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Investigation of a tripped turbulent boundary layer flow using time-resolved tomographic PIV

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The spatial and temporal development of turbulent boundary layer flows is governed by the self-organization of coherent structures like hairpin-like or arch vortices and spanwise alternating wall bounded low- and high-speed streaks. For a detailed analysis of the topologies of the wall normal fluid exchange namely of the four quadrants of the instantaneous Reynolds stresses Q1,…,Q4 a 4D- measurement technique is desired.

In this feasibility study the tomographic PIV technique (Elsinga et al. 2005) has been applied to time resolved PIV recordings. Four high speed CMOS cameras are imaging tracer particles which were illuminated in a volume inside a boundary layer flow at 4 kHz by using two high repetitive Nd:YAG pulse lasers. The instantaneously acquired single particle images of these cameras have been used for a three dimensional tomographic reconstruction of the light intensity distribution of the particle images in a volume of voxels (volume elements) virtually representing the measurement volume. Each of two subsequently acquired and reconstructed particle image distributions are cross-correlated in small interrogation volumes using iterative multi-grid schemes with volume-deformation in order to determine a time series of instantaneous 3D-3C velocity vector fields.

The measurement volume with a size of ~ 34 x 19 x 35 mm³ was located near the wall in a flat plate boundary layer flow with zero pressure gradients and downstream of spanwise tripping wires. At a free stream velocity of U = 7 m/s a turbulent boundary layer flow develops downstream of the tripping device. The time resolved tomographic PIV method enables capturing the spatio-temporal development of the complete flow structures. The measurement method offers the possibility to determine the complete time dependent three-dimensional velocity gradient- tensor within the measurement volume. The 3D vorticity operator has been applied to the dataset in order to identify the three dimensional development of the vortical structures inside the turbulent flow, which enables the analysis of the role of coherent structures for flow exchange mechanisms in such wall bounded turbulent flows.

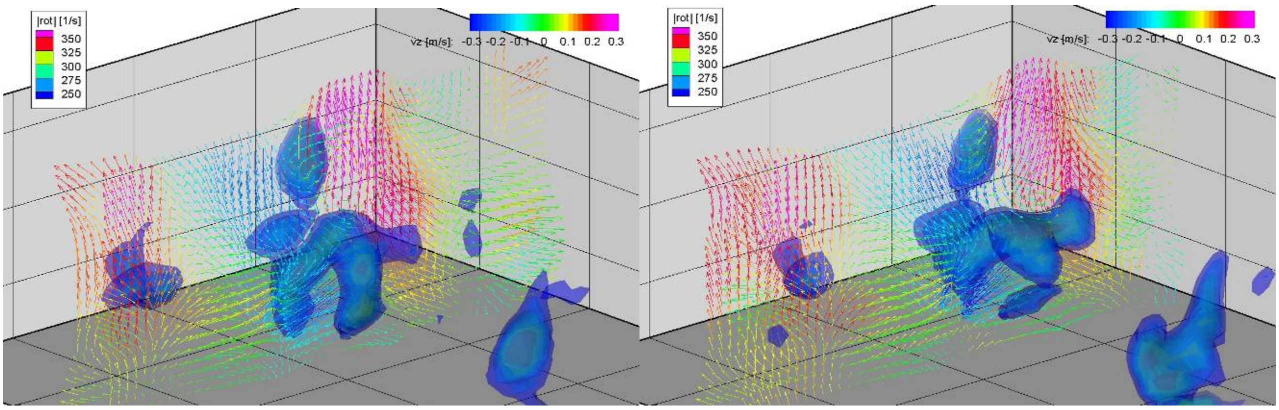

Fig. 1. *Two instantaneous 3D iso-vorticity surfaces and two x-y-planes of 3C fluctuation velocity vector fields of a 4 kHz time series with t = 500 µsec shift each in a tripped turbulent boundary layer, Vy color c.*