Simultaneous Positioning and Orienting of a Single Nano-object Using Flow Control

Pramod P. Mathai,[1,2] Peter T. Carmichael,[1] Andrew J. Berglund,[1] Benjamin A. Shapiro[3] and J. Alexander Liddle[1]

[1]*Center for Nanoscale Science and Technology, National Institute of Standards and Technology (NIST), Gaithersburg, MD, USA*

[2]*University of Maryland, College Park, College Park, MD, USA*

[3]*Department of Bioengineering, University of Maryland, College Park, MD, USA*

pramod.mathai@nist.gov

We describe a newly-developed technique for simultaneously controlling both the position and orientation of a single nano-object in a fluid by creating and precisely manipulating the flow around the object. This method holds promise for applications in nanostructure fabrication and force microscopy. We use electro-osmotic flow (EOF) to produce the desired flow field. EOF offers significant advantages as compared to other approaches: it allows for manipulation of a wider class of particles (the particle does not have to be magnetic or have a significant dipole moment), the particle can be controlled over a long range (>100 μm) while being rotated, a gain parameter in the control law can in principle be tailored to the shape of the particle, and the PDMS device is easy to make.

We use vision-based feedback control in a microfluidic device with 2-dimensional EOF. The position and orientation of the rod is estimated at regular intervals using a camera and a robust vision algorithm. A controller uses this estimate to calculate the deviation of the rod from a user-specified desired trajectory, and computes the required voltages to be applied at the electrodes located at the periphery of the device. The applied voltages generate EOF in the device that imparts a velocity to the nano-object that corrects this deviation and steers it along a desired trajectory in a 2D plane.

In Fig. 1, we show a series of snapshots that demonstrate flow-based control of a single fluorescently labeled SU-8 rod (10 μm x 1 μm) as it is held at a fixed location while simultaneously being rotated by 90 degrees. Our ability to control the orientation of the particles is limited by rotational Brownian motion which scales inversely as the cube of the particle length. For the rods used in these experiments, we were able to rotate the rod by 90 degrees within 6 s when its center of mass was fixed using a control update rate of 30 Hz. The rod can also be translated along a desired path at a velocity of 10 μm/s, while being simultaneously rotated.

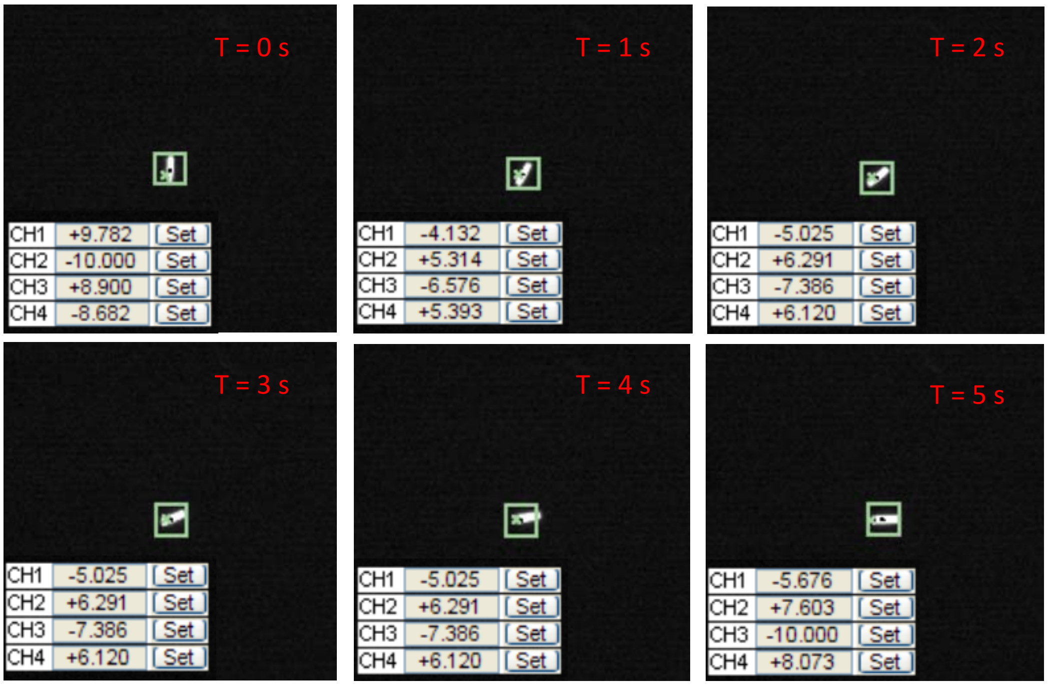

Figure 1: Six snapshots showing the position and orientation of a single fluorescently labeled SU-8 rod (10 microns long, 1 micron wide) being controlled in a 2-D plane by electro-osmotic flow control. The center of mass of the rod is controlled to be trapped at a fixed location while its orientation is simultaneously being controlled to rotate by 90 degrees within 6 s. The flow generated by the four control voltages (shown in the inset of each snapshot) compensates the random translational and rotational Brownian motion that perturbs the rod as well as rotates the rod in place.