

Achievements in sheet and volumetric PIV techniques with micron resolution

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My first contact with PIV happened on a demonstration performed by Chris Willert, Markus Raffel and Jürgen Kompenhans at the Technical University of Clausthal, in the spring-time of 1995. Coincidentally, I had a deep interest in coherent near wall flow structures in turbulent boundary layers at the time and the demonstration made a strong impression on me. I became excited about using this method and fortunately I had the opportunity to join the PIV group of Jürgen Kompenhans at DLR Göttingen to work on my diploma project. In August of 1995 I started my first measurements using photographic PIV with the rotating mirror system, developed by Markus. For the illumination, a heavy 70 mJ Lumonics HY 200 SPECIAL Nd:YAG laser was available. Instead of optically evaluating the contact copies of the 36mm film after the experiment, which was the state-of-the-art at that time, I digitized the recordings with a brand-new scanner in order to evaluate them digitally. I was deeply impressed by the large-scale coherent flow structures I could resolve with the system (figure 1), but the spatial resolution was far too low to resolve the velocity profile down to the viscous sub-layer.

In February of 1996 Chris had integrated a 1kx1k digital camera (Pulnix) in the DLR PIV system. Apart from the low spatial resolution compared to photographic PIV, digital PIV was a fantastic improvement, particularly due to the multi-pass cross-correlation analysis with window-shifting (already of second order at that time). I was able to much better resolve the velocity profiles (up to the buffer layer, see figure 2) but when I plotted the histogram, I saw what today we refer to as peak-locking (figure 3). This effect was not known from photographic PIV (probably due to the noise) and none of my famous colleagues or visitors at the DLR at that time (Jerry Westerweel and others) had observed it before. As the implication of this effect on velocity measurements was obvious, Jürgen Kompenhans recommended that we do not publish the graph in my diploma thesis, though I did nevertheless [1].

Enthusiastic by the technical improvements and my first findings, in March 1996 Jürgen Kompenhans sent me to Ron Adrian at Urbana Champaign to get familiar with digital stereo PIV. Learning from Ron was a great honor for me. Additionally, Jerry spent some weeks visiting Ron during the same period to work on "The Book". So I was able to discuss all my findings at lunch with Jerry and, at least once a week, with Ron. Back in Germany, I evaluated the 2kx2k stereo PIV recordings made during my stay at Urbana Champaign, with the stereo software that Chris developed in my absence. Surprisingly the out-of-plane motion was always on the same side of the low-speed streaks. I realized that this effect was caused by slight differences between the calibration and the measurement configuration. So I worked on a way to compensate for this effect, which is known today as disparity correction [2], and I learned that even when you are doing everything right there might still be something wrong!

After finishing my Diploma thesis, I continued the work at DLR during my Ph.D. with the development of the multi-plane stereo-PIV technique, to estimate unsteady and 3D flow characteristics in air, and I was able to analyze turbulent boundary layers in much more detail [3]. Thanks to Michel Stanislas and Jürgen Kompenhans I could perform the experiments in Lille, which is greatly appreciated. Besides my work on boundary layers, I was also involved in many international test campaigns where I learned to apply PIV with a team in large scale catapult- and wind- tunnels and in 1998 I had the privilege, together with my colleague Andreas Schröder, to work in Mory Gharib's group at Caltech. California was just wonderful and I learned that life is not just work. In September of 2001 I left the DLR PIV group after six exciting and extremely fruitful years which have influenced me greatly.

From October, 2001 until April, 2008 I focused my attention on intrusive and non-intrusive flow control concepts and the development, improvement and application of all kinds of PIV variants at the TU

Braunschweig. I worked, particularly, on a long-range micro-PIV system with single pixel resolution in order to resolve the viscous sub-layer. In 2005 I was able to measure the boundary layer velocity profile with a resolution of 0.028 viscous units in a wind-tunnel, at a free stream velocity of 10 m/s. The resolution of one thousand measurement points within a millimeter over a distance of 0.5 m was far beyond my highest expectations when I began my research in 1995 at DLR Göttingen. So I tend to believe that there is always a solution, we just have to explore it!

Today, I still like the Particle Image Velocimetry, mainly because

1. the technique still puzzles and inspires me to come up with improvements,
2. as a physicist, I like the components involved (laser, CCD camera, optics, image analysis),
3. I met many good people in this community and it is always a pleasure to meet them at conferences or events such as the 25 years of PIV at DLR Göttingen in 2009.

[1] Kähler CJ: Ortsaufgelöste Geschwindigkeitsmessungen in einer turbulenten Grenzschicht. Forschungsbericht der Deutschen Forschungsanstalt für Luft- und Raumfahrt, DLR-FB-97-32, 1997

[2] Kähler CJ, Adrian RJ, Willert CE: Turbulent boundary layer investigations with conventional and stereoscopic PIV. 9th Int. Symp. on Appl. of Laser Techn. to Fluid Mech., Lisbon, Portugal, June 13-16 1998, paper 11-1

[3] Kähler CJ: The significance of coherent flow structures for the turbulent mixing in wall-bounded flows. Forschungsbericht des Deutschen Zentrums für Luft- und Raumfahrt, DLR-FB-2004-24, 2004 (<http://webdoc.sub.gwdg.de/diss/2004/kaehler/kaehler.pdf>)

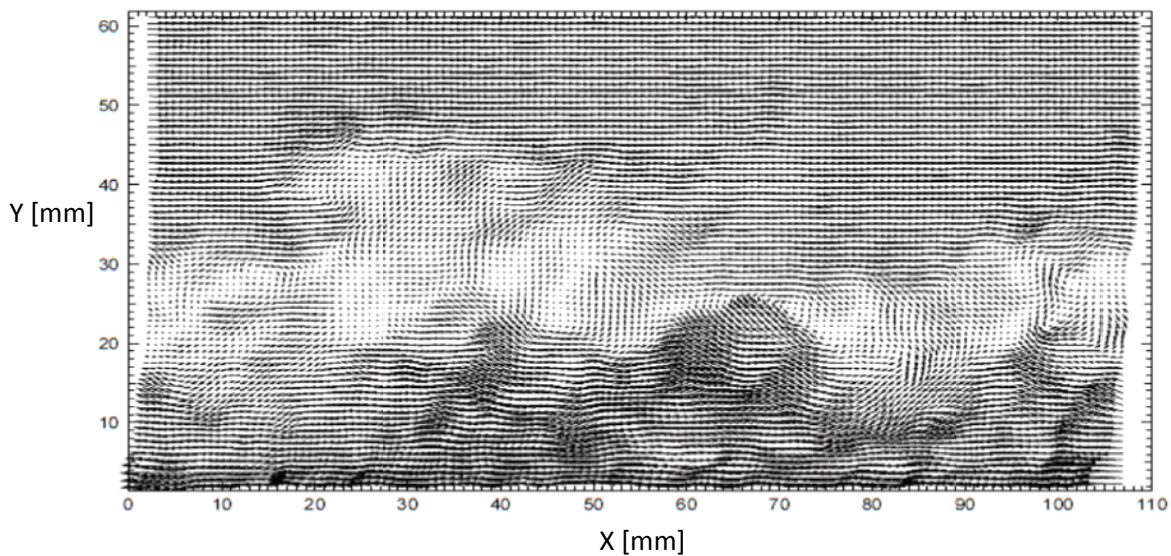


Figure 1. Photographic PIV measurements of a turbulent boundary layer [1].

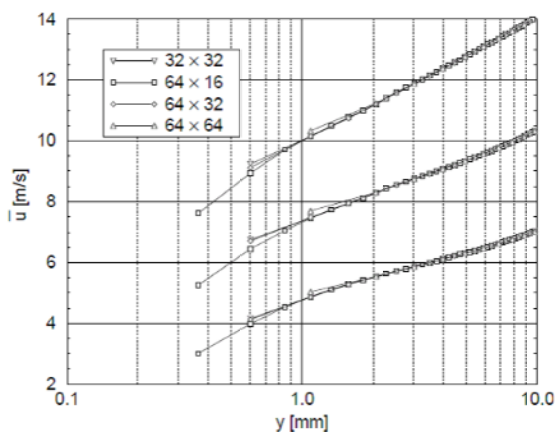


Figure 2. Near-wall velocity profile measured with digital PIV [1].

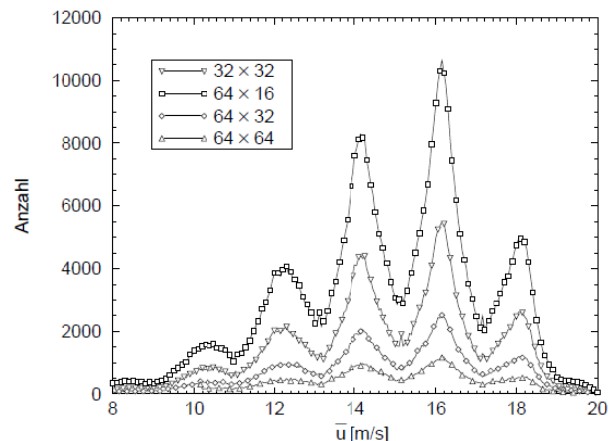


Figure 3. Histogram of the velocities measured with digital PIV [1].