POWERSIGHT MEASUREMENTS OF HIGH-SPEED FLOWS

APPLICATION NOTE FLOWSIZER-001 (A4)

High Speed Velocity Measurements

Laser Doppler Velocimetry (LDV) has several advantages when it comes to measuring high speed flows. The first is that the measurement system is noninvasive in the sense that there is not a physical probe in the flow that could potentially alter the flow itself, or even be destroyed! There are several requirements; however, those are that the flow has seed particles for LDV to measure the speed of, and that there is optical access to the measurement region. Both of these considerations are very important when choosing the hardware setup, but will not be discussed in detail in this application note. Rather, this Application Note focuses on the specifics of setting up the hardware and software in order to achieve high quality measurements in high-speed flows.

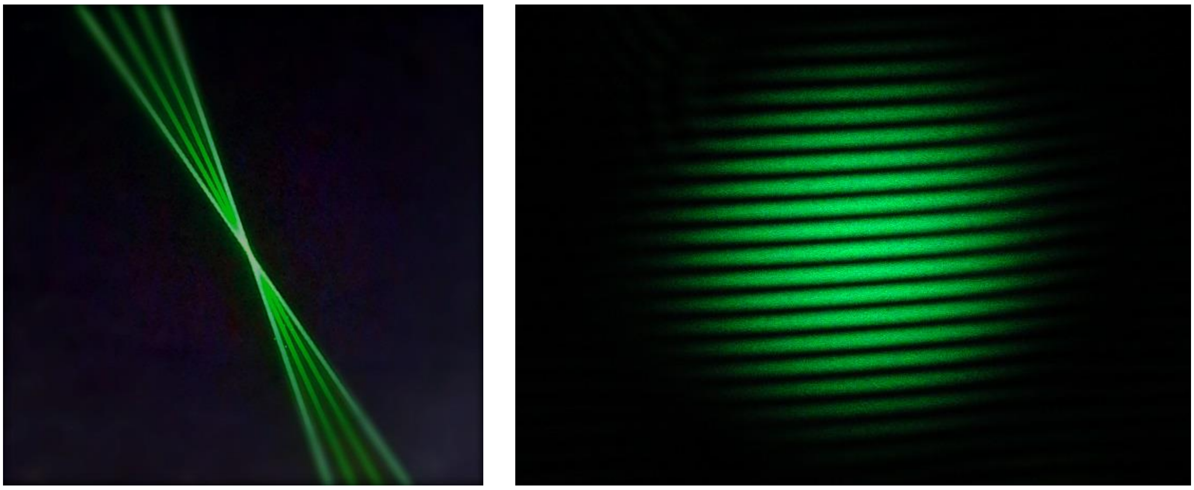

Fig. 1. Measurement region of a 2-component LDV system (*left*), and the interference fringe pattern created by crossing laser beams (*right*).

Hardware

The primary considerations when selecting LDV hardware for high speed flows are the generated fringe spacing and the maximum frequency of the signal processor. LDV measures flow velocity by determining the speed at which flow tracers scatter light as they pass through the interference fringe pattern generated by two crossing laser beams. The velocity is related to the frequency of the scattered fringe pattern and the fringe spacing, as is seen in the following relationship.

$$v = fd$$

Where the velocity (v) is directly proportional to the measured frequency (f) and the fringe spacing (d). The higher the maximum measurable frequency of the signal processor, the higher the measurable velocity, and the wider the fringe spacing, also the measurable velocity increases.

The TSI FSA4000 signal processor is an excellent choice for measuring high velocities with its maximum measurable frequency of 175 MHz. Depending on the fringe spacing, this corresponds to velocities well over 1000 m/s.

The fringe spacing (d_f) is also important in determining the maximum measurable velocity and depends on the laser wavelength (λ) and the half-angle between intersecting laser beams (κ), as shown in the following relationship.

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

Optics such as lenses with long focal lengths and beam contractors are useful tools in increasing the fringe spacing and allowing for larger velocities to be measured.

Once the hardware is configured, there are still options available to increase the measurable velocity range. A typical LDV system has a 40 MHz shift applied to one of the laser beams in order to give the fringes motion. This allows for stationary or reverse flows to be measured. Normally the fringe motion is opposite that of the dominant velocity direction. In the case of very high speed flows, the hardware can be arranged such that the fringes *move* ***with*** *the dominant flow direction*, rather than against it. This simple change effectively subtracts 40 MHz from the incoming frequency signal, allowing higher velocities to be reached. This method only works if there are not negative velocities that are also being measured, and the velocities fall within the new range of measurable frequencies.

Software

TSI's FlowSizer™ Data Acquisition and Analysis Software allows for the easy implementation and calculation of high speed velocities. In the case where the hardware is arranged such that the fringes are moving *with* the direction of motion, the change is very simple, with only one setting change in the software. This change is that the Bragg Cell Frequency in the **Run Setup >> Optics** page is set to -40 MHz (from the standard 40 MHz), since the optics have been reversed, so there is a sign change in the shift applied to the fringes.

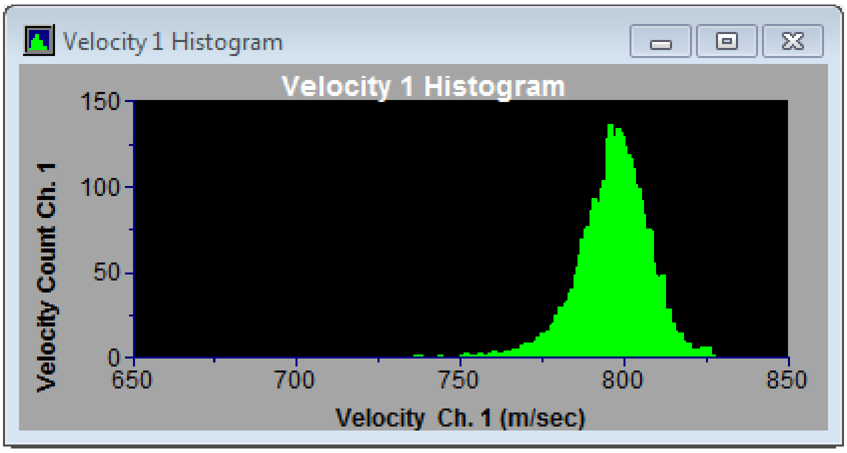

Fig. 2. Velocity Histogram with velocity mean near 800 m/s.

Conclusion

One of the advantages of Laser Doppler Velocimetry is its ability to measure very high speed flows non-intrusively. The TSI system provides hardware and software to allow for high velocity measurements.

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