Laser Doppler Velocimetry

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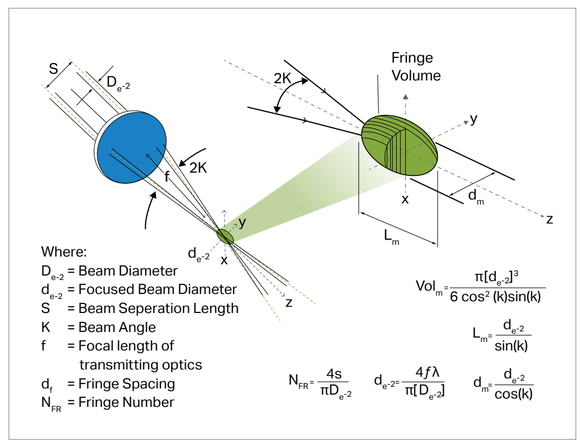
Laser Doppler Velocimetry (LDV) – A non-invasive technique for measuring velocity at a point in the flow with very high temporal resolution and high sampling rate.

Principle

To measure one component of velocity, a single laser beam is split into two parallel beams which are focused to cross at the focal point of the transmitting lens. Particles in the flow that pass through the intersection, or measuring volume, scatter light in all directions and are the signal source for velocity information. Scattered light collected by the receiving lens is focused onto the photodetector system, the output of which is sent to the signal processor. The result is velocity measurements displayed by the software.

Definition of Parameters in the Measurement Region at Beam Crossing

For Gaussian beams, the e^{-2} intensity points are used to define the beam diameter and the beam crossing region (measuring volume). The size of the measuring volume is critical to achieving an accurate velocity measurement. The measuring volume has an ellipsoidal shape with dimensions defined by the following equations.

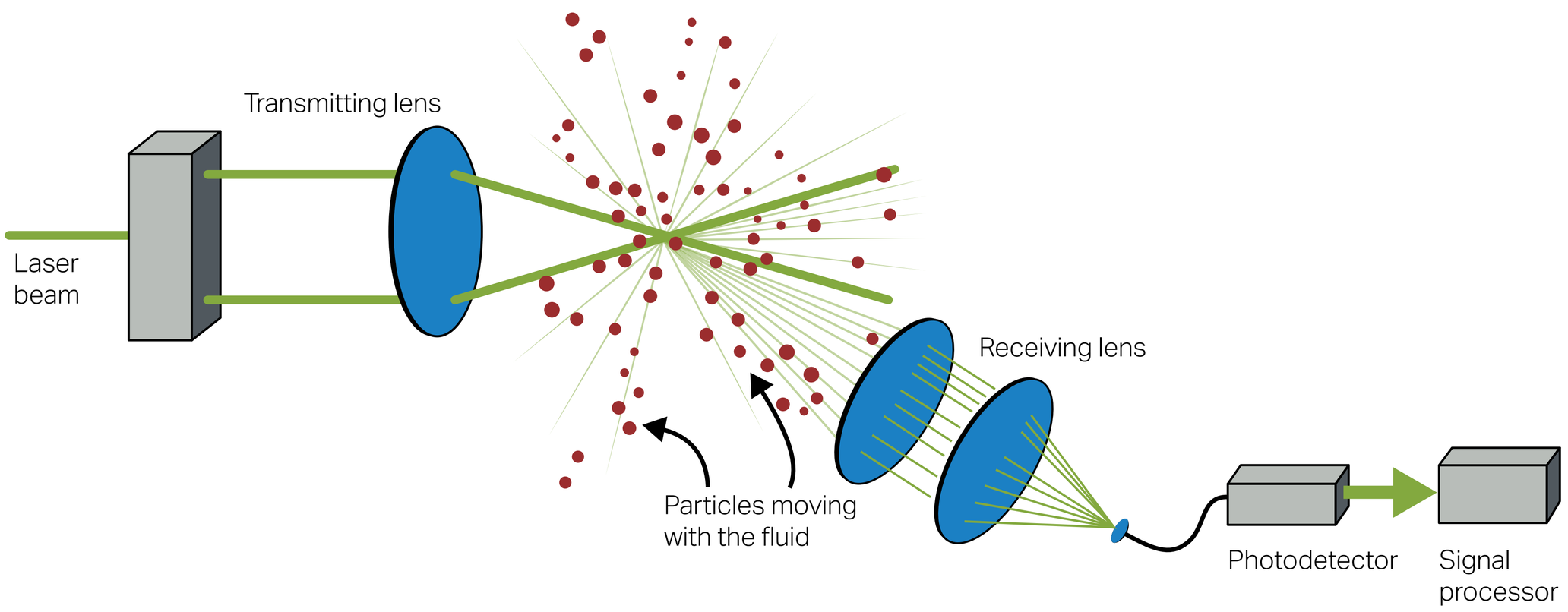


Where:
$D_{e^{-2}}$ = Beam Diameter
$d_{e^{-2}}$ = Focused Beam Diameter
S = Beam Seperation Length
K = Beam Angle
f = Focal length of transmitting optics
d_f = Fringe Spacing
N_{FR} = Fringe Number

$$Vol_m = \frac{\pi[d_{e^{-2}}]^3}{6\cos^2(k)\sin(k)}$$

$$L_m = \frac{d_{e^{-2}}}{\sin(k)}$$

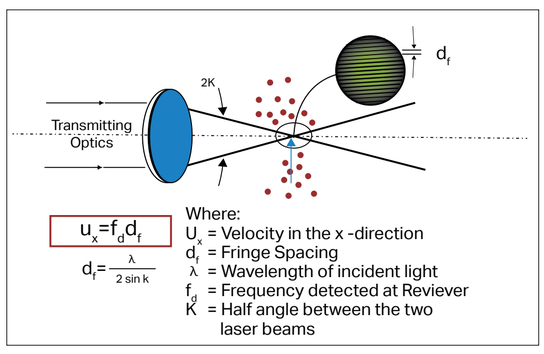
$$N_{FR} = \frac{4s}{\pi D_{e^{-2}}} \qquad d_{e^{-2}} = \frac{4f\lambda}{\pi[D_{e^{-2}}]} \qquad d_m = \frac{d_{e^{-2}}}{\cos(k)}$$



Velocity from Fringe Spacing and Doppler Frequency

The measuring volume formed at the intersection of the two laser beams has a fringe pattern with definite spacing between the fringes (d_f) which is determined by the angle and the focal distance of the two beams.

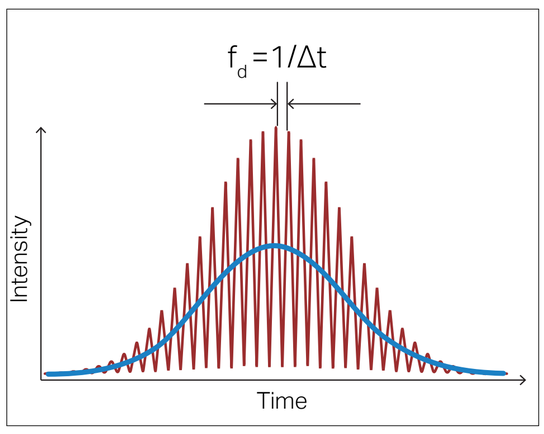
When a particle passes through the fringe pattern in the measuring volume, it creates a scattered light signal (burst) with sinusoidal varying intensity. The signal's burst envelope is caused by the Gaussian beam intensity distribution. The sinusoidal varying signal has a frequency called Doppler frequency (f_d). The signal is processed to find the period (Δt) with high accuracy. The Doppler frequency is then computed to be $1/\Delta t$. Velocity (U_x) is calculated as a function of the Doppler frequency (f_d) and the fringe spacing (d_f).



$$u_x = f_d d_f$$

$$d_f = \frac{\lambda}{2\sin k}$$

Where:
U_x = Velocity in the x -direction
d_f = Fringe Spacing
λ = Wavelength of incident light
f_d = Frequency detected at Reviever
K = Half angle between the two laser beams



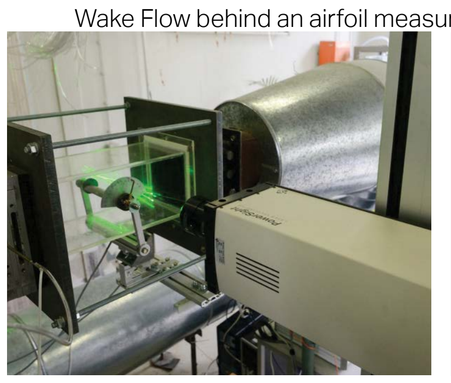
$$u_x = f_d d_f$$

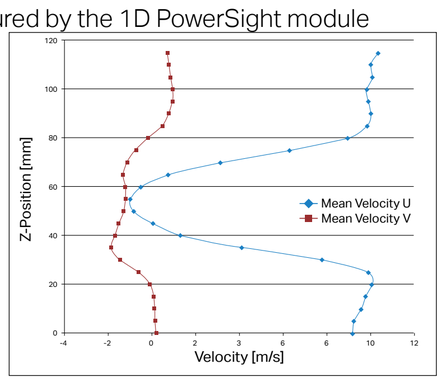
LDV System Configuration with Itasca or PowerSight Laser Module

Itasca-Based LDV System

The LDV system can be made up from either the Itasca or the PowerSight laser module. Either module can be upgraded from 1D to 2D or 3D arrangement for the measurement of u, v and w velocity components. A fiber optic transceiver probe is required to be used with the Itasca solid-state laser module while the PowerSight is a standalone transciever to measure the velocity component(s) directly.

Wake Flow behind an airfoil measured by the 1D PowerSight module





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