Measurement of Micro-scale Fluid Phenomena with μ-PIV
-Analysis of Apparent Fluid Slip

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As the dimensions of fluidic devices decrease, traditional macroscopic assumptions may no longer be valid, and additional forces on particle and fluid motion may dominate. With micron-resolution particle image velocimetry (μ-pIV), we seek to identify and characterize key parameters at the microscale and validate the applicability of macroscopic assumptions. This will enable more accurate modeling of microdevices and ultimately aid in developing new devices. At the macroscopic level, it is well accepted that the boundary condition for a viscous fluid at a solid wall is one of "no-slip," i.e., the fluid velocity matches the velocity of the solid boundary. With μ-PIV, we measure the velocity profiles of water flowing through 30x300 μm channels with velocity measurements to within 436 nm of the microchannel surface. When the surface is hydrophilic, the measured velocity profiles are consistent with Stokes equation and the well-accepted no-slip boundary condition. However, when the surface is coated with a hydrophobic monolayer, an apparent fluid slip is observed. A possible mechanism for this apparent fluid slip is proposed. Some suggest a depleted water region or vapor layer develops near a hydrophobic surface, while others observe nanobubbles. By modeling the presence of either a depleted layer or nanobubbles as an effective air gap at the wall, we calculate slip lengths for flow between two infinite parallel plates. The calculated slip lengths are consistent with experimental values when the gas layer is modeled as a continuum and significantly higher when rarefied gas conditions are assumed. The results suggest that the relatively large apparent fluid slip observed experimentally at hydrophobic surfaces may arise from either the presence of nano-bubbles or a layer of low-density fluid at the surface.