APPLICATION NOTE
Laser Doppler Anemometry

Challenge

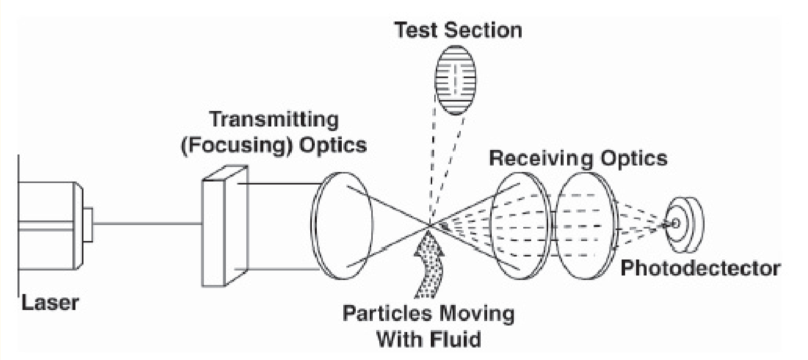
Laser Doppler Anemometry, or LDA, is a technique for measuring the flow velocity of fluids or gases. This technique offers many advantages over traditional flow measurement techniques. LDA produces a very precise velocity measurement of many different particles with no need for instrument calibration. It is a non-intrusive technique with a high frequency response and large dynamic range capabilities.

Some popular applications of LDA include steam flow measurements, turbulence flow measurements conducted in wind tunnels, and fuel flow measurements in the design of internal combustion engines. The CompuScope 82G Data Acquisition Card has proven to be the ideal interface to capture, store, and transfer the signals generated by the LDA system.

This application note is adapted with permission from the original paper written by Mike Morton.

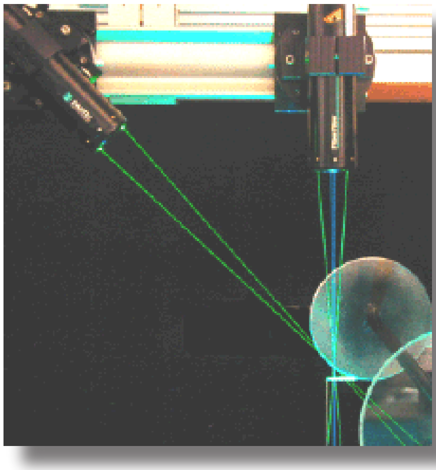
LDA theory of operation

The system uses a laser beam to emit coherent light (i.e. a beam of light comprised of many amplitude-modulated light source waves, all having the same frequency and in phase with each other). The laser beam is split in two; and these subsequent beams are focused through the transmitting optics and crossed perpendicular to the particle stream. At the point where the beams cross, an interference pattern is generated. The flow particles pass through the test section and scatter the light beams of the interference pattern. The beam scattering is then collected by the receiving optics and focused on the photodetector, where the light is converted to electrical energy.



Laser Doppler Anemometry, or LDA, is a technique for measuring the flow velocity of fluids or gases. LDA has been used traditionally without other flow measuring techniques that provide accurate measurement and therefore, the start up cost for installing LDA has been very high.

The combination of the LDA with a high-speed digitizer such as Gage's CompuScope 82G, which is an 8 bit digitizer with up to 2 GS/s sampling rate, is a versatile, accurate and reliable solution for flow measurement. Furthermore, the start up costs associated with the installation of LDA is greatly reduced.



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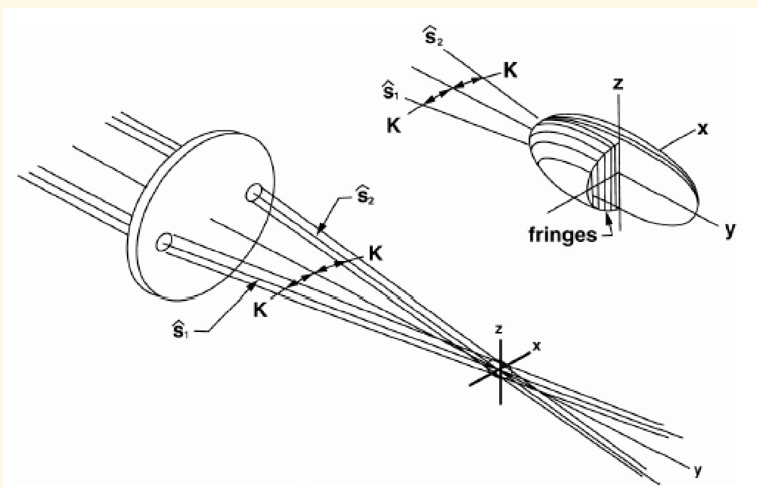
The interference pattern

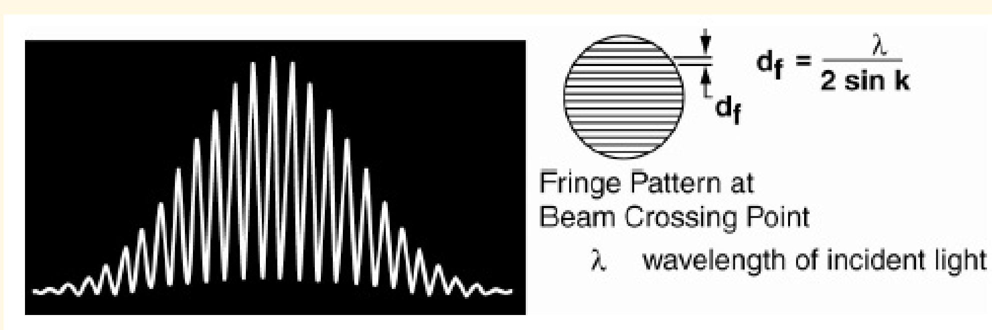
In order to interpret the data collected by the photodetector, one must first understand what pattern the dual beams produce at their crossing point. The focusing optics cause the coherent light to cross, which creates a fringe pattern. A measuring volume is defined by the light intensity distribution of the fringe pattern (i.e. the Doppler components). The measuring volume is the ellipsoidal surface shown below, that corresponds to the surface on which the amplitude of the fringes is 1/e2 of the maximum amplitude, which occurs at the center of the fringe pattern.



It should also be noted that by decreasing the beam angle (K) with respect to the Normal (y); the measuring volume is displaced further from the focusing beam, its length is increased, and its width is decreased.

The signal

The leftmost oscilloscope trace shown below is a sample of the beam collected by the photodetector.



As mentioned earlier, the signal (or Doppler Burst as it is commonly known) is made up of the scattered light reflected by a particle passing through the interference pattern. The varying amplitudes represent the light intensity associated with each fringe. Note that the peaks appear to rise and fall in an exponential pattern which is consistent with the measuring volume's ellipsoidal shape.

The frequency of oscillations of the Doppler Burst is called the Doppler frequency. This value is multiplied by the fringe spacing constant (df) to produce the velocity measurement.

As illustrated in the right hand side of Figure 3, the fringe spacing constant (df) is determined by dividing the wavelength of the laser light by twice the sine function of the angle of beam deflection (K). The wavelength of the laser light can be measured precisely (accurate to 0.01%) to produce the very accurate flow of velocity measurements associated with LDA.

Another advantage of LDA flow velocity measurements, mentioned in the introduction, was the fact that virtually any particle stream of any chemical composition can be measured with no instrument calibration. This is obvious because regardless of particle size, shape, conductivity, or chemical composition, the particles will still scatter light to form the same pattern as they move through the measuring volume.

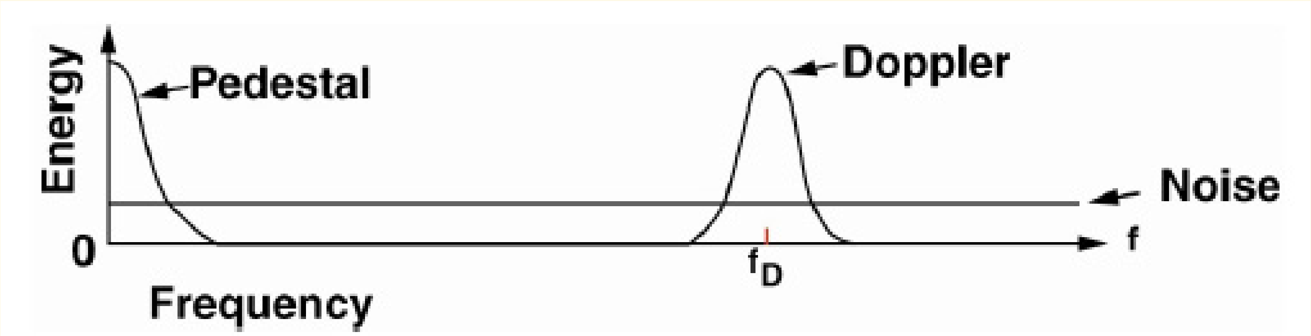
Solution

Signal capture and data processing

The Doppler Bursts were captured using the CompuScope 82G Data Acquisition Card. Because the Bursts are not periodic; the CompuScope is set to trigger, above the noise threshold, at the amplitude of the starting point of the measuring volume. The AutoSave Mode can also be used to supply the user with the time and date that the event occurred.

Typical signal frequencies are in the order of Megahertz, so the CompuScope 82G Card, with a sampling frequency of 1 GS/s in dual channel mode, is more than adequate for accurate and reliable signal reconstruction.

The Fast Fourier Transform (FFT) available with the CompuScope software is the ideal tool to change the acquired signal from the time domain to frequency domain. To correctly interpret the transformed signal one must be aware that it may contain at least three separate components.



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These components can be described as follows:

1) Low frequency “pedestals” caused by the particles passing through the focused beams

2) Doppler signals that are superimposed on the pedestals and oscillate at the fringe crossing frequency, fD

3) Wide bandwidth noise generated in the photodetector and in subsequent electronics.

CompuScope 82G

CompuScope 82G is a single slot, PCI bus card capable of performing 8-bit A/D conversion at sampling rates up to 2 GS/s in one-channel mode and 1 S/s in dual channel simultaneous mode.

The CS82G uses two monolithic A/D converters each running at 1 GS/s.

In single-channel mode the two ADCs are clocked in a “ping-pong” mode to achieve up to 2 GS/s sampling.

In dual channel mode, the two ADCs are clocked absolutely simultaneously to provide coherent sampling.

Features

- 2 Billion Samples Per Second Digitization on one channel
- Simultaneous 1 GS/s Sampling on 2 channels
- Features Bus Mastering
- Features Multiple Record
- Including capture of Pre-trigger data
- 1.2 GHz Bandwidth
- Up to 16 Meg On-Board Acquisition Memory
- 45 dB Signal to Noise Ratio
- Variable Gain Input Amplifier
- Internal or External Clock & Trigger
- Supports PCI Bus Transfers
- Up to 8 Cards in a Master/Slave System for up to 8 Simultaneous channels at 2 GS/s and 16 channels at 1 GS/s
- Software Development Kits for C/C#, MATLAB, and LabVIEW under Windows

Results

The Laser Doppler Anemometry system used in conjunction with the CompuScope 82G Data Acquisition Card offers a versatile, accurate, and reliable combination for flow measurement. Traditionally, LDA has been used for applications where no other flow measuring techniques could provide accurate measurements. Industry has been wary of installing LDA systems because of the high startup costs. However, with the advanced technology of fast data acquisition cards, high reliability of LDA, and virtually no maintenance costs associated with this combination; we may, in the future, see this system become the method of choice for all flow measurements.