

Non-contact boundary layer profiler using low-coherence self-referencing velocimetry

Andreas Kempe¹, Stefan Schlamp², Thomas Rösgen³

1: Institute of Fluid Dynamics, ETH Zurich, Switzerland, kempe@ifd.mavt.ethz.ch

2: Institute of Fluid Dynamics, ETH Zurich, Switzerland, schlamp@ifd.mavt.ethz.ch

3: Institute of Fluid Dynamics, ETH Zurich, Switzerland, roesgen@ifd.mavt.ethz.ch

Keywords: low-coherence, interferometry, self-referencing velocimetry, boundary layer profiler, high resolution

A spatially self-referencing velocimetry system based on low-coherence interferometry has been developed. The measurement technique is contactless, it relies on the interference between back-reflected light from an arbitrary reference surface and from particles in the flow. Due to the measurement principle, the absolute spatial accuracy and the spatial resolution only depend on the coherence length of the light source. Normally this is a superluminescent diode (SLD) with a coherence length of tens of microns. Thus the system's primary use might be seen in boundary layer measurements, i.e., taking an object surface as reference.

Two approaches with very similar experimental setups are demonstrated – one based on the Doppler effect, the other on time-of-flight measurements (discussed in the full paper). The measurement location is always given relative to an arbitrary reference surface. Scanning of the measurement location along the beam direction does not require mechanical movement of the sensor head. The first approach measures velocities relative to the reference surface, the second relative to the sensor head.

The presented prototype is an all-fiber assembly. Optical fibers of arbitrary lengths connect the self-contained optical and electronics setup to the sensor head. Proof-of-principle measurements for two generic flows (Poiseuille and Taylor-Couette flow) are reported in the full paper.

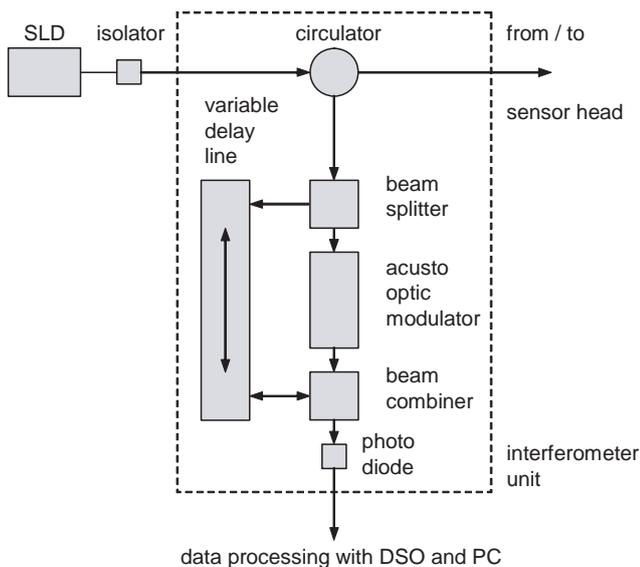


Fig. 1 Schematic setup of optical components in the interferometer unit, which also includes the light source.

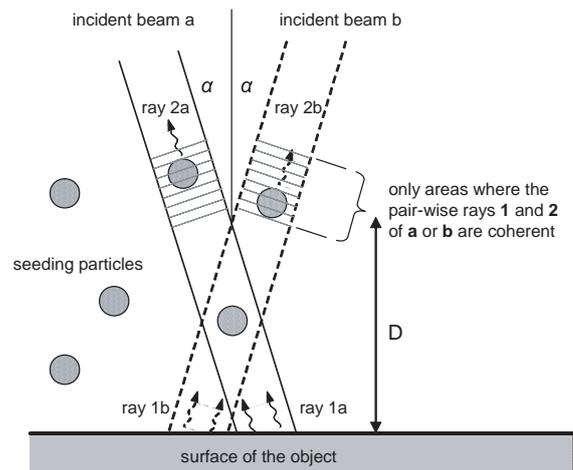


Fig. 2 Schematic of the interaction between laser and particles.

Fig.1 shows the schematic setup of the optical components in the interferometer unit of the system. A SLD emits low-coherence light into a single-mode fiber. A fiber-optical isolator protects the sensitive light source from back-reflections and guides the light to a polarization insensitive optical circulator. The circulator is used to transfer the light through a single-mode optical fiber to the sensor front end (SFE), where a lens couples the light out of the fiber and into the measurement volume.

A fraction of the incident light is reflected back from the surface of the test object onto the lens and back into the fiber towards the circulator, where it is deflected into the interferometer. A small fraction of the light is also reflected off the particles passing the laser beam (see Fig.2). All light back-reflected is fed into the two interferometer arms by a beam splitter. In the reference arm, an acousto-optical modulator shifts the frequency of the light. The delay arm contains a motorized variable delay line (VDL). The light from the two interferometer arms is recombined by another beam splitter/combiner and a broadband photo-receiver serves as detector.

The distance D between the measurement volume and the wall can be adjusted by adjusting the delay of the VDL (independent of the vertical position of the SFE). Irrespective of any movement of the surface, measurements are always performed at a set distance from the wall. The Doppler-shift in the beat signal is then proportional to the relative velocity between the particle and the surface along the propagation direction of the laser beam. Unlike in common LDV only a single beam is required to measure one velocity component. Incident beam b in Fig.2 represents a second independent measurement to determine the out-of-plane velocity, too.