Contractile actuation and dynamical gel assembly of paramagnetic filaments in fast precessing fields

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Paramagnetic beads are highly attractive bases for dynamic materials due to the relative ease and precision with which researchers can control magnetic fields in many media. One-dimensional (1D) chains of magnetic colloids, or magnetic filaments, are of particular interest on account of their rich behavior arising from the interplay of their elastic and magnetic properties. Chain synthesis techniques have advanced steadily over almost two decades, and a wide variety of bead-linking methods are now available to scientists Most work to date has focused on static or relatively slow field changes with single filaments. Here, we focus on exploiting dynamic effects common to many types of filaments in order to produce desired behaviors. In the case of single filaments under fast precession, we find that for large precession angles the filaments naturally form helices with harmonic potentials. These helices can be used for well-controlled contraction at the microscale. For multichain ensembles, we show that aggregation behavior is a function of two effects.
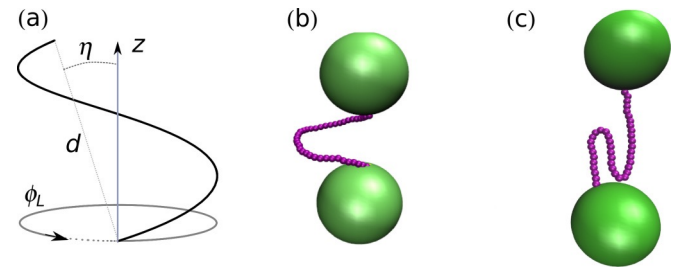

Figure. Helical contraction. (a) Schematic of the boundary conditions on a contracting helix. (b) Frame from MD simulation using LAMMPS with a 40-bead magnetic filament connecting two inert test masses. Under the influence of a precessing field with M >0, the helix attempts to contract to the x-y plane. Here = 40, µ2σ −3 = 4kT , and β = π/2. (c) IfM <0, the filament attempts to align with the z axis and forms planar solutions. Both bending and magnetic energy costs are localized to hairpin turns, so the state is metastable.

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