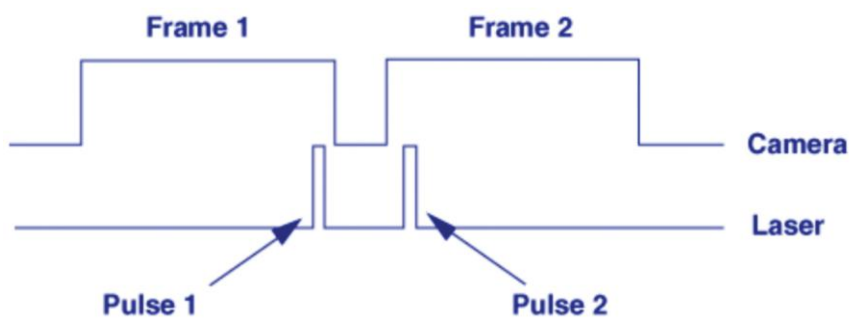
HOW FRAME-STRADDLING WORKS

PIV/PLIF SYSTEMS

The essential principle of PIV is to illuminate a seeded flow-field with two pulses of laser light and record the particle images with a CCD or photographic camera. Traditionally, both exposures have been recorded on a single frame, creating a "double exposure." The double exposed frame is then processed using auto-correlation techniques. However, this leads to a directional ambiguity arising because the double exposed frame contains no information about which set of particle images were recorded from the first laser pulse, and which from the second. Image shifting using a rotating or spinning mirror can be used to overcome this ambiguity, but does increase experimental complexity.

A better alternative when using CCD cameras is to record each of the two exposures on separate frames, followed by analysis based on cross-correlation of the two frames. Recording on separate frames preserves the time sequence of the pulses so no directional ambiguity occurs. Also, cross-correlation processing provides improved dynamic range for velocity compared with auto-correlation of double exposures. It is this technique of positioning the two laser pulses on sequential CCD frames that is known as "Frame-Straddling."



Unfortunately, traditional CCD cameras allow frame-straddling only when the time between laser pulses (pulse separation) is relatively long. This because, after the CCD picture elements (pixels) are exposed by the first laser pulse, this information must be read-out from the CCD chip line-by-line before the next exposure can take place. In effect, the two laser pulses must straddle this read-out time. Since the minimum laser pulse separation is limited, this limits the maximum flow velocity for which the technique can be applied. In practice, for traditional interlaced or full-frame transfer type CCD cameras, frame-straddling can only be used for velocities below a few milli-meters per second.

However, modern CCD camera technology has allowed cameras to be optimized for PIV work. TSI's range of "PIVCAM" CCD cameras uses progressive-scan, interline transfer technology to reduce the "read-out" time between successive frames down into the micro-second range. With these cameras each pixel is in effect mapped onto a memory element, so that the information from all pixels can be read-out simultaneously, and therefore very quickly. With these cameras it is possible to employ "frame-straddling" for laser pulse separations down to only a few micro-seconds. This means that frame-straddling followed by cross-correlation processing can now be used for almost all applications, even when the flow velocity is several hundreds of meters per second.

TSI frame-straddling PIV cameras have another advantage too. This camera allows "asynchronous double-exposure mode," meaning that the frame straddling sequence can be triggered externally. This allows PIV data capture to be synchronized with the experiment and is therefore particularly useful in rotating, periodic or transient flows.

The use of frame-straddling, particularly if using short frame-straddle times, requires very precise synchronization and control of the PIV lasers, CCD camera, framegrabber and perhaps the experiment. With any TSI PIV system, this control is provided by the LaserPulse Synchronizer.

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