Particle dynamics in dense suspensions flowing through microchannels

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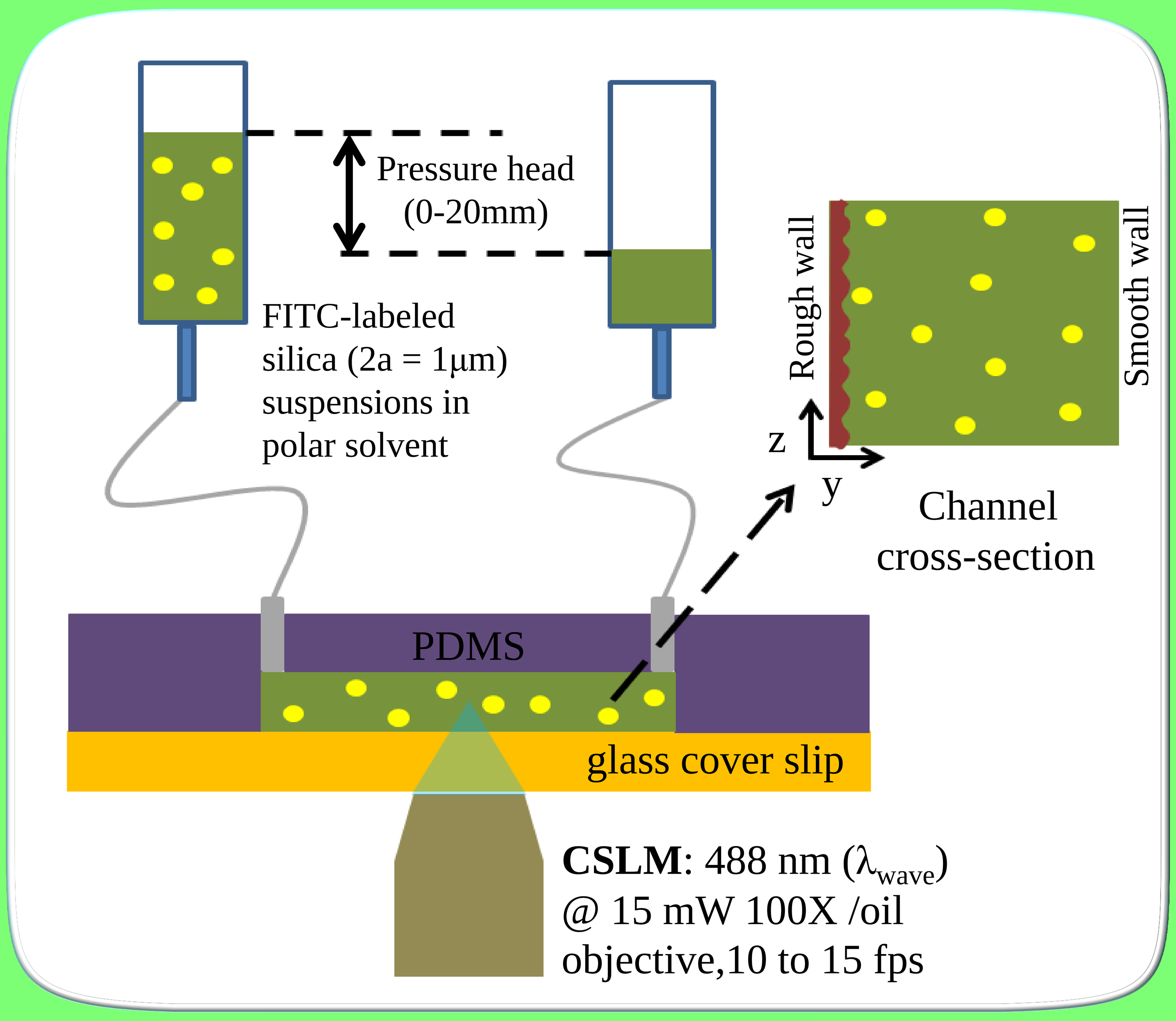
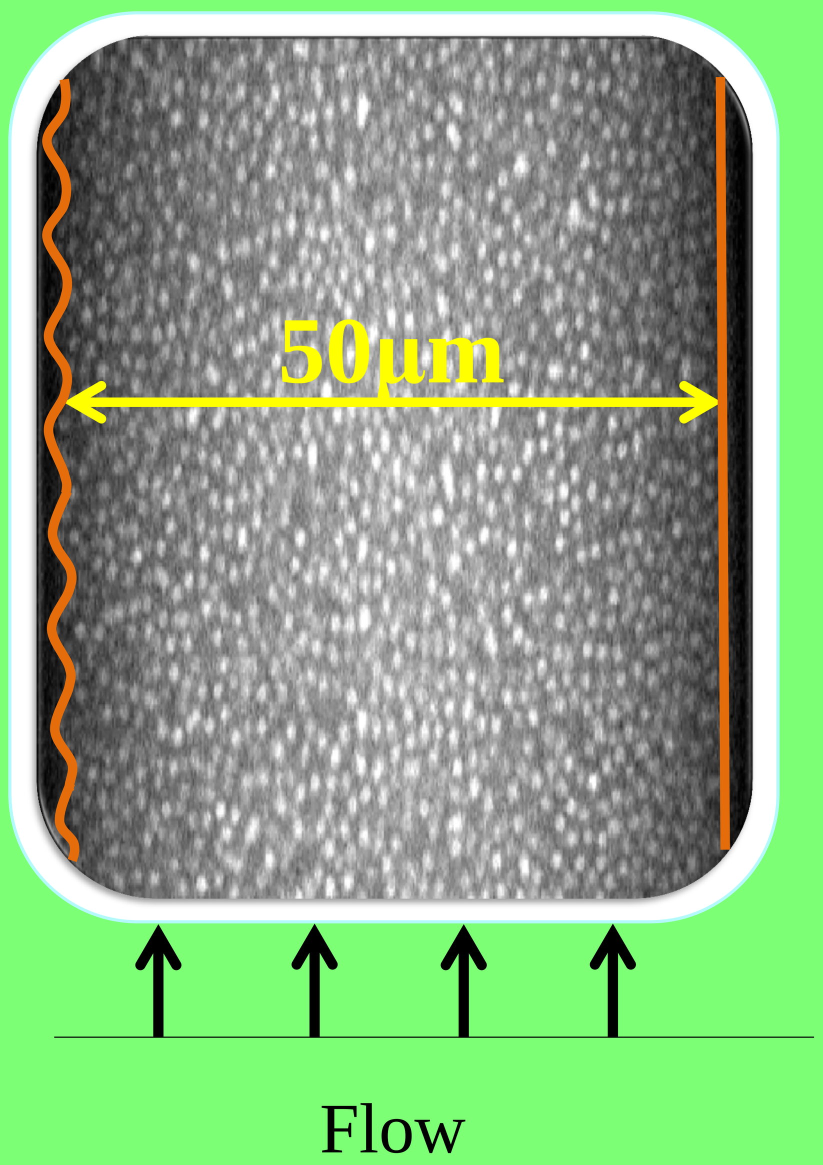
Introduction

While colloidal hard sphere suspensions are well-known as model fluids, much less is known about their behavior when they are made to flow through microchannels. We have initiated a study into the spheres' spatial distribution, flow profile and (apparent) diffusive behavior, as a function of the volume fraction (0.01-0.4), and the Péclet number (0 to 40) which indicates the strength of the shear flow as compared to Brownian motion: Pé=$\frac{6\pi\eta_0\gamma' a^3}{kT}$. Cross-sectional channel dimensions are taken 30-50 particle diameters, while also the roughness of the wall is varied. After confocal microscopy measurements, the particles' positions and displacements are analyzed using (adapted) tracking codes written in IDL language.

Experiments





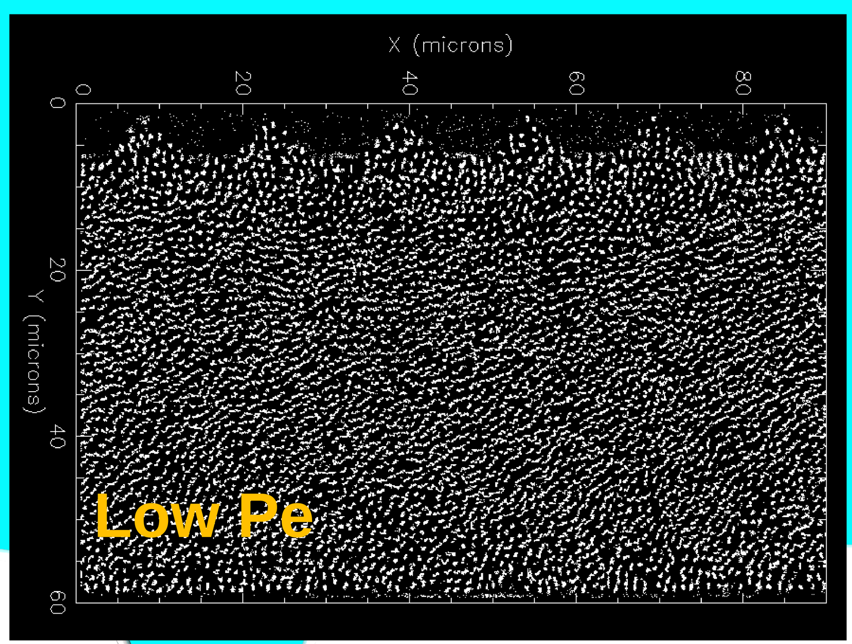
solvents:
1. Methanol + Bromoform (low viscous)
2. Water + Glycerol (high viscous)
both refractive index matching for silica
solvent 1 is also density-matching.

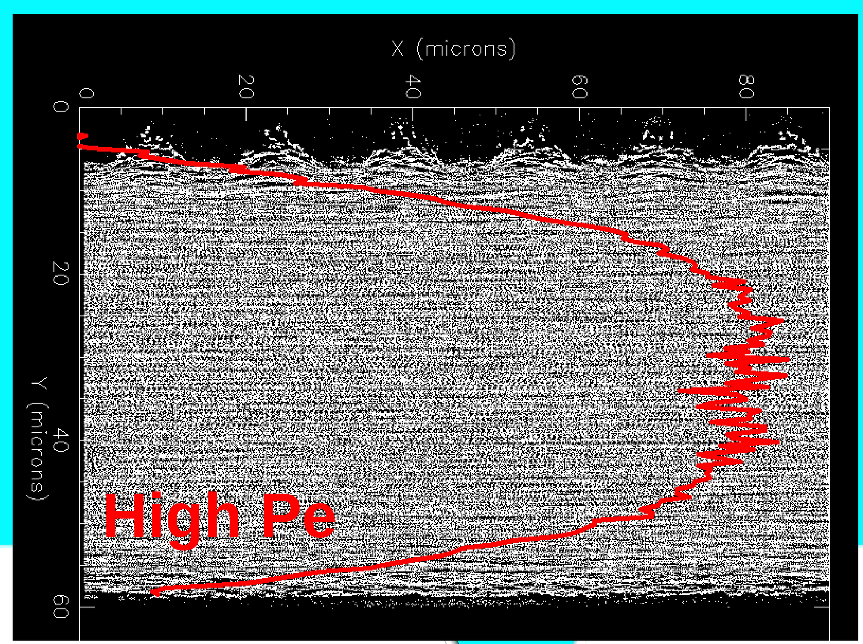
flow speeds: 0.1 – 10 μm/s

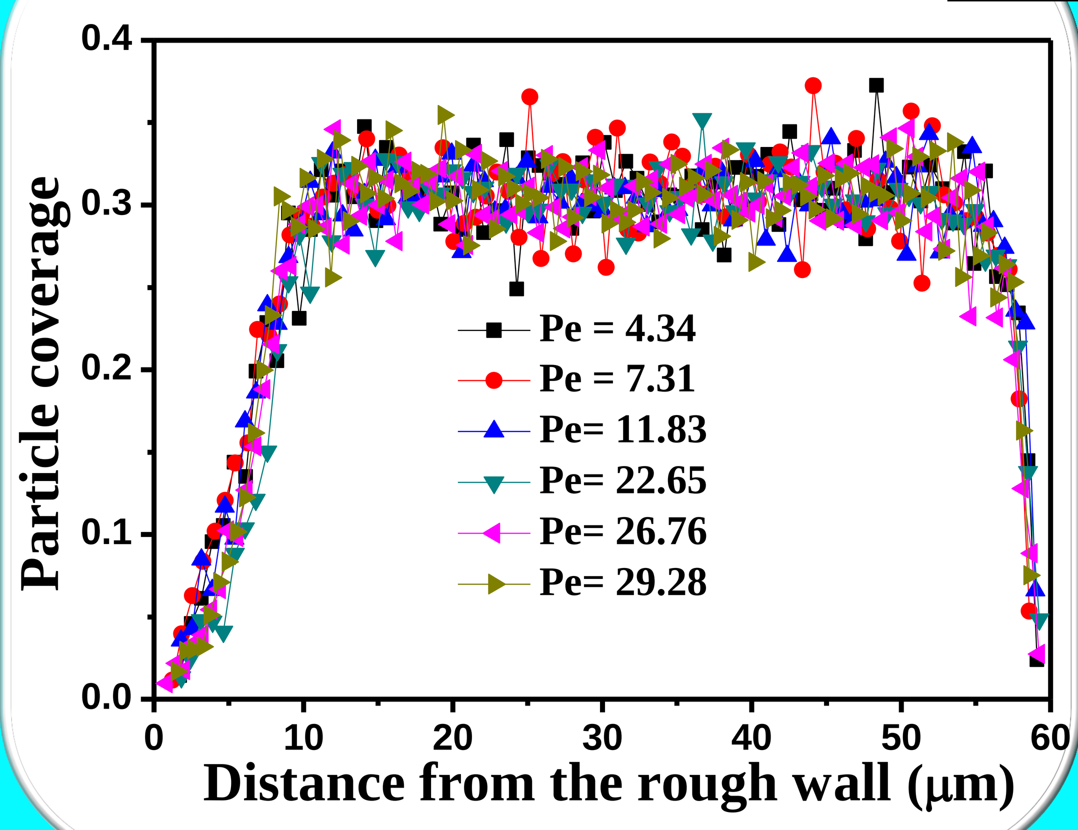
movies: 500-1000 frames per condition

measurables:
1. local particle number density
2. local mean velocity along flow direction
3. Mean Square Displacement normal to flow: $\langle\Delta y^2\rangle = 2 D_\perp t$

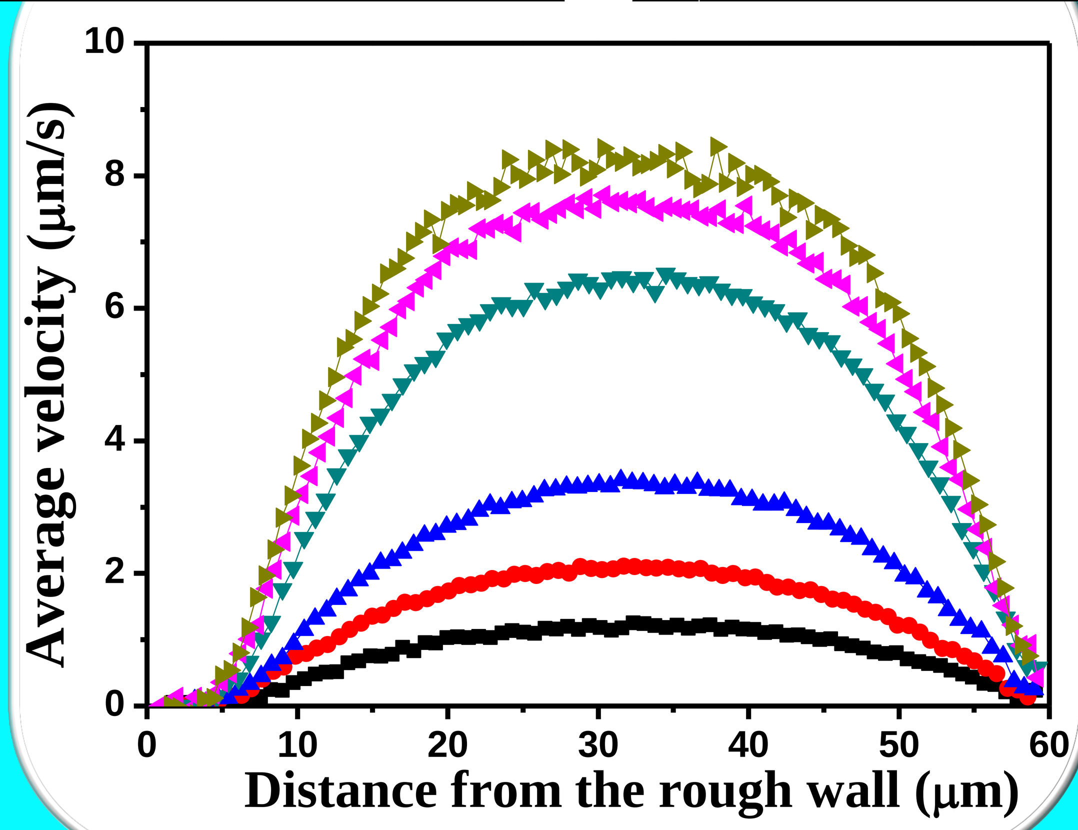
Observations



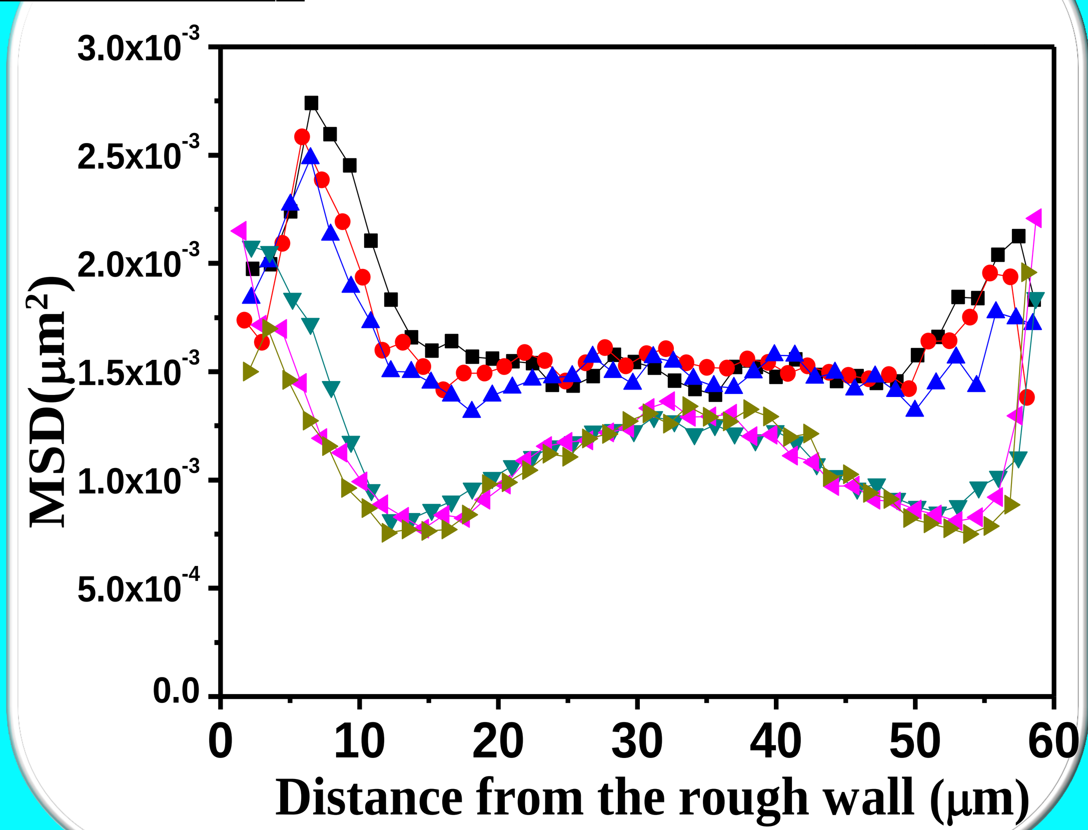




Concentration profile



Velocity profile



Apparent diffusivity normal to the flow

Conclusions

- Use of both low- and high viscous solvents allows to address a broad range of Peclet numbers, while keeping the maximum flow velocity low enough for particle tracking.
- Separating the diffusive displacements from the convective ones requires great care, both at high and low Pe.
- Velocity profiles are nearly parabolic. Slip is always suppressed at the rough wall.
- The dependence of $D_\perp$ on Pe and the distance relative to the walls still needs to be understood.