پرتونگار تجهیز امین
(دانش بنیان)

سرعت‌سنجی ذرات بوسیله لیزر
(Particle Velocimetry by Laser)

آزمایشگاه هیدرولیک دانشکده عمران
دانشگاه تهران
آذر ۱۳۹۸

ارائه دهنده: محمدامین بصام

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Types of methods to measure velocity & concentration:

- Acoustic Doppler Velocimetry (ADV) (intrusive) (signal capturing)
- Laser Doppler Velocimetry (LDV) (non-intrusive) (signal capturing)
- Laser Induced Fluorescence (3D-LIF/ PLIF) (non-intrusive) (image capturing)
- Particle Shadow Velocimetry (PSV) (non-intrusive) (image capturing)
- Particle Tracking Velocimetry (PTV) (non-intrusive) (image capturing)
- Particle Imaging Velocimetry (PIV) (non-intrusive) (image capturing)

Acoustic Doppler Velocimetry (ADV)

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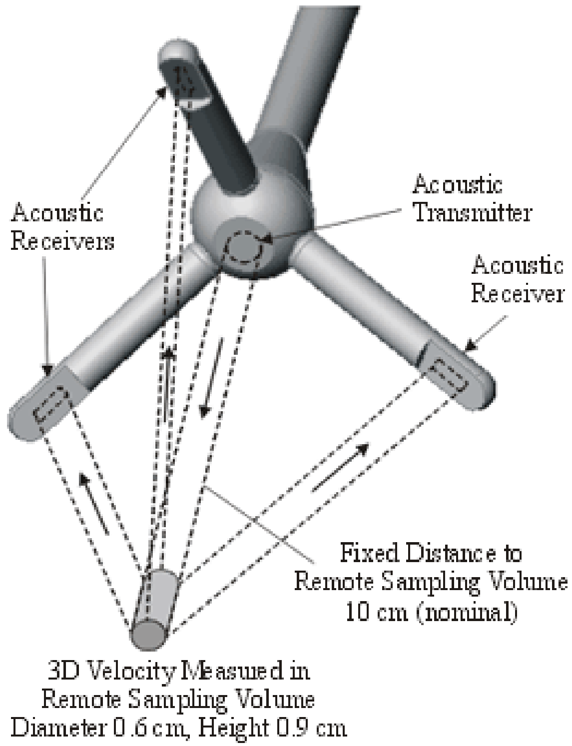

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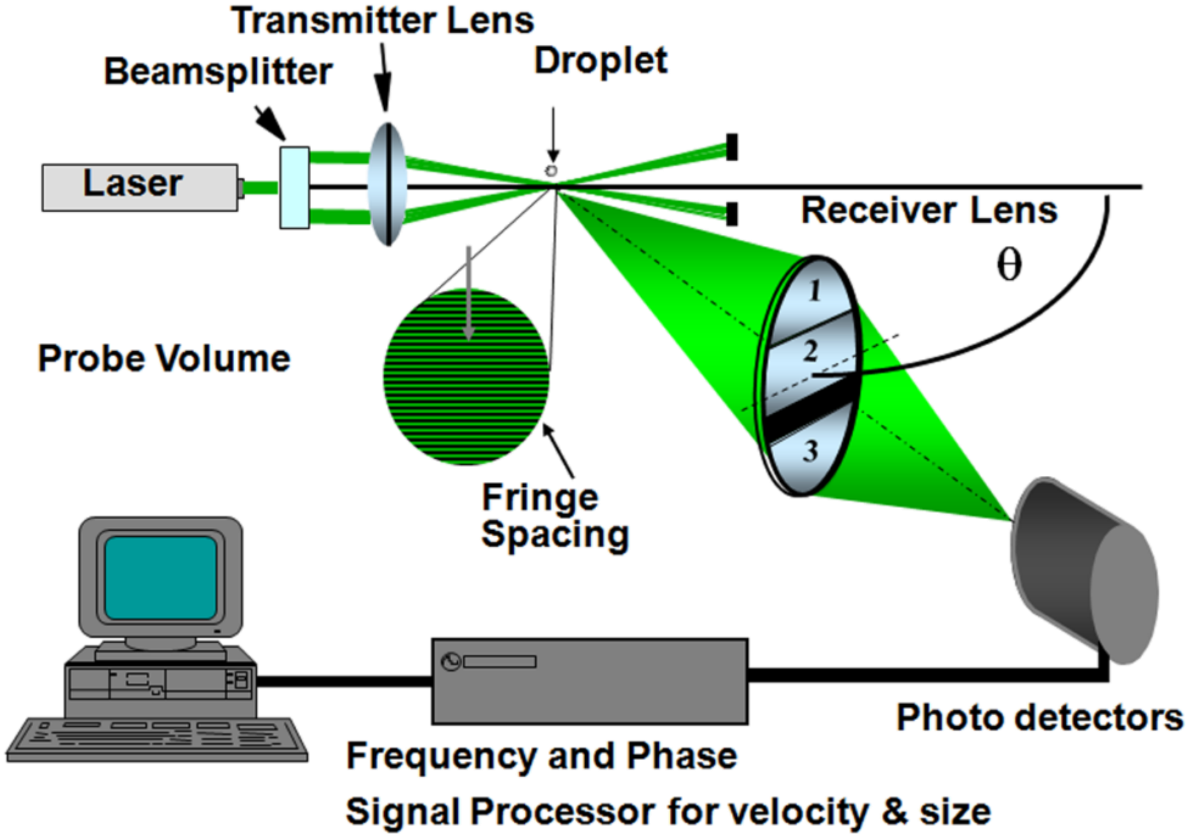
Laser Doppler Velocimetry (LDV)



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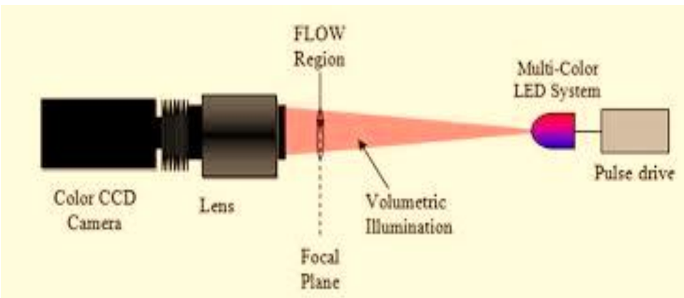
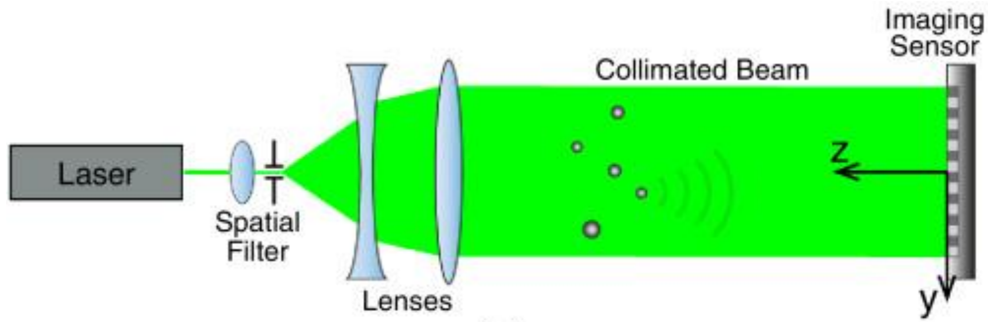
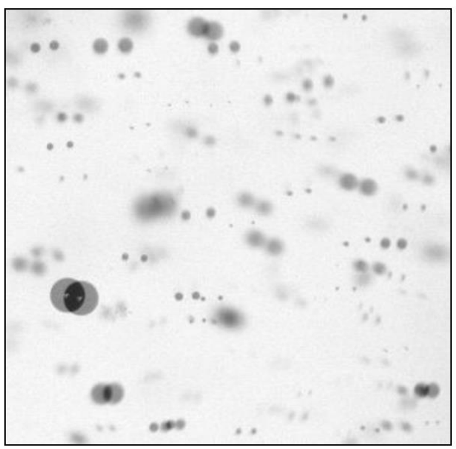
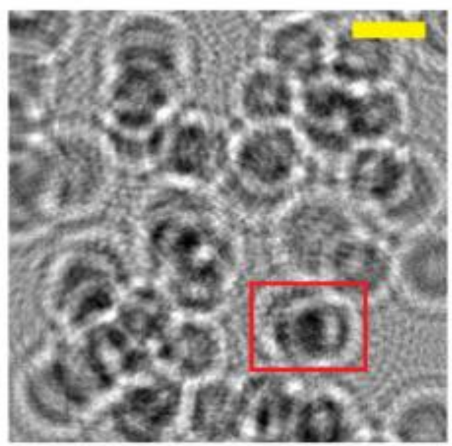
Particle Shadow Velocimetry (PSV)



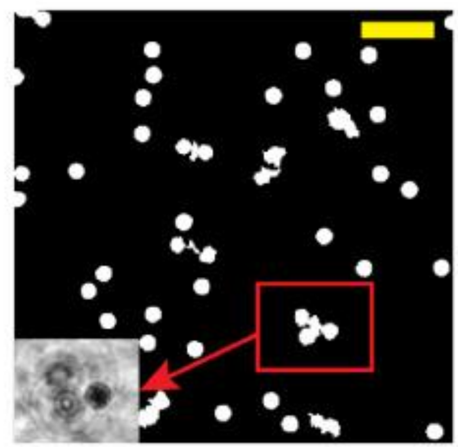


(a)





(b)



(c)

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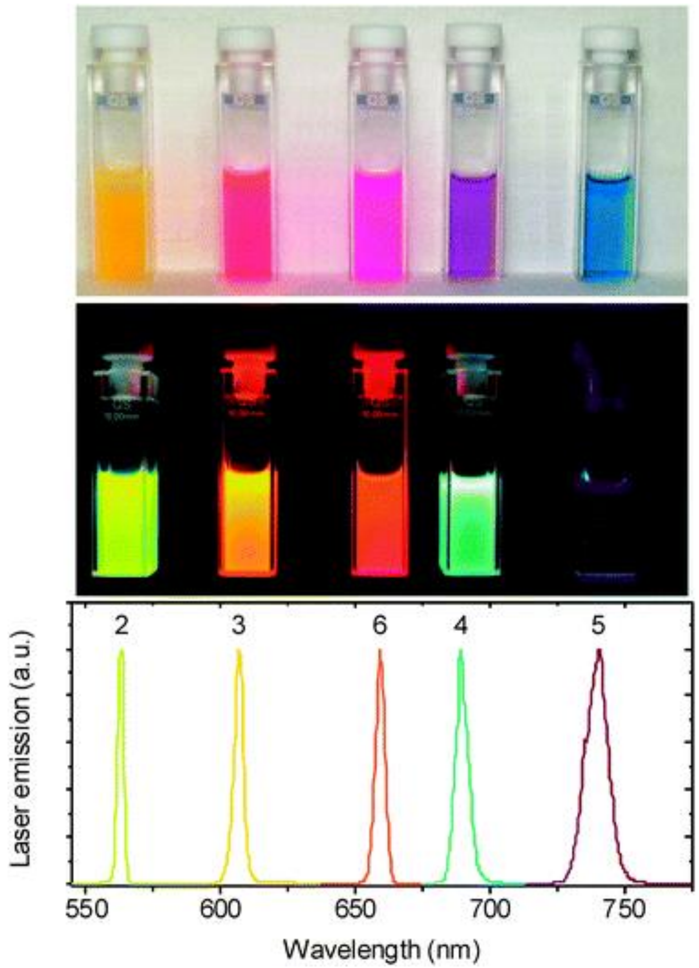
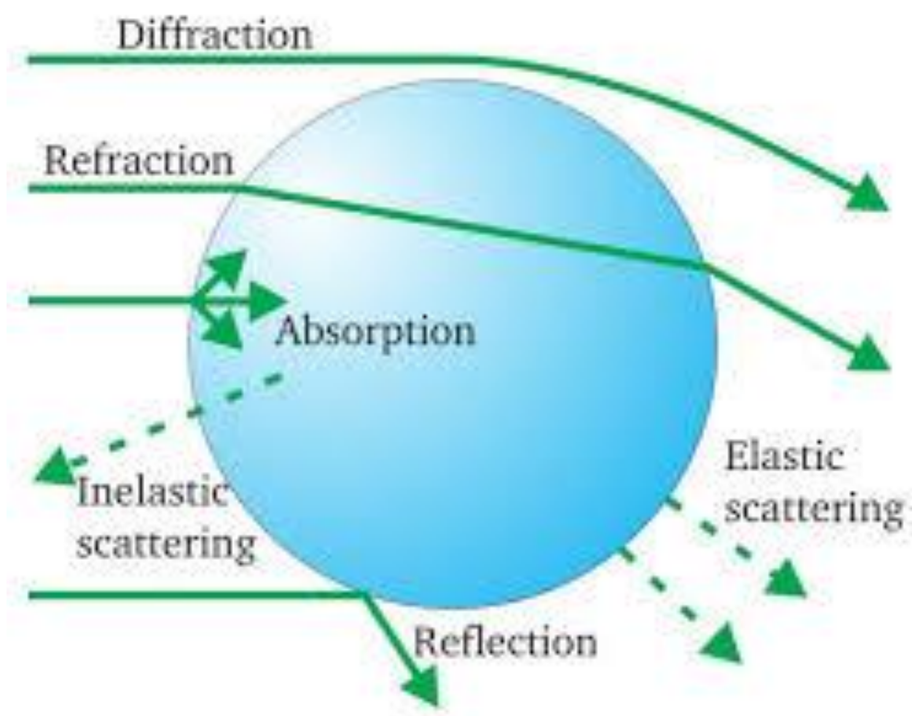
Laser Induced Fluorescence (LIF)



Is a technique to obtaining the instantaneous tracer concentration field measurements using the fluorescence of dye solution

interaction between Light and particle



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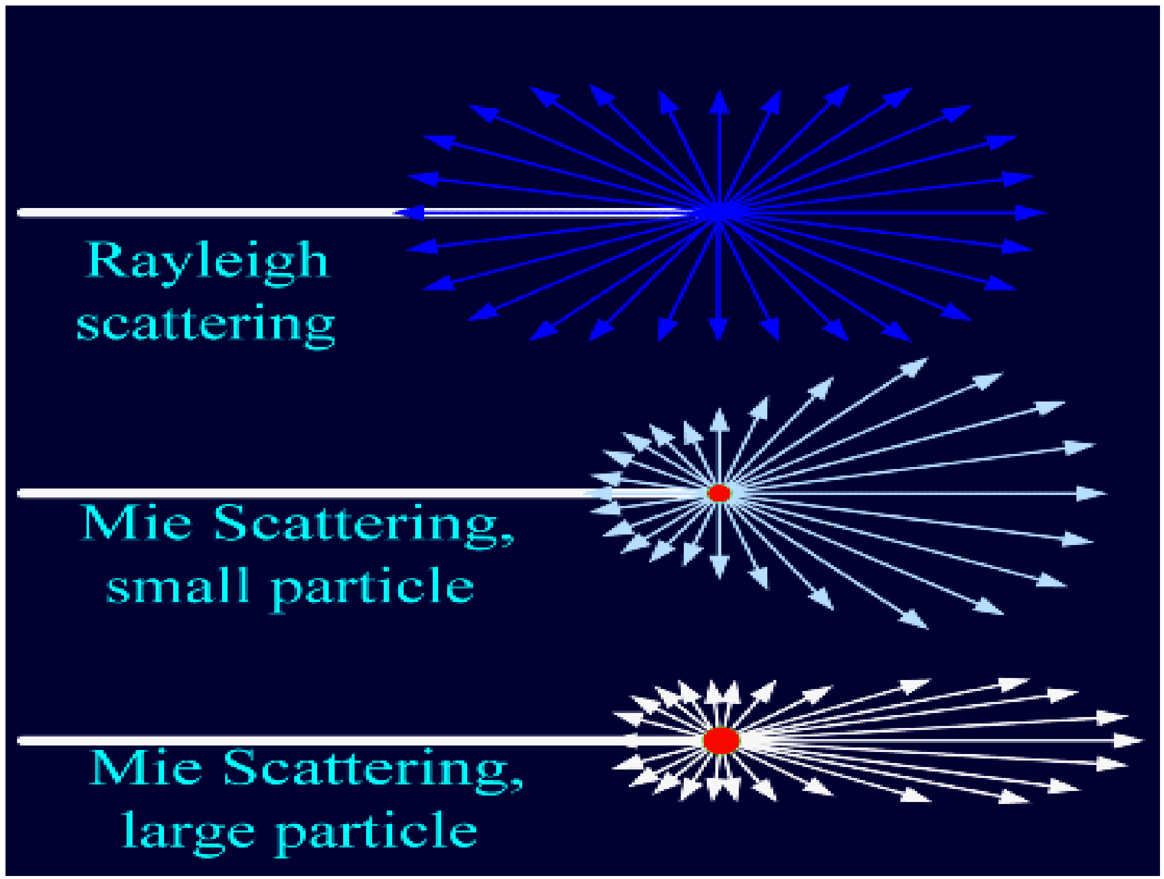
Scattering mechanism

$d_p < \lambda$

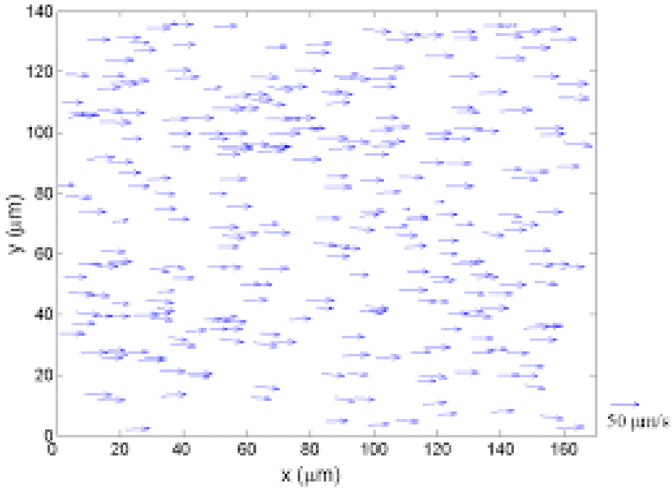
$I_{sc} \propto \lambda^{-4}$

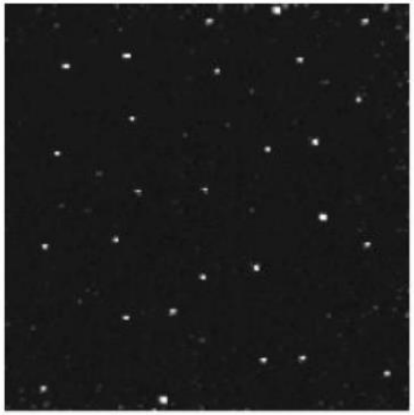
$d_p \approx \lambda$

$d_p > \lambda$

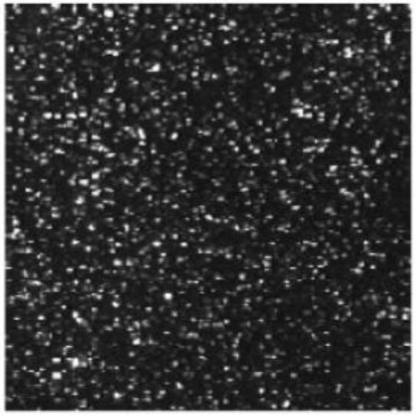


Particle Tracking Velocimetry (PTV)





(a)



(b)

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Particle Imaging Velocimetry (PIV)

Is a technique to obtaining the instantaneous whole field velocity measurements using the scattering of seeds

Basic principles of PIV

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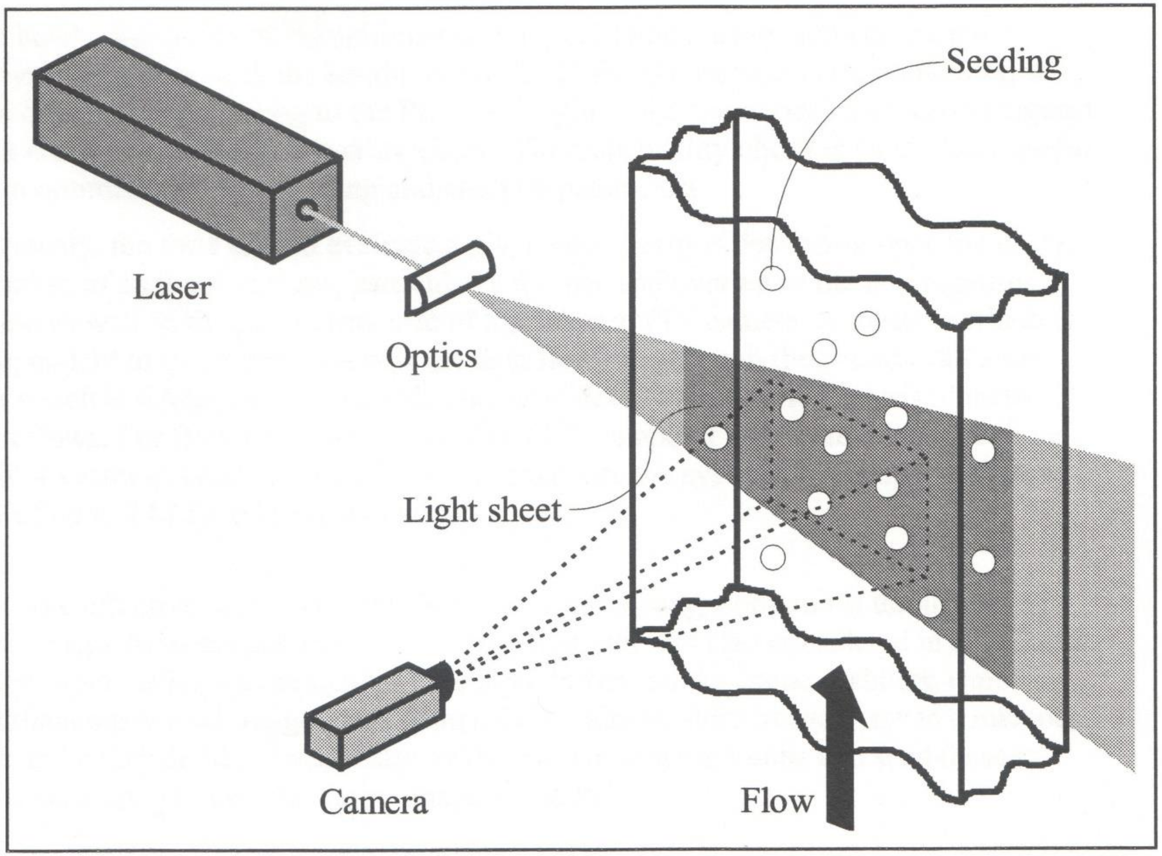
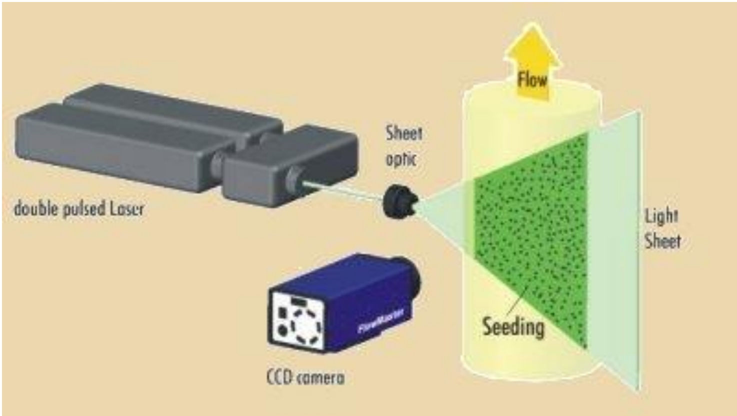


$$\text{speed} = \frac{\text{distance}}{\text{time}}$$



2D-PIV

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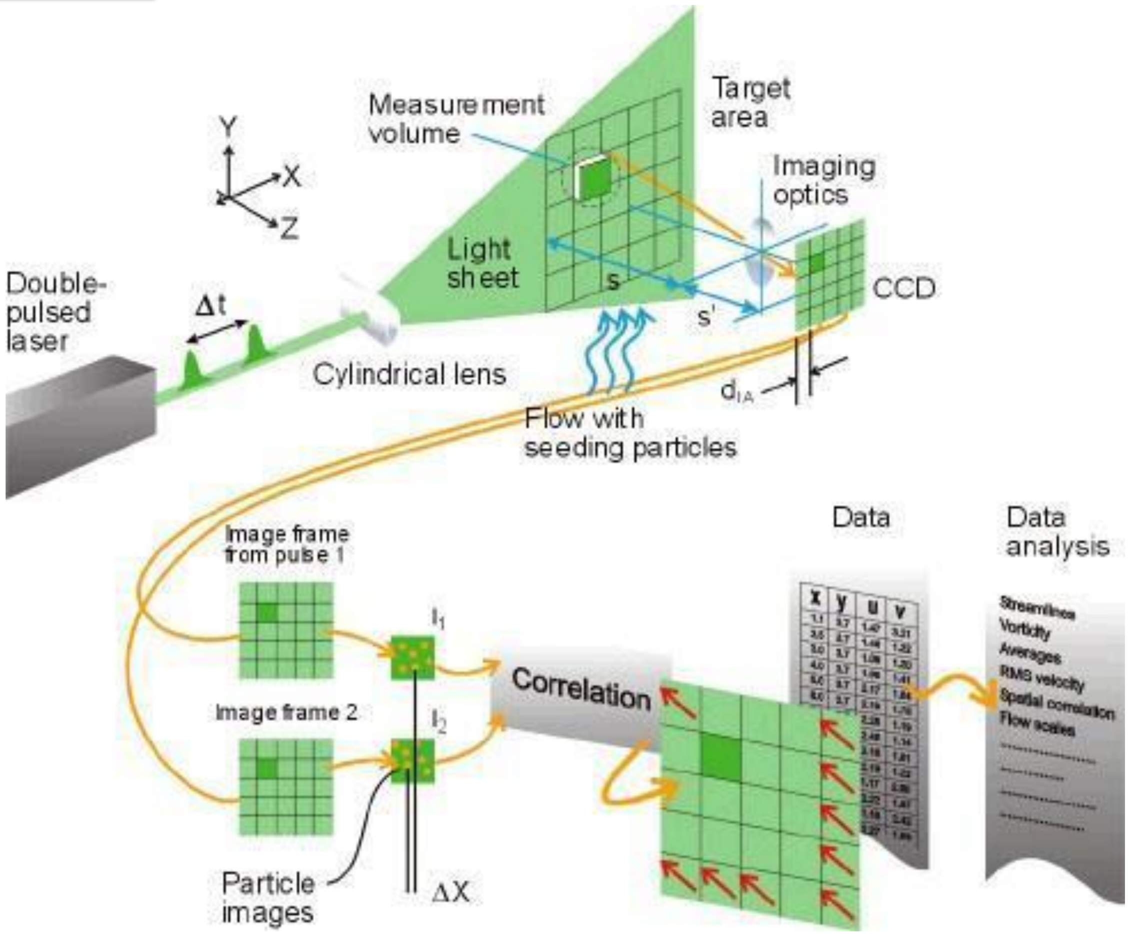

3D-PIV

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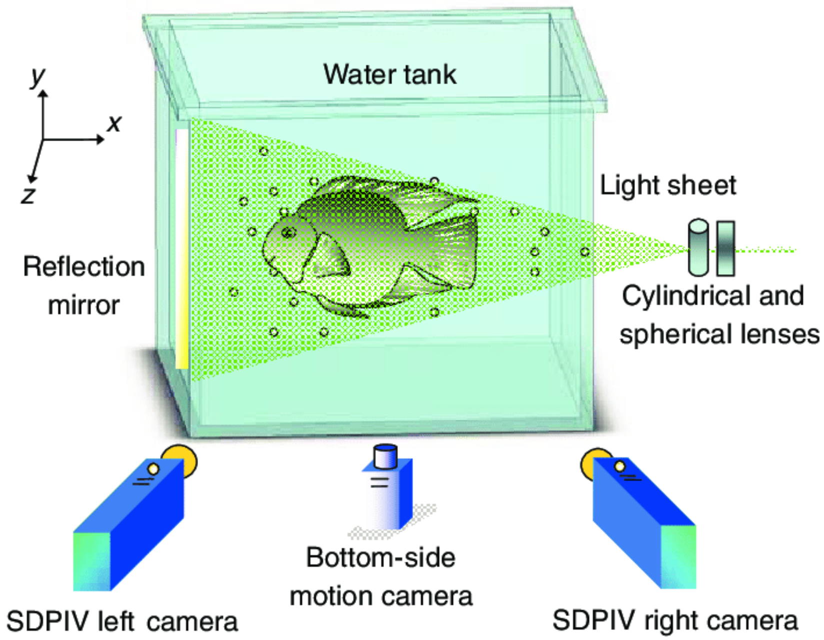

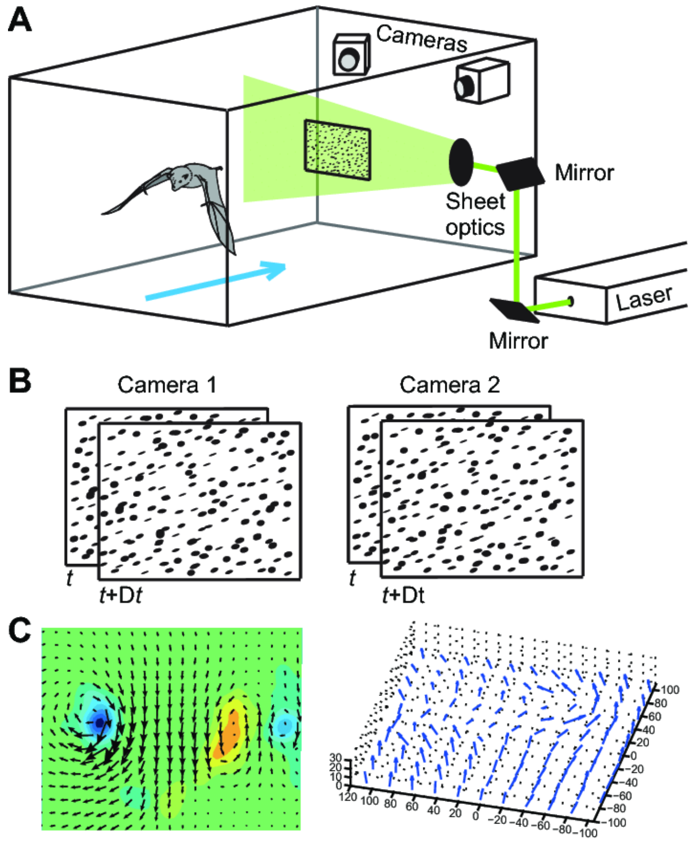

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Main feature of PIV

by Raffel et al. (2007)

- Non-intrusive velocity measurement
- Indirect velocity measurement
- Whole field technique
- Velocity lag
- Illumination
- Duration of illumination pulse
- Time delay between illumination pulses

Main feature of PIV

by Raffel et al. (2007)

- Distribution of tracer particles in the flow
- Density of tracer particle images
- Number of illuminations per recording
- Number of components of the velocity vector
- Extension of the observation
- Temporal resolution
- Repeatability of evaluation

Seeding

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- **ویژگی ذرات**
  - هم چگالی با سیالی باشند که در آن شناور می‌شوند.
  - قادر به دنبال کردن سیال باشند.
  - پراکننده خوب نور لیزر باشند.
  - ارزان قیمت/ غیرسمی/ غیرخورنده
  - از نظر شیمیایی غیر فعال باشند.

- **عوامل موثر بر حرکت ذرات درون سیال**
  - ✓ شکل ذرات
  - ✓ ابعاد ذرات
  - ✓ چگالی نسبی ذرات و سیال
  - ✓ غلظت ذرات در سیال
  - ✓ نیروهای وارد بر ذره

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Equation Of Motion For Spherical Particle

$$\frac{\pi}{6} d_p^3 \rho_p \frac{d\hat{U}_p}{dt} = -3\pi\mu d_p \hat{V} + \frac{\pi}{6} d_p^3 \rho_f \frac{d\hat{U}_f}{dt} - \frac{\pi}{12} d_p^3 \rho_f \frac{d\hat{V}}{dt} - \frac{3}{2} d_p^2 \sqrt{\pi\mu\rho_f} \int_{t_0}^{t} \frac{d\hat{V}}{d\xi} \frac{d\xi}{\sqrt{t-\xi}}$$

- Accelerating force
- Stokes viscous drag
- Pressure gradient force on fluid
- Fluid resistance to accelerating sphere
- Drag force associated with unsteady motion

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Seeding

Typical seeding materials for use in air flows are:

Material	Particle Diameter [μm]	Comments
Al_2O_3	< 8	Generated by fluidisation. Useful for seeding flames on account of a high melting point.
Glycerine	0.1 - 5	Usually generated using an atomiser.
Silicone oil	1 - 3	Very satisfactory.
SiO_2 Particles	1 - 5	Spherical particles with a very narrow size distribution. Better light scatterer than TiO_2, but not as good as glycerine.
TiO_2 Powder	From submicron to tens of microns	Good light scatterer and stable in flames up to 2500°C. Well known from LDA, but not recommended for PIV on account of a very wide size distribution and lumped particle shapes.
Water	1 - 2	Generated by atomisation. Evaporation inhibitor must be added.
MgO		Generated by combustion of magnesium powder giving a dirty unsteady supply of seeding.

Typical seeding materials for use in water flows are:

Material	Particle Diameter [μm]	Comments
Aluminium powder	< 10	Preserves polarisation by scattering.
Bubbles	5 - 500	Can only be used if two-phase flow is acceptable.
Glass balloons	10 - 150	Cheap even in large volumes, but with a large spread in particle size.
Latex beads	0.5 - 90	Can be delivered with relatively narrow size distribution, but quite expensive.
Milk	0.3 - 3	Cheap and efficient.
Pine Pollen	30 - 50	Egg-shaped and swell somewhat after some time in water. Can be supplied in large volumes.

Illumination

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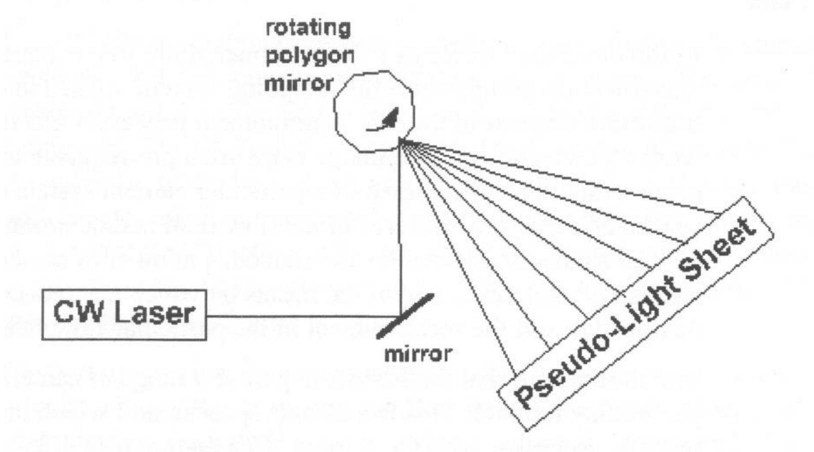
CW Laser System With Polygon Scanner



Arc angle= $\frac{1}{4\pi N}$

Period(T)= $\frac{1}{FN}$

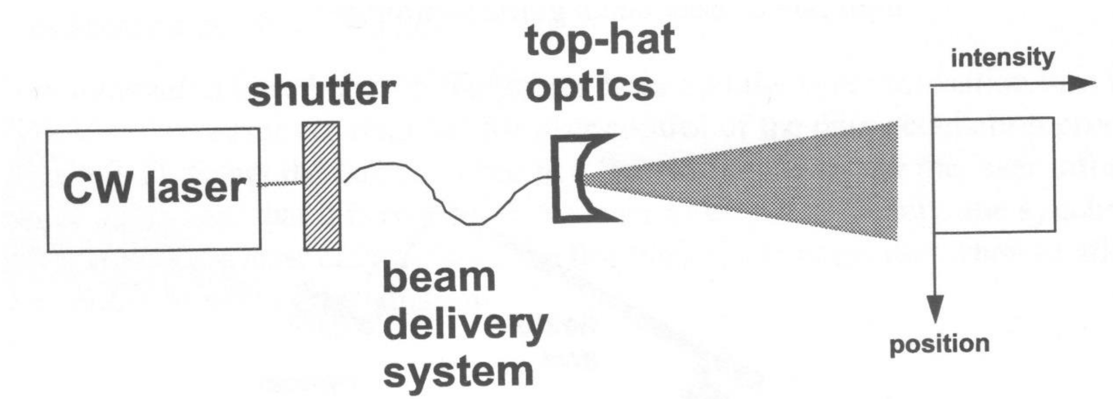
Velocity: 1-2 $m/_{s}$

Area: $1m^2$

For F=6000 rev/min , N= 6
T= 1.6 msec

Illumination

Shutter gated CW Laser System



Velocity: $\sim 0.1\ {}^{cm}/_{s}$

area: $\sim 1cm^2$

Dantec PIV System

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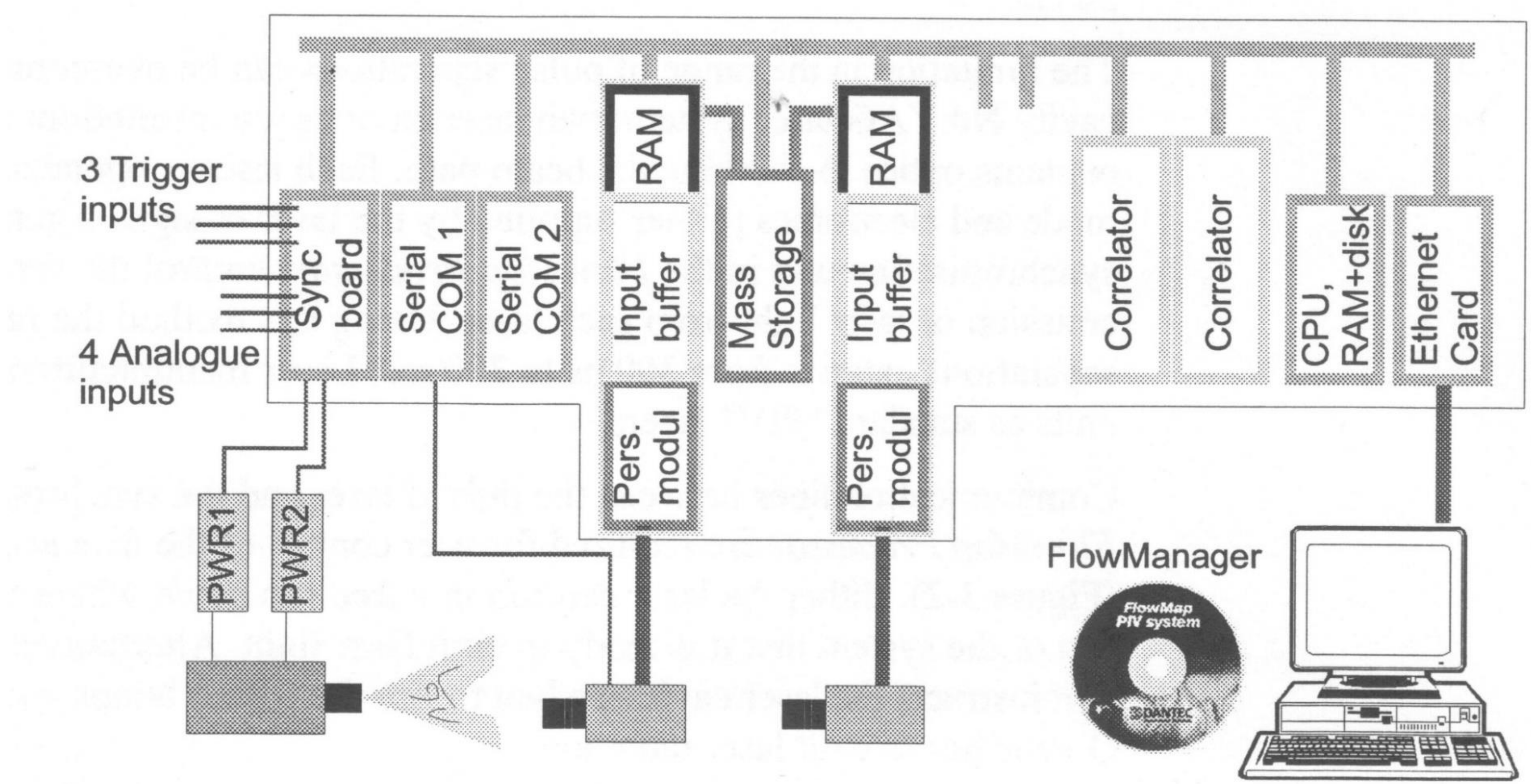
Dantec PIV System Structure



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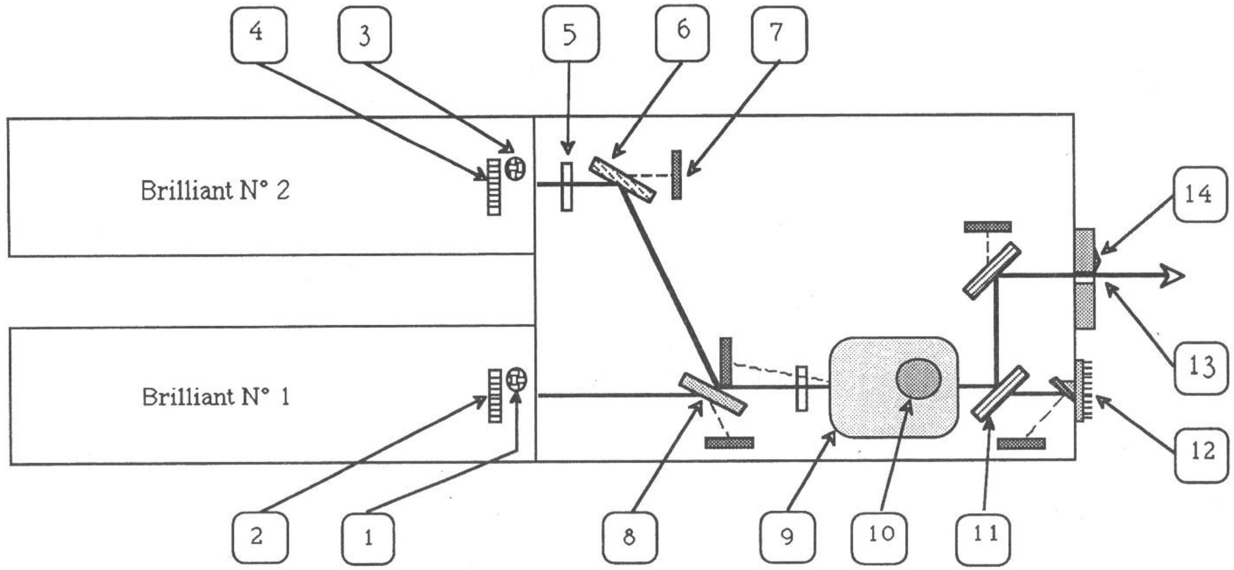
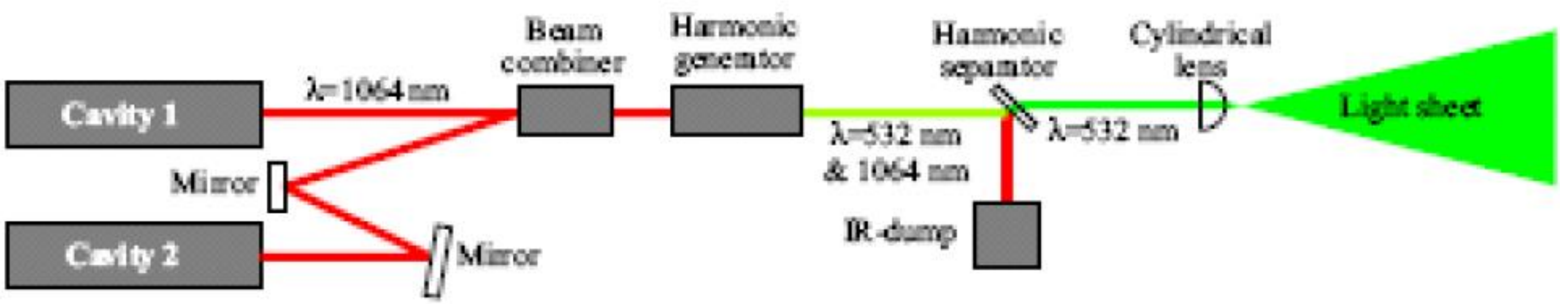
Illumination





Illumination

- **Double pulsed laser**
  - Energy: $400mj, 5nsec, 4W\ @1064nm$
    $200mj, 4nsec, 2W\ @532nm$
  - Repetition rate: $\leq 10Hz$
  - Delay between two pulses: $200nsec \sim 110msec$

Recording

Double Image 700: min. time between two frames $2\mu sec$

Kodak Megaplus ES1.0: min. time between two frames $1\mu sec$

HiSense: min. time between two frames $0.2\mu sec$,

12bits resolution, $1.3k \times 1k$ pixels, Peltier Cooled

Recording

Camera specifications:

Sensor	CCD type	Progressive scan interline
	Active pixels	1280 × 1024
	Pixel pitch	6.7 × 6.7 µm
	Microlens array	Standard
	Active area	8.6 × 6.9 mm
	Anti-blooming protection	1000 times, vertical drain overflow
Output	Gamma	Unity
	Digital output	812 bit parallel, differential RS 422 format
	Dynamic range	> 60 dB
	Pixel clock rate	14.7 MHz
	Maximum frame rate	9 Hz
	Readout noise	8-13 electrons rms

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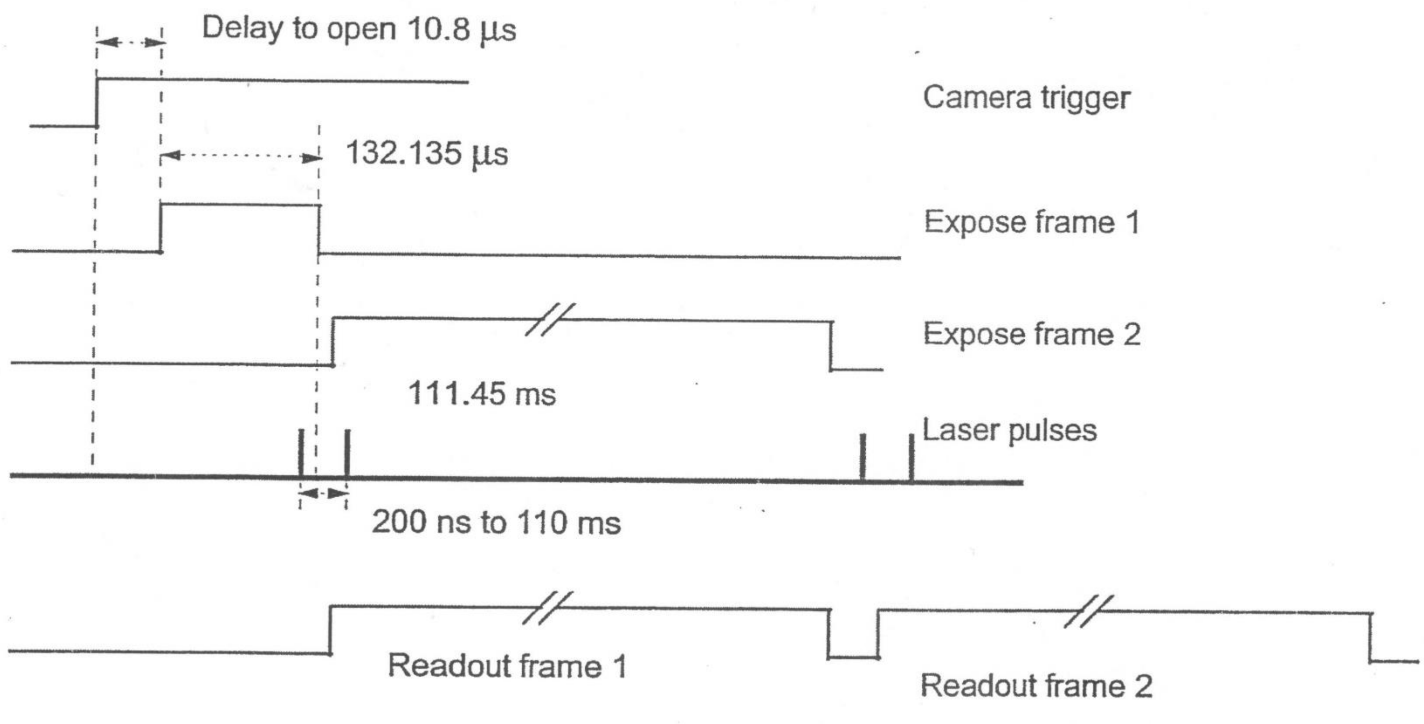
Recording

Cameras: Auto & cross-correlation

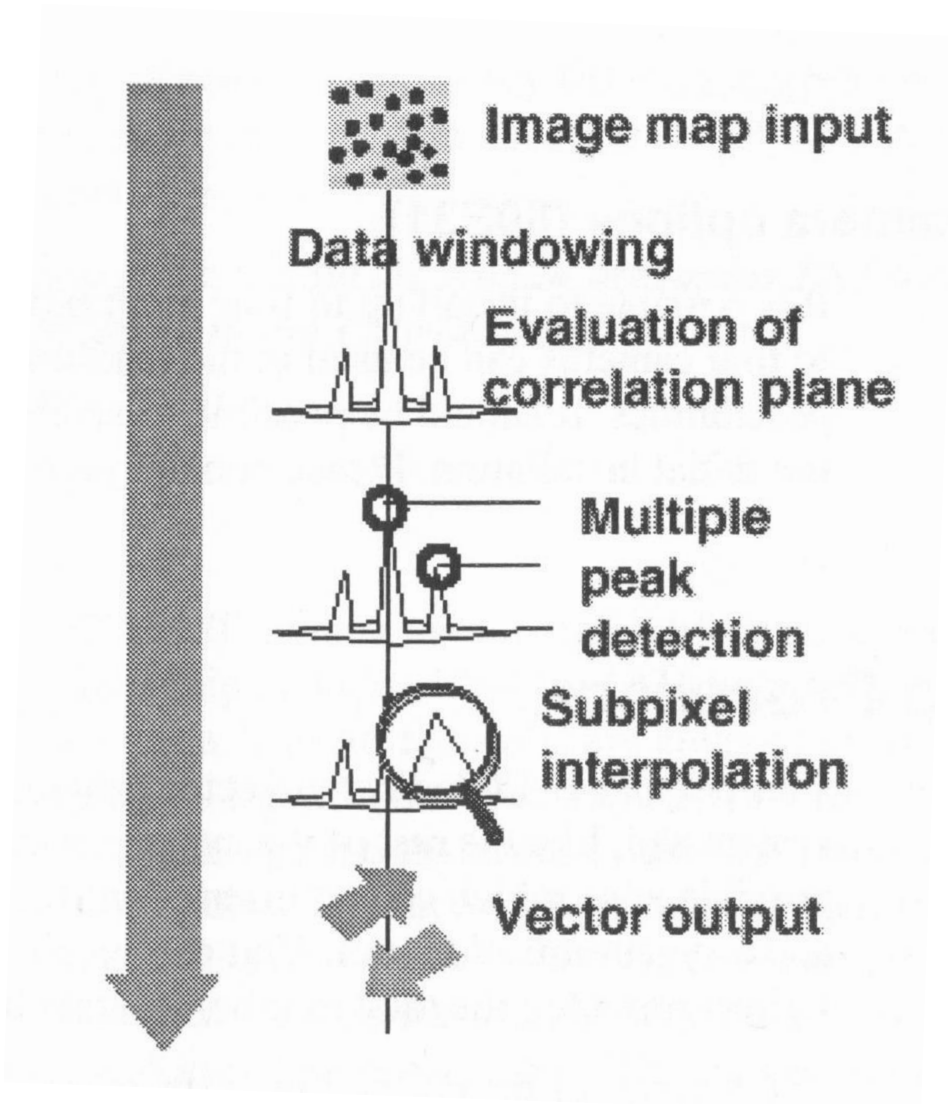
2 modes:
- mono recording (2D-PIV)
- stereo recording (3D- PIV)

Recording

Camera: Double Frame Camera Timing



Processing



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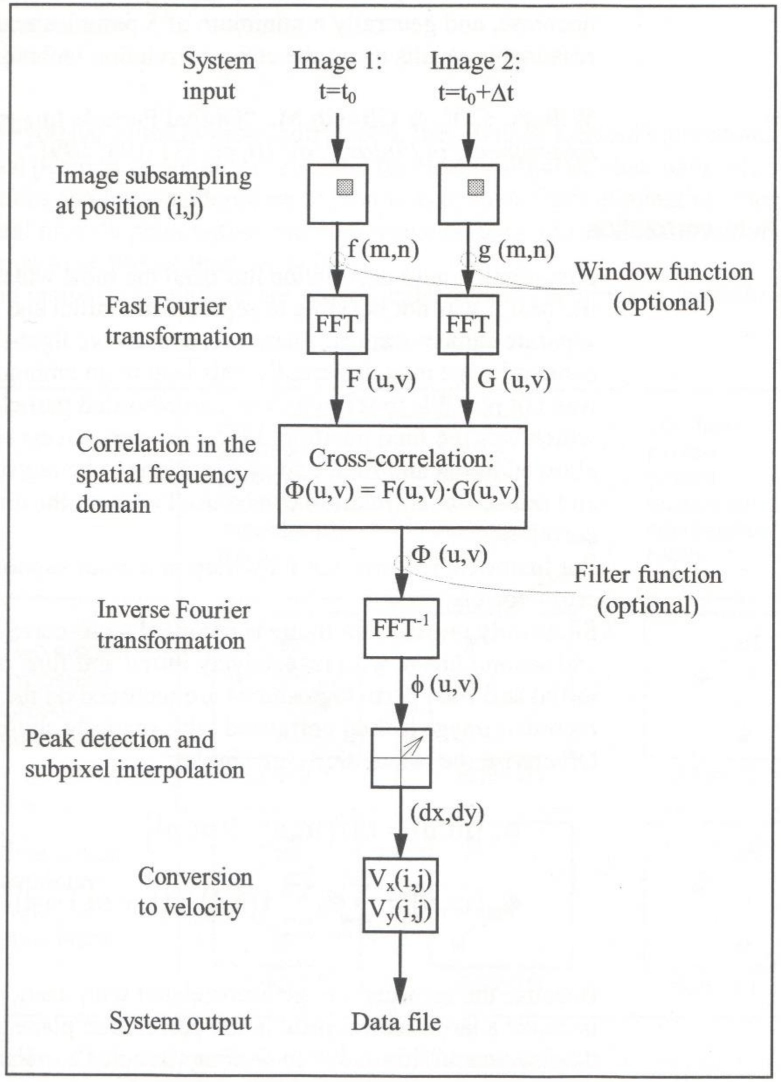
Analyzing



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با تشکر از توجه شما

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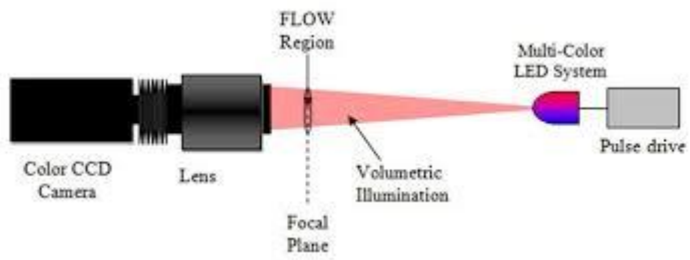
Laser Doppler velocimetry, also known as **laser Doppler anemometry**, is the technique of using the Doppler shift in a laser beam to measure the velocity in transparent or semi-transparent fluid flows or the linear or vibratory motion of opaque, reflecting surfaces. The measurement with laser Doppler anemometry is absolute and linear with velocity and requires no pre-calibration.

laser Doppler velocimetry crosses two beams of collimated, monochromatic, and coherent laser light in the flow of the fluid being measured. The two beams are usually obtained by splitting a single beam, thus ensuring coherence between the two. Lasers with wavelengths in the visible spectrum (390–750 nm) are commonly used; these are typically He-Ne, Argon ion, or laser diode, allowing the beam path to be observed. A transmitting optics focuses the beams to intersect at their waists (the focal point of a laser beam), where they interfere and generate a set of straight fringes. As particles (either naturally occurring or induced) entrained in the fluid pass through the fringes, they reflect light that is then collected by a receiving optics and focused on a photodetector (typically an avalanche photodiode).

PIV with LED: Particle Shadow Velocimetry (PSV)

A particle-shadow-velocimetry (PSV) technique that employs light sources with significantly lower power than lasers is introduced as a variant of particle-image velocimetry (PIV). The PSV technique uses a non-scattering approach that relies on direct in-line illumination by a pulsed source such as a light-emitting diode (LED) onto the camera imaging system. Narrow-depth-of-field optical setups are employed for imaging a twodimensional plane within a flow volume, and images that resemble a “negative” or “inverse” of the standard PIV scattering mode are produced by casting particle shadows on a bright background. In this technique the amount of light reaching the image plane and the contrast of the seeding particles are significantly increased while requiring significantly lower power than scattering approaches. The limitations of the technique, its velocity ranges, and the setup parameters are discussed.



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Particle tracking velocimetry (PTV) is a velocimetry method i.e. a technique to measure velocity of particles that are resident in a fluid. As the name suggests, individual particles are tracked, so this technique is a Lagrangian approach. In contrast to particle image velocimetry (PIV), which is an Eulerian method that measures the velocity field of a fluid at a (rectangular) grid. There are two very different experimental methods:

the two-dimensional (2D) PTV, in which the flow field is measured in the two-dimensional slice of the flow, illuminated by a laser sheet (a thin plane) and low density of seeded particles allow for the tracking each of them individually for several frames.

the three-dimensional *particle tracking velocimetry* (3D-PTV) is a distinctive experimental technique, based on multiple camera-system, three-dimensional volume illumination and tracking of flow tracers (i.e. particles) in three-dimensional space by using photogrammetric principles

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Sensor	CCD type	Progressive scan interline
	Active pixels	1280 × 1024
	Pixel pitch	6.7 × 6.7 µm
	Microlens array	Standard
	Active area	8.6 × 6.9 mm
	Anti-blooming protection	1000 times, vertical drain overflow
Output	Gamma	Unity
	Digital output	812 bit parallel, differential RS 422 format
	Dynamic range	> 60 dB
	Pixel clock rate	14.7 MHz
	Maximum frame rate	9 Hz
	Readout noise	8-13 electrons rms
Cross-correlation	Pulse interval range	0.2 µs to 110 ms and n×110 ms
	Maximum pulse duration	132 µs
	Double-frame rate	up to 4.5 Hz
	Asynchronous reset delay	142.9 µs

PIV instrumentations

- Seeding- Particles
- Illumination- Lasers
- Recording- Cameras
- Processing- Flowmap Processor
- Analyzing- Flowmanager Software