

## Instantaneous two-frequency planar Doppler velocimetry using pulsed Nd:YAG lasers

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### 1. Introduction

Planar Doppler Velocimetry (PDV) also known as Doppler Global Velocimetry (DGV) is a flow measurement technique that allows the measurement of velocity information over a plane defined by a laser light sheet. In PDV the velocity is determined by measuring the Doppler shift of light scattered from particles that have been seeded into the flow. A region of the illuminated flow is imaged, through a glass cell usually containing iodine vapour, onto the active area of a CCD camera. Iodine has numerous narrow absorption lines over a large part of the visible spectrum. The laser frequency is chosen to coincide with one such line and hence the optical intensity at any position in the camera image is a function of the Doppler shift experienced at the corresponding position in the flow, via the frequency-dependent iodine absorption.

However the intensity over a PDV image is affected by other factors such as the intensity profile of the illuminating laser sheet and spatial variations in the seeding density. To prevent these variations obscuring the velocity information it is usual to amplitude-divide the image beam onto two cameras. In one imaging path the iodine cell is omitted and this image can be used as a reference to normalise the signal image.

### 2. Two-frequency Planar Doppler Velocimetry (2v-PDV)

In two-frequency Planar Doppler Velocimetry (2v-PDV) the signal and reference images are acquired sequentially on a single CCD camera, figure 2, by using two illumination frequencies, separated by ~1GHz and positioned at different positions on the iodine absorption line.

This overcomes several problems identified with conventional PDV. In conventional PDV superposition of the two images to sub-pixel accuracy is essential if errors in the calculated velocities are to be minimized. In 2v-PDV alignment of the reference and signal images on the active area of the camera is no longer an issue and the signal/reference image misalignment problem found in conventional PDV is avoided. The 2v-PDV method also eliminates the polarization sensitivity of the split ratio of the beam splitter used in two-camera systems. Ideally the beam splitter used in a conventional PDV imaging head would

split the incoming light 50:50 between the signal and reference cameras with no variation for different polarizations of light. However even the 'non-polarizing' beam splitters typically used retain a slight sensitivity to polarization, typically quoted as  $\pm 3\%$  variation in the split ratio for S and P polarized light, leading to typical velocity errors of  $\pm 7\text{ms}^{-1}$ .

A method of increasing the sensitivity of the measurements is also possible by tuning both illumination frequencies to coincide with an absorption line. One on the falling slope and the other on the rising slope of an absorption line, any Doppler shift will cause an increase in the signal level for one illumination and a decrease for the other. The image can then be normalised by dividing the difference of the images by the sum.

The 2v-PDV technique has been previously demonstrated - Charrett et al. (2004), Charrett and Tatam (2006) - making time-averaged velocity measurements using a CW argon ion laser, however the images were acquired with a separation of tens of seconds and assumes that the seeding is unchanged. This paper describes the extension of this work to allow instantaneous velocity measurements to be made using the 2v-PDV technique.

A pulsed 2v-PDV system is described which uses two independently seeded Nd:YAG lasers to illuminate the flow with the two frequencies of light required. A CCD camera capable of capture two closely spaced images (~300ns) is used to capture the signal and reference images sequentially. As the time separation between the images is small the motion of the seed particles in the flow is effectively frozen. Preliminary results on the velocity field of a rotating disc and a seeded air jet are presented.

### References

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