Micrometer and Nanometer Spatial Resolution with µPIV

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In the autumn of 1997, 13 years after the initial PIV experiments at the University of Oldenburg and DLR, a group of researchers were presented with a problem: obtain a spatially-resolved measurement of the flow through a supersonic microthruster. To make these measurements researchers at the University of California Santa Barbara and the University of Illinois developed the micron-resolution Particle Image Velocimetry or µPIV technique. Initial work began with a simple measurement of flow around a surface irregularity on a frosted glass slide (Santiago, et al., 1998). Subsequently µPIV has grown from a niche technique to one of the most commonly used forms of PIV. The first µPIV article (Santiago, 1998) is the second-most cited paper in Experiments in Fluids history (following Willert and Gharib's 1991 Digital PIV paper) and typically about 100 journal papers per year are published featuring the technique. The typical planar µPIV system has changed little from the apparatus used to make these initial measurements, consisting primarily of an epifluorescent microscope, a sensitive CCD camera, and a light source. While µPIV retains quite a bit of its macroscopic PIV heritage, there are a number of unique constraints and a few opportunities created by working in the microscopic world. For example epifluorescent microscopes are typically used for µPIV which necessitate a number of changes: volume illumination being chief among them. The absence of a light sheet required developing the optics theory underlying the depth of correlation, particle visibility, etc. (Wereley and Meinhart, 2004). However, typically steady flows have allowed development of the correlation averaging algorithm (Meinhart, et al., 2000) which was subsequently used to drive the spatial resolutions down to a single pixel, enabling sub-micron spatial resolutions (Westerweel, et al., 2004). Advances have been made in many areas, including 3D velocity measurement using a variety of techniques: stereo microscopy (Lindken, et al., 2006), 3-hole mask (Yoon and Kim, 2006), defocused diffraction pattern (Park and Kihm, 2006), and astigmatism (Cierpka, et al., 2009).

This talk will begin by discussing the history of µPIV and the development path that brought the technique to its present state. Then it will proceed to discuss the areas where advances are being made today.