Optical Trapping for Biological Instrumentation Teaching Laboratories

David C. Appleyard[1], Hyungsuk Lee[2], Kelsey Y. Vandermeulen[3], Peter Lee[1], Matthew J. Lang[1,2]

[1]Biological Engineering, [2]Mechanical Engineering, [3]Materials Science, Massachusetts Institute of Technology

Optical trapping has become a powerful tool for probing the biomechanics of single molecules and cellular structures. Bringing optical trapping technology to the classroom offers exceptional hands-on exposure to advanced instrumentation and assays. We have designed an economical optical trapping system, costing less than $12,000, which has a simple layout and maintains functionality for a great variety of experiments. The instrument features a quadrant photo diode and computer controlled stage movement to allow for comprehensive stiffness calibration. The instrument is also capable of fluorescence imaging with a 532nm laser and has been used to visualize individual microtubules. With these components, our design has demonstrated nearly 6nm position resolution and can produce a trap stiffness of 0.07pN/nm. In addition, core laboratory modules have been developed to expose students to optical trapping measurements. A calibration experiment serves to introduce the instrument by examining trapping theory and characterization of trap stiffness through equipartition, Stokes drag, and roll off measurements. An assay examining the flagellar motor output of *E.coli* permits measurement of the rotation speed and stall torque. A traditional tether stretching module studies the force – extension relationship of double stranded DNA to extract persistence and contour lengths. Five instruments have been constructed and applied successfully in an undergraduate laboratory course.