

# DEVELOPMENT OF A TIME RESOLVED MICRO-PIV SYSTEM FOR FLOW VELOCITY MEASUREMENT

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## Introduction

We present a time-resolved micro-Particle Image Velocimetry ( $\mu$ -PIV) system capable of measuring transient, high-velocity flows [1]. The temporal resolution of the system is such that it can resolve the instantaneous flow field in micro-vessels that exhibit vasomotion (arterioles, venules, lymphangions, etc.).

## Methods

The  $\mu$ -PIV optics were configured to measure the flow field in the mid-plane of micro-vessels with moving walls. In the present setup, flow was seeded with neutrally buoyant mono-disperse polystyrene micro-particles (Polysciences Inc.) 1 to 3  $\mu\text{m}$  in diameter.

The flow field was illuminated by a bespoke, low-cost light source developed at Strathclyde, utilising a single, high-power LED (Luminus Devices) and driver that can supply a current of up to 36A at frequencies up to 3 kHz. The minimum light pulse duration is of the order of 2-5  $\mu\text{s}$ , making it ideal for capturing high velocity micro-flows. Light was guided with a fibre optic cable and was delivered either through the microscope optical path to image in bright-field or fluorescence modes, or from the side, to image scattered light from the particles.

Images were acquired with high-speed CMOS cameras (Photron SA3, MC-1). Synchronization of camera and light source was achieved with LabView software and a National Instruments Multifunction DAQ device (NI-6341).

The images were processed using a standard PIV cross-correlation algorithm available via the open-source Matlab toolbox PIVlab. Custom edge-detection algorithms were implemented to locate the vessel wall in experiments with micro-vessels.

## Results

Preliminary experiments in micro-channels were conducted to demonstrate proof of concept. The results confirm that the system is capable of measuring flows of up to 25mm/s at 20x magnification, but can potentially measure flows in the range of 100mm/s at the same

magnification [2]. Moreover, the power of the LED is sufficient to excite fluorescence emission from particles, although only relatively slow flows can be resolved with the current setup.

## Discussion

With micro-PIV, it is possible to measure fluid velocity, and other flow parameters, without making any a priori assumptions regarding the nature of the flow. Our system can readily be extended into 3-D with the addition of appropriate hardware and software [2]. Provided sufficient optical access is available measurements can be performed within isolated vessel preparations either *in situ* or *ex vivo*.

The full potential of the LED used has yet to be fully exploited, since, as demonstrated by [3], much higher currents can be tolerated by the LED without damage, which promises further improvements in temporal resolution.

Although micro-PIV is a method for fluid flow measurements, optically based systems such as the one developed here can be used for cell trafficking studies, or tracing fluorescently tagged macromolecules of physiological importance, with minor modification. The system offers an inexpensive and reliable platform that offers researchers a cost-effective alternative to lasers and halogen lamps commonly used in fluorescence microscopy applications, and is equally suited to imaging of MEMS devices and any microfluidic device with optical access.

## References

- [1] M. Raffel *et al.*, “*Particle Image Velocimetry: A practical guide*”, 2007, 2nd ed, Springer.
- [2] C. Cierpka and C. J. Kahler, “*Particle imaging techniques for volumetric three-component (3D3C) velocity measurements in microfluidics*”, *Journal of Visualization*, vol 15, 2012, pp 1-31.
- [3] C. Willert *et al.*, “Pulsed operation of high-power light-emitting diodes for imaging flow velocimetry”, *Meas. Sci. Technol.*, vol 21, 2010, 075402