**Summer Vacation Scholarship 2008-09**

**Optical Tweezers: Hydrodynamics near interfaces**

*with Assoc. Prof. E.M. Sevick and Polymers & Soft Condensed Matter Group, RSC*
*project suitable for student interested in experimental physics/ physical chemistry*

Optical Tweezers (OT) is a relatively new device, promoted as a tool for nanotechnologists, biologists and clinicians. In OT, a strongly focussed beam of light forms a trap that holds a small colloidal particle. The trap is a result of the refraction of light through the micron-sized particle. The refracted rays differ in intensity over the volume of the particle and the change in the momenta of the photons upon refraction gives rise to a piconewton–scale force (1 pN = $10^{-12}$ N) on the particle, drawing it towards the region of highest light intensity (Fig. 2). By translating the focal point of the light, trapped objects can be moved and sorted. This tool is popularly used as an optical scalpel to dissect delicate parts of biological objects, such as the lining of ovum in clinical *in vitro* fertilization procedures, and is a highly sought after tool in biological, medical, and clinical laboratories. The OT can also be used to measure very small, piconewton-scale forces, and this provides opportunities to solve a number of important problems in physical sciences. Such harmonic traps have been used to measure attractive forces between like–charged colloidal particle and to demonstrate new theorems in non-equilibrium statistical mechanics.

The OT is also the device of choice in the field of **microrheology** which studies how complex materials store and dissipate mechanical energy. The fluctuations of the particle in the optical trap depend sensitively upon the surrounding fluid properties (such as the viscoelastic modulii). In microrheology, the surrounding material is characterised by analysis of the particle's fluctuations. A current emphasis is to relate these measurements to the microstructure of complex fluids, including polymer, colloids, and biological assemblies. OT has the additional benefit that the probe particle can be micro-positioned within small fluid volumes, so that fluids in micro-containers, such as cells, can be rheogically measured. **However, miniaturisation of fluid vessels means that the vessel walls become important, and this requires that we consider the hydrodynamic interactions between the probe particle and the soft container walls.** This consideration has not yet been made.

It is well known that a colloidal particle diffusing near a rigid surface experiences an increase in drag forces as it approaches the surface. This effect is due to hydrodynamic interactions with the hard wall: the particle motion causes a "wake" which is reflected off the rigid surface, further perturbing the particle motion. The Polymers & Soft Matter Group in RSC at ANU has developed a method to use OT to measure the drag on a particle that is optically trapped near an interface. (This summer vacation program project will apply this experimental method to interfaces of increasing complexity, and coincide with on-going projects within the group. )

Our aim is to use this OT method to probe model soft interfaces, such as phospholipid bilayers and ultra-low surface tension interfaces generated in polymer/colloid solutions, where the motion of the colloid and surface are coupled. The particle creates a local flow field which imposes a stress on the soft surface, and the surface then deforms in response. When the surface deformation relaxes, the "rebound" results in a back-flow which modifies the colloidal particles Brownian fluctuations. For liquid-liquid interfaces, these deformations relax at a time scale proportional as $\gamma^{-1/2}$, where $\gamma$ is the surface tension coefficient. For typical interfaces, $\gamma \sim \mathcal{O}(10^2)$ mN/m, and the relaxation time is of the order of milliseconds. In contrast, in ultra-low surface tension interfaces, where $\gamma$ is a million times smaller than normal liquid-liquid interfaces, elastic surface deformations persist over time scales of the order of seconds. Hydrodynamic interactions can lead to counterintuitive particle motion near these soft interfaces. For example, in the case of ultralow surface tension interfaces, the liquid-liquid interface can deform over several microns and the particle is actually accelerated towards the soft surface, in contrast to a particle ap- proaching a rigid wall. Such hydrodynamic interactions might explain the dynamics of macromoleuclar absorption or docking on biomembranes: hydrodynamic interactions may well facilitate membrane approach and counter conservative interactions, including repulsive electrostatic interaction. Many of these predictions have not however been tested experimentally.