PSD-based optical tweezers sense smallest forces in nature

Adhesion processes in biological systems involve very delicate forces. To study these forces, at a single molecule level, instrumentation that can sense pico Newton (10^{-12} N) forces is required. Laser aided micromanipulation, i.e. force measuring optical tweezers, has turned the microscope from a passive observation device into an active manipulation tool that allows for both manipulation of micrometer-sized objects with nm resolution and force measurement with sub-pN resolution.

Optical tweezers are a technique in which microscopic-sized particles, including living cells, bacteria and various types of semi-transparent objects, can be non-intrusively trapped with high accuracy solely using focused light. In addition, the technique provides outstanding manipulation possibilities of the trapped objects. Optical tweezers can also measure minute forces ($< 10^{-12}$ N), probe molecular interactions, including their energy landscapes, and apply both static and dynamic forces in biological systems, including individual macromolecules, in a controlled manner (Fig. 1). The assessment of intermolecular forces with force measuring optical tweezers (FMOT), and thereby the biomechanical structure of biological objects, has therefore considerably facilitated our understanding of interactions and structures of biological systems.

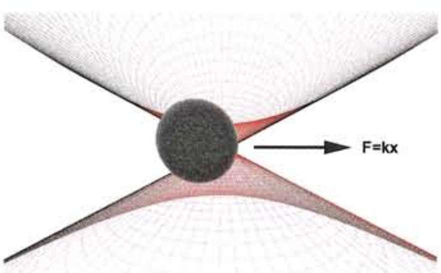

Figure 1. Illustration of a particle close to the focus of the laser beam. The restoring force is proportional to the displacement.

Optical tweezers have therefore become a powerful tool in the field of biophysics.

The restoring force of an optical trap increases with the deflection, wherefore the deflection of an object is a direct measure of the applied force. Deflection of the object can be monitored by a weak probe laser. The trapped object in combination with the condenser of the microscope act as an image system that magnifies the movement of the trapped object ~1000-fold (Fig. 2).

Monitor the smallest forces in nature

The use of SiTek 2L20 PSD, with its good position resolution and excellent linearity, for measurement of the deflection of the HeNe laser light, and thereby the trapped object, allows for nm resolution position tracking and sub-pN force probing.

The force resolution is more than 10 times better than the best AFM (Atomic Force Microscopy) systems and can monitor the smallest forces in nature, i.e., those due to thermal fluctuations. The technique thus allow for monitoring of the smallest relevant forces in biological systems.

The optical tweezers group at Umeå University has developed and applied the FMOT technique on adhesion organelles (so called pili) expressed by uropathogenic Escherichia coli.

Their research has among other things revealed the detailed biomechanics of the pili that help the bacterium to sustain the natural rinsing action of the urine flow, mechanisms that can be a possible target for new anti-bacterial drugs.

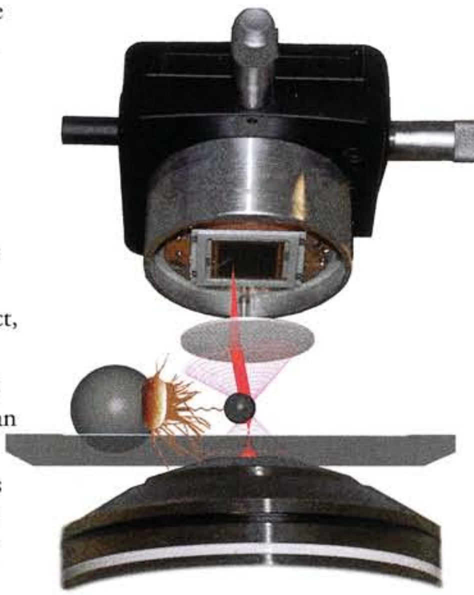

Figure 2. Illustration of the force measurement system. The biological system under investigation, a urinary tract bacterium expressing pili, is mounted on a functionalized 9 μm bead attached to the cover slip. The force is applied to a probe bead, attached to an individual pilus, via a highly focused IR laser, and monitored by a weak probe laser and a Position Sensing Detector (SiTek 2L20).

For more information: http://www.phys.umu.se/exphys/OpticalTweezers/