Magnetocapillary self-assemblies: Swimming and micromanipulation

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Microswimmer

Simple microswimmers are created using floating steel spheres. Magnetic and capillary interactions cause the particles to self-assemble. Magnetic oscillations generate motion. Three in-line spheres behave like the Najafi-Golestanian swimmer [1]. Speed is proportional to the cycle described by the two elongations. A spring model gives predictions.

Micromanipulator

Different kinds of structures can be built for different purposes. Triangular swimmers are faster (~100 µm/s) and controllable [3]. Larger swimmers can transport cargo. Rotating swimmers generate local mixing at low Reynolds number.

Remote-control

Triangular swimmers: Can reach higher speeds, above 100 µm/s. Can be finely controlled by rotating horizontal field $B_x(t)$.

Cargo transport

Floating objects are captured through capillary interaction. Transport can be achieved. The cargo can be released using a magnetic field gradient.

Mixing

Micromixing relies on diffusion instead of convection. The goal is to maximize the contact area between the fluids. In a rotating field, we can swirl fluids together, enhancing diffusion.

Acknowledgements

Financially supported by the FNRS (PDR T.0043.14) and the ULg (FSRC 11/36). GG thanks FRIA for financial support. GLa was financed by the ULg and the E.U. through MSCA-COFUND-BelIPD.

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References


Results and model

A sinusoidal field $B_x(t)$ generates deformations and motion. The magnetocapillary interaction acts as a spring force [2]. Using spheres of different sizes allows to have different spring constants.

Speed is maximal close to the spring's resonance. It is proportional to the area enclosed in the trajectory described by the elongations. A linear spring model predicts the speed profile accurately, analytically, and with no adjustable parameter [1].

Setup

Three steel spheres float on a water bath. Surface curvature induces an attraction. Coils generate magnetic dipolar attractions and repulsions.

0 turns ~8 turns CW ~8 turns CCW

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