Particle Image Velocimetry (PIV)

Quantitative Flow Visualization

Knowledge Beyond Measure.

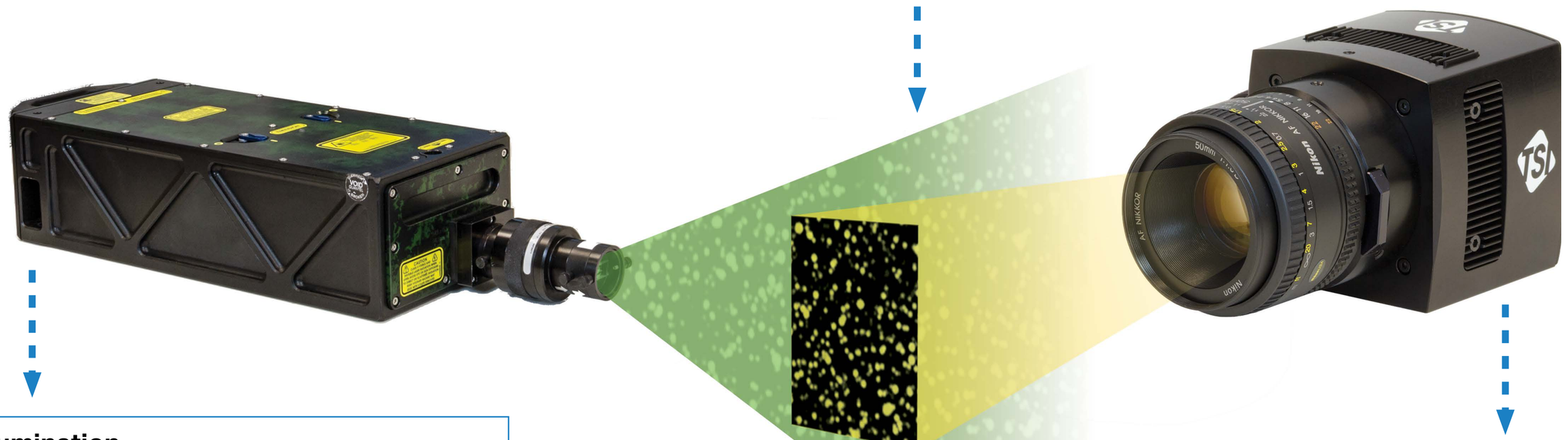
Particle image velocimetry is a laser-based imaging technique that combines the accuracy of non-intrusive point measurements with the global flow imaging capability of flow visualization to obtain time-resolved, instantaneous velocity information over an extended region of the flow.

Measurement Region

- Small tracer particles are added to the flow
- Light is scattered from the tracer particles in the light-sheet
- The measurement region, called Field of View (FoV), increases with pixel resolution:*

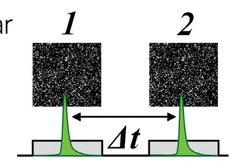
$$FoV = \frac{P_1 \cdot P_2}{M}$$

*P_1 = Pixel resolution of the camera P_2 = Size of Pixels M = Magnification of the Camera Lens



Illumination

- A laser beam is formed into a light-sheet using a combination of lenses
- The light-sheet is pulsed, "freezing" the location of particles in the planar measurement region
- The laser pulses are separated by a known time (Δt)

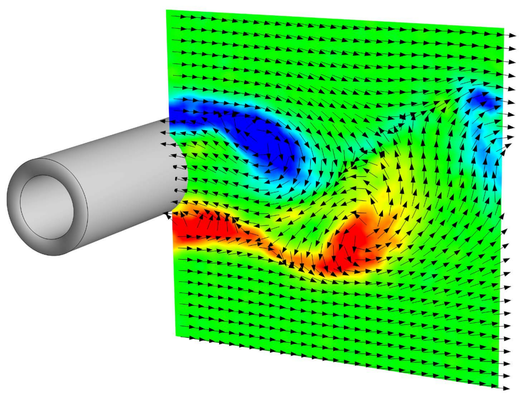


The Camera System

- A camera captures an image of the particles in the light-sheet
- The magnification (M) is determined by the camera lens
- Two images are taken - one corresponding to each laser pulse
- Images are transferred to a computer for processing
- Spatial resolution increases with magnification
- Temporal resolution increases with image capture rate

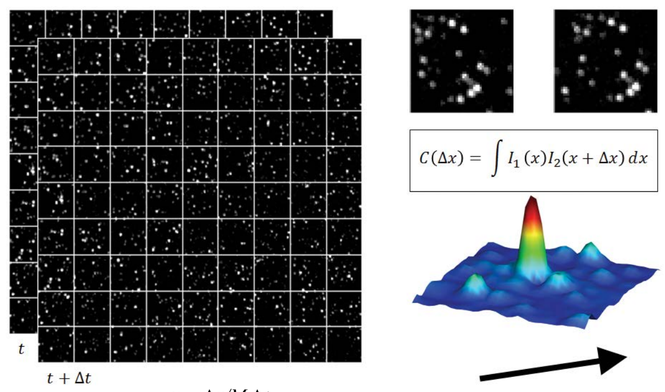
PIV Results

- Instantaneous planar velocity vector fields
- Higher-order quantities such as vorticity, shear stress, Q-criterion, and turbulent energy
- A sequence of images can provide temporal flow characteristics (flow evolution)



Processing Algorithms

- Images are divided into many small "interrogation windows"
- Particle motion (Δx, Δy) between images is determined through cross-correlation
- Velocity is found by dividing the particle displacements by the time between pulses



$$C(\Delta x) = \int I_1(x) I_2(x + \Delta x)\, dx$$

$$u = \Delta x / M\, \Delta t$$
$$v = \Delta y / M\, \Delta t$$

- The process is repeated for all interrogation windows to obtain the instantaneous velocity field

Extensions of the Technique

- StereoPIV - Two cameras at oblique angles can be used to obtain 3D velocity information in a plane
- Volumetric 3-Component Velocimetry (V3V) - Three cameras are used to determine 3D velocity fields in a volume
- A high speed camera and laser can be used to obtain time resolved velocity fields

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