Hydrodynamic Interaction of Confined Colloid Suspensions

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The motions of particles in a suspension are coupled via hydrodynamic interaction, which dictates the behavior of the suspension in confined geometries. Problems related to the dynamics of confined suspensions have attracted considerable interest in recent years, both due to their relevance to micro- and nano-fluidics and to the new physical effects that have been discovered in such systems. In an unbounded suspension this hydrodynamic coupling is positive, long-ranged (decaying as r^{-1} with the inter-particle distance r), and involves many-body effects. The presence of confining walls dramatically modifies the hydrodynamic interactions between particles, and, therefore, the suspension dynamics.

We present an overview of our recent theoretical and experimental studies concerning the hydrodynamic interaction in colloid suspensions confined in various geometries that mimic (1) quasi-one-dimension (q1D) in which colloid particles are tightly confined in a narrow channel (Fig. 1), (2) quasi-two-dimensions (q2D) in which colloid particles are confined between two flat hard-walls (Fig.2) and (3) a dimension that is intermediate between q1D and q2D in which particles are confined in a ribbon channel of various widths (Fig. 3). We found that the q1D confinement leads to a sharply screened hydrodynamic interaction, decaying exponentially with r / w (w: the width of the channel), while the coupling between the particles in q2D remains long-ranged, decaying with $\left(r/H\right)^{-2}$ (H: the gap between the two walls). The crossover behavior between q1D and q2D is found to be multifaceted: while certain dynamic properties of the confined suspensions exhibit q2D characteristics already for relatively narrow channels, other properties continue to significantly deviate from the expected q2D behavior even for the widest channels studied, indicating that the transition between q1D and q2D behavior is apparent to different extents in different system properties.

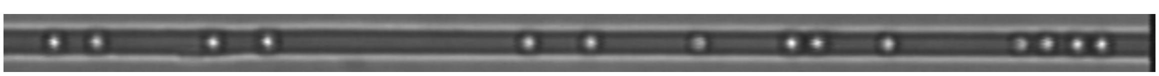

Figure 1. Colloid suspension (silica spheres, 1.58μm in diameter) confined in a straight linear channel (the width of the channel is 3μm), a q1D geometry.

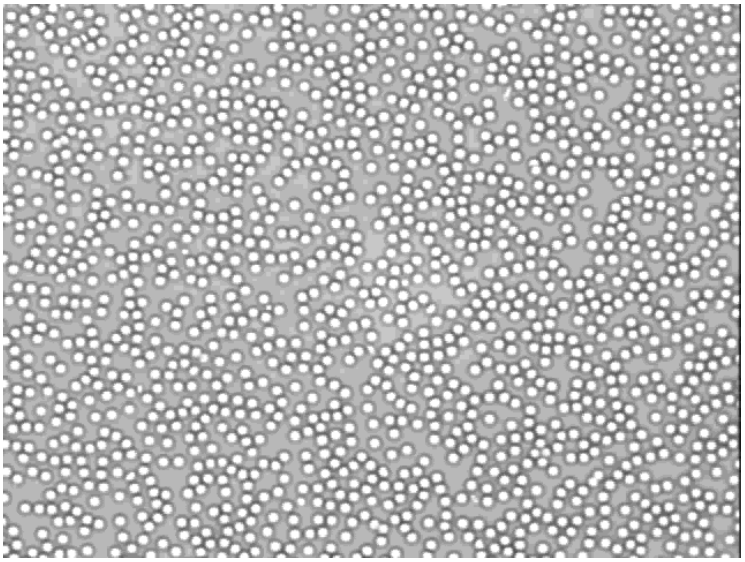

Figure 2. Colloidal particles (silica spheres, 1.58μm in diameter) confined between two hard-walls (separated by about 1.7μm), a q2D geometry.

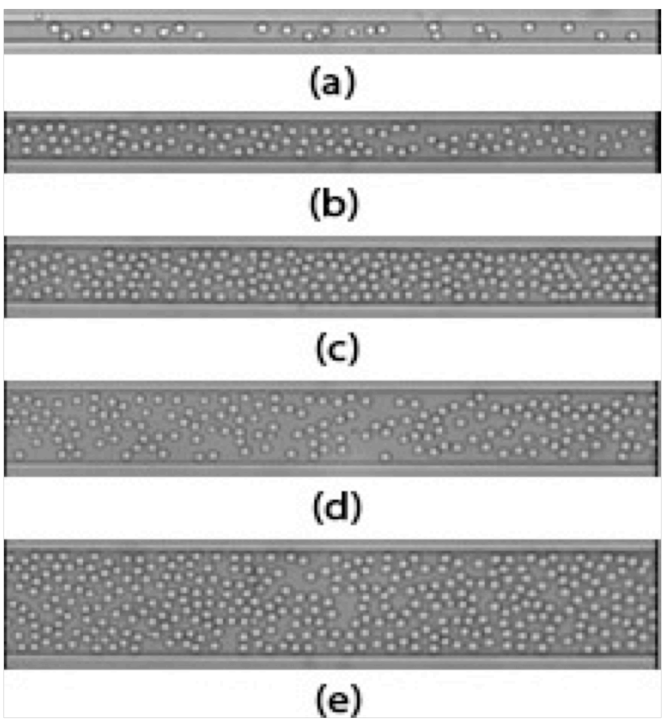

Figure 3. Colloidal particles (silica spheres, 1.58μm in diameter) confine in ribbon channels of various width (the widths are (a) 5μm, (b) 8μm, (c) 11μm, (d) 14μm and (e) 20μm), a geometry intermediate between q1D and q2D.