Chapter 7
Conclusions and Outlook

Optical tweezer is a robust tool for characterizing properties of soft materials at micro and nano meter length scales. The conventional way of measuring rheological properties of soft materials, via a rheometer, is limited to a narrow bandwidth and is disadvantageous when the available sample volumes are small or in scarce supply. Optical tweezer based technique provides an option to measure the properties over several MHz and only few micro liters of the sample is required for the measurement.

Understanding the dynamics of microorganisms and its role in changing the microrheological properties of the medium of suspension is a challenging task for a soft matter physicist. Changes in the microrheological properties of the medium due to dynamics of the microorganisms fall in the non linear regime and can lead to a violation of the fluctuation dissipation theorem. We have made an attempt to study the rheological properties of active systems under the linear regime, i.e., low concentration of the active microorganisms; this initial attempt can open up new arenas for further studies.

Analysis of power spectral density of the trapped bead in the presence of external force other than thermal force offers new methodologies to characterize the active response of the media to the applied forces. For example, in our study, power spectral density analysis has been used to characterize the activity of the bacteria as a function of concentration, antimicrobial activity of foreign bodies in the medium and active agro bacterial behavior of different bacterial strains. The initial methodology shown in this thesis can be improved and may have implications to medical diagnostics.

Rotation of microscopic particles in an optical trap takes place due to several reasons. One of the main reasons is the structural asymmetry present in the trapped body. Because of the interplay between an asymmetric rotor and the surrounding medium, rotations become irregular but however, show periodicity. Power spectral density analysis of the trapped rotating micro bead provides information of irregularity present in the rotation and also helps to characterize the possible hydrodynamic interplay between the rotor and the medium in altering the regular rotations of the trapped rotor. A detailed analysis has been made in the thesis based on the rotation frequency and peak heights with increase in frequency of the rotor. Further analysis can lead to developing methods
for precise characterization of a rotor in the media and understanding of microhydrodynamics in the system.

When working with dense colloidal suspensions in an optical tweezer, one often ends up trapping more than one particle at a time. We conclude from our observations that the trap is more stable for two beads than for traps with more than two particles. Understanding the interaction between trapped micro particles in a single tweezer is a big challenge. We have made an attempt to understand the interaction between micro particles trapped simultaneously in a conventional laser tweezer by monitoring the positions of the two trapped micro particles and subsequently calculating the positional correlation coefficients.

In directions that enlarge and extend the scope of the work carried out as described earlier, we have initiated further work related to the problems addressed in this thesis:

Absorption of light energy by trapped objects results in melting of the micro objects and thus leads to the formation of micro bubbles. Further heating leads to convection of heat in the medium, called Marangoni convection. Marangoni convection of heat in a laser trap results in attraction of surrounding particles to the epicenter of the convection with a greater speed. It is looked upon as hot micro vortices in the medium attracting the surrounding stuff in a destructive manner. Understanding this micro vortex dynamics may throw a light on vortex formations and their dynamics in nature.

We know that microorganisms like bacteria are very sensitive to any sudden change in the surrounding environment; they respond to such changes in an immediate manner. We have come across pattern formation in bacterial suspensions around the heated spots. Investigations on the nature and dynamics of such patterned structures and their implication to the local rheology of the medium is an area that has not been addressed so far to the best of our knowledge, and can yield rich dividends.

Rotation of non-symmetric rigid objects has been discussed in chapter 5. Rotation of non rigid objects like blood cells are influenced by several factors, namely, the inherent birefringence, form birefringence, structural asymmetries present in the material and asymmetry in the trapping beam itself. Understanding non rigid body dynamics is a challenging task that it has opened many avenues of research. Rotation and orientation dynamics of RBCs in an optical tweezer is a current topic to the research community all over the world for the better understanding of RBCs and other cells, particularly, in
gaining a better understanding of the membrane morphological changes that accompany such movement.

Quite often, optical tweezezing with dense colloidal suspensions leads to the trapping more than one particle in a single beam optical tweezer. A trap containing two particles is more stable than traps consisting of more than two particles. Theoretical and experimental studies on inter particle interactions throw light on the understanding of many interesting phenomena in the field of colloids and interfaces. In this regard, viscosity dependent interaction between the particles, modulation in the interactive forces, etc., are interesting topics for the further studies.