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Optically Induced Magnus Effect on Birefringent Particles

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OPTICALLY INDUCED MAGNUS EFFECT ON BIREFRINGENT PARTICLES

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Focused light can exert significant forces upon polarizable microparticles. In addition, circularly polarized light can be theoretically shown to induce a torque upon birefringent particles. In the absence of other influences, then, birefringent particles placed under circularly polarized light should undergo angular acceleration, due to this ìoptical torque.î However, the presence of any surrounding medium will introduce a hydrodynamic drag, with should lead to an angular "terminal velocity." In the microfluidic regime that we explore, the effects of drag overwhelm all inertial tendencies.

It can also be shown, theoretically, that a particle spinning within a fluid stream will experience a force perpendicular to the fluid flow, though no one has explored this "Magnus" or "Robbins" Effect in the microfluidic limit. Again, we must account for the fact that there is drag from the medium that opposes the spinning of the particle as well as drag from the medium that opposes the lateral displacement due to the "Magnus" Effect. We have shown theoretically that the forces associated with both the induced torque due to incident circularly polarized laser light as well as the lateral forces associated with the "Magnus" effect are significant enough to observe their effects. We have shown that since the lateral force associated with the "Magnus" effect varies with the cube of the particle size and the lateral velocity associated varies with the square of particle size, working in the microfluidic regime with micron sized particles greatly changes the expected outcome.

After presenting our calculation on the experimental accessibility of such effects, we will describe our experimental design, which uses focused circularly polarized light to both trap and spin micrometer-scale birefringent particles suspended in a uniform microfluidic flow. Our goal is to observe and measure any displacement in the direction normal to the imposed fluid flow; that is, to quantitatively measure the Magnus Effect at the micrometer scale.

The magnitude of achievable rotational rates has, for example, consequences for optical control of micromachines. In addition to the obvious applications to optically actuated micro-gears, pumps and motors, information gleaned from such basic studies may find application in a variety of micro-rheological (viscosity) studies and even in all-optical sorting technologies.