



PARTICLE IMAGE VELOCIMETRY (PIV)

Particle Image Velocimetry (PIV) is a non-intrusive, optical flow diagnosis technique for the instantaneous measurement of two velocity components within a planar domain of interest. This technique relies on the statistical determination of the displacement of naturally buoyant tracer particles seeded into the flow. Various aspects related to the theoretical background of this technique are given in a recent book by Raffel *et al.* (2007). More details on its historical development and reviews on the technique are given by Adrian (1991, 2005), Willert and Gharib (1991), and Willert (1996). Typical state-of-the-art PIV systems include a dual cavity laser, CCD camera, a synchronizer, data acquisition computer and can yield velocity fields with dynamic ranges in the order of 10^2 according to Raffel *et al.* (2007) based on the developments on the cross-correlation algorithms such as discrete window offset proposed by Westerweel *et al.* (1997).

In order to determine the velocity field in the plane of interest, the flow is seeded with naturally buoyant tracer particles and a pair of images, each synchronized with the laser pulses, is captured with a known time interval in between the images. The synchronization of the laser pulses and the camera image capturing is maintained such that the first frame of the image pair, Frame A, is exposed to the laser light reflected by the particles for a very short amount of exposure time. This effectively captures the snapshot of the particle locations at that particular time. After the digital information on the CCD array is transferred onto the data acquisition medium, the second frame, Frame B, is recorded within the second pulse of the laser after a certain amount of time. This type of data acquisition is referred to as *double frame-single exposure* and the synchronization method is known as *frame straddling* (Raffel *et al.*, 2007). While this method is limited in the maximum measurable velocity (especially for supersonic flows) due to the timing limitations between the laser pulses, it lacks the directional ambiguity in the velocity vector and provides an advantage over its previous version of *double exposed-single frame* recording. Once the image pair, defined as a PIV recording, is transferred to the computer, cross-correlation of these images within small interrogation windows is performed for the statistical determination of the particle displacements. In PIV literature, the physical size and the overlapping ratio of these interrogation windows define the vector resolution in a given velocity vector field.

The PIV system available for TUFFP projects is acquired from TSI Inc., and its details are given in the table below. Also, photographs of the system components are given from Figure 1 to 3.



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Component	Specification
Nd:YAG Dual Cavity, High Power Laser	200 mJ/pulse @ 532nm Maximum operation frequency: 15 Hz
CCD Camera	4 MP (2048x2048 pixels) resolution Can operate up to 16 Hz



Figure 1. Nd:Yag Laser (power unit not shown) with the laser guide arm attached to the laser emission port.



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Figure 2. The assembly of a linear stage for the CCD camera with the laser collimator.



Figure 3. Laser safety goggles (on the left) and laser radiation sign (on the right).

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References

Adrian R.J., 1991, Particle-Imaging techniques for experimental fluid mechanics, *Annu. Rev. Fluid Mech.*, **23**, 261-304.

Adrian R.J., 2005, Twenty years of particle image velocimetry, *Experiments in Fluids*, **39**, 159-169.

Raffel M., Willert C.E., Wereley S.T., Kompenhans J, 2007, Particle Image Velocimetry: a practical guide, 2nd Edition, *Springer*.

Westerweel J., Dabiri D., Gharib M., 1997, The effect of a discrete window offset on the accuracy of cross-correlation analysis of digital PIV recordings, *Experiments in Fluids*, **23**, 20-28.

Willert C.E., Gharib M., 1991, Digital particle image velocimetry, *Experiments in Fluids*, **10**, 181-193.

Willert C.E., 1996, The fully digital evaluation of photographic PIV recordings, *Applied Scientific Research*, **56**, 79-102.