Effect of non-uniform, out-of-plane illumination, shear rate and particle distribution on the accuracy of nPIV velocity measurement

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Nanoparticle image velocimetry (nPIV) uses evanescent-wave illumination to measure two velocity components, \( U \) and \( V \), tangential to a wall in a region with thickness of the order of hundreds of nanometers. In this region the illumination intensity decays exponentially with distance normal to the wall, \( z \), and hence tracers closer to the wall have ‘brighter’ and ‘bigger’ images than those that are further away, i.e. at larger \( z \). Moreover, fluid velocity varies in this region with \( z \) and hence tracers at different distance from the wall move at different speeds. Furthermore, presence of the wall has a significant effect on particle distribution, and particle displacement due to local fluid velocity and Brownian displacement of particle tracers in this region. The variation in the displacement of particle images in this region, with different brightness and velocities, can bias the near-wall velocities obtained using standard correlation-based PIV method.

Artificial nPIV images of nanoparticles in a flow field with linear out-of-plane velocity profile were used in this work to investigate the impact of these issues upon the accuracy of nPIV data. Uniform and Gaussian random distribution noise were added to the images to simulate electronic noise and shot noise, respectively. The artificial images were obtained and processed for various experimental parameters to incorporate different illumination profiles, shear rates and distribution profiles. The results demonstrate that non-uniform illumination, as well as particle distribution, affects the bias in the estimated tracer velocity for the shear flow. Non-uniform intensity also affects the bias due to Brownian diffusion; however, correction for Brownian diffusion can reduce this bias error.