Studying liquid flow near solid surfaces by total internal reflection fluorescence cross-correlation spectroscopy (TIR-FCCS)

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The dynamics of flow in confined geometries, such as in microfluidic and nanofluidic devices, can be accurately described only if the physics of the flow at the interface between the fluid and the solid is thoroughly understood. An important step towards such understanding lies in determining the correct boundary conditions. The existence and the extent of boundary slip for a Newtonian liquid flowing over a solid surface has been debated over the past two centuries, but a convincing conclusion is still lacking [1]. To rationalize this controversy, new highly sensitive and accurate experimental techniques are required.

Here, we present a new method for direct studies of flows in the close proximity of a solid surface based on total internal reflection fluorescence cross-correlation spectroscopy (TIR-FCCS). The effect of TIR is used to create an evanescent wave that extends only ~100 nm from the glass wall of a micro-channel and excites fluorescent tracer particles flowing with the liquid. A high numerical aperture microscope objective and a pair of avalanche photodiodes are employed to monitor simultaneously the fluorescent light from two small and laterally shifted (in flow direction) observation volumes. The cross-correlation $G(\tau)$ of the fluorescent signals $I_1(t)$ and $I_2(t)$ originating from these volumes contains information for the tracer’s and hence the flow velocity [2]. To extract this information we employed Brownian-Dynamics techniques to simulate the tracers’ motion through the observation volumes and generate a “numerical” cross-correlation curve that was consequently used to fit the corresponding experimental data.

After optimising several important parameters of the setup, e.g. tracer size, distance between the observation volumes, ionic strength of the solution, we have applied the TIR-FCCS method to measure the boundary slip of water on hydrophilic and hydrophobic surfaces.