Volumetric Time Resolved Measurements of Temperature and velocity in Microscopic Flows Using Thermo-Liquid Crystals (TLCs)

R. Segura1,*, M. Rossi2, C. Cierpka3, C. J. Kähler1

1: Institute of Fluid Mechanics and Aerodynamics, Bundeswehr University Munich, Germany
* Correspondent author: rodrigo.segura@unibw.de

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Two years ago, a method was presented in LISBON12 to estimate the temperature of non-encapsulated thermo-liquid crystal (TLC) particles using the color of their digital images. Since then, new technological improvements have allowed for the initial concept to evolve into a robust measurement method, which, combined with Astigmatism Particle Tracking Velocimetry (APTV), allows for the simultaneous temperature and velocity estimation of micro-flows in three dimensions (3D), and is now ready for real-life scientific investigations.

Balanced illumination and circular polarization

TLC thermography has been around for many years and is not only a standard tool for temperature flow diagnostics but it has also been combined with Particle Image Velocimetry (PIV) to make simultaneous velocity and temperature measurements of all kinds of flow fields (Dabiri, 2009). In microfluidics, however, the methods used in conventional applications of these measurement techniques are not possible to realize due to a number of limitations. Segura et al. (2013) proposed a method, that uses non-encapsulated TLC particles to simultaneously track the position and temperature of tracer particles using their color. However, in order for this method to work, even higher quality color images of the TLC particles are necessary.

The first step towards achieving this task was to use a balanced white light source instead of a high power flash lamp in order to avoid the inhomogeneous spectra produced by their light bulbs. A Lumencor Spectra X is a so-called light engine that combines the illumination of six light pipes which shine specific wavelength bands of the visible spectrum. The light pipes are individually adjusted and can be normalized to produce a more homogeneous spectrum.

On the other hand, TLC materials have a particular and convenient physical quality. They reflect circularly polarized light with a constant polarization chirality, independent of the type of light that is shone upon them. Using this optical characteristic, a circular polarizer was designed, following the ideas of Basson and Pottebaum (2012), to filter out background noise and improve the signal-to-noise ratio (SNR) of the TLC color images. Fig. 1 shows a comparison of TLC particle images illuminated using a Mercury flash lamp and the Lumencor Spectra X light engine, combined with the circular polarizer.

3D Temperature and Displacement Tracking in a Cooling Droplet

High quality color images of non-encapsulated TLC particles, acquired using the balanced light source and the circular polarization filter, were used to track the 3D displacement and temperature of TLC tracer particles in a cooling droplet lying on a substrate (1 mm-dia). The 3D position of Hallcrest R20C1W (temperature response range of 1 K, and red start temperature of 20 °C) TLC particles was estimated with APTV (Cierpka et al., 2011). Fig. 2 shows a 3D plot of particle tracks for particles whose images were properly detected in more than 5 consecutive frames, such that a trajectory could be reconstructed, with the temperature of the particles given by the color map.

References


