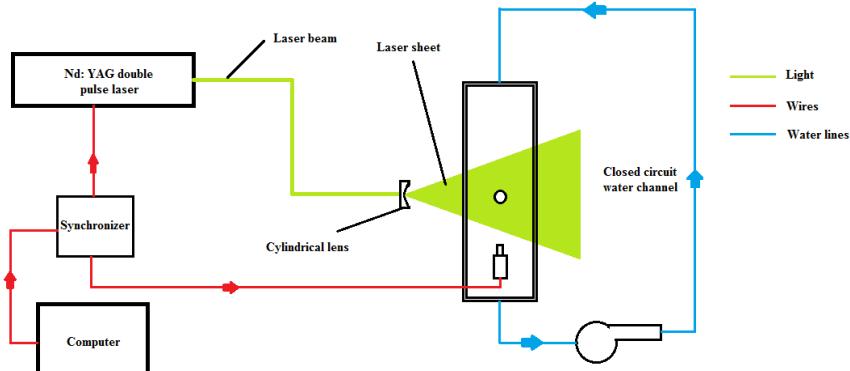


## INTRODUCTION

- Basic Idea: Add tracer particles to the flow; image the position of particles; find displacement of particles between two time instants; obtain velocity
- Allows wholefield measurement of velocity in a flow
- Optical based technique
- PIV has become a standard tool in Fluids labs across the world
- PIV can be used in a wide range of flow conditions (laminar/ transition/ turbulent; compressible/ incompressible; Newtonian/ non-Newtonian; steady/ unsteady; etc)

# PARTICLE IMAGE VELOCIMETRY

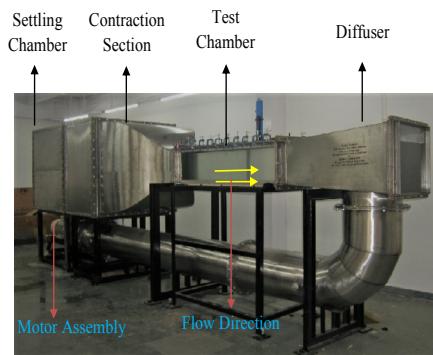


Schematic of PIV setup

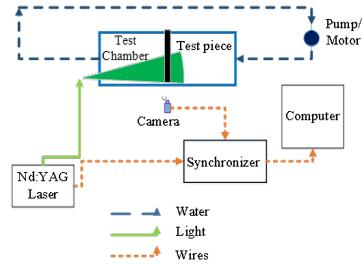
*PIV gives two-dimensional velocity in a plane:  $(u, v) = f(x, y)$*

3

## Plane of Measurement



Water Tunnel facility @ IIT Bombay



Schematic of PIV setup

## PARTICLE IMAGE VELOCIMETRY :SAMPLE IMAGE 1

Image A

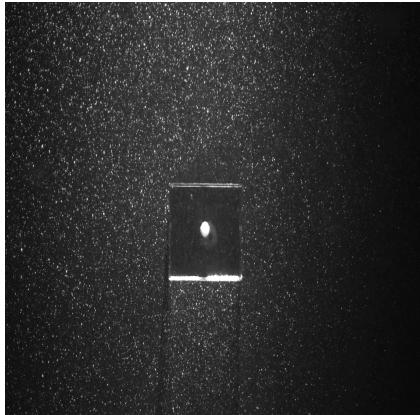
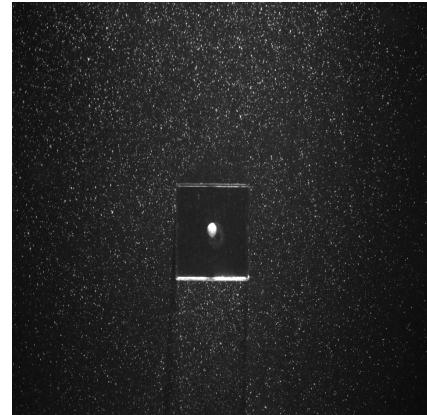


Image B

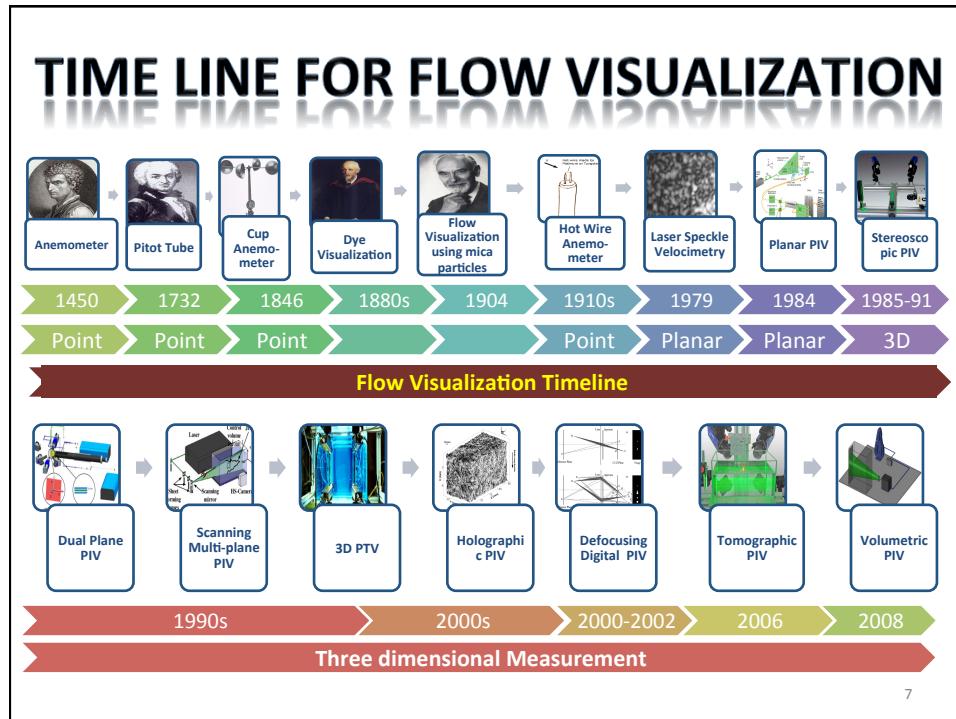


5

This section explains the position of PIV on a timeline of evolution of flow visualization technique and mentions different components of PIV.

## EVOLUTION AND COMPONENTS OF PIV

6



## Conventional Techniques versus PIV

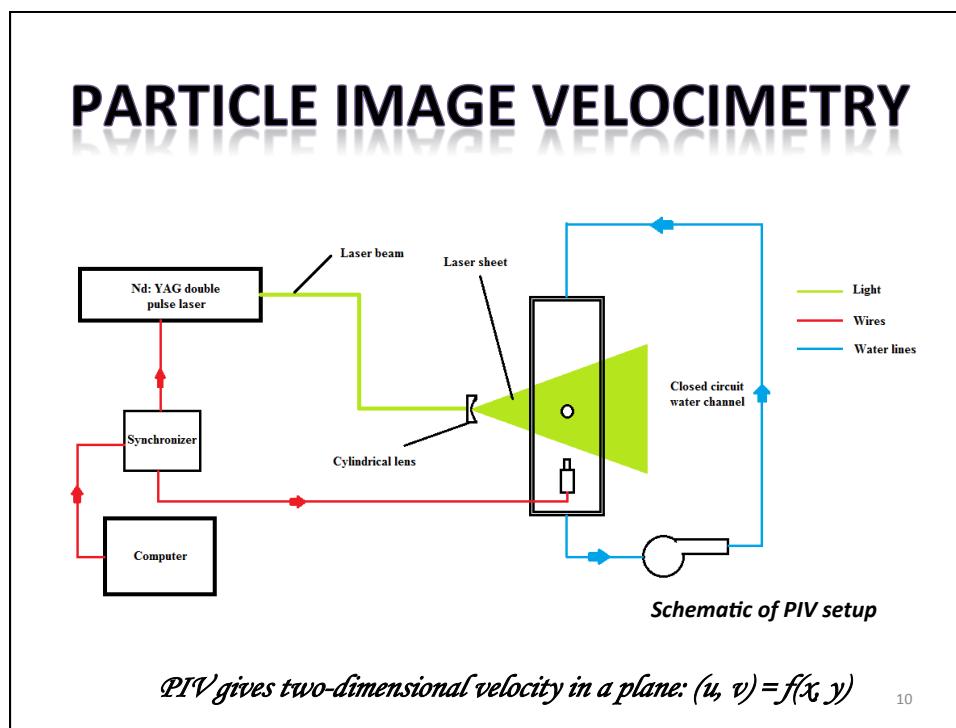
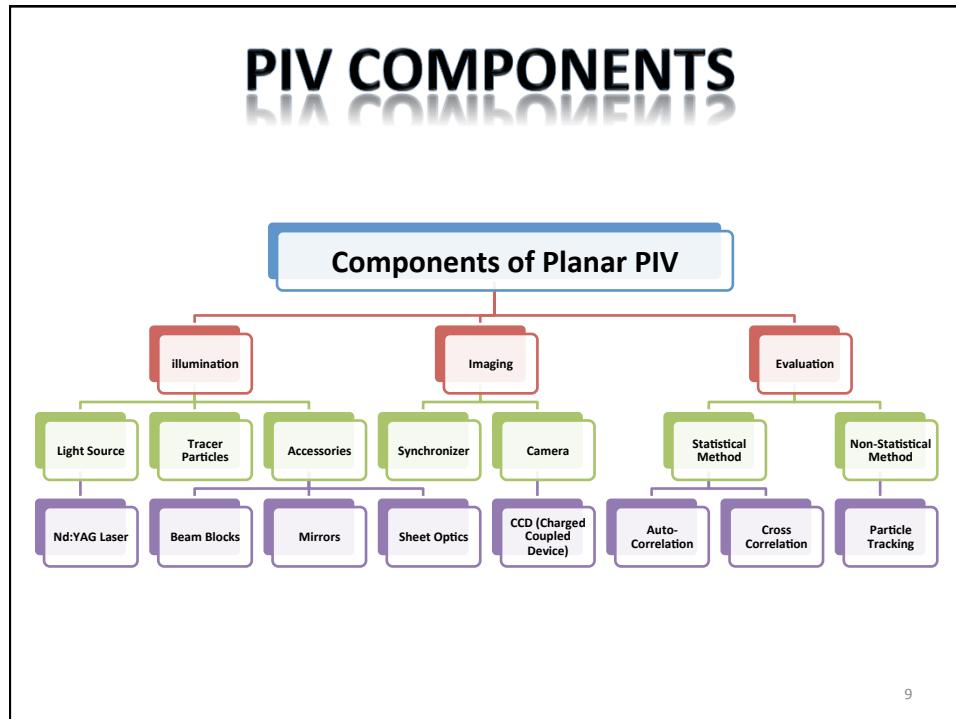
### Pitot tube

- Intrusive
- Point-wise
- One velocity component
- Steady flow
- Easy to use
- Cheap
- Optical access not required
- No special requirement

### PIV

- Non-intrusive
- Wholefield (5000+ points)
- Two-velocity components
- Time-varying velocity can be measured
- Not so easy to use
- Expensive
- Requires optical access
- Requires clean, controlled environment

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## ILLUMINATION

### Laser

- Nd:YAG pulsed laser, 25-200 mJ/pulse with a pulse width of 4-9 ns

### Sheet Optics

- Spherical lens followed by a cylindrical lens

### Particles

- Mean particle size of 8-11  $\mu\text{m}$ , density around 1.1 g/cm<sup>3</sup>, made of fused borosilicate glass

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## COMMON LASERS FOR PIV

Helium-neon lasers

Copper-vapor lasers

Argon-ion

Semiconductor lasers

Ruby lasers

Neodym-YAG lasers

• Most Commonly used

Neodym-YLF lasers

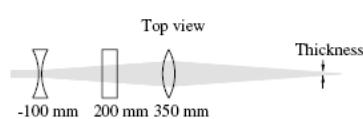
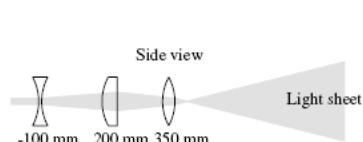
12

# LIGHT SHEET OPTICS ...

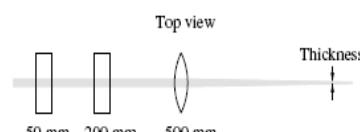
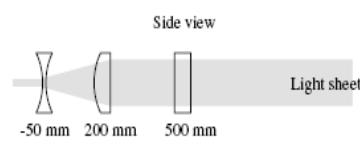
The essential element for the generation of light sheet element is cylindrical lens.

Diverging lens is used to avoid focal lines.

The combination of cylindrical lens together with two telescope lenses make the system more versatile.



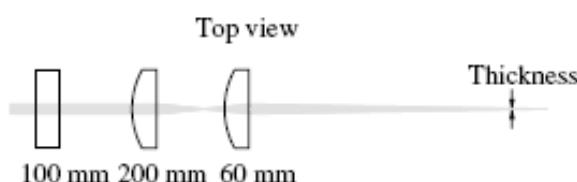
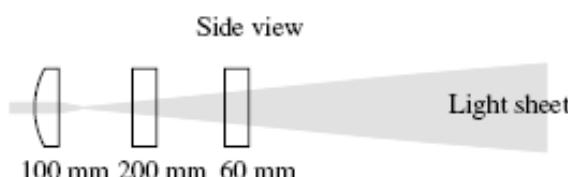
**Light sheet optics using two spherical lenses** (one of them with negative focal length) and one cylindrical Lens.



**Light sheet optics using three cylindrical lenses** (one of them with negative focal length).

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# LIGHT SHEET OPTICS ... CONT

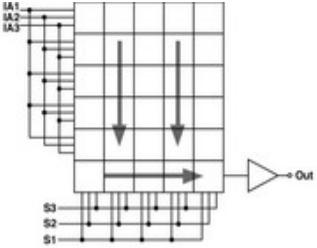


**Light sheet optics using three cylindrical lenses.**

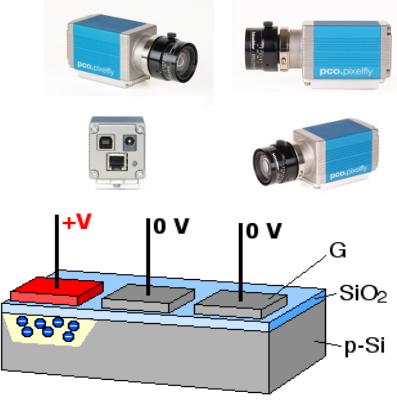
14

## IMAGING DEVICE

- CCD – Charge coupled device.
  - 1.4 Megapixels
  - Normal Used Range:
    - 1-4Megapixels for Planar PIV
    - 3-12 Megapixels for 3D PIV



a. Full-frame imager

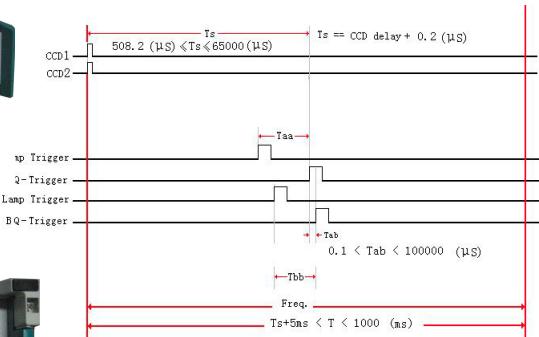


Working of CCD

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## SYNCHRONIZATION AND TIMING DIAGRAM

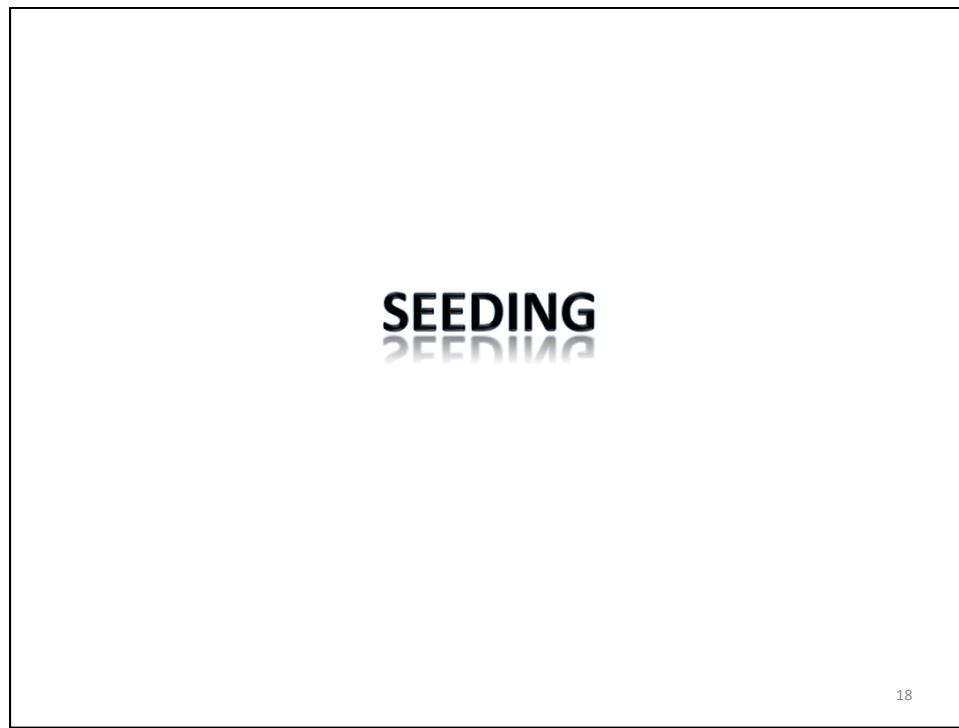
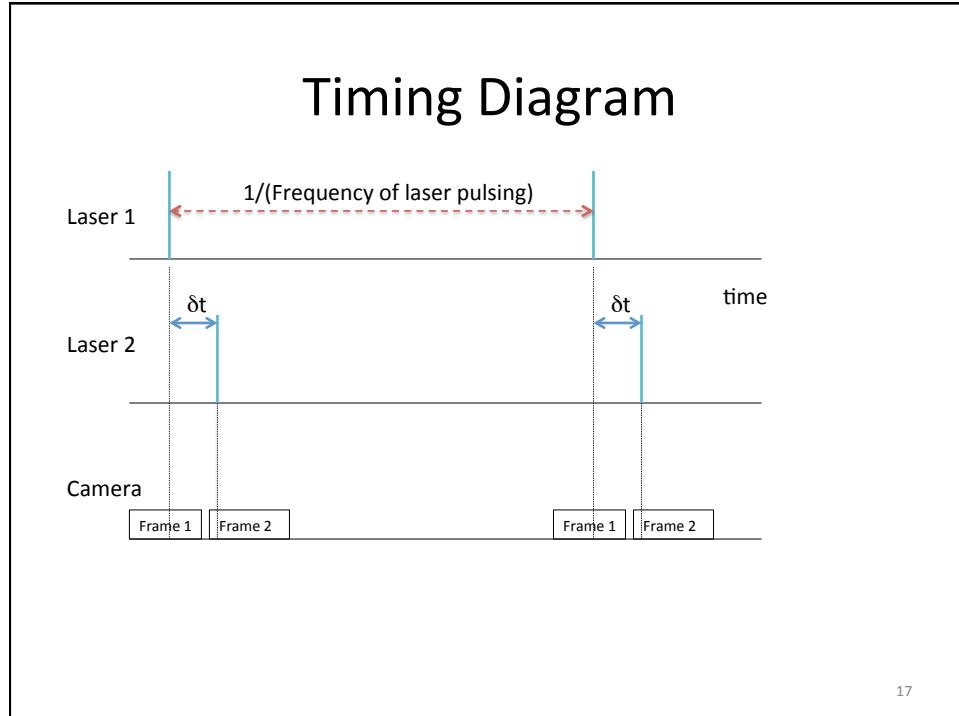


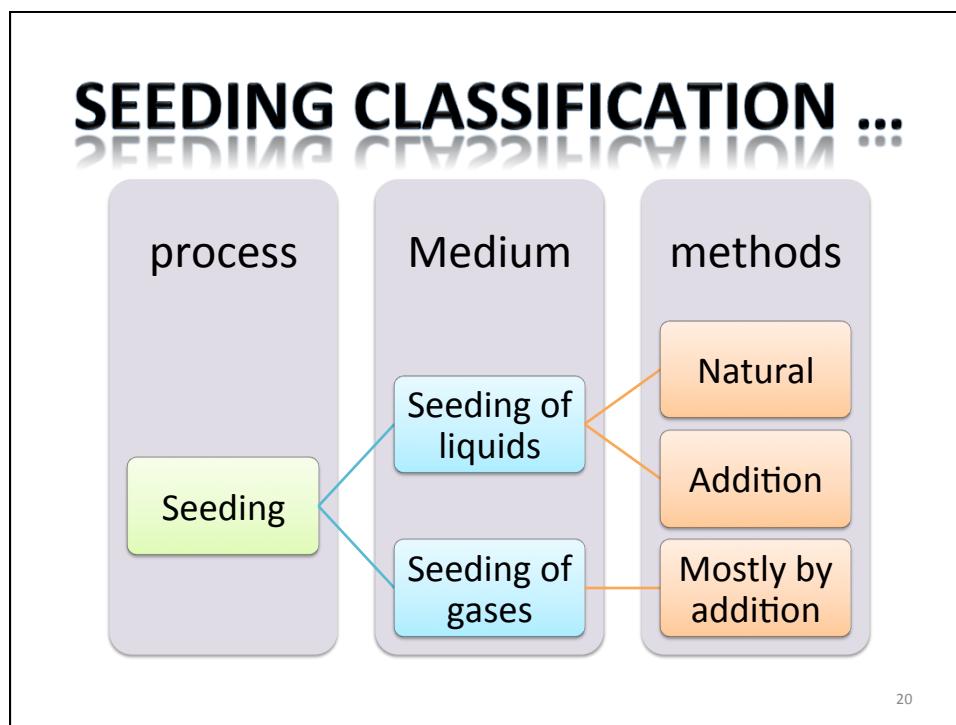
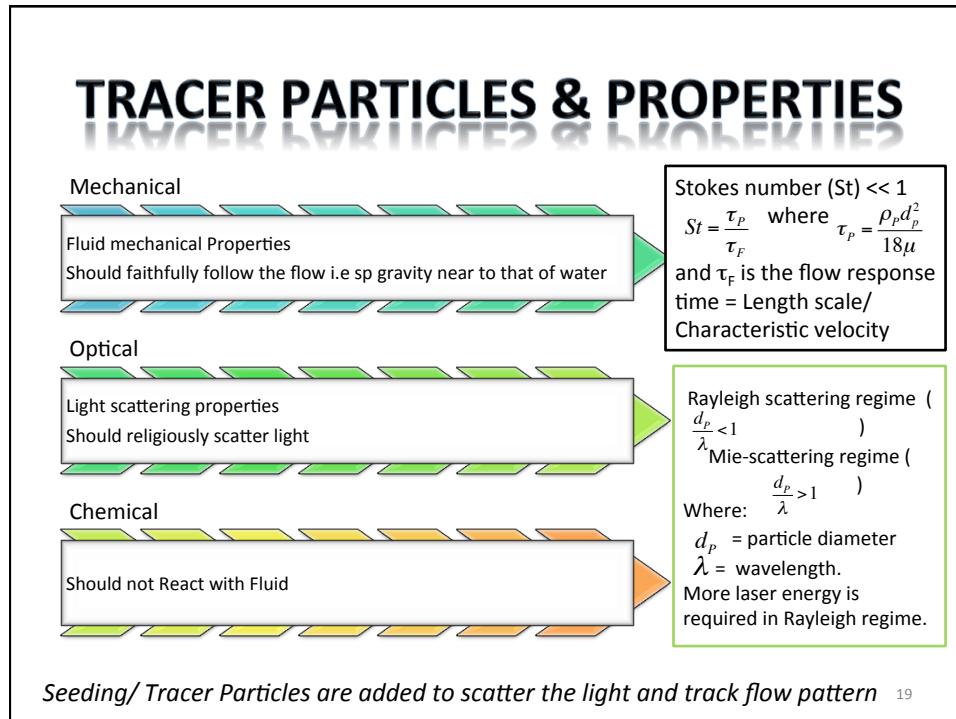



Timing Diagram Labels:

- $T_s$ : 508.2 ( $\mu$ s)  $\leq T_s \leq 65000$  ( $\mu$ s)
- $T_{aa}$
- $T_{ab}$ :  $0.1 < T_{ab} < 100000$  ( $\mu$ s)
- $T_{bb}$
- Freq.
- $T_s + 5ms < T < 1000$  (ms)

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## SEEDING MATERIALS FOR LIQUIDS

Type	Material	Mean Diameter in microns
Solid	Polystyrene	10-100
	Aluminum flakes	2-7
	Hollow glass spheres	10-100
	Granules for synthetic coatings	10-500
Liquid	Different oils	50-500
Gases	Oxygen bubbles	50-1000

The general trend is hollow coated glass spheres of 10 microns

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## TECHNIQUES FOR GASES FLOWS

To generate and supply particles

Disperse dry powders

- In fluidized bed
- By air jets

Evaporate liquid followed by condensation in generators

Atomization

Use atomizers to disperse solid particles suspended in evaporating liquids

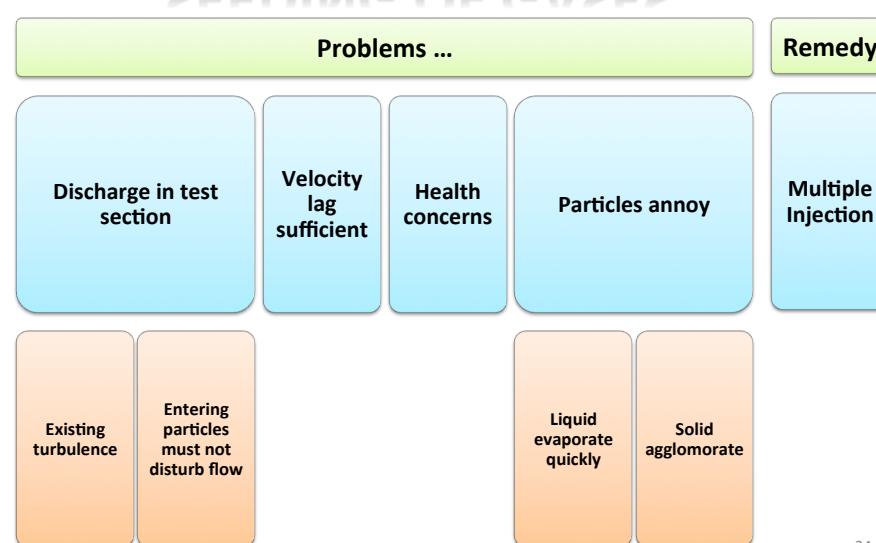
22

## SEEDING MATERIALS FOR GASES

Type	Materials	Mean diameter in microns
Solid	Polystyrene	0.5-10
	Alumina	0.2-5
	Titania	0.1-5
	Glass microspheres	0.2-3
	Glass micro balloons	30-100
	Granules for synthetic coatings	10-50
	Dioctylphthalate	1-10
	Smoke	< 1
Liquid	Different oils	0.5-10
	Di-ethyl-hexyl-sebacate(DEHS)	0.5-1.5
	Helium filled soap bubbles	1000-3000

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## SEEDING OF GASES ...



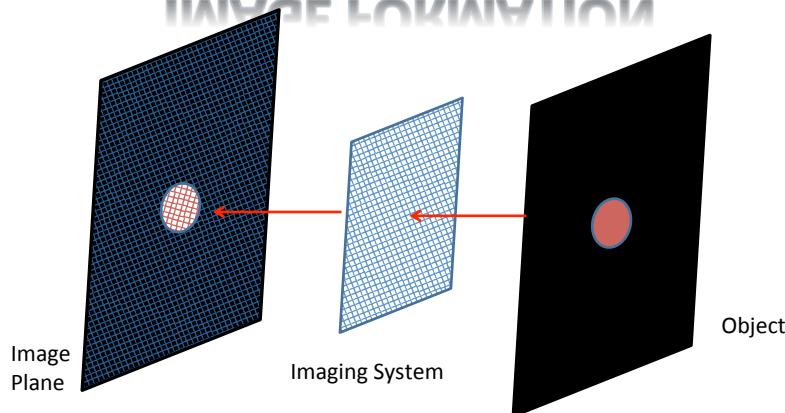
24

This section Explains the how an image is formed and in PIV how image is recorded after certain displacement of  $\delta x$ . Principle behind PIV as a velocity measurement technique is explained.

## IMAGE FORMATION AND NATURE OF PARTICLE IMAGE

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## IMAGE FORMATION



Input Distribution  
(object)

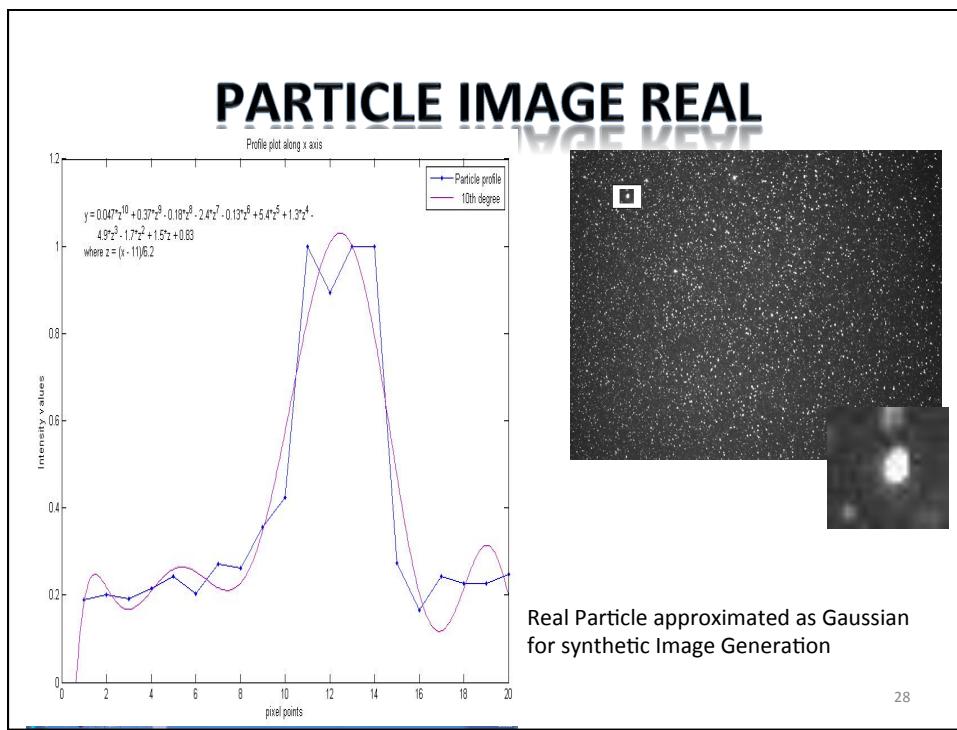
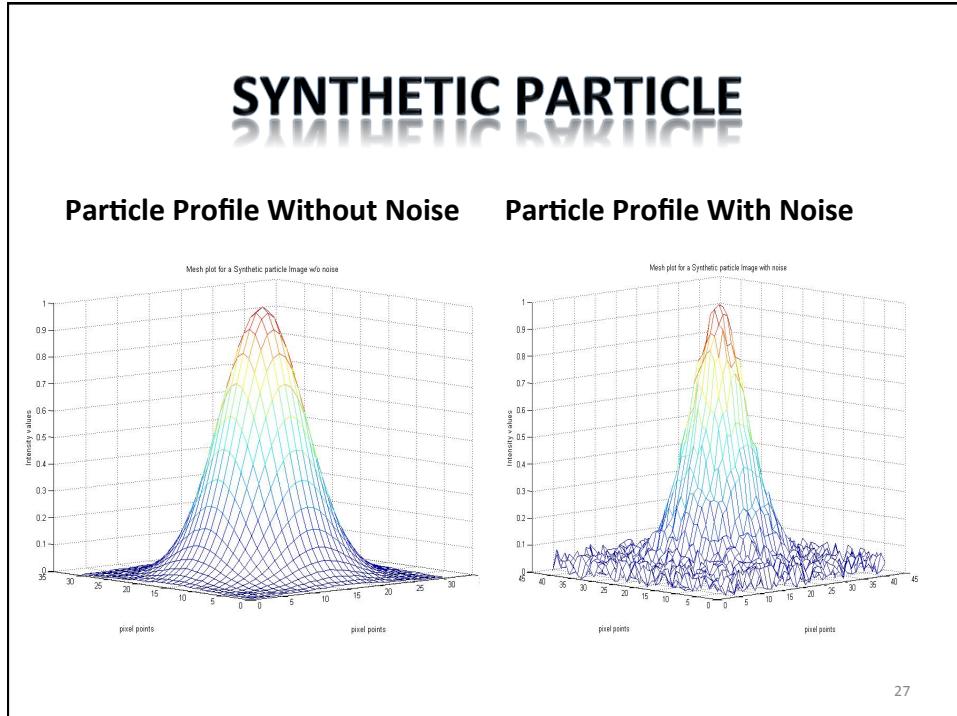


Imaging System  
PSF( $o$ )+noise



Output Distribution  
( $s$ )

26

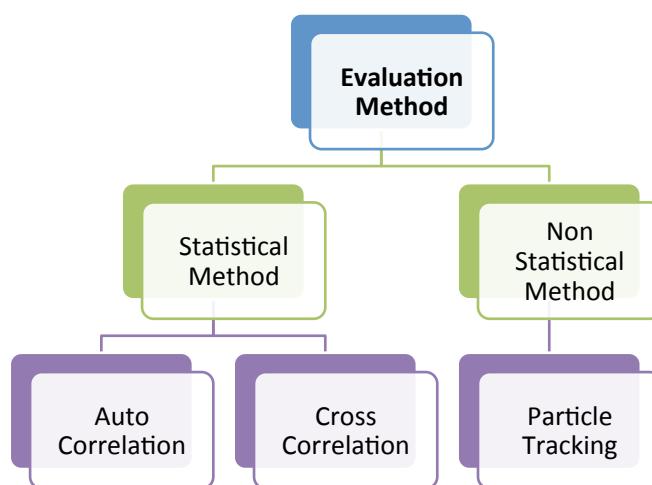


This section mentions the evaluation method used in PIV. Detailed discussion about FFT-based cross-correlation is mentioned.

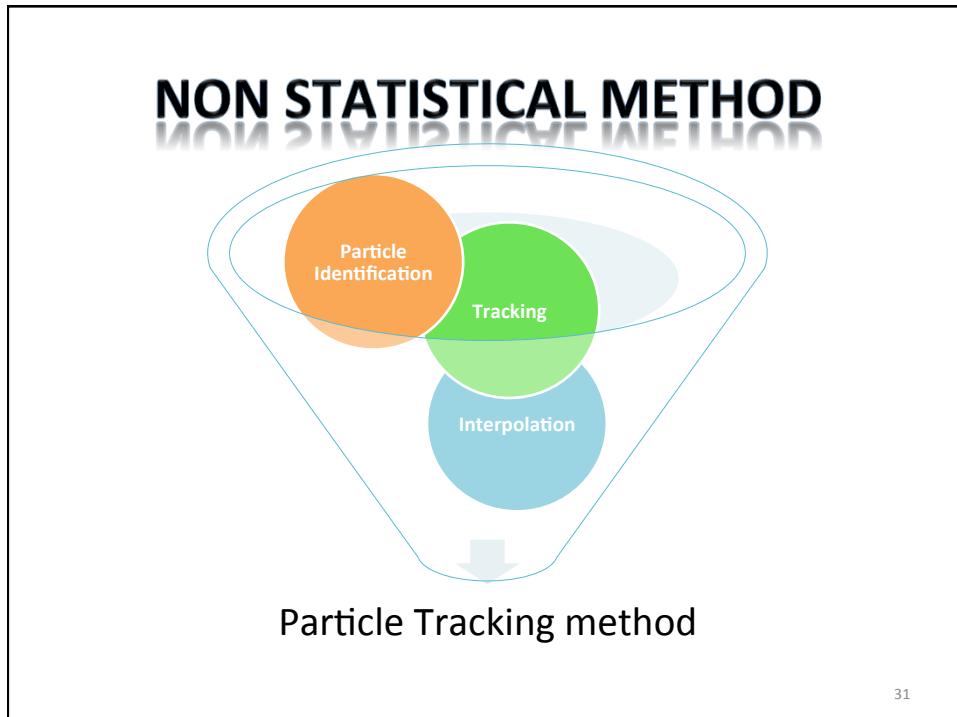
## EVALUATION OF IMAGES

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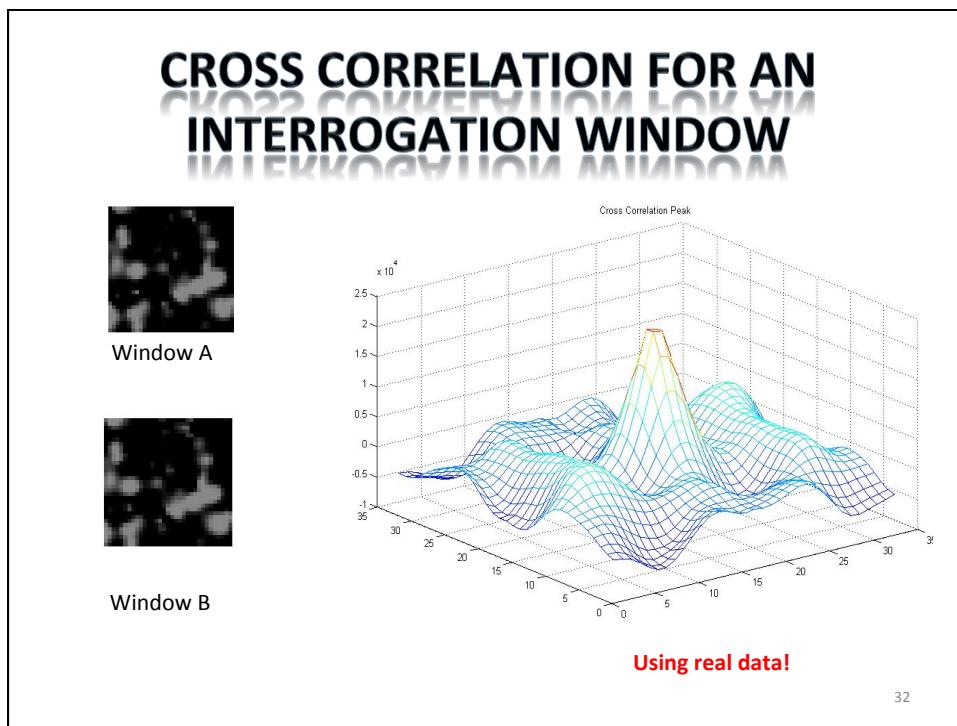
## EVALUATION



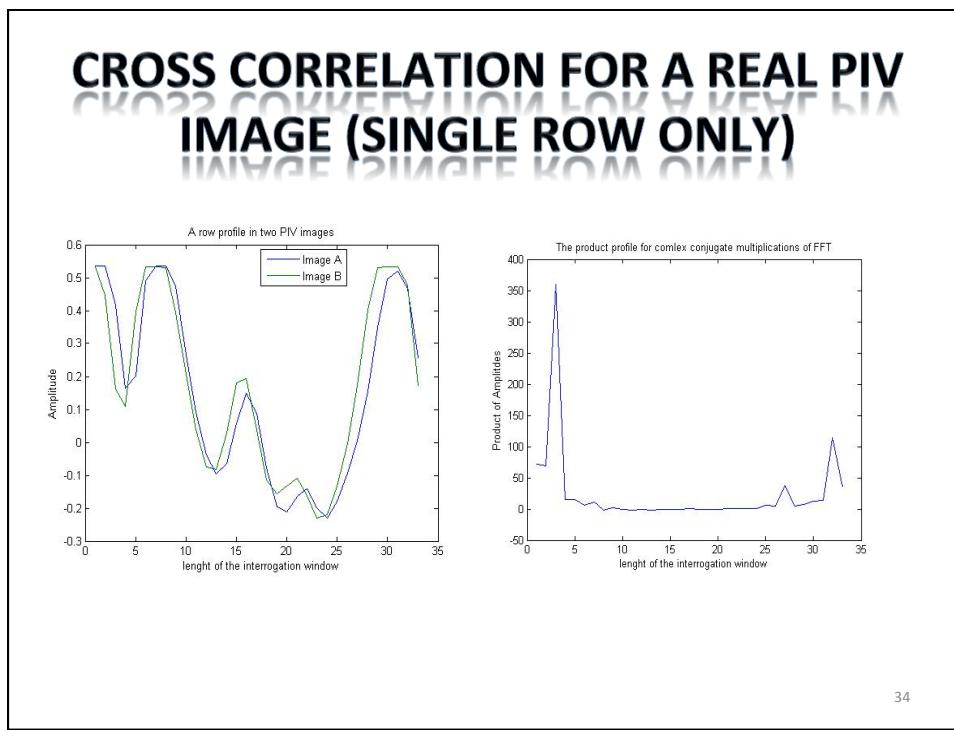
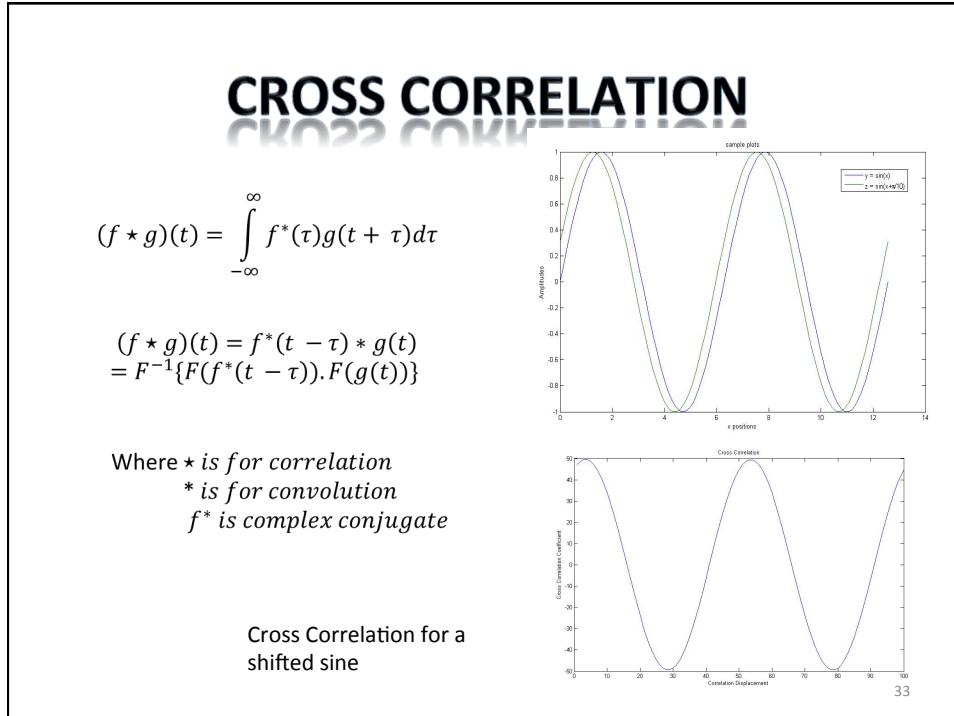
30

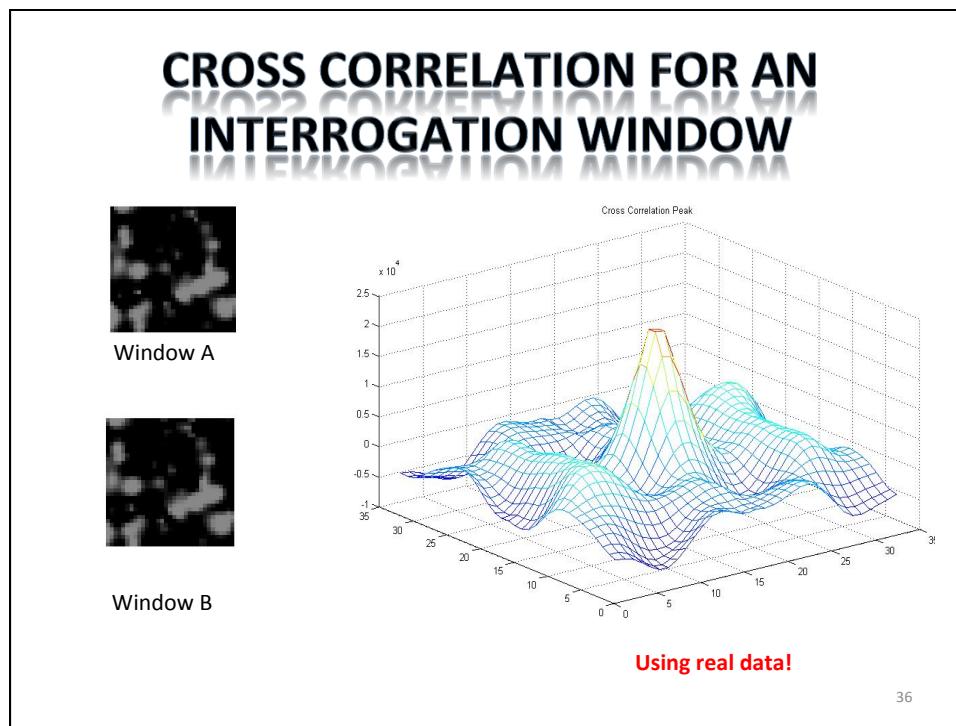
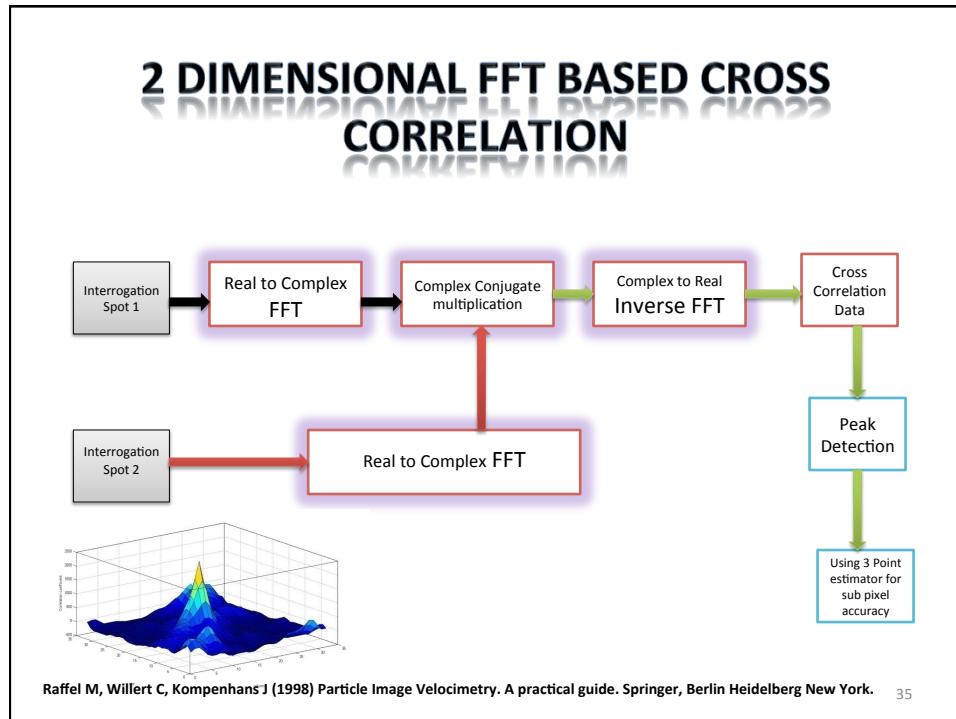


31



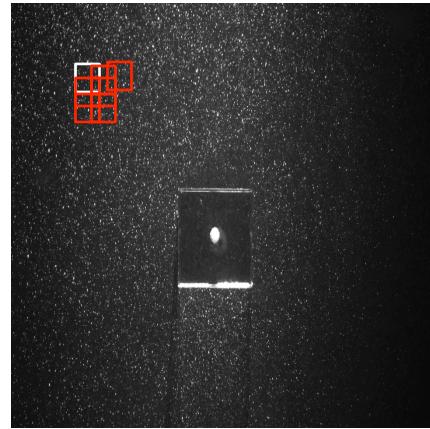
32





## INTERROGATION SPOT

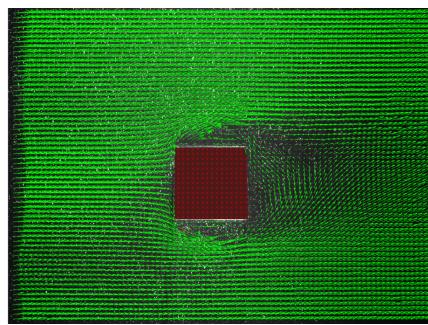
- Interrogation spot is the smallest region taken from the bigger image to detect the particle movements pattern.
- Size of Interrogation spot should be 3 times the particle displacement to avoid aliasing.
- Total Number of particles is determined by the % overlap between two interrogation spots.
- For Image of 1024x1392 px. An interrogation spot of 32x32 pixels with 50%(16x16px) overlap has 63x86 vectors



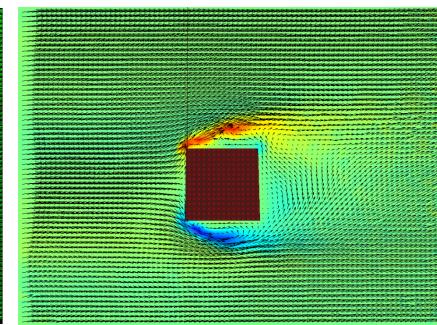
37

## AFTER EVALUATION

Mean Velocity Field



Vectors and Vorticity contours



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## Sample Image 2 without any obstacle

Image A

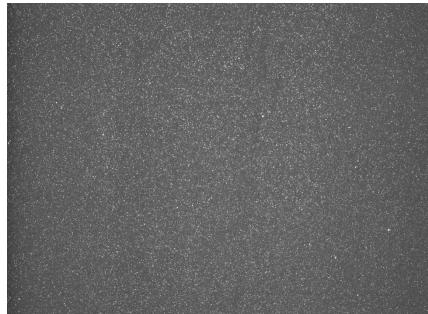
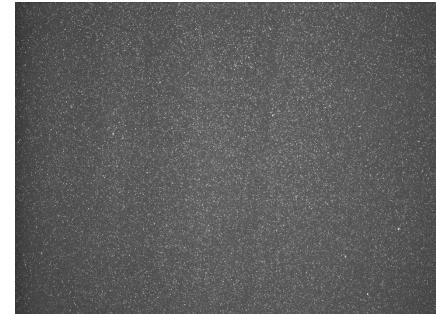
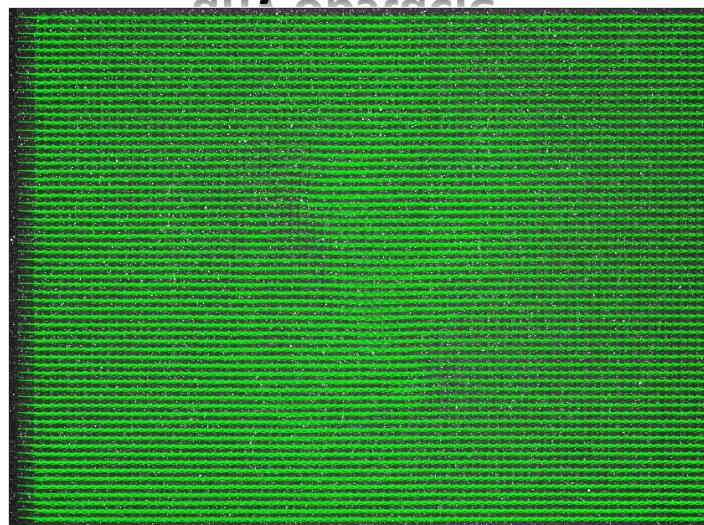


Image B



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## Evaluated sample Image 2 without any obstacle



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## Sample Image 3

Image A



Image B

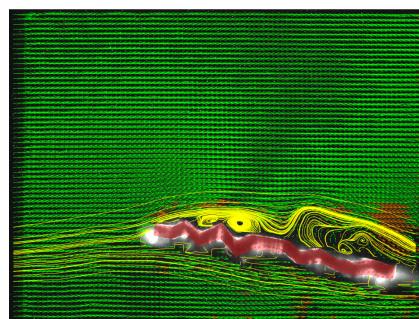


Corrugated airfoil angle of attack 8°

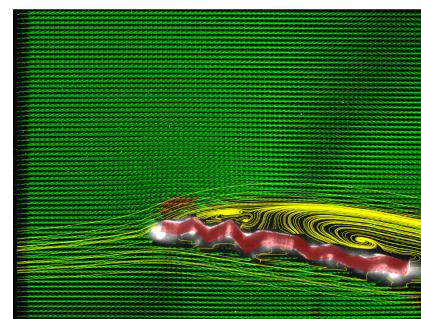
41

## Evaluation of Sample Image 3

Instantaneous Velocity field



Mean Velocity field



Corrugated airfoil angle of attack 8°

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## Sample Image 4

Image A



Image B

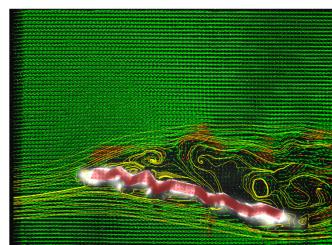


Corrugated airfoil angle of attack 12°

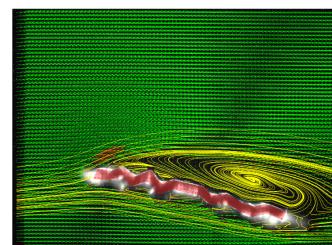
43

## Evaluation of Sample Image 4

Instantaneous Velocity field



Mean Velocity field



Corrugated airfoil angle of attack 12°

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