Dense Lagrangian particle tracking in homogeneous turbulence

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We present measurements of dense fields of fluid particle trajectories in homogeneous turbulence at $Re_\lambda = 270$ and 350 in a von Kármán flow between two counter-rotating propellers. With the novel Lagrangian Particle Tracking (LPT) algorithm Shake-The-Box, introduced and further developed by Schanz et al. (2016) [1], we are able to instantaneously track up to 100.000 particles in a volume of $50 \times 50 \times 50$ mm^3.

The experiment was conducted in the Göettingen Turbulence Faclity 3 (GTF3) von Karman Flow Apparatus at the Max- Planck-Institute for Dynamics and Self-Organization (MPIDS). The setup (see Figure 1,a,b) consists of a cylindrical tank of water (500mm diameter) with two counter-rotating propellers at the top and at the bottom, generating a von Kármán flow with a homogeneous turbulent region at the center. From earlier experiments [2], the expected Kolmogorov length is $\eta \sim$100m at a propeller frequency of 0.5Hz. The Kolmogorov time is $\tau \sim$ 10ms, cf. a recording frequency of 1.25kHz, which results in temporal oversampling by a factor of 12.5. Seeding particles (spherical, monodisperse, ρ=1.05g/cm^3, 20μm diameter) are illuminated by a fibre-coupled 150 W Nd:YAG high frequency laser (IB Chronos 400 MM IC SHG) in a measurement volume of 50x50x15mm^3 at the center of the tank. Four CMOS cameras (Phantom v640, 2560x1600 pixel, 12bit) equipped with 100mm Zeiss macro lenses ($f_\#$=16) and Scheimpflug adapters record the particles in $\sim$45° forward scattering. Prisms attached to the tank guarantee the camera windows are perpendicular to the camera axes.

For a propeller frequency of 0.5Hz, 1000 time series of 200 time steps and 2000 time series of 40 time steps have been recorded to obtain converged statistics of velocity and acceleration, to compute the dissipation rate, the dissipation tensor, and statistics of the velocity gradient tensor, as well as (conditional) Eulerian and Lagrangian spatial and temporal correlation functions. For the analysis of pair and tetrad dispersion, 40 time series of 14000 time steps (full camera RAM) were recorded. A total amount of 40 TB particle image data have been acquired.

Large particles (120μm diameter) with a larger Stokes number have also been used in order to study the inertial effects and to compare inertial particle models [3] and experimental data.

The study of the coherent structures using high density flow fields, the effect of clustering, transport barriers and the turbulent flow will be analyzed in detail. The motion of inertial particles is described by Maxey-Riley equations [4] and the weight of their different terms to account for the experiments will be shown.

Here, we describe the experiment in detail and present the turbulence statistics of this extensive data set.

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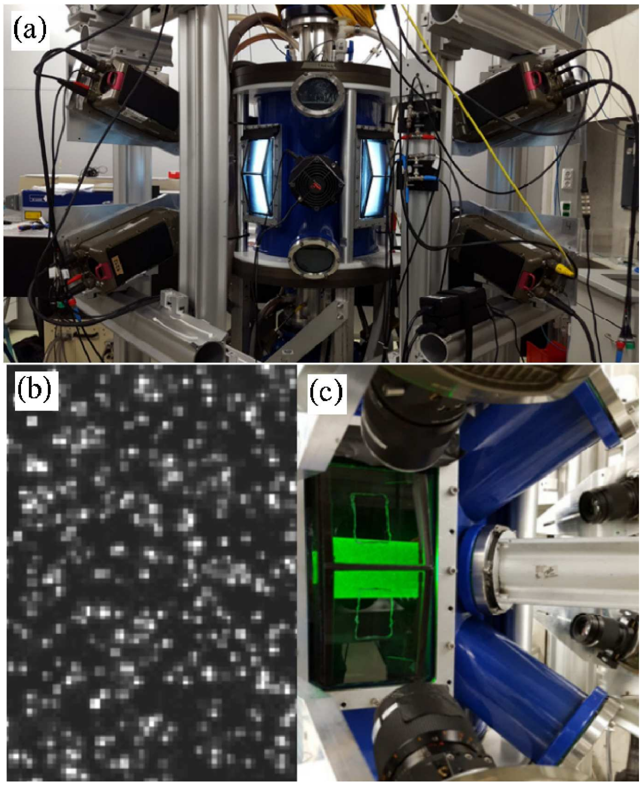

Figure 1: (a) Experimental setup with tank and 4 cameras. (b) Cut-out of a typical particle image at moderate seeding density. (c) Close-up of camera lenses, prisms, and illuminated volume with particles.

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