Laser Velocimetry

Several modern velocimeter techniques utilize lasers to make rapid measurement of fluid velocities at well-defined "point" locations in a fluid flow. In this section we outline the principles behind two of these instruments, namely the laser doppler velocimeter (LDV) and the laser two-focus velocimeter (L2F).

The principle behind the LDV is depicted schematically in Figure 1. Light from a laser enters a beam splitter following which the two beams are focussed at the location in the flow where a measurement of the velocity is desired. The intersection angle is small so that the interference pattern produced in the focal region (usually of the order of $500\mu m$ long and $50\mu m$ wide) consists of a standing wave pattern with peaks and troughs running in a direction between those of the two beams as shown by the red lines in Figure 1. Then a small particle in the flow that proceeds through this focal region will scatter light at a frequency,

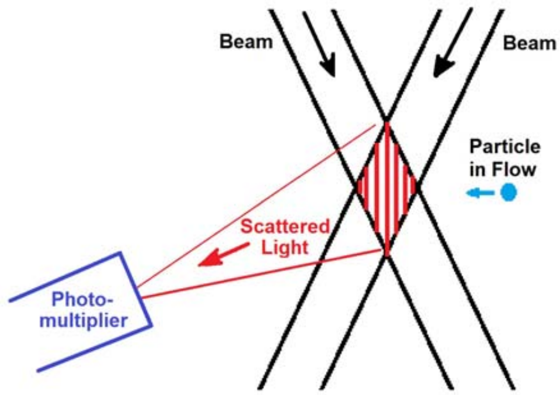

Figure 1: Laser Doppler Velocimeter.

f, that is given by $f = \lambda/U$ where U is the particle velocity (and therefore the fluid velocity) and λ is the wavelength of the interference pattern (which is a function of the beam intersection angle and the wavelength of the light). Then a photomultiplier focussed on the same focal region will detect a pulse like that shown in idealized form in Figure 2 and a signal analyzer processing the output of the photomultiplier can yield the frequency, f, from a whole series of particles producing the scattered light. This will then yield the average particle (and fluid) velocity over a chosen window of time. The technique requires very small,

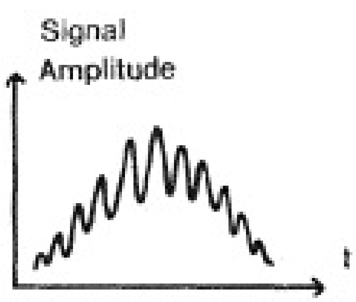

Figure 2: Typical scattered light pulse from a Laser Doppler Velocimeter.

microsized particles that will follow the fluid and travel at the same velocity. Consequently it requires interference pattern wavelengths that are comparable with these small particle sizes. It also requires a sufficient particle content in the fluid to supply a reasonable signal to the photomultiplier. In air this usually requires adding small particles to the flow; in contrast normal tap water usually contains sufficient particle content.

The second, commonly utilized instrument is known as the laser two-focus velocimeter or L2F. The

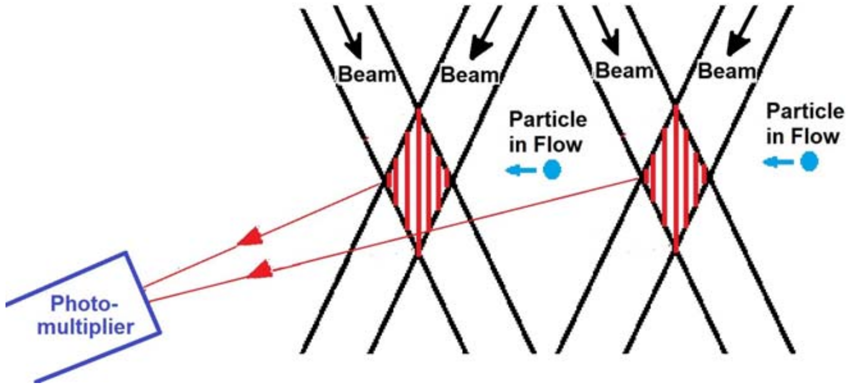

Figure 3: Laser Two-focus Velocimeter.

technique behind this instrument is depicted in Figure 3. Two laser beams are focussed at locations a short distance apart. The light from a particle passing through the first focal volume and then the second focal volume is collected either (1) by a single photomultiplier focussed in the same region or (2) by two photomultipliers, one focussed on each of the two laser focal volumes. The scattered light signal(s) collected by the photomultiplier(s) are then processed to find the embedded delay time produced as the particle (or particles) pass from one laser focal volume to the other. In the case of a single photomultiplier arrangement the lone signal is auto-correlated to obtain that delay time. In the case of two photomultipliers the two signals are cross-correlated to find that delay time. We note that auto-correlation and cross-correlation are signal processing techniques that are commonly used in a wide variety of the instrumentation described in these pages. The details of these techniques are described separately in section (Kcb) along with simple demonstrations.