STANFORD COMPUTER OPTICS, Inc.

Technical Note

Particle Imaging Velocimetry

Particle imaging velocimetry, 2-dimensional flow analysis

Auto correlated (ac) PIV (Particle Imaging Velocimetry) employs double exposures (with camera shutter, flash or laser) on a single image. Portions (e.g., 32 X 32 pixels) of this image are subsequently shifted against itself and added pixel by pixel (auto correlation). This leads to magnitude and direction of a velocity vector at the center of mass of this image portion. The drawback of this method is an inability to produce a signed direction. Thus the correlation co-efficient for "left" or "right" movement are the same.

Our 4 Picos/4 Quik E intensified CCD camera has the unique ability to produce not only multiple exposures, but multiple exposures having different parameters. It is therefore possible with the 4 Picos/4 Quik E to obtain two multiple exposures in which one is brighter than the other; thus it is possible to obtain the 'missing sign' in a second run of any appropriate imaging software.

The 4 Picos/4 Quik E perfectly matches the ac PIV. No other competitive intensified camera has this internal double exposure programming capability, nor does any such convenient Windows programming function exist. For ac PIV you would normally need an intensified camera system which works with a CW laser in the 100 mW to 1 W range.

Two of our older 4 Quik 05A cameras are currently being used for such applications at the University of Lausanne (Ecole Polytechnique Fédérale), Switzerland. The first one was even originally purchased together with an expensive 'double pulse' laser, due to 'old habits'. Once our cameras were setup, they never used this laser nor will they ever need to. Instead, a cheap 5 mW HeNe laser was good enough in this case to do velocity analysis of small field flow measurements around a heart valve. Please see the article on PIV using our camera which appeared as the feature article of the May 1996 issue of laser Focus World, by K. Eisele, et. al. As demonstrated, non-intensified solutions need hundreds to thousands times brighter illumination than that required when using an intensified 4 Picos/4 Quik E camera. Thus, the very high cost of a high-intensity laser is saved when our camera is used.

To avoid the signed vector problem, many in the PIV community now seem to favor cc PIV. In this method, the sign of the velocity vector is directly retrieved from the data through the use of two intensified cameras, instead of one, for (cross) correlation. Since it is known which camera took the first image, it is easy to determine the direction of movement. This is obviously a more expensive solution since either two intensified cameras are required plus two frame grabbers, or two non-intensified cameras plus two frame grabbers and an expensive high-intensity, double pulsed laser. Another drawback is the need for correct alignment of the two images. This is usually accomplished by using one objective in front of a beam splitter. On the sensor (camera) side, care must be taken to assure that both sensors are exactly parallel, and that they are also exactly the same distance so that both have the same image scale. With half the vertical resolution and a sophisticated triggering setup, cc PIV may also be accomplished with just one Intensified CCD camera plus frame grabber, or one non-intensified CCD camera plus frame grabber and a high-intensity, double pulsed laser.

The third method Particle Tracking Velocimetry (PTV) needs a reasonable 'low number' of seeding particles in the flow. In such a case, more than two multiple exposures can be made. Thus, every single particle can be traced separately by the software. To establish flow direction, it would be necessary to attach a 'marker', such as a longer exposure (brighter illumination) of the first or last exposure. Again, the 4 Picos/4 Quik E is the only intensified CCD camera which can directly program an automatic sequence of multiple exposures of more than two exposures with one being a 'marker'. Therefore, our camera is the only "best" match for PTV.

In summation, using the 4 Picos or the 4 Quik E intensified CCD camera with a low-cost, low power laser is the best and least costly equipment choice for Particle Imaging Velocimetry.

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