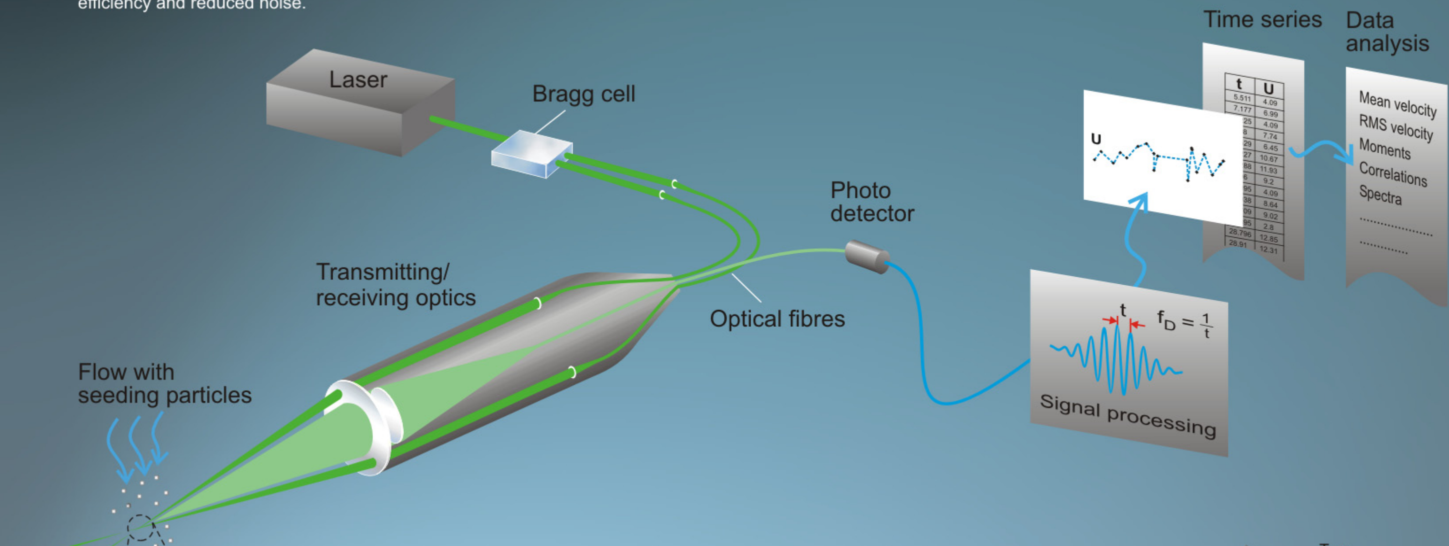
Laser Doppler Anemometry

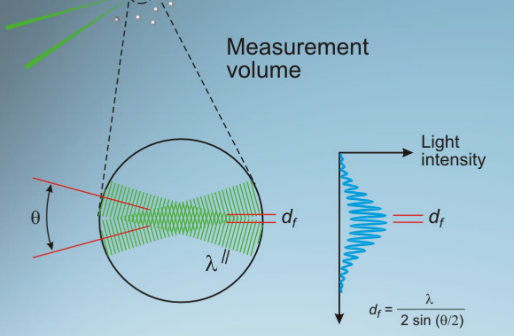
Introduction

Laser Doppler Anemometry (LDA) is a non-intrusive optical technique used to measure velocity and turbulence at specific points in gas or liquid flows. Applications include measurements of free flows around road vehicles, aircraft and ships, and internal flows in pumps, mixers, turbines and engines. Measurements improve knowledge about the flow and can lead to better efficiency and reduced noise.

Features

- Non-intrusive
- No calibration required
- Velocity range from zero to supersonic
- One, two or three velocity components simultaneously
- Measurement distance from centimetres to metres
- Flow reversals can be measured
- High spatial and temporal resolution
- Instantaneous and time-averaged information





Principles

The basic components are a laser, a beam splitter, transmitting/receiving optics, a photo detector, a signal processor and a data analysis system. A Bragg cell is often used as the beam splitter. It is a glass block with a vibrating piezo crystal attached. The vibration generates acoustical waves acting like an optical grid. The output of the Bragg cell is two beams of equal intensity with frequencies f_0 and f_{shift}. These are focused into optical fibres bringing them to a probe containing transmitting/receiving optics. In the probe, the parallel exit beams from the fibres are focused by a lens into the measurement volume where the beams intersect.

The measurement volume

The measurement volume is typically a few millimetres long. The light intensity is modulated due to interference between the laser beams. This produces parallel planes of high light intensity, known as "fringes". The fringe distance d_f is defined by the wavelength λ of the laser light and the angle between the beams θ.

Flow velocity

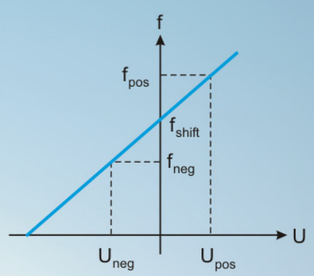
Flow velocity information comes from light scattered by tiny particles (seeding) carried in the fluid as they move through the measurement volume. It is collected by a receiving lens and focused on a photo detector, producing a signal at the Doppler frequency f_D. The velocity is calculated from the Doppler frequency and the fringe distance:

$$U = d_f \cdot f_D = \frac{\lambda}{2 \sin(\theta/2)} f_D$$

Signal processing

The Doppler bursts are filtered and amplified in the signal processor, which determines f_D for each particle by frequency analysis, using the robust Fast Fourier Transform algorithm.

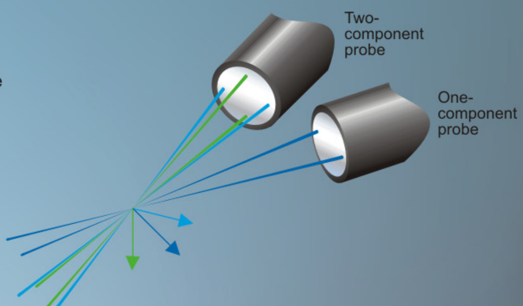
Frequency shift



The frequency shift produced by the Bragg cell makes the fringe pattern move at a constant velocity. Particles which are not moving will generate a signal of the shift frequency f_{shift}. The velocities U_{pos} and U_{neg} will generate signal frequencies f_{pos} and f_{neg}, respectively.

Two- and three-component measurements

To measure two velocity components, two extra beams can be added to the transmitting optics in a plane perpendicular to the first beams. All three velocity components can be measured by two separate probes measuring respectively two components and one component, with all the beams intersecting in a common measurement volume. Different wave lengths are used to separate the measured components.



Modern LDA systems employ probes connected by fibre-optical cables to a compact transmitter unit which splits the laser beam into colour and frequency-shifted and unshifted beams.

Seeding particles

Liquids often contain sufficient natural seeding, whereas gases in most cases must be seeded.
Ideally, the particles should be small enough to follow the flow, yet large enough to scatter sufficient light to obtain a good signal-to-noise ratio at the photo detector output. Typically the size range of particles is between 1 μm and 10 μm. The particle material can be solid (powder) or liquid (droplets).

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