

# **LECTURE 19:                      ADVANCED 3D PARTICLE IMAGE VELOCIMETRY TECHNIQUE**

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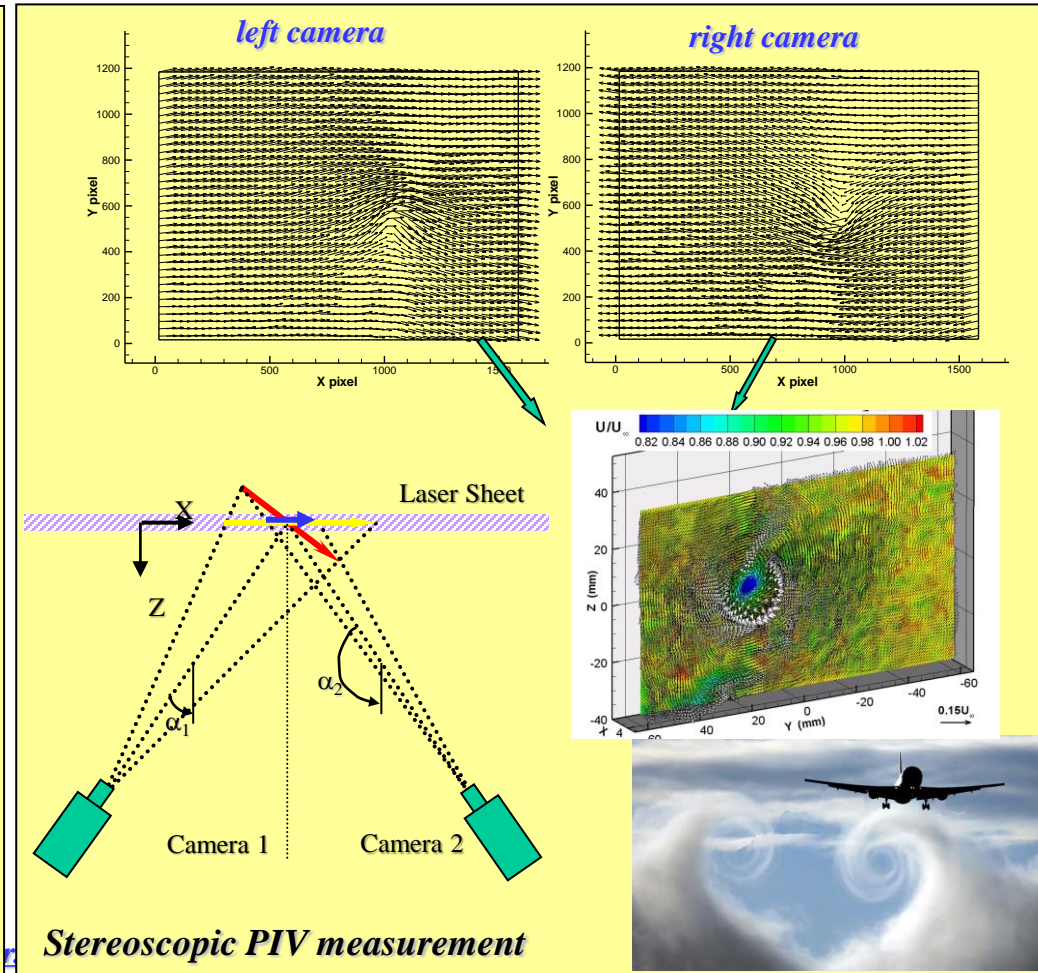
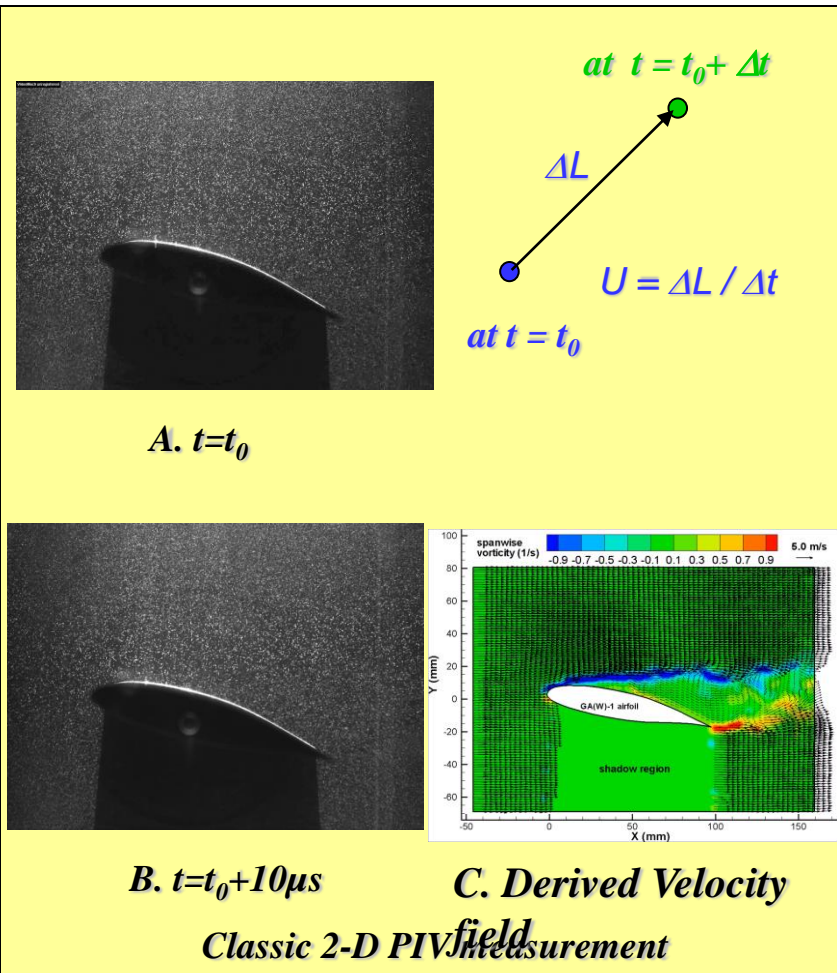
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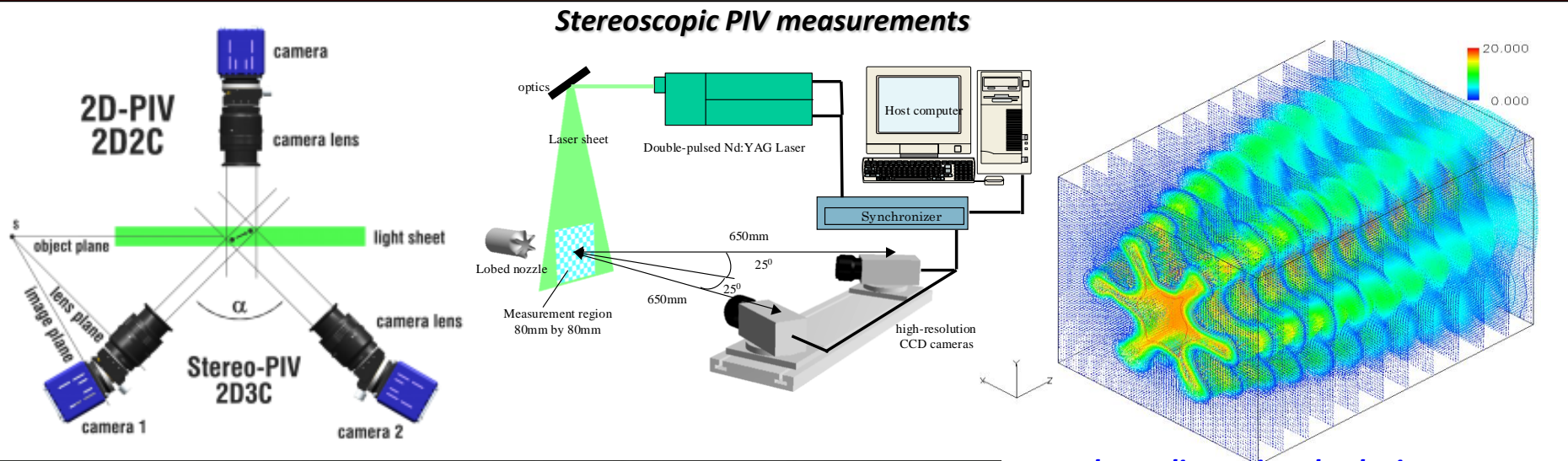


# □ PARTICLE-BASED TECHNIQUES: PARTICLE IMAGE VELOCIMETRY (PIV)

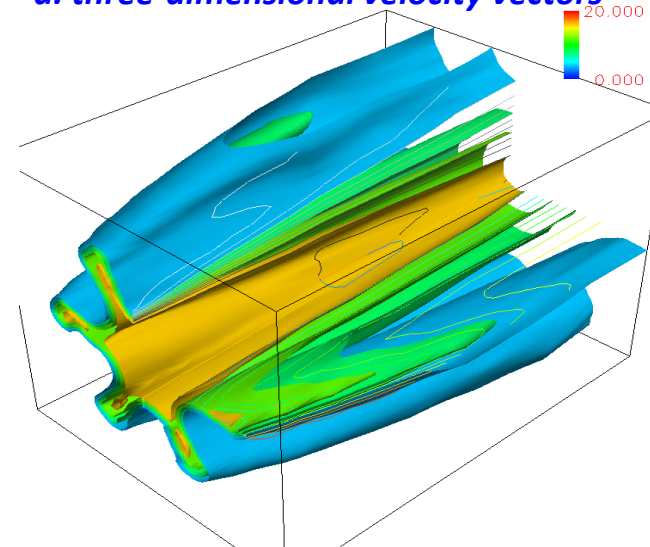
- To *seed fluid flows* with small tracer *particles* ( $\sim \mu\text{m}$ ), and assume the tracer particles moving with the same velocity as the low fluid flows.
- To measure the *displacements* ( $\Delta L$ ) of the tracer particles between *known time interval* ( $\Delta t$ ). The local velocity of fluid flow is calculated by  $U = \Delta L / \Delta t$ .



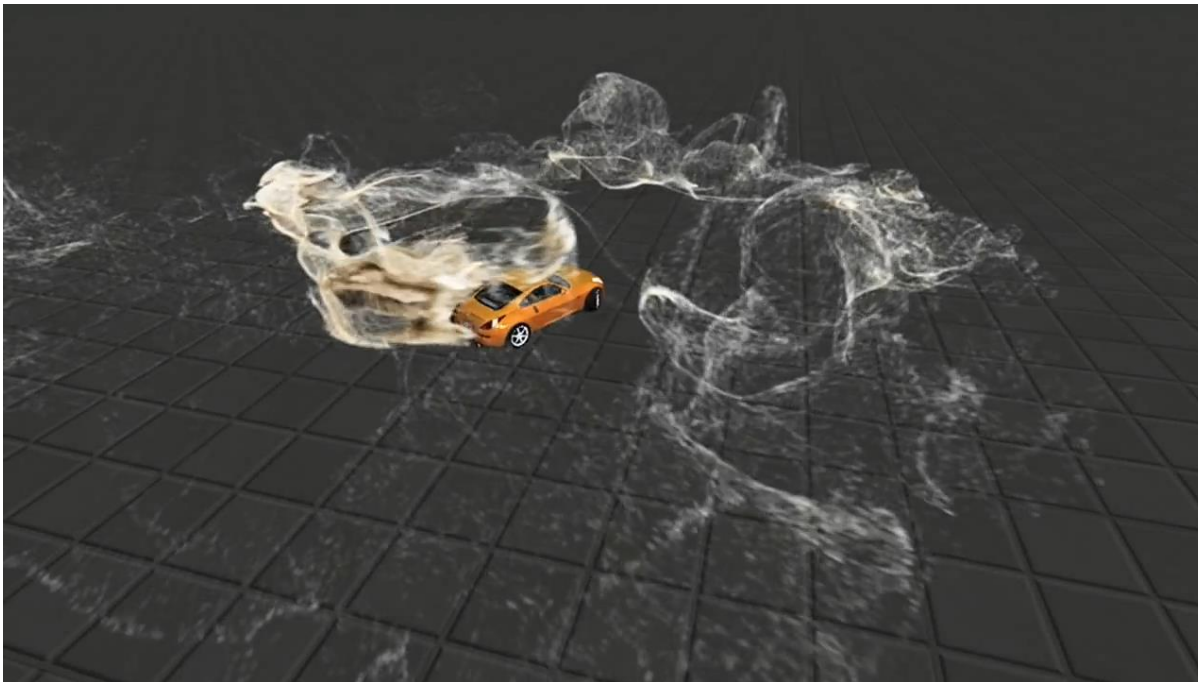
# Reconstructed Three-dimensional Flow Field



*a. three-dimensional velocity vectors*



*b. iso-surface of velocity field*





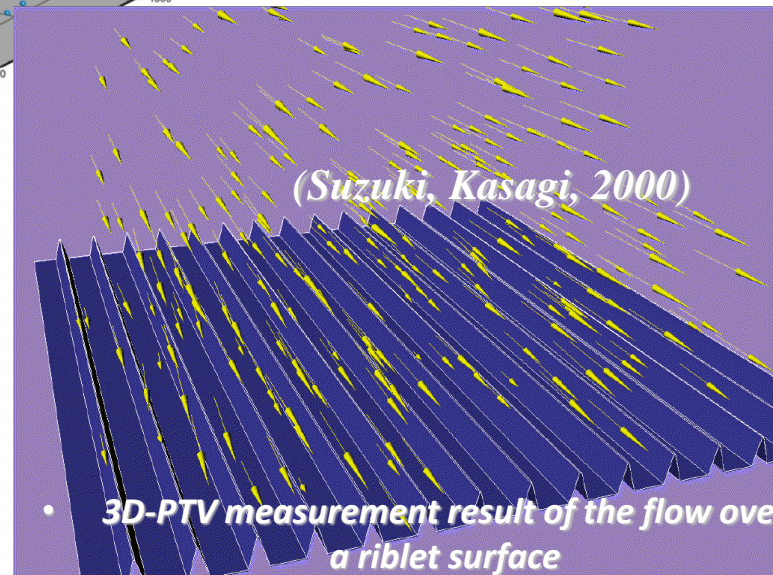
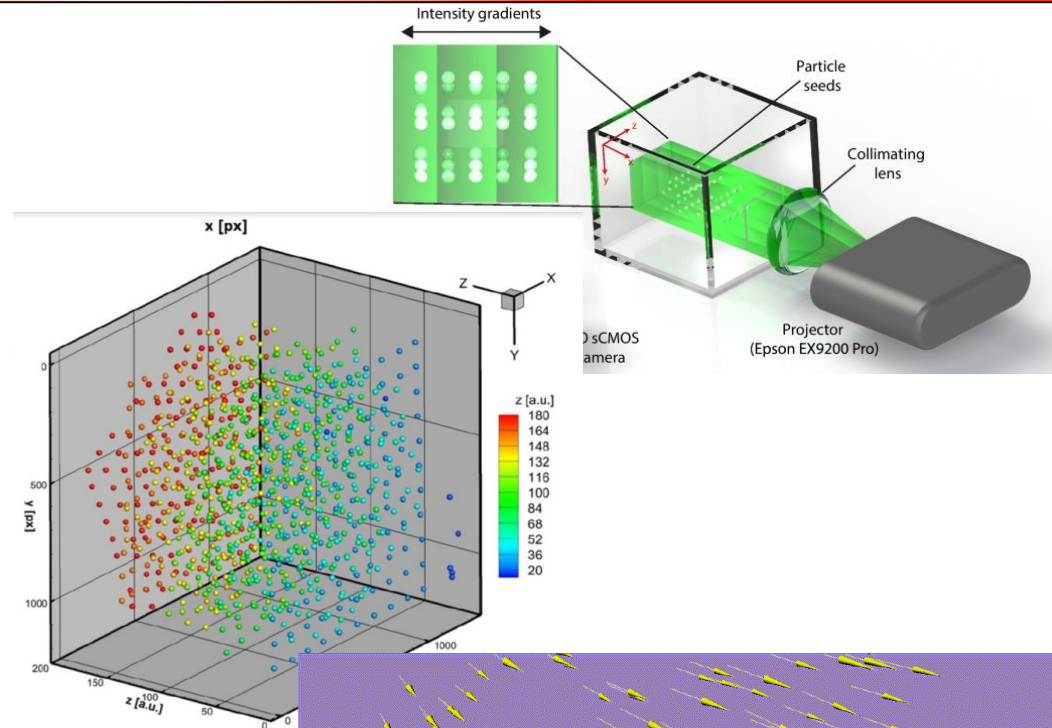
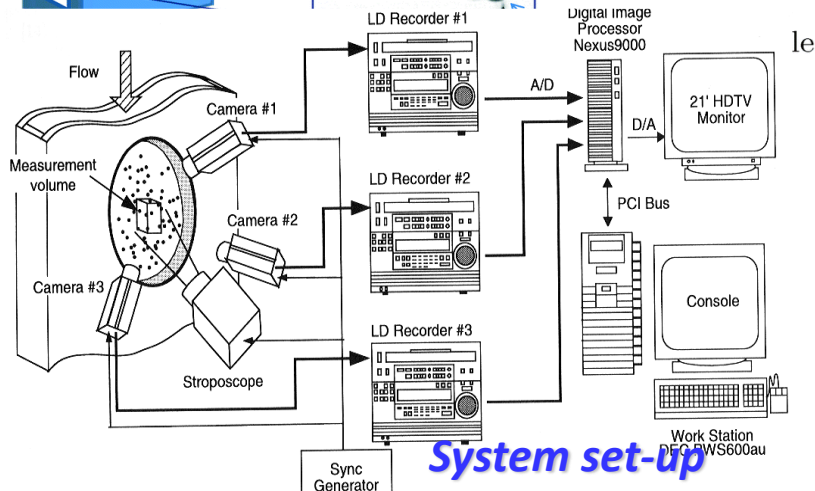
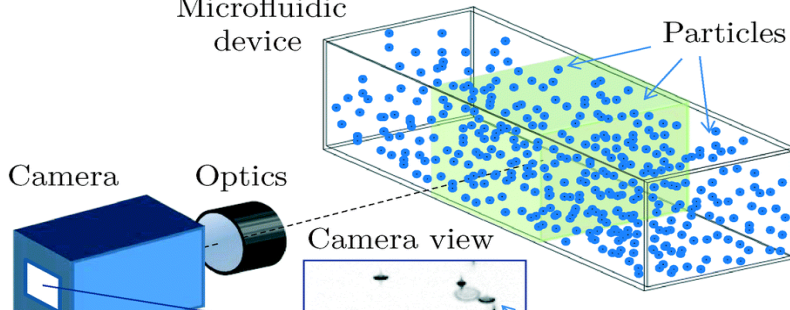
# 3D-PTV Techniques

$$X^{(c)} = F^{(c)}(x_i)$$

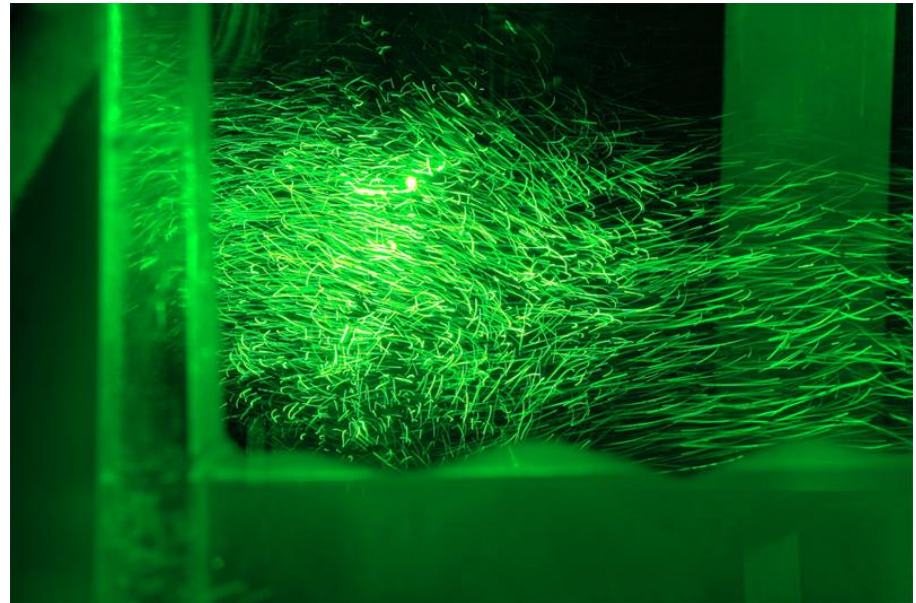
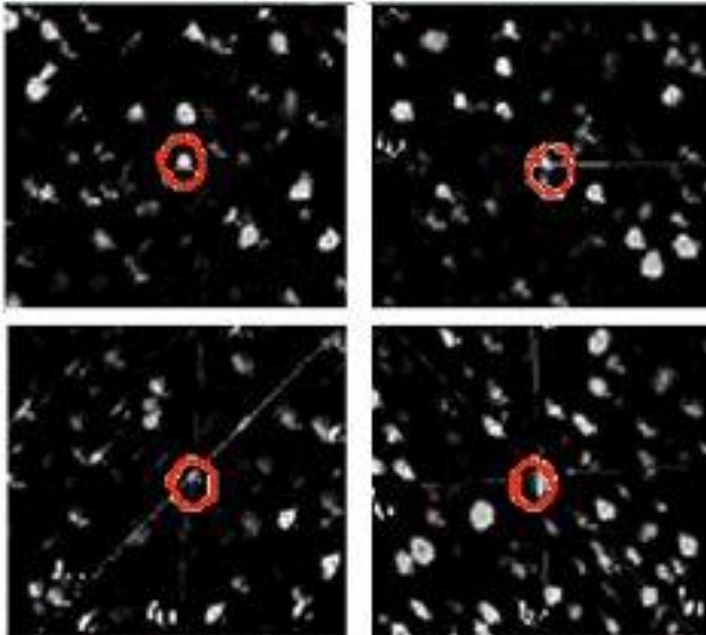
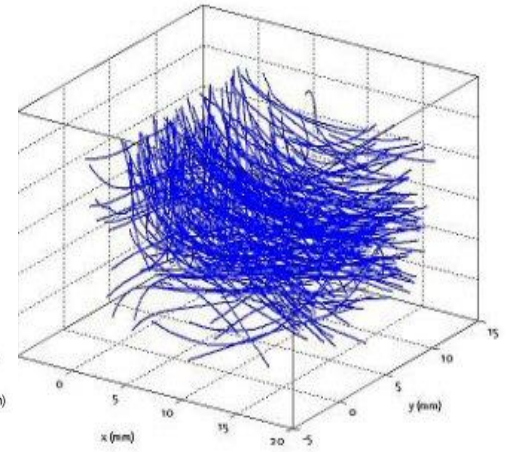
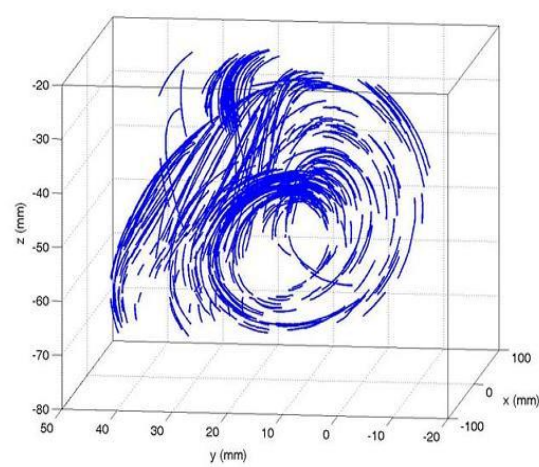
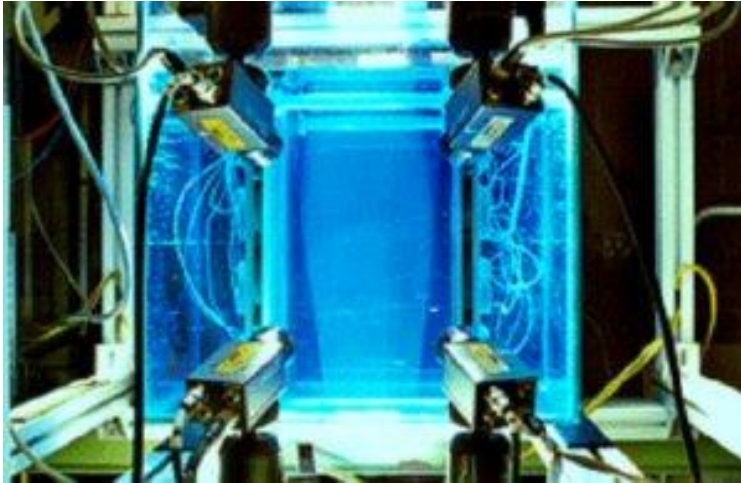
$$\begin{pmatrix} \overline{\Delta X_1^{(1)}} \\ \overline{\Delta X_2^{(1)}} \\ \overline{\Delta X_1^{(2)}} \\ \overline{\Delta X_2^{(2)}} \end{pmatrix} = \begin{pmatrix} F_{1,1}^{(1)} & F_{1,2}^{(1)} & F_{1,3}^{(1)} \\ F_{2,1}^{(1)} & F_{2,2}^{(1)} & F_{2,3}^{(1)} \\ F_{1,1}^{(2)} & F_{1,2}^{(2)} & F_{1,3}^{(2)} \\ F_{2,1}^{(2)} & F_{2,2}^{(2)} & F_{2,3}^{(2)} \end{pmatrix} \begin{pmatrix} \overline{\Delta x_1} \\ \overline{\Delta x_2} \\ \overline{\Delta x_3} \end{pmatrix}$$

$$F_{i,j}^{(c)} = \frac{\partial F_i^{(c)}}{\partial x_j} \quad c=1,2 \quad , \quad i=1,2 \quad j=1,2,3$$

Microfluidic device



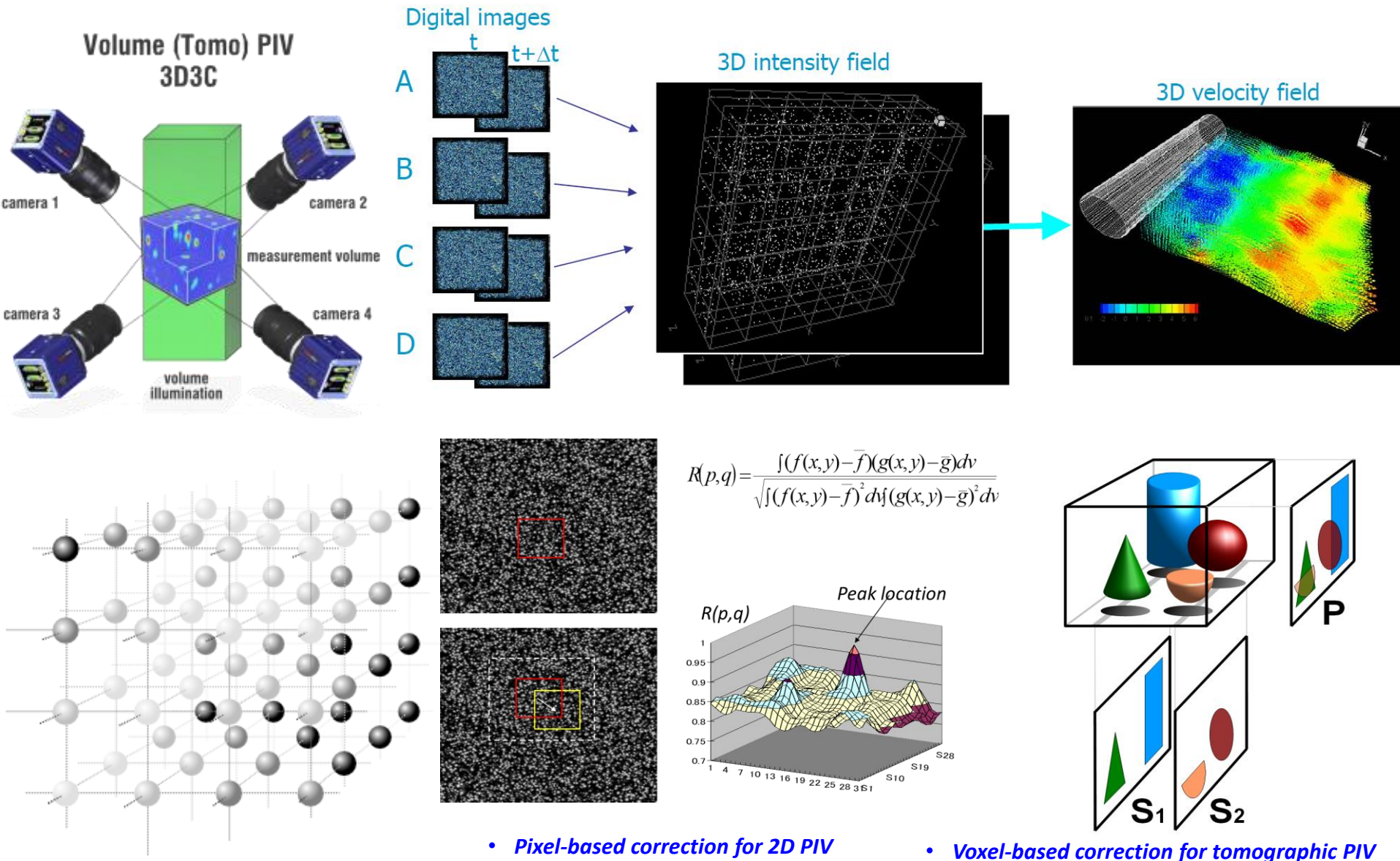
# 3-D PTV



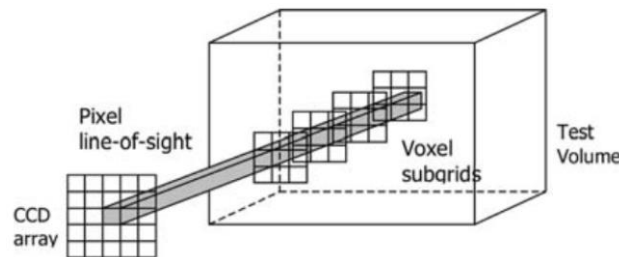
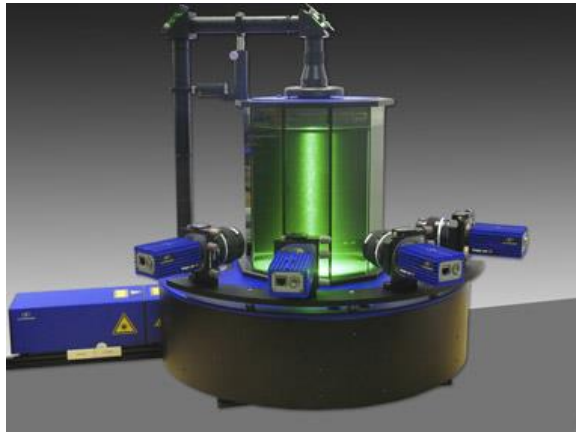
(Willneff, ETH Zurich, 2003)



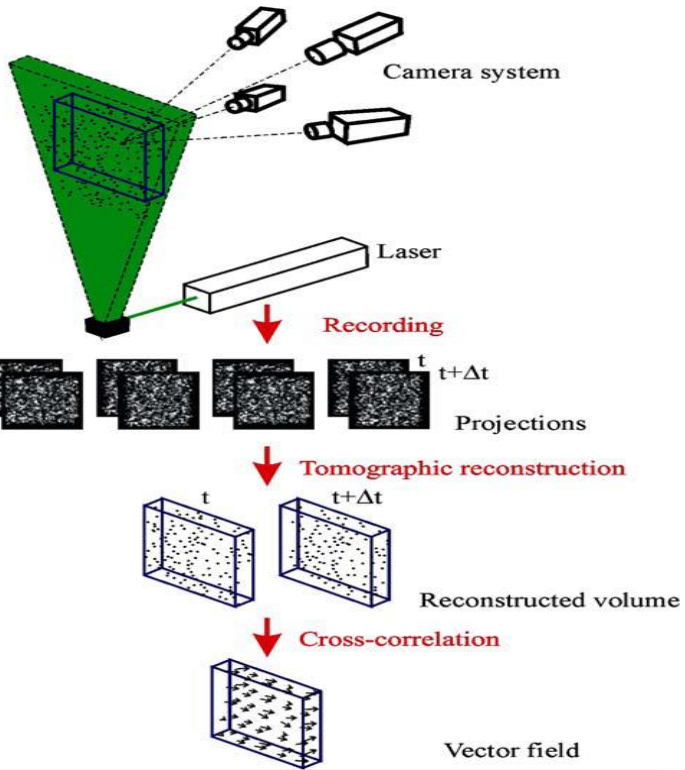
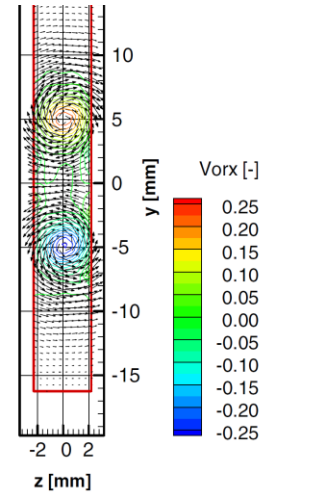
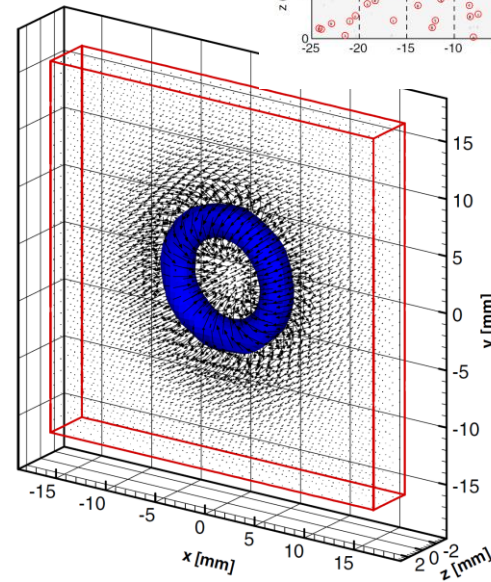
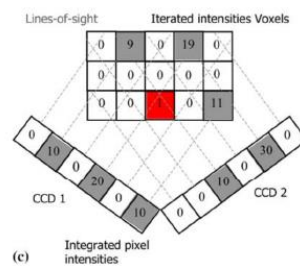
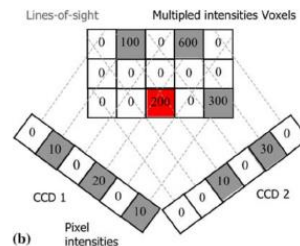
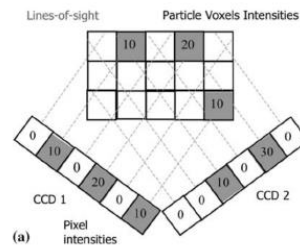
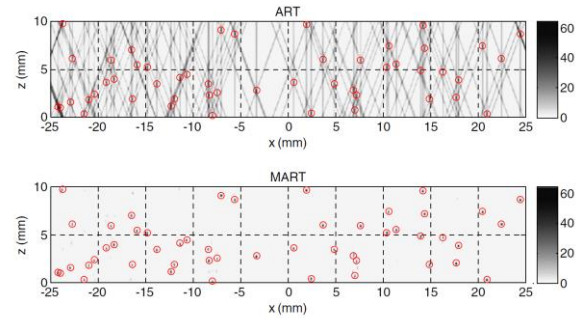
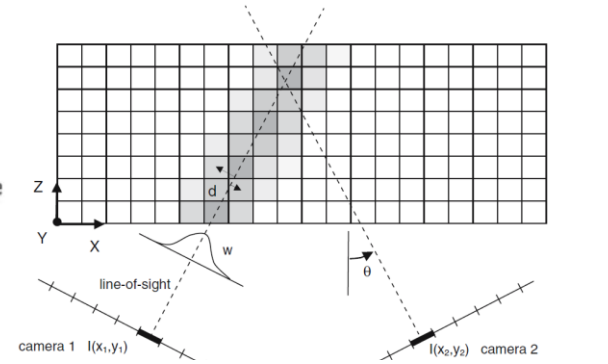
# Tomographic PIV Technique



# Tomographic PIV Technique



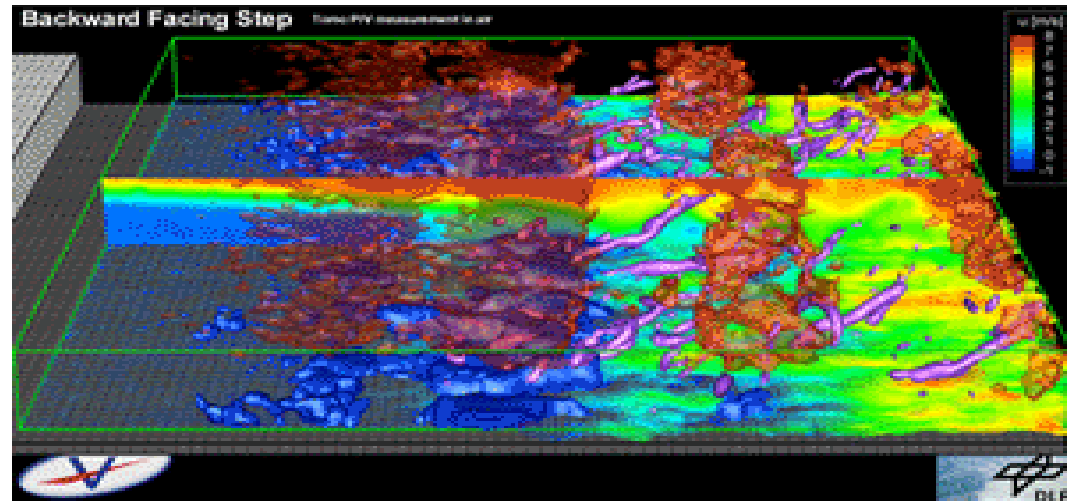
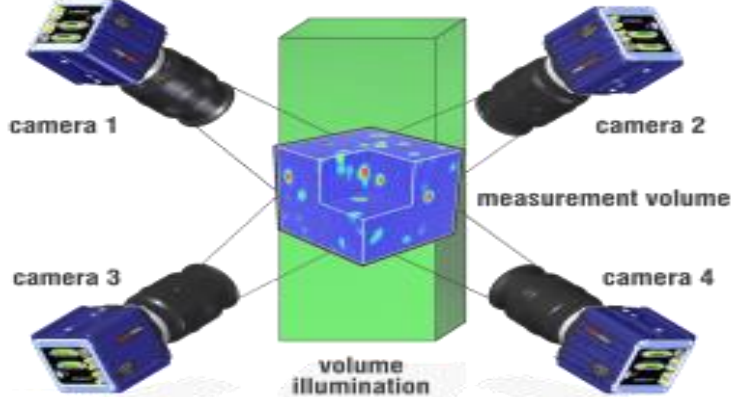
$$\sum_{j \in N_i} w_{ij} E(X_j, Y_j, Z_j) = I(x_i, y_i),$$



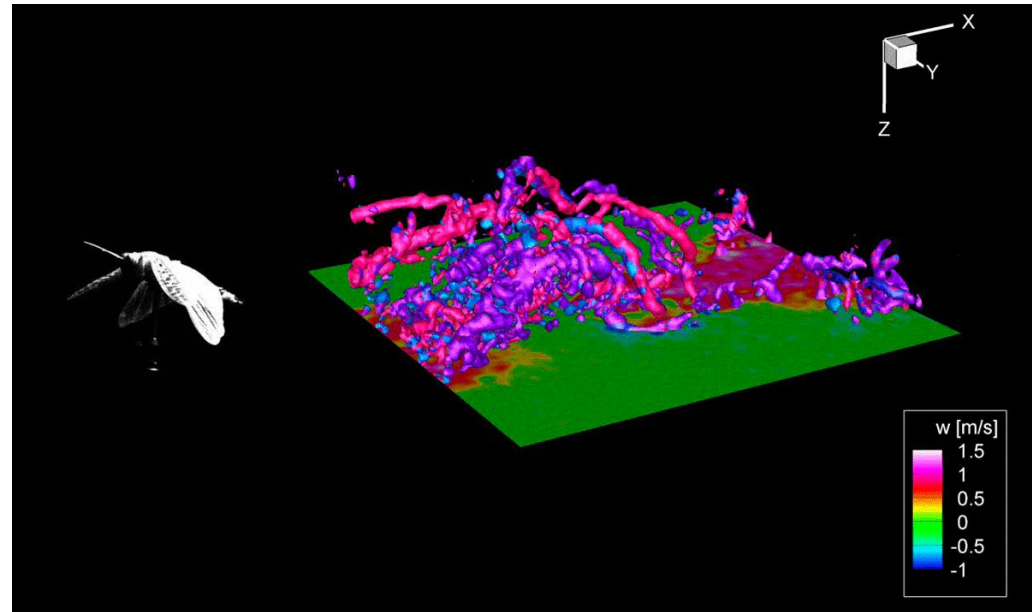
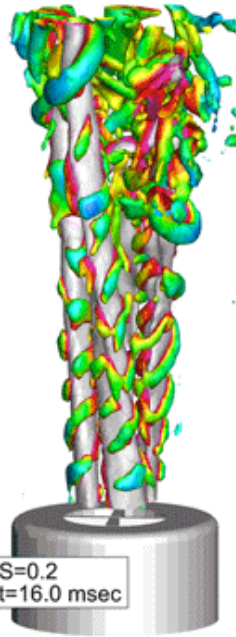
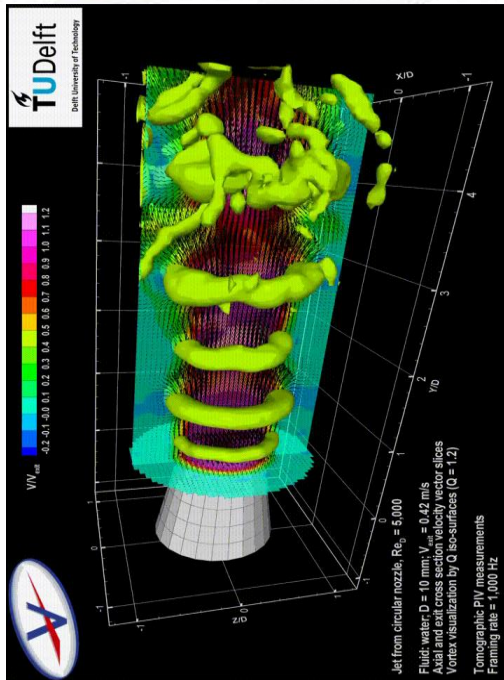


# Tomographic PIV Technique

## Volume (Tomo) PIV 3D3C



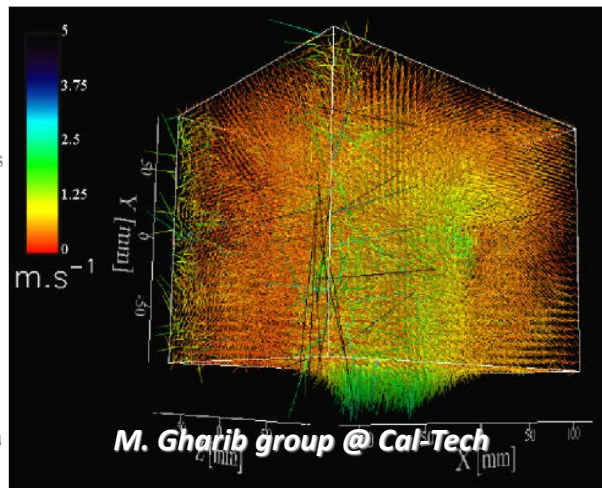
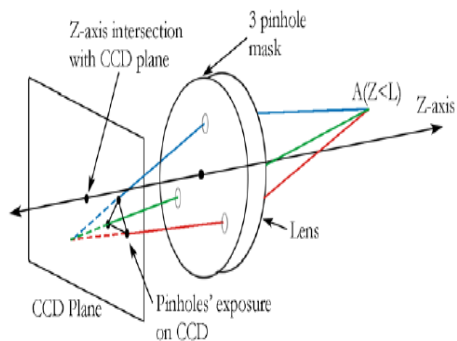
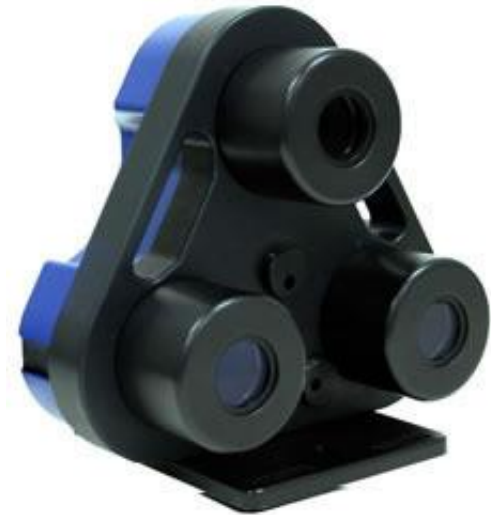
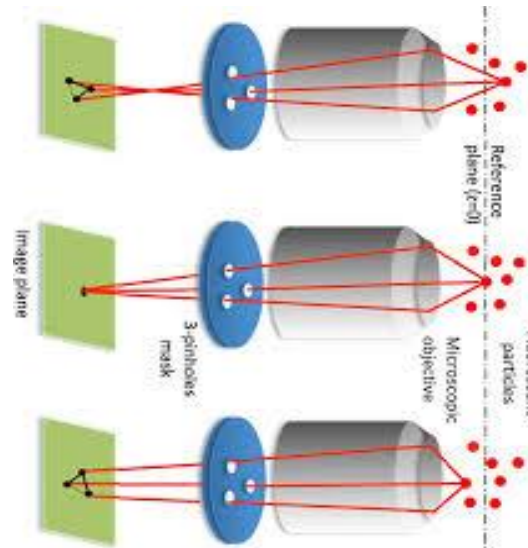
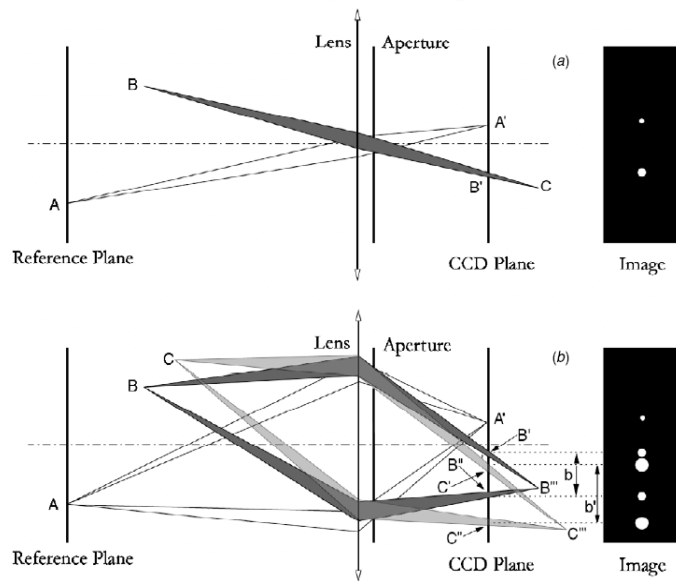
<http://www.lavision.de/en/>





# Defocusing Digital Particle Image Velocimetry (DDPIV)

## Defocusing concept



M. Gharib group @ Cal-Tech



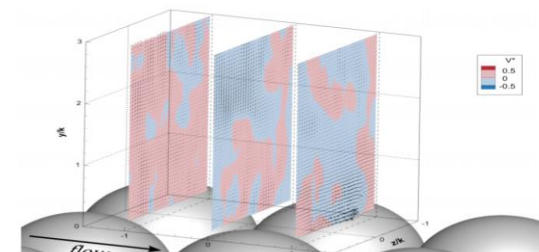
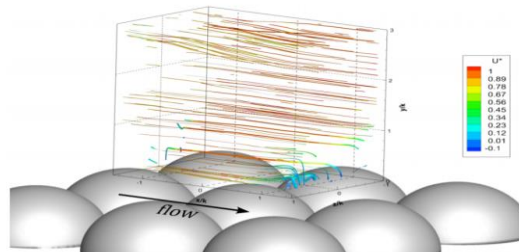
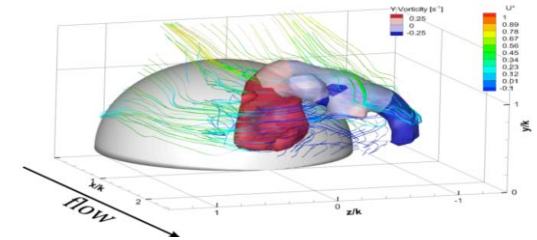
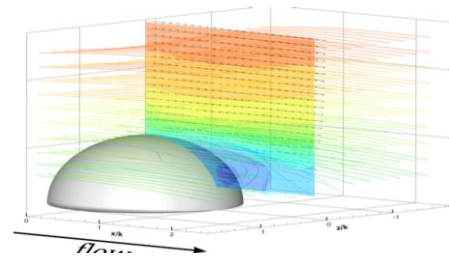
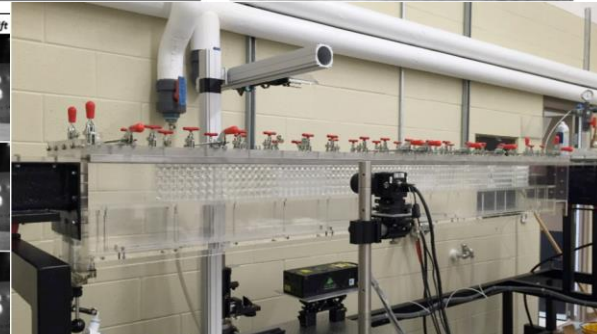
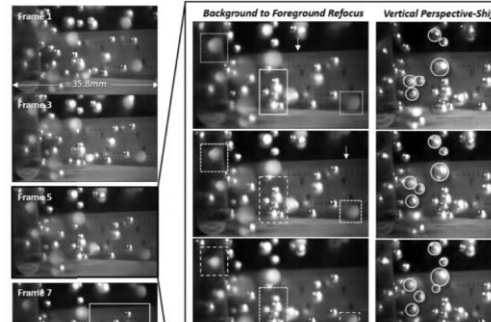
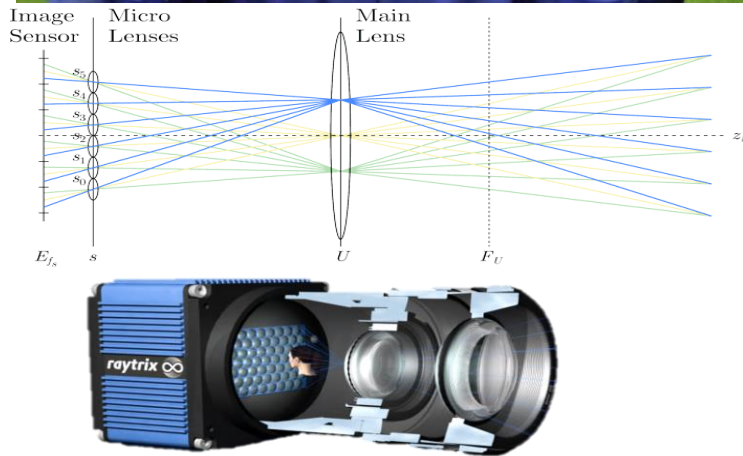
Volumetric 3-Component Velocimetry (V3V)



Figure 3. DDPIV using a three-pinhole mask (adapted from Pereira *et al* (2000)).

# Plenoptic PIV technique

- Plenoptic or light-field Camera



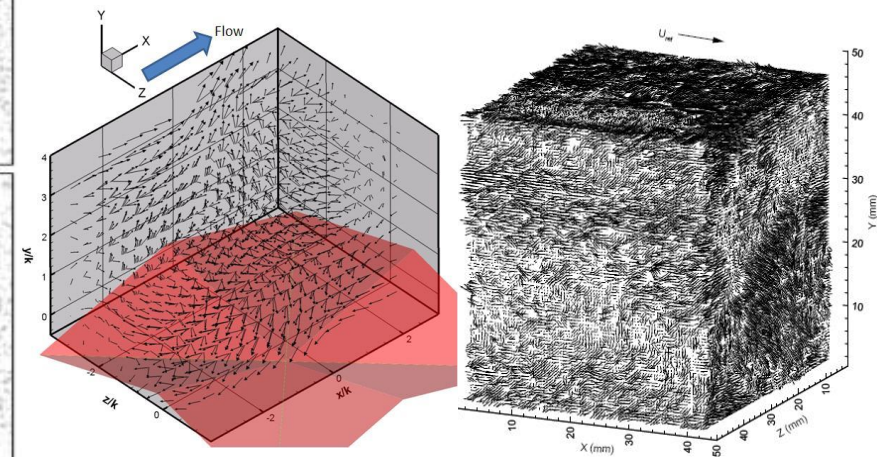
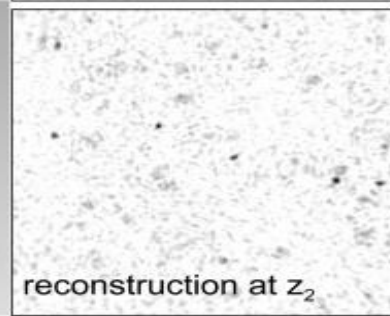
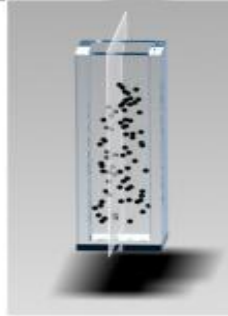
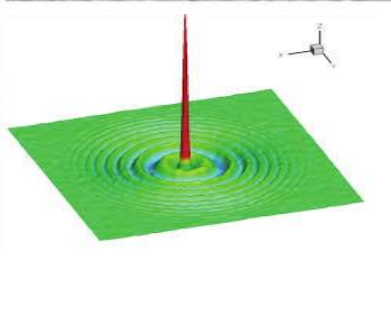
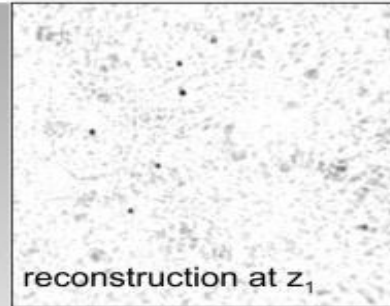
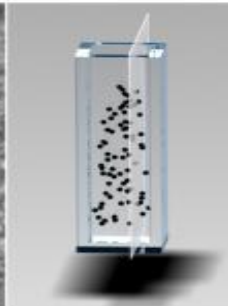
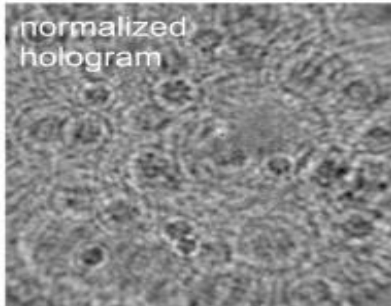
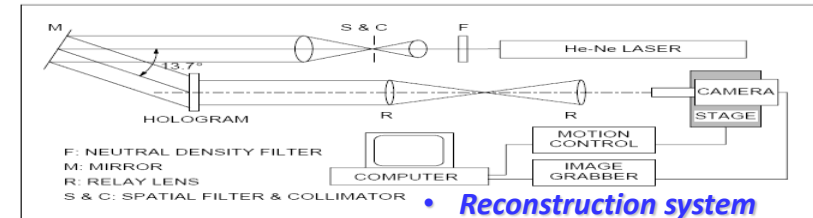
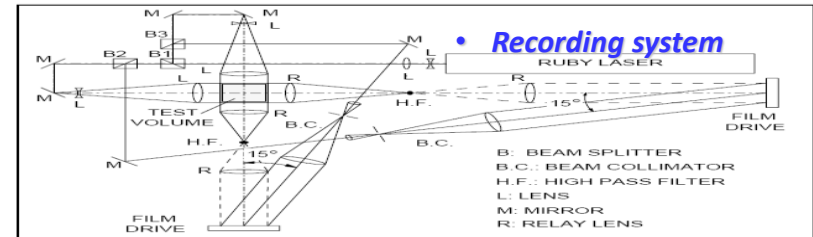
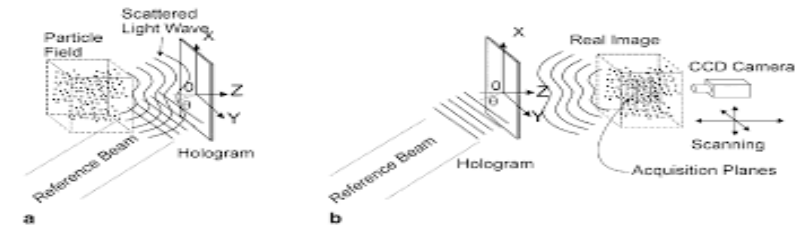
- Johnson, K., Thurow, B., Kim, T., Blois, G., Christensen, K. "Three Dimensional Plenoptic PIV Measurements of a Turbulent Boundary Layer Overlying Rough and Permeable Surfaces," 18th International Symposium on Applications of Laser and Imaging Techniques to Fluid Mechanics, Lisbon, Portugal. July 2016

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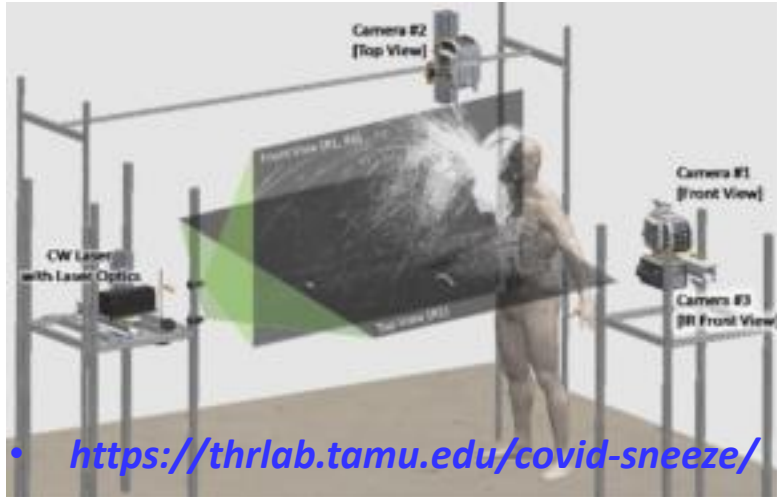
# Holographic PIV (HPIV) technique

<https://www.youtube.com/watch?v=0ics3RVSn9w>

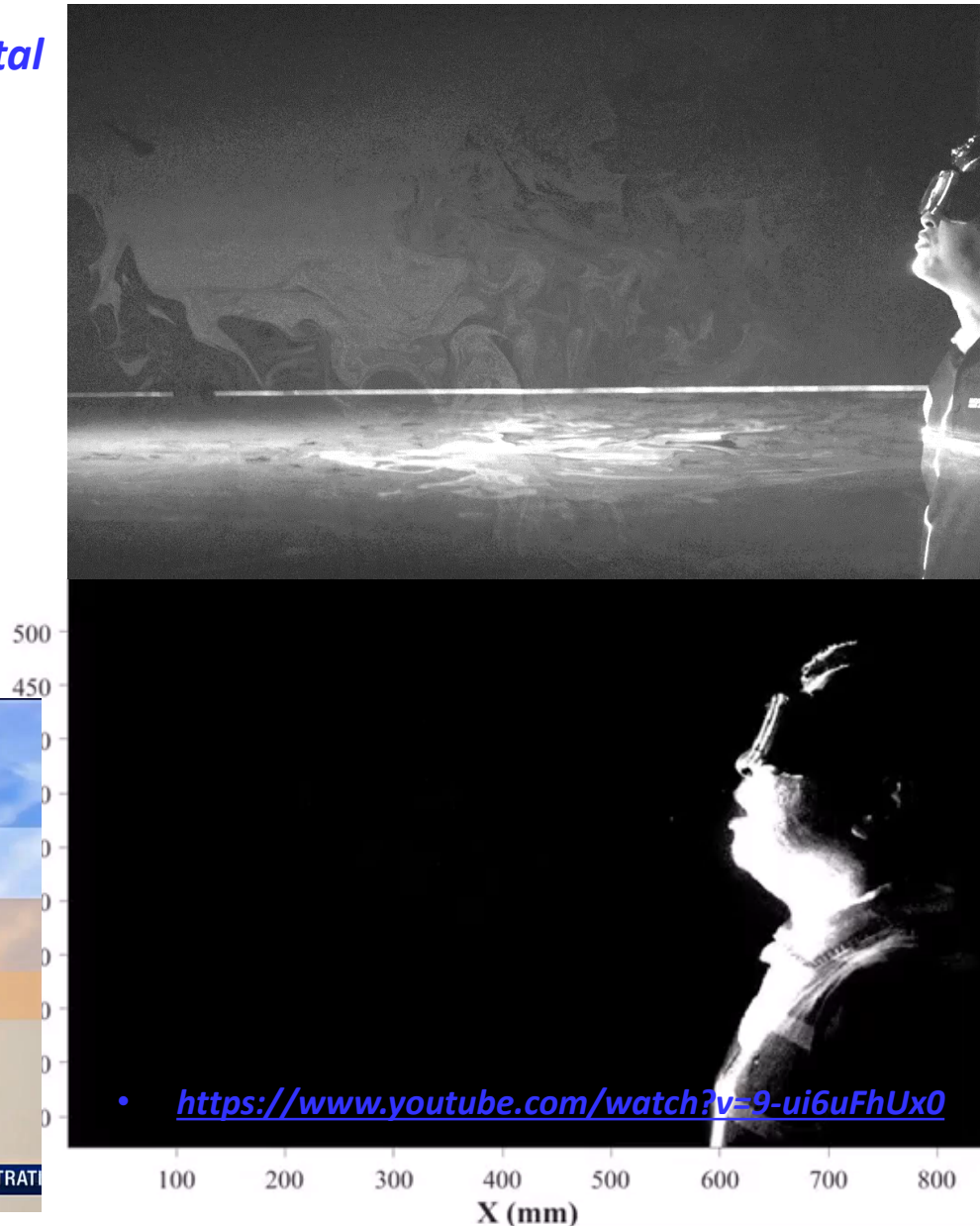


# PIV Application Examples

- A supportive COVID-19 study: Experimental Investigation on a Human Sneeze



- <https://thrlab.tamu.edu/covid-sneeze/>



- <https://www.youtube.com/watch?v=9-ui6uFhUx0>

WELLNESS  
WEDNESDAY  
WITH DR. MCGILLORGE

5:55 60°  
WDIV

4

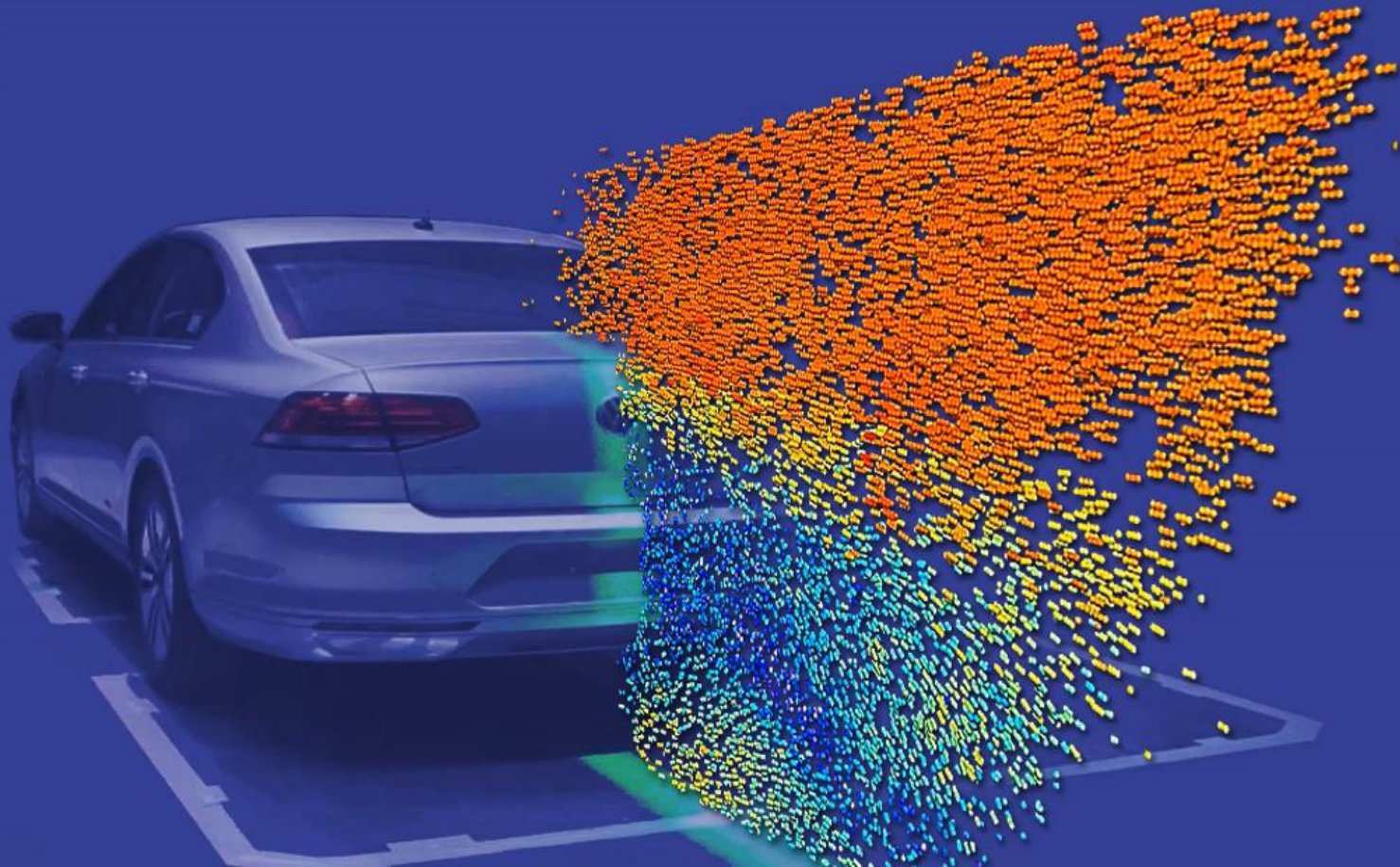
TOP  
STORIES

THE DEADLY POLICE SHOOTING OF A BLACK MAN 4 THE DEMONSTRATION



# PIV Application Examples

## Time-Resolved 3D Flow Field Imaging



# PIV Application Examples

<https://www.youtube.com/watch?v=yn-H9DEXsHg>



**Robotic large scale volumetric PIV**

Constantin Jux

Jan Schneiders

Andrea Sciacchitano

Fulvio Scarano

**2017**

The robot is setup by placing the CVV in the home position

**Full-scale CVV wind tunnel experiment**

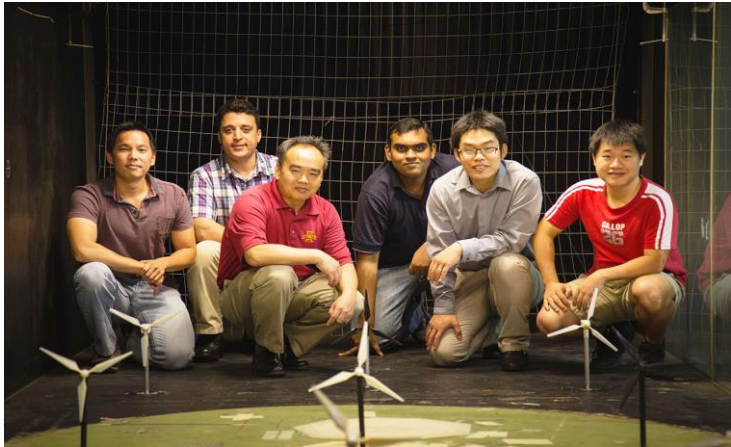
3d printed 'Tom Dumoulin' Cyclist

Speed: 14 m/s (50 km/h)

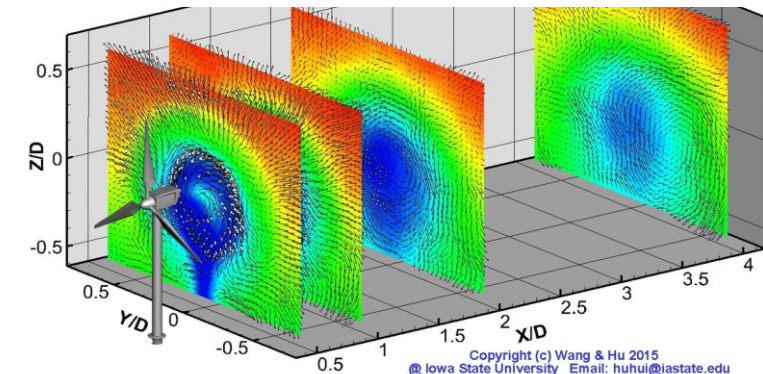
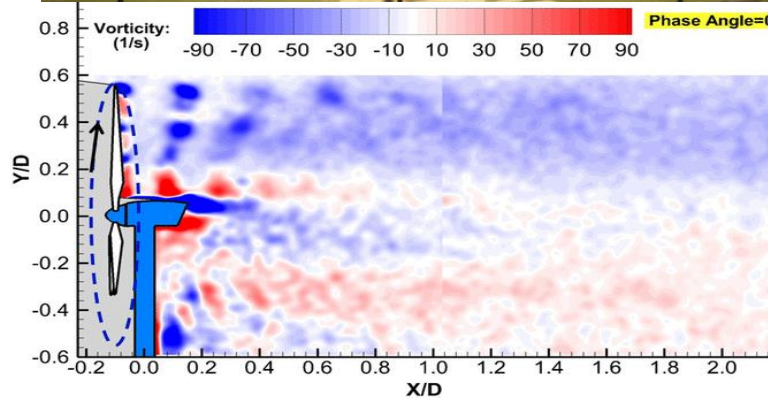
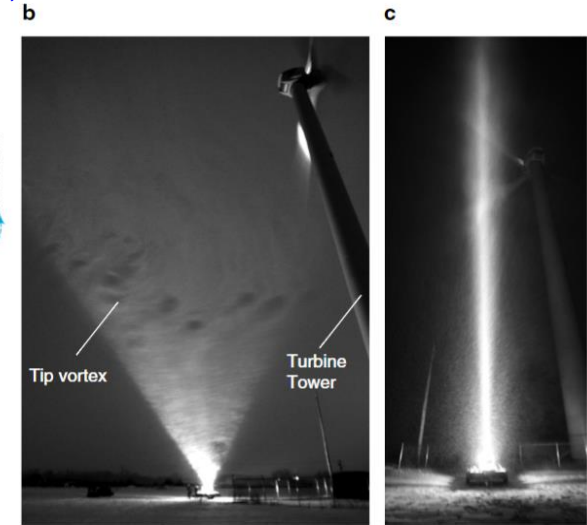
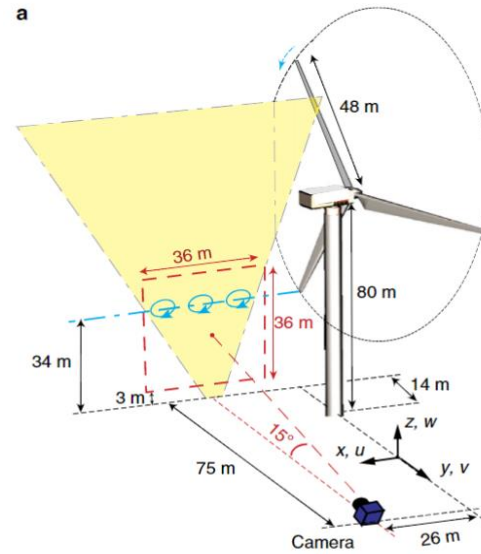
Technique: Co-axial Volumetric Velocimetry



# PIV Application Examples



- Hong, J., Toloui, M., Chamorro, L. P., Guala, M., Howard, K., Riley, S., & Sotiropoulos, F. (2014). Natural snowfall reveals large-scale flow structures in the wake of a 2.5-MW wind turbine. *Nature Communications*,



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