Abstract

The aim of this thesis is to construct a dual optical tweezer setup and use it to investigate the small length scale properties of various soft materials. A dual optical tweezer has been built and then calibrated for measurements of microrheological properties of soft materials. This setup has been used to investigate the rheology of regenerated silk fibroin solution of Tasar silk. The techniques of microrheology are extended to investigate active suspensions of live bacteria and are developed further, to quantify the antimicrobial action of silver nanoparticles. The emphasis of the studies is then shifted to addressing certain physical aspects of laser tweezers: Asymmetric shaped microscopic objects show rotations on being optically trapped. These rotations have been characterized and experimental results have been modeled by considering effects of hydrodynamics on the rotor. The setup is modified for simultaneous forward and back scattering detection to look at the situation wherein multiple particles are trapped in a single beam tweezer. The modified setup enables one to investigate the bead pair coupling with the optical field.

Chapter 1: This chapter provides a brief introduction to soft materials and properties of soft materials. Different techniques employed to characterize soft materials are also described in detail.

Chapter 2: This chapter describes the theory of optical tweezers both in Mie and Rayleigh regime. The design and construction of a dual optical tweezer is explained in detail with schematic of the setup. Various components required for the construction of optical tweezer and interfacing them to a PC are described in detail. Tracking of position of a trapped bead using quadrant photo detectors and displacement power spectrum analysis is described with relevant theory.

Chapter 3: Calibration of an optical tweezer setup for microrheological studies using water for both video microscopy and optical tweezer based techniques is detailed here. Further, a study on the rheological behavior of regenerated silk fibroin solutions of Tasar silk is described in detail and the results are compared with similar studies on mulberry silk based RSF to investigate the gel forming propensity of Tasar RSF.

Chapter 4: Results on microrheological properties of bacterial suspensions and bacterial activity as a function of cell concentration is described here. Bacterial activity is
quantified by a term called Activity Factor, which is defined as the ratio of power spectral density of the trapped bead in active bacterial suspensions to that of trapped bead in inactive bacterial suspensions at the same cell counts. We have observed an increased activity factor with increase in concentration of the bacteria. Modeling of power spectral density of a trapped bead in presence of active bacteria using Langevin equation is explained here. Measurement of collective bacterial kicking force based on the model is given here. In addition, tweezer based characterization of agro bacterial growth and the antimicrobial effect of silver nano particles on bacterial suspensions are discussed in detail.

Chapter 5: Torque generation on a trapped asymmetric micro particle is discussed briefly. Characterization of such microrotors based on power spectral density measurements using video microscopy analysis as well as quadrant photo detector based detection technique is explained here. The measured PSD turns out to be the expected modified Lorentzian, but with the additional peaks at integer multiples of the fundamental frequency of rotation. We have modeled this PSD using a modified one dimensional Langevin equation. Our model fits the experimentally observed data. Torque exerted on the trapped bead is determined and explained briefly. Measurement of rotational frequency of a low reflection biological entity such as a trapped rotating RBC is also explained using video microscopy.

Chapter 6: Tracking of trapped beads using simultaneous forward and back scattering techniques in an optical tweezer is demonstrated. When a pair of trapped beads is characterized through forward and back scattering techniques, they show different trap stiffnesses. An explanation for this is given. Analysis on a pair of trapped beads in single beam tweezer through correlation coefficient measurement between two trapped beads’ displacements, detected via forward and back scattering techniques is also presented here.

Chapter 7: This chapter summarizes the conclusions drawn from this work and also provides a brief outlook for future work.