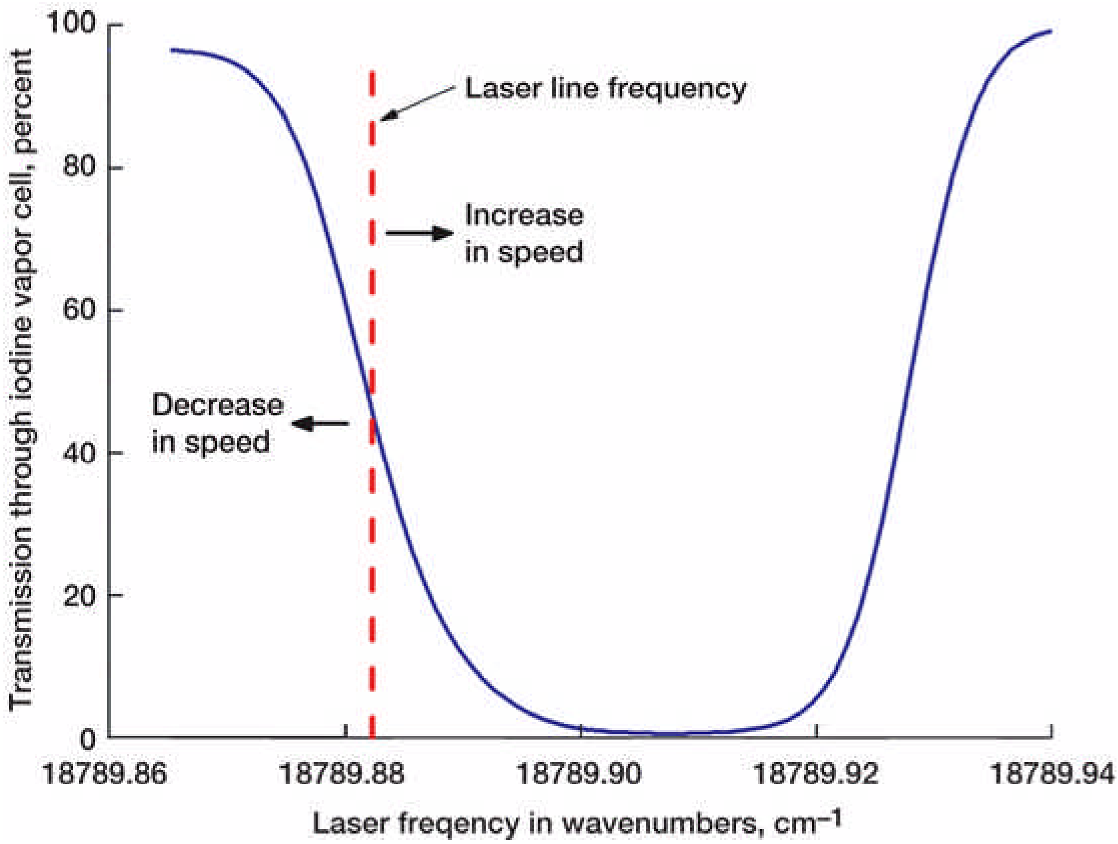
Planar Particle Imaging Doppler Velocimetry Developed

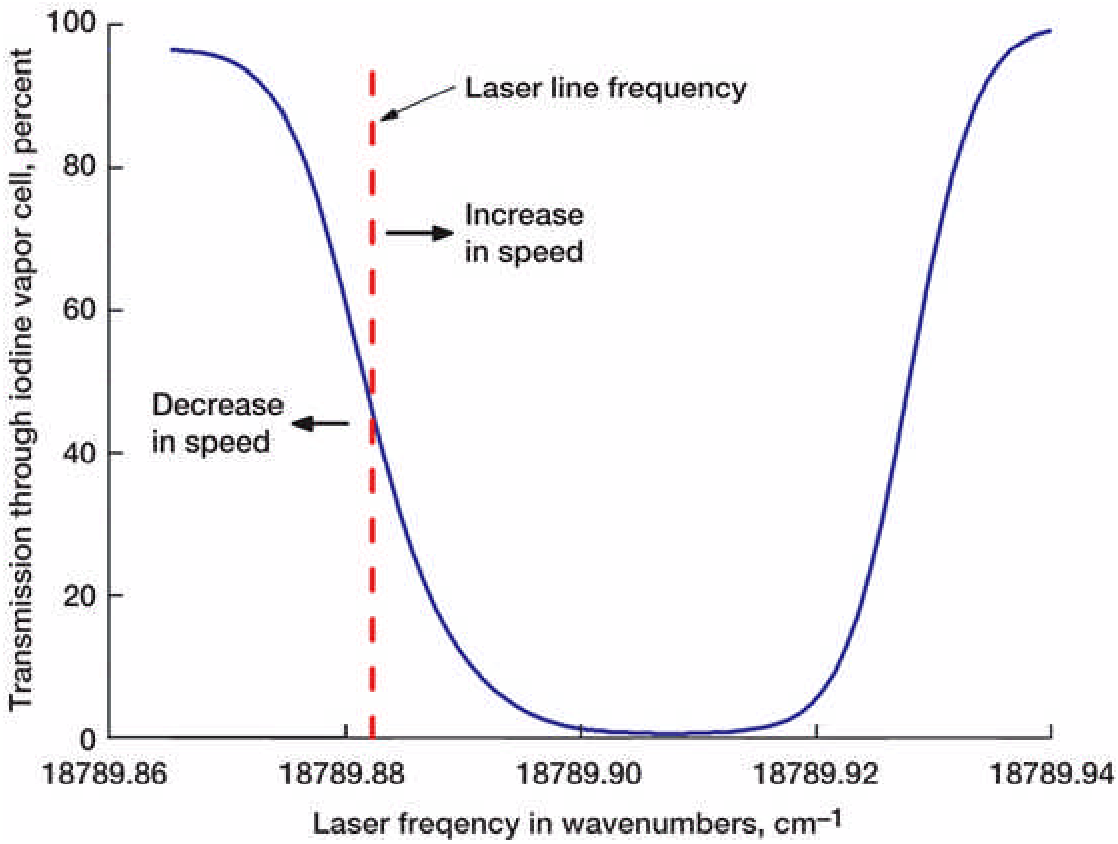
Two current techniques exist for the measurement of planar, three-component velocity fields. Both techniques require multiple views of the illumination plane in order to extract all three velocity components. Particle image velocimetry (PIV) is a high-resolution, high-accuracy, planar velocimetry technique that provides valuable instantaneous velocity information in aeropropulsion test facilities. PIV can provide three-component flow-field measurements using a two-camera, stereo viewing configuration. Doppler global velocimetry (DGV) is another planar velocimetry technique that can provide three-component flow-field measurements; however, it requires three detector systems that must be located at oblique angles from the measurement plane. The three-dimensional configurations of either technique require multiple (DGV) or at least large (stereo PIV) optical access ports in the facility in which the measurements are being conducted. Optical access is extremely limited in aeropropulsion test facilities. In many cases, only one optical access port is available. A hybrid measurement technique has been developed at the NASA Glenn Research Center, planar particle image and Doppler velocimetry (PPIDV), which combines elements from both the PIV and DGV techniques into a single detection system that can measure all three components of velocity across a planar region of a flow field through a single optical access port.

In the standard PIV technique, a pulsed laser is used to illuminate the flow field at two closely spaced instances in time, which are recorded on a "frame-straddling" camera, yielding a pair of single-exposure image frames. The PIV camera is oriented perpendicular to the light sheet, and the processed PIV data yield the two-component velocity field in the plane of the light sheet. In the standard DGV technique, an injection-seeded Nd:YAG pulsed laser light sheet illuminates the seeded flow field, and three receiver systems are used to measure three components of velocity. The receiver systems are oriented at oblique angles to the light sheet in order to accurately resolve the three-component velocity. Each DGV receiver system contains two cameras, which share a common view of the illuminated flow through a beam-splitting cube. One camera views the illuminated flow directly (reference camera) and the second camera images the illuminated flow through an iodine vapor cell (signal camera). The laser frequency (wavelength) is adjusted so that the Doppler-shifted light from particles in the flow falls on an iodine absorption feature, see the following graph. The iodine vapor cell acts as a frequency-to-velocity filter by modulating the intensity of the transmitted light as a function of the flow velocity (Doppler shift). The ratio of the signal and reference images yields the component of the flow velocity along the bisector of the laser sheet propagation direction and the receiver system observation direction.



Iodine vapor cell absorption feature showing percent transmission through the cell versus frequency. Also shown is the illumination laser line position relative to the iodine absorption profile. Any increase in velocity will result in an upshift in frequency and a decrease in the amount of transmitted light. A decrease in velocity will cause a downshift in frequency and a resultant increase in the amount of transmitted light.

The hybrid system employs a single-component DGV receiver system configured to simultaneously acquire PIV image data, as shown in the following diagram. The cameras used in the DGV receiver are replaced with PIV frame-straddling cameras, and the receiver system views the illuminated light sheet plane at 90° (as in the standard PIV configuration).



Layout of the planar particle imagery and Doppler velocimetry receiver head. The collected light passes through a beam-splitting cube. Half of the light goes to a reference camera, while the other half goes through the iodine vapor cell before reaching the signal camera. Taking the ratio of the intensity-modulated signal image to the reference image yields an intensity map that is proportional to the gas velocity in the plane of the light sheet. The component of the velocity measured via the Doppler shift (DGV) is depicted by the arrow that lies 45° out of the plane of the light sheet. The Doppler-shifted out-of-plane measurement is combined with the in-plane two-dimensional PIV measurements to compute the full three-component velocity field across the illuminated plane of the flow.

Find out more about this research: http://www.grc.nasa.gov/WWW/OptInstr/piv/

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