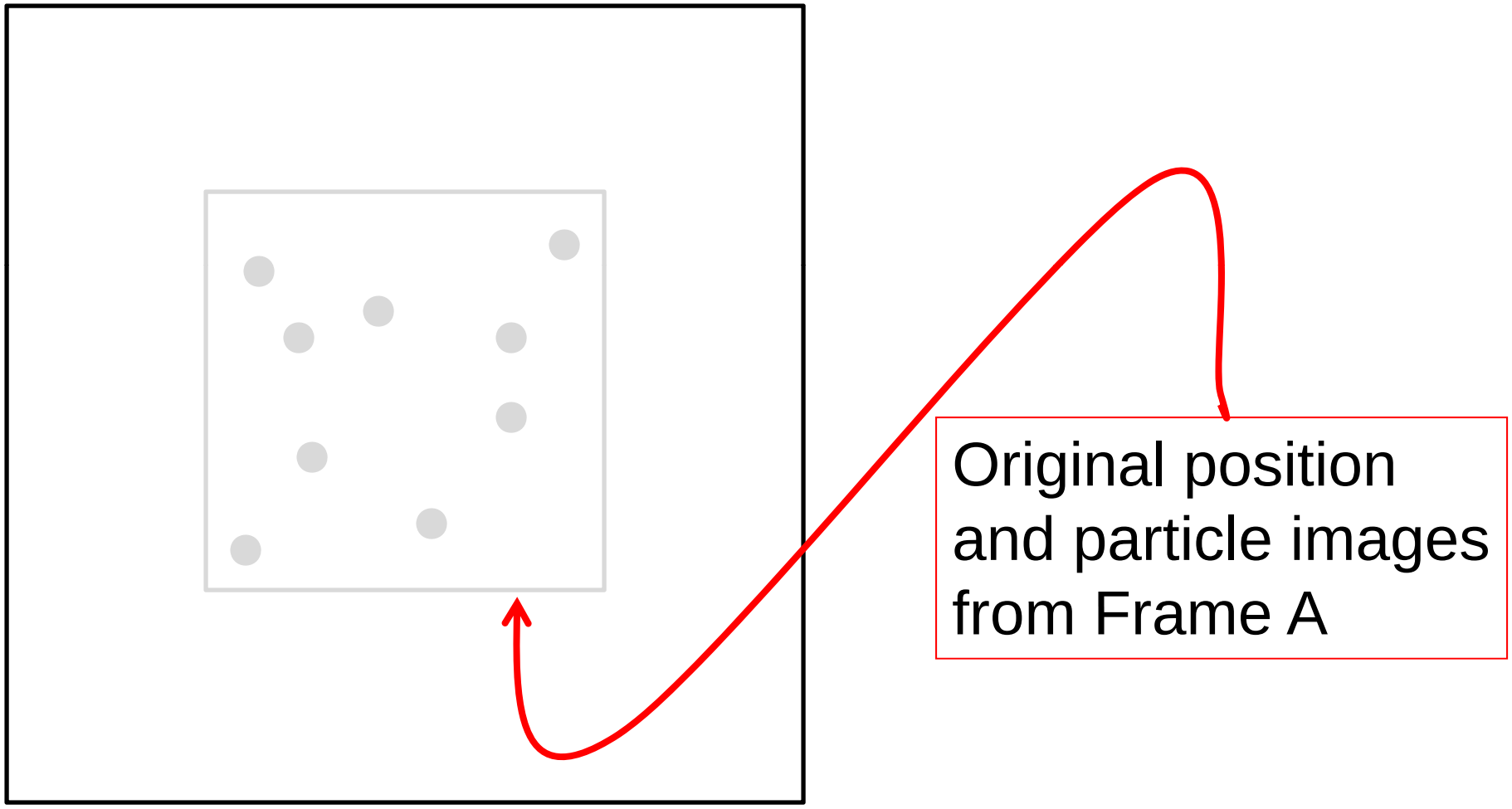


Search Area

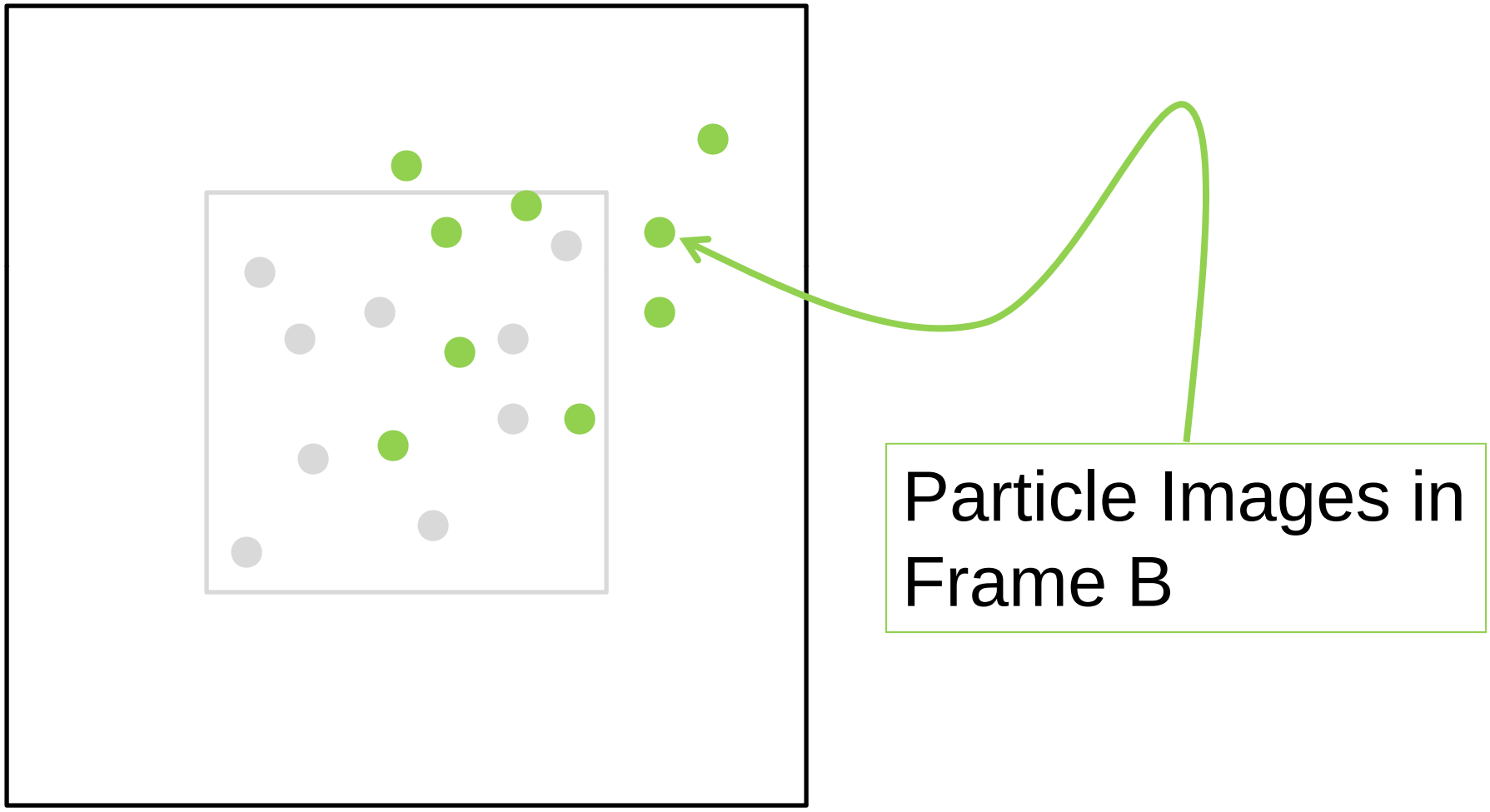
- A search area is defined in Frame B of the PIV Image Pair
- The relative location of the original interrogation region in Frame A is known

Original Interrogation Region

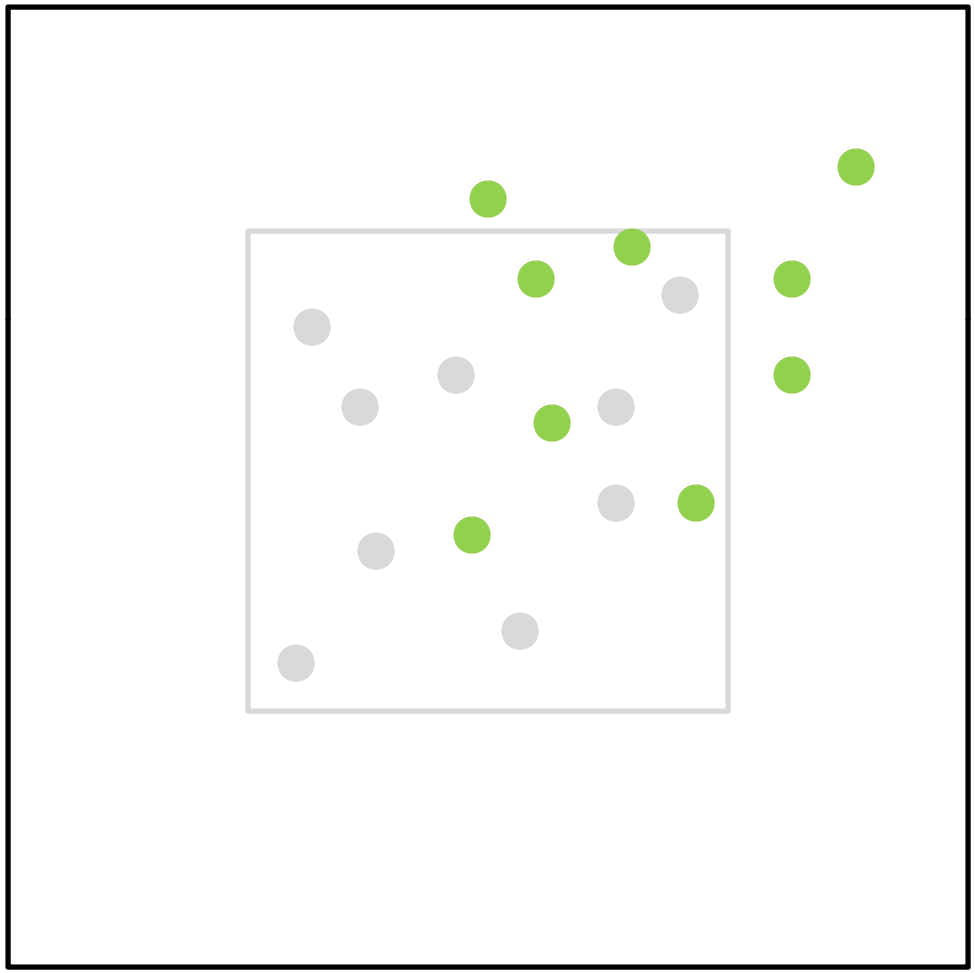
Cross Correlation

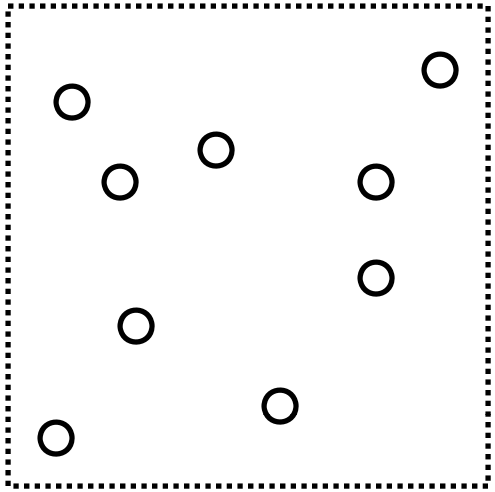


Cross Correlation



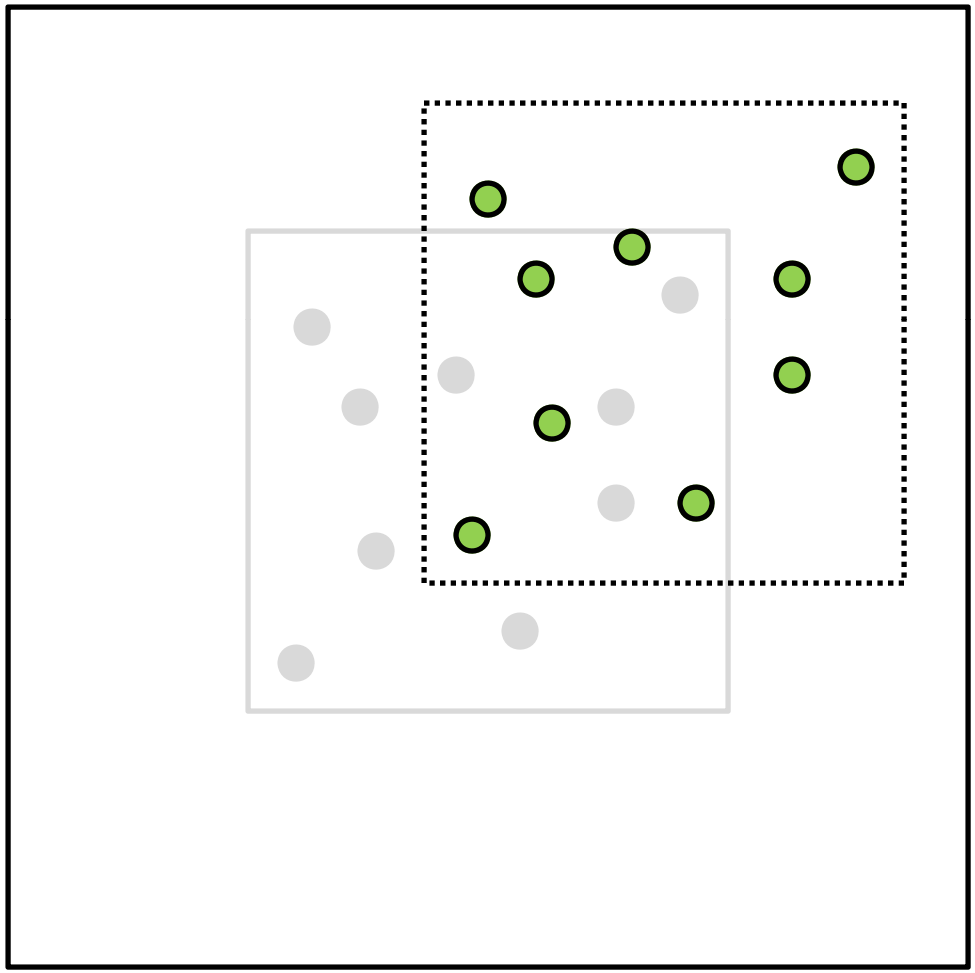
Cross Correlation





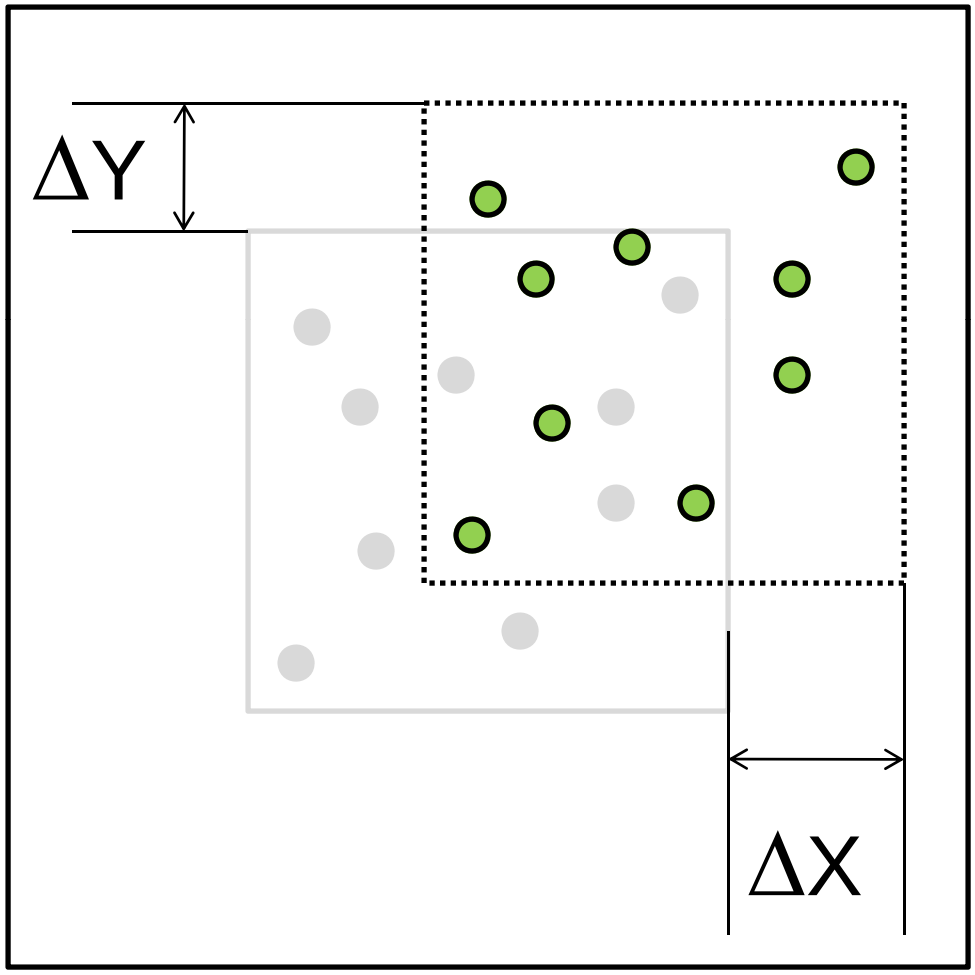
A ‘Spot Mask’ (above) is scanned through the search area in Frame B, and a correlation value is calculated at each position

Cross Correlation



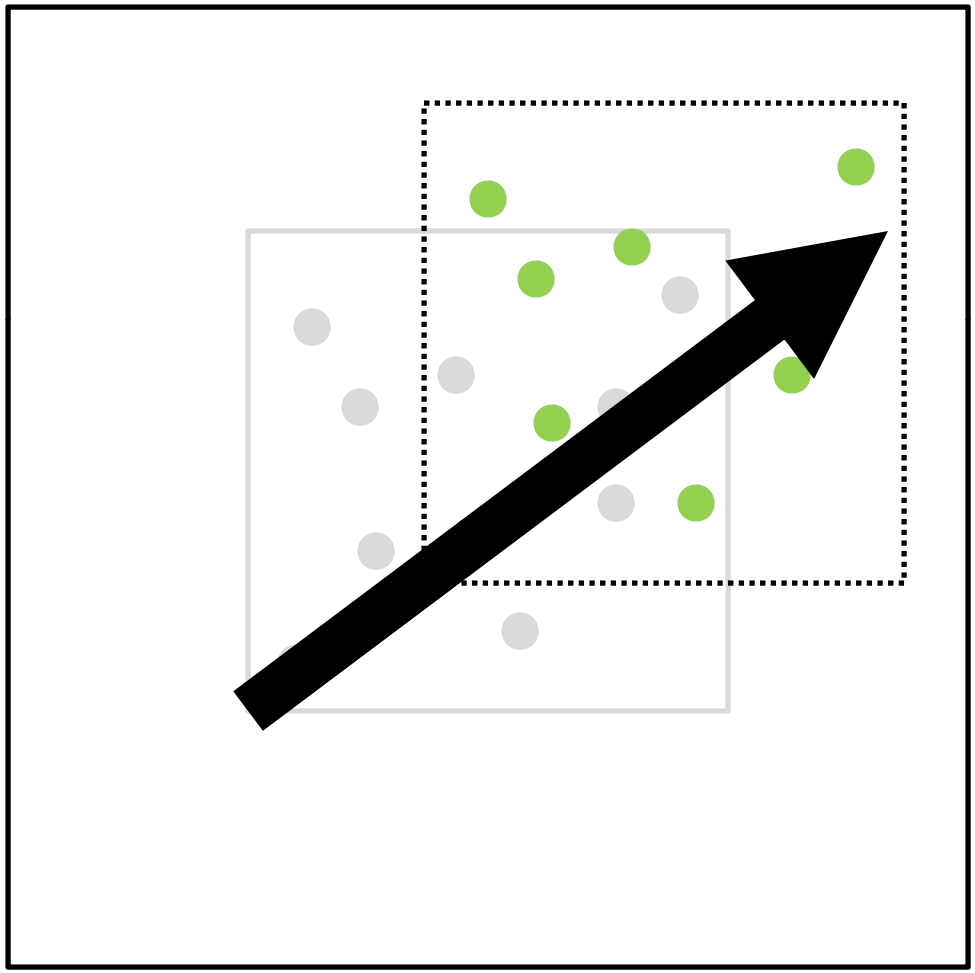
The value of the correlation function will be maximum when the ‘fingerprint’ in the Spot Mask is identified in Frame B

Cross Correlation



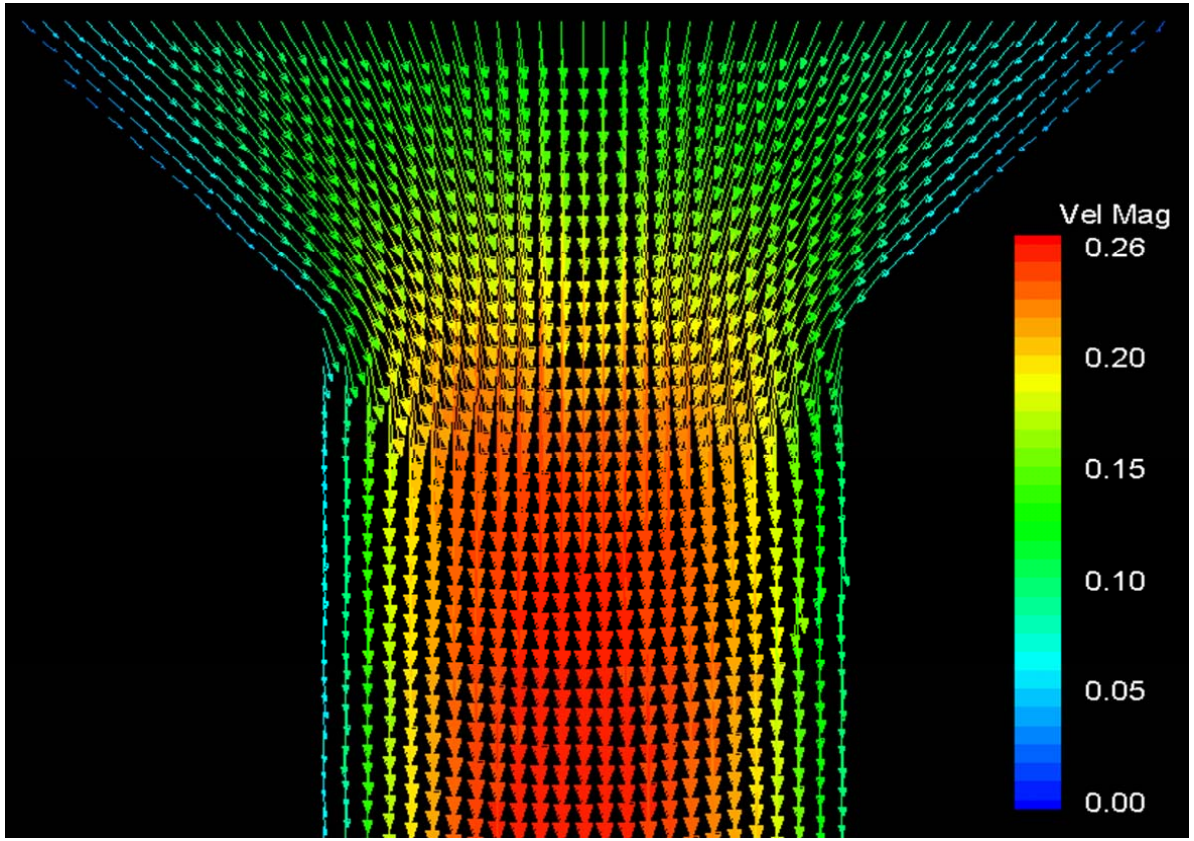
The X and Y displacements of the particles are determined by the offset of the interrogation regions

Cross Correlation



Since we know the time separation (Δt) between the 2 laser pulses very accurately, we can measure the group velocity as the displacement / Δt, and assign a single velocity vector

Cross Correlation



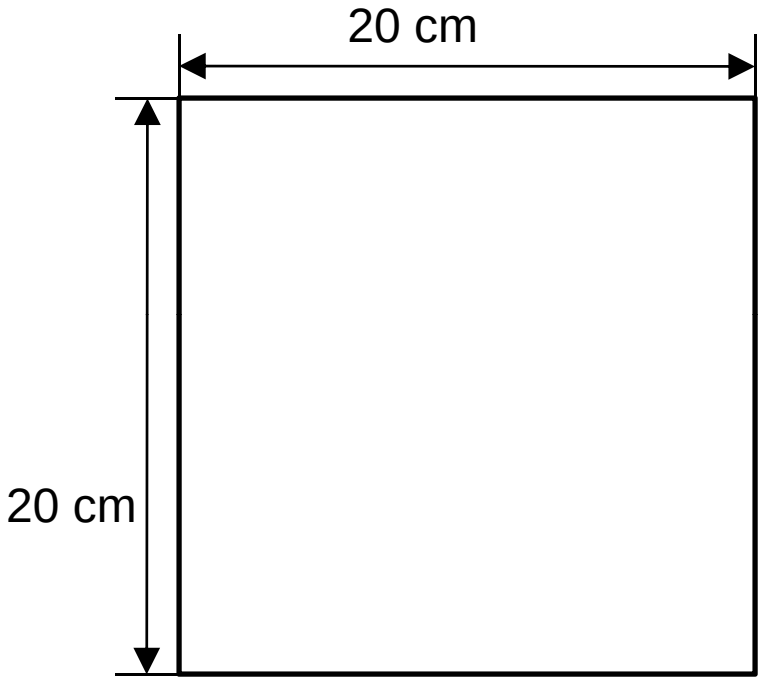
The process is repeated for each interrogation region in Frame A, resulting in a 2-Dimensional velocity field for the imaged region

PIV Rules of Thumb

- The raw data of PIV measurements are particle images
- The key to good measurements is good raw data
- In the Ideal Case
  - **Seed particle images are 3 – 5 pixels in diameter**
  - **5 – 15 particles per interrogation region**
  - **Maximum particle displacement approximately 25% of size of interrogation region**
- It is not always possible to satisfy these in all measurements, but they are good experimental goals

Experiment Design

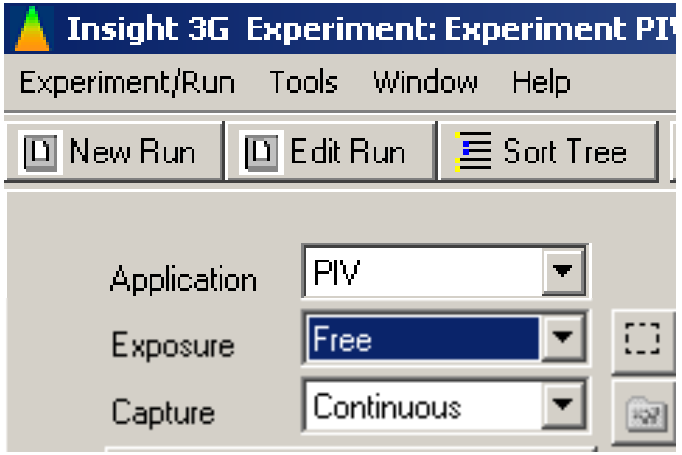
- Important considerations:
  - What size field of view?
  - What desired spatial resolution?
    - Are the above 2 realistic together?
  - Appropriate seeding
  - Optical access
    - Camera can view measurement region at 90 degrees
    - View is not distorted
    - What does it look like when you view the measurement region from the perspective of the camera?



With a 4MP (2k x 2k) Camera
- 100 microns per pixel
- Spatial resolution
  3.2 mm at 32 pixel IR
  6.4 mm at 64 pixel IR

Experimental Setup

- Assuming laser is set up to illuminate desired plane in flow, camera at 90 degrees to light sheet with good optical access (no distortions)
- Initial setup steps should be performed in ‘free, continuous’ mode in the Insight 3G software
  - Using room light, no laser



- For final setup, the best practice is to focus the camera on seed particles in the flow
  - This assures us that our focus is optimized to the laser sheet

Experimental Hints

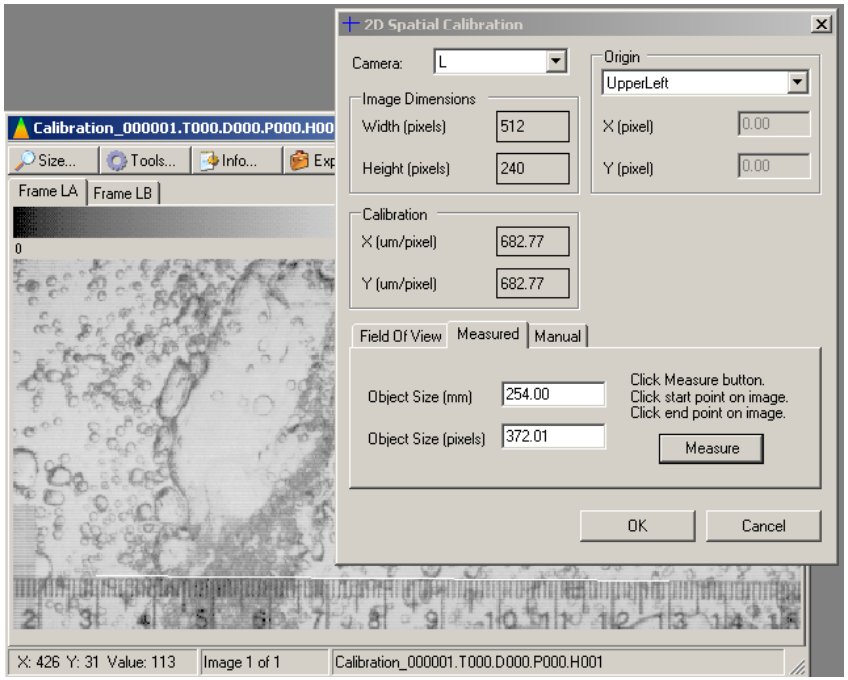
- When setting up the cameras to view laser light scattered from particles
  - Start on a large f-number (small aperture) and fairly low laser energy
  - Increase alternately until seed particles are well-illuminated with minimal pixel saturation
  - WARNING: IF LARGE REGIONS OF SATURATED (PINK) PIXELS APPEAR, STOP CAPTURE IMMEDIATELY
    - Laser light can damage camera pixels
    - Reduce laser energy and/or increase f-number

Calibration

- What are we ‘calibrating’?
  - We need to show the software how to convert from pixel units on the images, to the physical units in our flow space
- We are considering the simplest case in 2D PIV, where we view the light sheet at 90 degrees with good optical access
- Off-axis viewing and optical distortions are sometimes unavoidable, and appropriate corrections can be made
  - In these cases, we need to give the software more information to be able to convert pixels to mm over the entire image region
  - Addressed in future webinars

Calibration Procedure

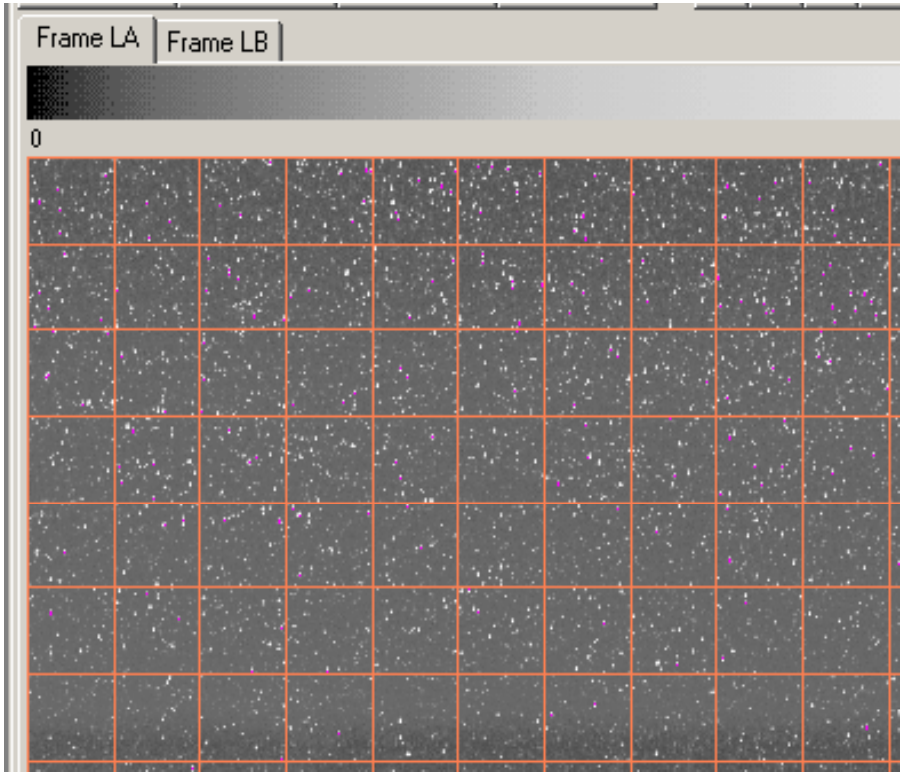
- Assumption: Cameras focused on laser light sheet
- Calibration Steps
  1. Capture and save image of “Ruler” in plane of laser light sheet
  2. Create a calibration file with the saved image
  3. Measure across a known distance in the calibration image



Seed Density

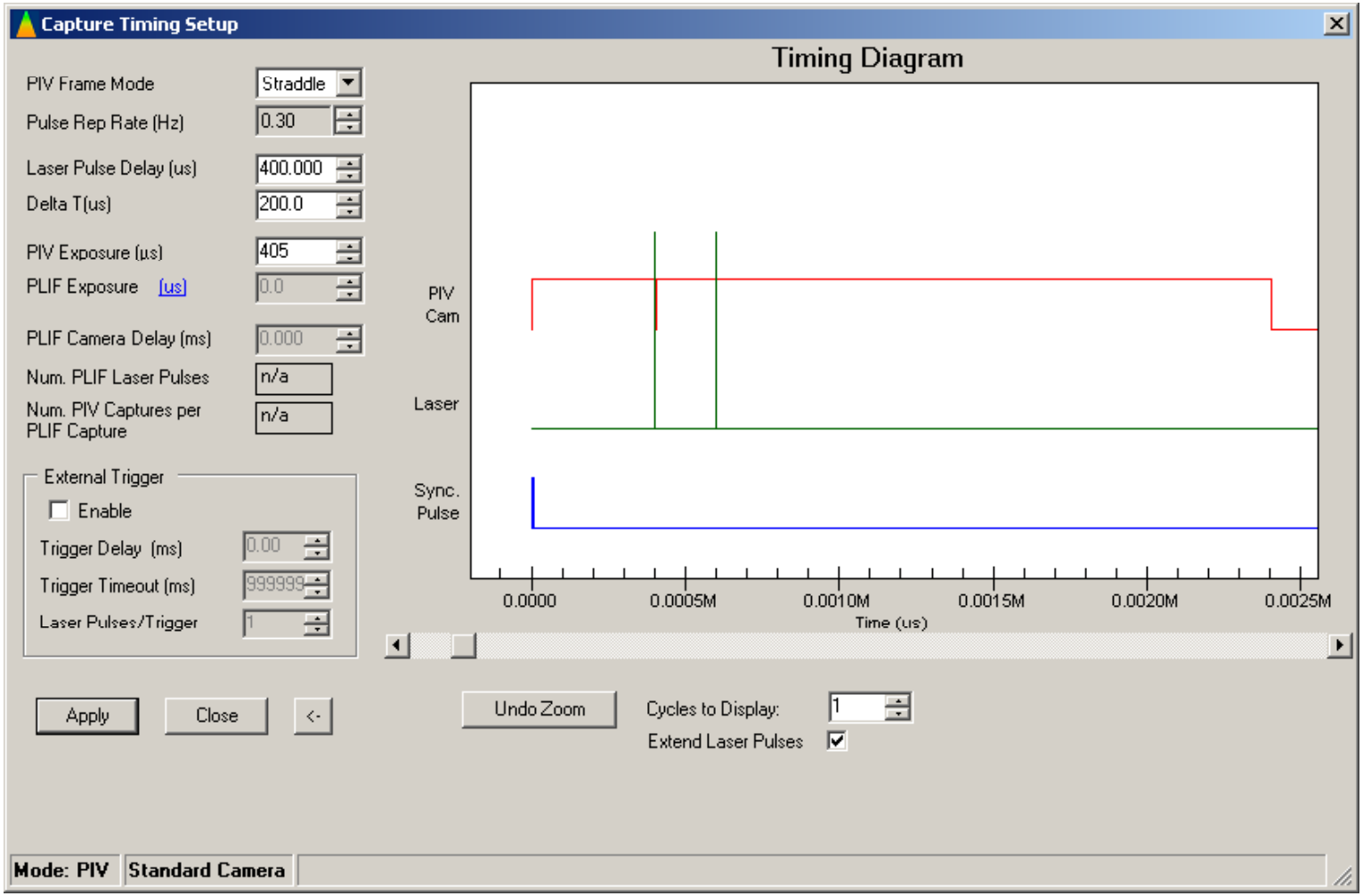
- The true test of appropriate seed particle density is examining the Particle Images

- Field of View is known
- Desired Spatial Resolution known
- Do I have enough particles in each interrogation region?



Timing Setup

- The Timing Setup Window in Insight 3G



Optimizing Δt

- The next step to Good PIV Data is setting an appropriate value for Δt

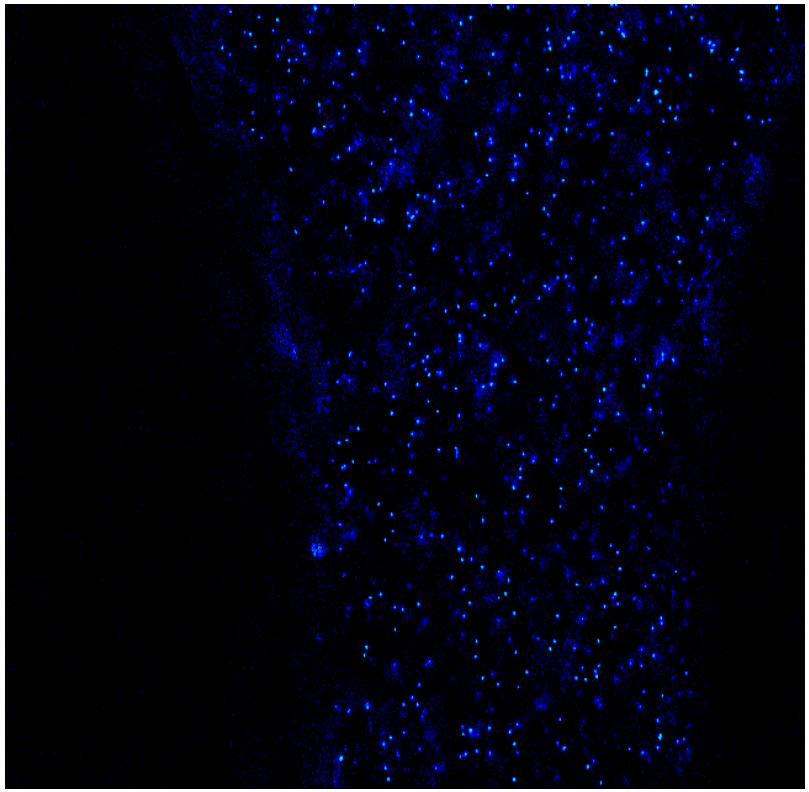
- Δt determines the particle image displacement in PIV images

- We must select appropriate Δt so that particle image displacement is consistent with experimental objectives
  - Field of view
  - Spatial resolution
  - Appropriate limits on particle displacement

Optimizing Δt

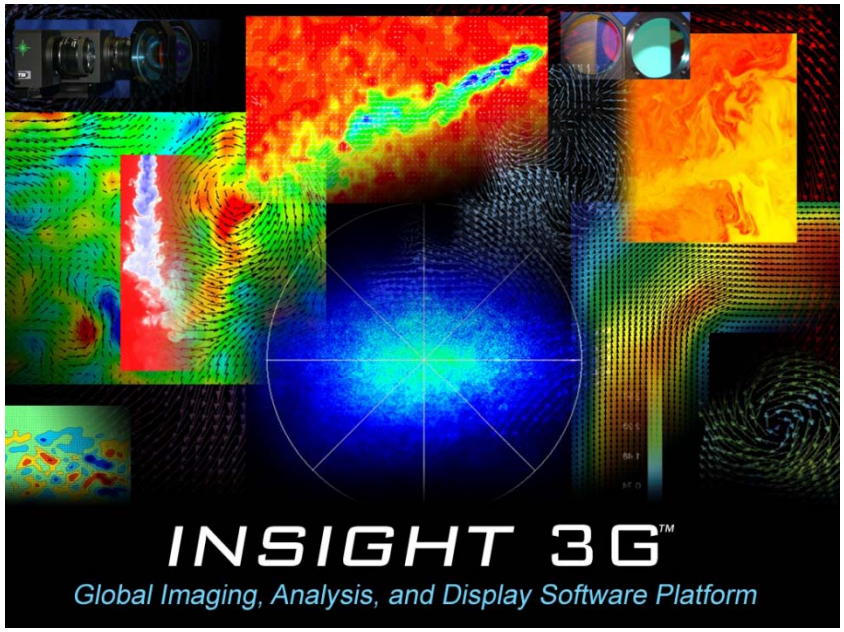
- The first step in optimizing Δt is developing “the eye”
- Can you see the displacement?

- Although qualitative, this is a critical step in optimizing a PIV measurement
  - If displacement appears random, reduce Δt
  - If there is little / no displacement, increase Δt



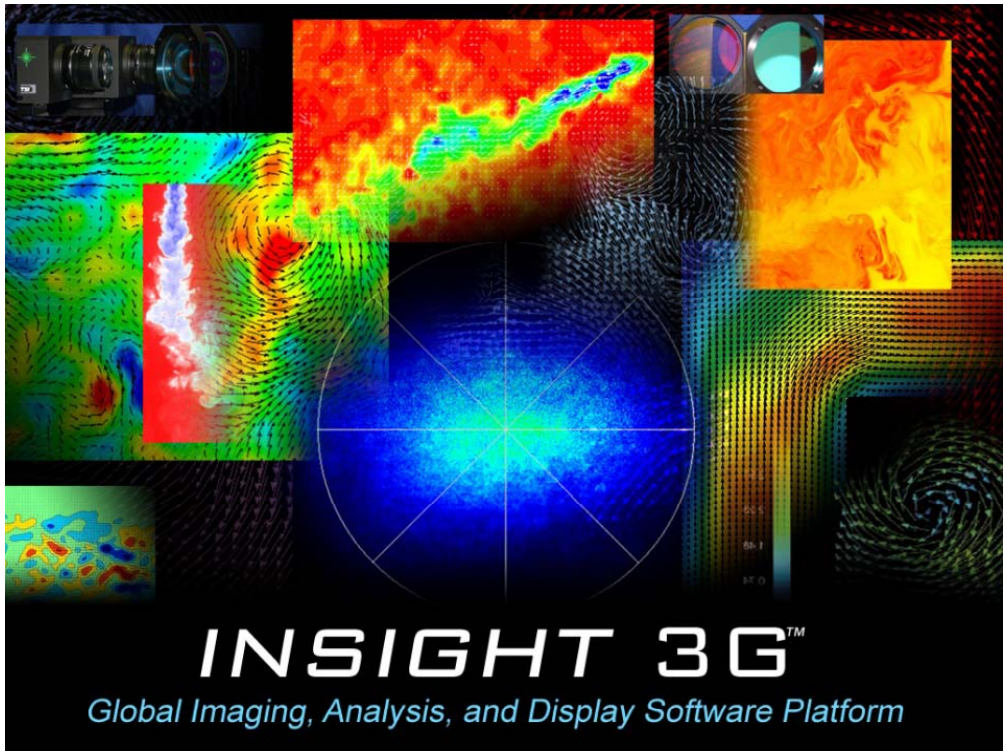
Optimizing Δt

- There are several ways to ‘measure’ the displacement for a more quantitative assessment
  - Zoom into individual particles
  - Perform ‘Point Processing’ and assess displacement of individual spots
- These will be illustrated in the following demonstration of the Insight 3G Software



Introduction to INSIGHT 3G

- Tricks and techniques for helping you to optimize your measurements using Insight 3G
  - Calibration
  - Timing Setup
  - Assessing Δt
  - Image Zoom
  - Point Process



Thank you!

- Questions?

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