LASER DOPPLER VELOCIMETRY

When 2 coherent, collimated laser beams intersect, they form a fringe pattern. This process can be illustrated by 2 "beams" of parallel lines that intersect, as shown in Fig 1. At the point where the beams intersect, the wavefronts interact with each other constructively or destructively and form a pattern of horizontal lines that were not present until the beams intersected. This is called the fringe pattern.

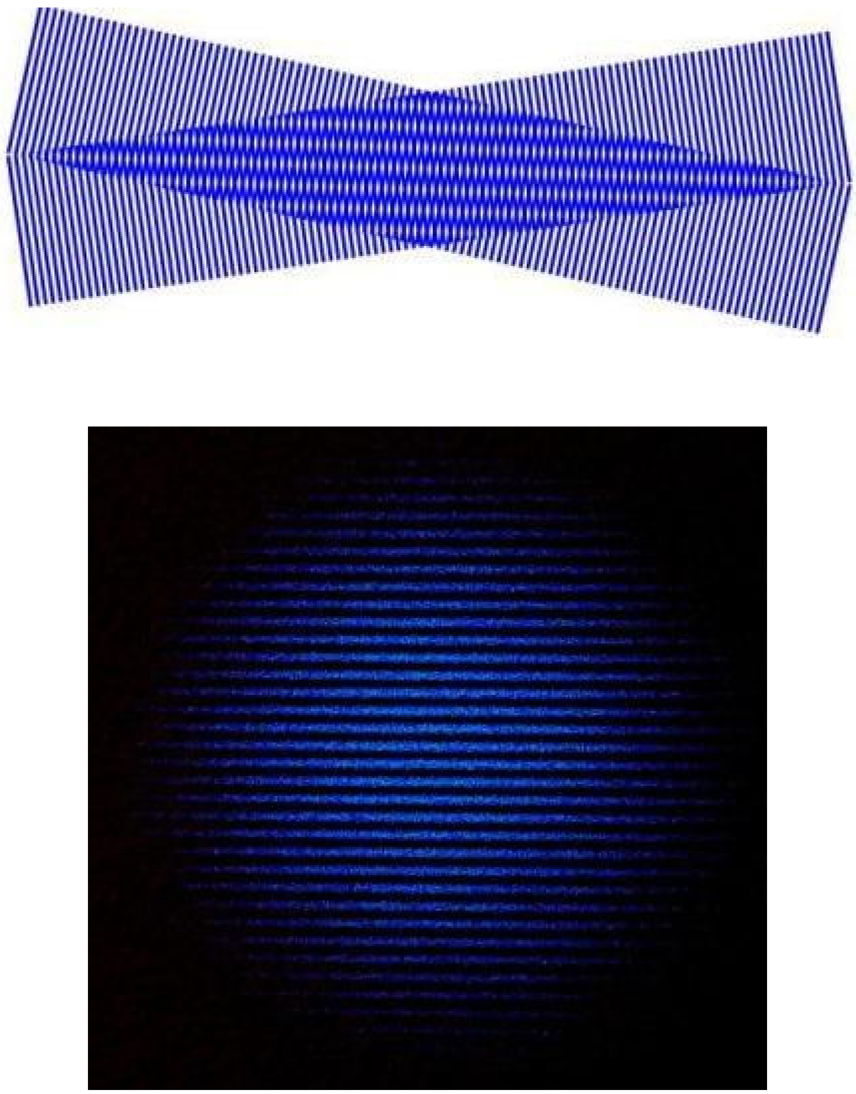

Fig 1: Fringe pattern when two collimated laser beams intersect [1]

Figure 1 shows the top view (top) and the cross sectional view (bottom) of the fringe pattern. Imagine that a particle in the air or water passes through this fringe pattern from top to bottom. As it travels, it alternately reflects the light (as it passes through a fringe), and does not reflect light (as it passes *between* fringes). A signal detector that is focused on the beam crossing can pick up these minute flashes of light and determine their frequency. Once the frequency of these flashes of light is known, it is multiplied by the distance between the fringes to get the velocity.

(Velocity = Distance/Time = Distance*Frequency)

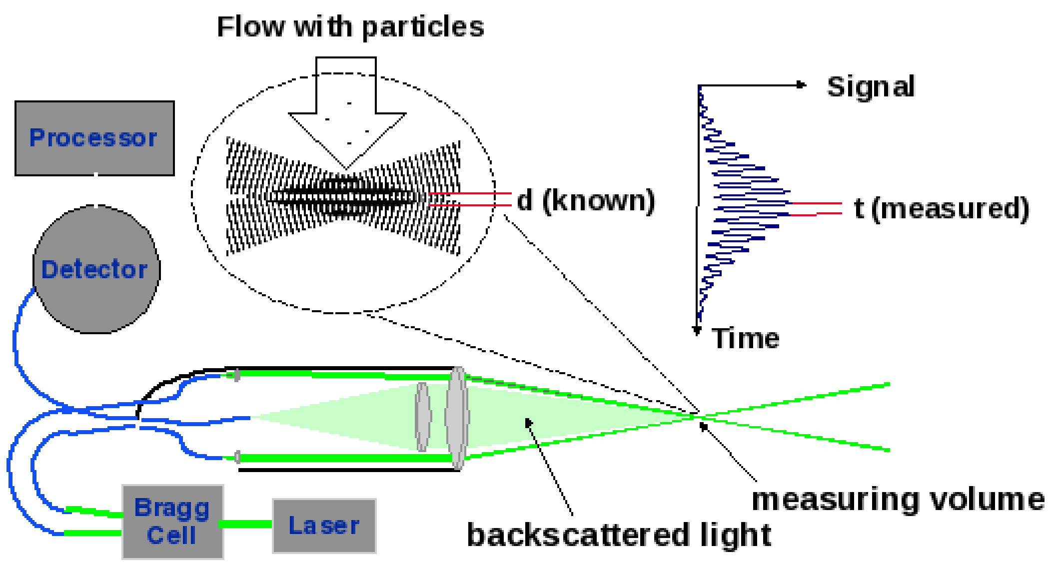

Fig 2: Schematic of an LDV system [2]

An LDV (Laser Doppler Velocimetry) system consists of the following components: a laser, a beam separating device, a transceiver (which emits the laser beams and also collects the reflected signals), a photomultiplier unit to convert the optical signal to an electrical signal, a signal processor, and software to analyze the results.

LDV can also be expanded to measure the velocity in 3 dimensions. In this case, there will be 6 laser beams all crossing at a common point (2 beams for each component). The procured system is a FSA 3500 (TSI Inc., USA) based three-component Laser Doppler Velocimetry (3D LDV) system, using one co-axial 5 beam Transceiver probe with 2D traverse.

The 3D LDV system consists of:

1. Fiberlight™ FBL-3 wavelength separation module with Bragg cell frequency shifting capabilities and six fiberoptic couplers
2. TR360 Fiberoptic transmitter cum receiver (transceiver) probe with 61mm clear aperture, 1.8 mm beam diameter, 261 mm focal length lens, for channels 1, 2 and 3 velocities.
3. PDM1000-5 multicolor signal receiving module with interference filters, photomultiplier tubes,

pedestal amplitude (intensity) measurement electronics, high pass filters for pedestal removal, and calibration diode.

4. FSA3500-3 three-channel digital burst correlator for velocity measurements, 100MHz maximum Doppler frequency, 400 MHz maximum sampling rate, IEEE 1394 (FireWire) interface, and FlowSizer software package.
5. T2DE two-axis, computer-controller traverse with 600 mm of travel on each axis, includes remoter controller, software interface, all necessary mounting hardware for rails and probes.
6. Rail and rotating stage for the transceiver fiber probes.
7. 4W continuous COHERENT® INNOVA 90 Argon Ion Laser.
8. COHERENT® LaserPure 20 Heat Exchanger.

LASER: The Laser being used for the experimental setup is COHERENT® INNOVA 90, 4W continuous wave Argon Ion Laser (Fig 3). If an electron at certain energy level is hit by a photon with a corresponding energy content this will stimulate the electron to emit another photon. The second, emitted photon will have the same energy and direction as the original photon. This is known as stimulated emission, the principle behind the laser.

Fig 3: Argon Ion Laser

The laser purchased needs three phase electric supply with 210 +/-10 V phase to phase voltage and 45 Amp current. A custom made step down servo transformer (fig 4) is used. The maximum heat load for the laser is 20 KW. The wavelengths available are 488, 496, 501.7 and 514.5 nm.

Figure 4: The 3 phase transformer

Utility Requirements

Input Power 3-phase with ground

Voltage	208 VAC ±10%, 50 or 60 Hz
Current	50 amps/phase @ 208 VAC

Cooling Water

Flow Rate/Minute	8.5 liters (2.2 U.S. gallons)
Pressure	1.80 - 4.23 kg/cm^2 (25 - 60 psi)
Inlet Temp	10 - 35°C (50 - 95°F)

The heat is removed from the laser tube and power supply unit using a heat exchanger LaserPure 20 (fig 5). The Coherent LaserPure is a family of closed cycle water-to-water or water-to-air heat exchanger systems designed especially for the cooling requirements of ion lasers. The LaserPure affords optimum laser performance by controlling the flow rate, pressure, and temperature of the cooling water. By also controlling the resistivity of the cooling water, LaserPure eliminates any concerns with water quality. Among the standard features of LaserPure are audible and visible indicators for the water reservoir level, temperature, and filter change. The LaserPure comes with a deionizing/de-oxygenating filter, an in-line water strainer, and two 3.7 m hoses. A single-phase AC (220VAC,50/60Hz) is required for this exchanger and it possesses a maximum operating load of 7.8A@50Hz or 7.1A@60Hz and has an interlock contact rating of 5A@28VAC.

Fig 5: LaserPure20 Heat Exchanger

The Multicolor Beam Generator generates the beam required for 3 dimensional flow measurements. The Photo-detector Module (PDM) converts optical signals to electronic signals and conditions them for the FSA, which conditions the signal further and gives high Doppler frequency limit. FLOWSIZER™ is a simple most complete, easy-to-use, software package for LDV and PDPA systems. It includes the entire software package, including graphics, particle sizing, traverse control, power spectrum, and data export.

Fig 6: The PDM and FSA unit

References:

[1] LDV Principle, Troolin D., University of Minnesota

[2] Laser Doppler Velocimetry, Fontaine A., Penn State University