Quantitative Light Microscopy of Dense Suspensions: Colloid Science at the Next Decimal Place

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Since the days of Perrin [1], microscopy methods have played an important role in the study of colloidal suspensions. Along with the continued development of new imaging techniques, colloid scientists have also implemented a sophisticated range of computational analyses. These analysis techniques are often the unsung heroes that hold the promise of unlocking scientific mysteries at the next decimal place of colloid science. They now enable precision measurements of particle location and size [2,3] as well as measurements of local stresses and forces [4]. Here, we spotlight these exciting advances focusing on the analysis of simple brightfield and confocal microscope images of dense colloidal suspensions as well as the scientific mysteries they may unravel.

colloidal suspensions; microscopy; imaging; forces; measurement science [2010] 00-0199-00

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"Why should one wish to make measurements with ever increasing precision? Because the whole history of physics proves that a new discovery is likely to be found lurking in the next decimal place." (Floyd K. Richtmyer, 1931) [5]

Look through a colloid scientist's microscope and you'll find an amazing array of phenomena that scientists and engineers investigate with colloidal suspensions. Particles entropically assemble into a zoo of crystal structures [6,7,8,9,10,11]. Aided by patterned substrates [12,13], gel coatings [14], depletion interactions [15,16,17,18,19,20], charge induced interactions [21,22,23], magnetic interactions [24,25,26] and DNA programmable interactions [27,28,29,30] the variety of accessible structures that suspensions form is breath taking. Active colloidal particles jet around, providing fertile testing grounds for far-from-equilibrium physics [31,32,33,34,35,36]. The behaviors of liquids [37,38], interfaces [39], gels [17,40,41] and glasses [42,43,44,45,46,47] are resolved with fine detail. Confocal rheoscopes illuminate the structural underpinnings of rheological behaviors from thixotropy [48,49,45] to shear thickening under confinement [50]. And the particles are no longer just spheres [51]; particle shapes have blossomed into a beautiful set of rods [52], clusters [24,53], dimers [54], lock-and-key particles [55], and even designed shapes from pentagons to letters [56,57,58,59], with simulations promising new materials from many of these shapes [60].

Simple microscopy methods such as brightfield and confocal are a large reason for the continued excitement in exploring such colloidal phenomena. The particles' large, micron-scale size and slow, millisecond- to second-scale dynamics allow key behaviors to be easily investigated by microscopy [61,44,62,46,63,19,64,65]. A modern microscope can image thousands of particles in a blink of an eye, and simple automated software routines can locate these particles to within 30 nm, while missing only a few percent of the particles [66,67,68]. Importantly, microscopy allows for local measurements of a suspension.