Collective Diffusion in Circular and Straight Channels

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April 2011

We study the hydrodynamic interactions of colloidal particles confined to move in quasi-one-dimensional circular and straight channels. Digital video microscopy is used to track the motions of silica 1.57 μm spheres diffusing in circular and 2mm long straight channels with a 3μm $\times$ 3μm square cross section. The collective diffusion coefficient, defined as the number of particles in a channel times the diffusion coefficient of the center of mass, is measured for both geometries on a time scale of 200 ms, so that direct particle interactions can be considered negligible. In both the case of a circular channel and a long straight channel, the collective diffusion coefficient is found to be proportional to the mean linear density η of the particles in the channel. This supports the recently proposed relation by Frydel and Diamant [1] claiming that particles in a one-dimensional channel experience hydrodynamic correlations of unbounded range due to the propagation of longitudinal modes in the host liquid. Furthermore, it contrasts with the earlier hydrodynamic description of interaction between two particles in a quasi-one-dimensional system, which is exponentially screened on distances longer than the channel width, and thus implies that a dilute collection of particles in these systems diffuse in a basically uncorrelated way. Finally, by measuring collective diffusion of rings with radii between 3 and 35 μm, we demonstrate that on short time scales, the effect of ring curvature on the collective diffusion of the particles is negligible.

[1] Derek Frydel and Haim Diamant. Long-range dynamic correlations in confined suspensions. *Phys. Rev. Let.*, 104.