Spatio-temporal boundary dissipation measurements using Diffusing-Wave Spectroscopy

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The determination of the velocity gradients provides valuable information in many aspects of fluid dynamics (dissipative structures, boundary layers, drag, etc). In particular, the norm of the strain rate tensor $\frac{\Gamma}{\sqrt{2}} = \sqrt{\sum_{i,j}\left[\frac{1}{2}\left(\partial_i v_j + \partial_j v_i\right)\right]^2}$ gives the viscous dissipation rate $\eta\Gamma^2$ of a Newtonian fluid flow. However, it is difficult to measure Γ to a sufficient level of spatial and temporal resolution. A promising technique, called Diffusing-Wave Spectroscopy (DWS), allows for its direct measurement. It exploits the diffusive nature of multiply scattered light in a turbid colloidal suspension. In a DWS measurement, the time autocorrelation of the scattered intensity is measured and decays because of the phase shift of light in time at each scattering event [1]. This decay is due on the one hand to the Brownian motion of particles and on the other hand to the fluid motion and more specifically to Γ, which can therefore be deduced [2,3].

We recently reported [4] the first spatially and temporally resolved measurements of the boundary dissipation using DWS with commercially available high-speed cameras. We demonstrated the method on a Taylor-Couette flow, characterizing the spatio-temporal dynamics of the boundary dissipation rate up to the wavy vortex flow (see Figure 1). We now perform such measurements in a wall-bounded turbulent flow, up to $R_e = 3 \times 10^5$, allowing the study of the dissipative structures and the temporal fluctuations of the boundary dissipation rate.

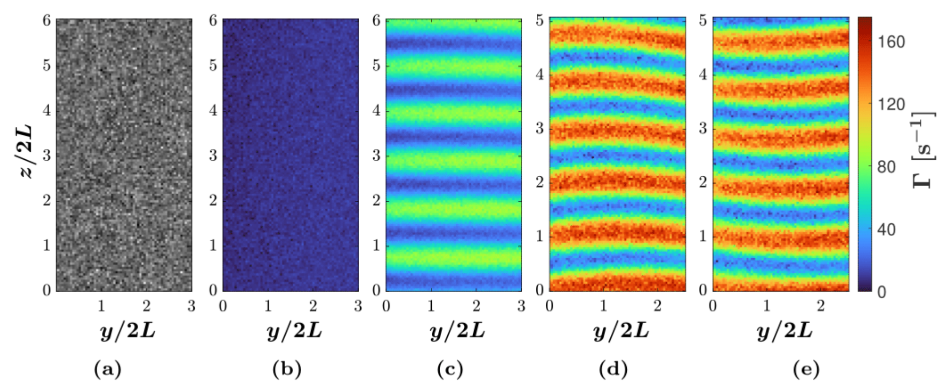

Figure 1. **(a)** Snapshot of the speckle pattern directly measured by the camera (arbitrary units of intensity). **(b)** Spatially resolved map of Γ in the linear regime ($Ta = 188$), and **(c)** in the Taylor vortex regime ($Ta = 3012$). **(d)(e)** Two spatially resolved map of Γ (0.25 s apart), in the wavy vortex regime ($Ta = 4706$).

References

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