Abstract
There has been a surge of interest in recent years to design and fabricate various
kinds of motile micro/nanoparticles that can be maneuvered using chemical, optical,
thermal, electrical or magnetic energy sources. A collection of such motile particles can be
used as a model system to study various active matter phenomena, which can answer
fundamental questions related to non-equilibrium statistical physics. This motile micro/Nano
system can also be important in various biomedical applications like targeted drug delivery,
microsurgery, biochemical sensing and disease diagnosis. Among several actuation schemes,
magnetic actuation deserves a special mention owing to its non-invasive and non-chemical
mode. In this thesis, micron sized helical structures have been fabricated, which are rendered
magnetic by a thin coating of magnetic materials and actuated by rotating _led. Using this
system, a study on generalized dynamics of elongated structures has been done, which is also
supported by analytical theory and numerical calculations. Both experiments and numerical
simulations show the existence of multiple cut-o_ frequencies related to the stability of
different dynamical modes of an elongated structure, whose analytical expressions have been
derived in the present work. Despite the observation of rich dynamical comigrations, the _led
dependent directionality of this mode of actuation by rotating _led fails to qualify the
experimental system as active matter, thus hinders the possibility of using it as a model
system to study a wide variety of phenomena like pattern formation in swarm motion,
synchronization, etc. In this thesis, a different actuation technique has been demonstrated,
which decouples the directionality from the applied external _led, thus enabling the helical
micro swimmers to propel in any direction. The system presented here is the rest
experimental demonstration of magnetically actuated active matter system, where the helical
structures show back and forth motion in a random direction, thus resembling a reciprocal
swimmer and shows enhanced disutility in accordance to earlier theoretical predictions. We
further extended this idea to report how the same actuating _led used for reciprocal motion
can be tuned to break the temporal symmetry to design a non-reciprocal swimmer. The
actuation principle is based on the idea of Brownian Motor, where the reciprocity is broken
using asymmetric _led pattern and incorporating thermal actuations into the system. A
detailed numerical study of the dynamics of the system is reported here which sets the criteria
to build a system with optimal performance where tuning from reciprocal to non-reciprocal
actuation can be achieved in a simple manner. In a related project, we report an actuation
scheme to manoeuvre geometrically identical nanostructures in different directions, and
subsequently position them at arbitrary locations with respect to each other. In comparison
to the other techniques where controlling the directionality and actuation are powered by
separate energy sources, the experiment reported here shows how these two factors can be
controlled only by magnetic _ends. The technique shown here requires proximity of the
nanostructures to a solid surface and is applicable for independent positioning of any number
of micro/nanobots; thus, can be useful in applications that require remote and independent
control over individual components in micro/molar environments. Finally, we report couple of
experimental techniques to study the hydrodynamic interactions between helical swimmers.
In one of the techniques, we investigate possibility of synchronization between two rotating
helical swimmers at low Reynolds number conditions. In the other technique, we discuss
different ways to study motion of a collection of magnetically actuated helical swimmers. The
methods presented here show different fabrication schemes that are useful to avoid magnetic
agglomeration. The preliminary experiments reported here can be useful to study the
behaviour of a collection of magnetic swimmers coupled via hydrodynamic interactions.