Assembly of Microparticles and Composite Materials Under Combined Electric and Magnetic Fields

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Background

Asymmetric, magnetic dimers show good potential for being used as the building blocks for micro-robots. The unbalanced electrohydrodynamic (EHD) flow surrounding these dimers causes linear and circular motion.

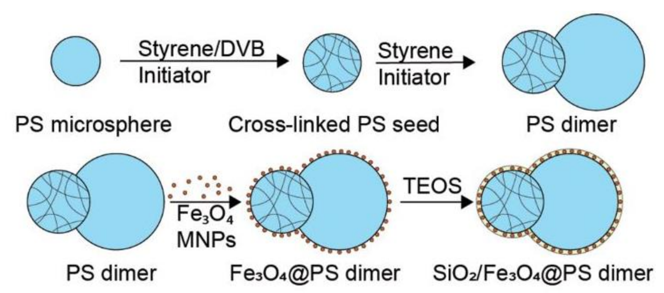


Figure 1. Synthesis of magnetic dimers used for robots.

By tuning the zeta potential of the dimers, as well as the magnitude and frequency of both the electric and magnetic fields that create the EHD flow, we can control the dimers such that their behavior matches that of a micro-car, which is necessary for cargo delivery and other applications.

Research Goals

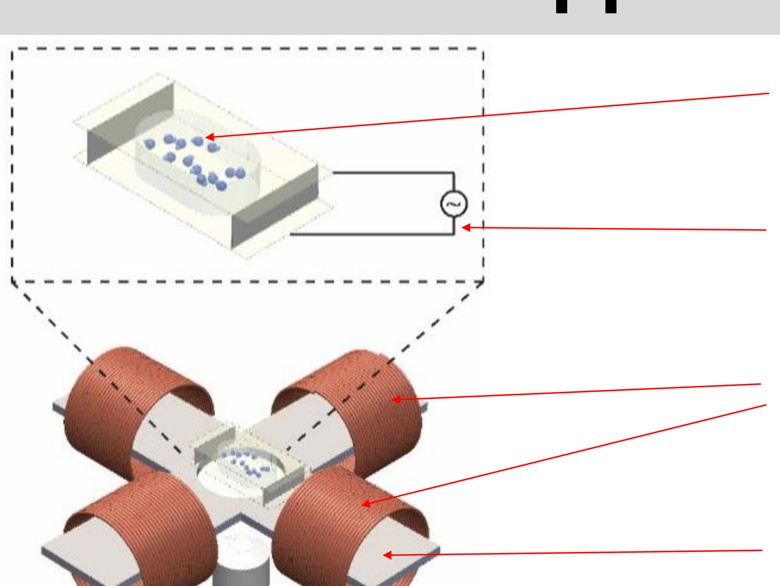
(1) Synthesize stable, functional magnetic dimer particles

(2) Determine the relationship between the applied magnetic frequency and the rotational frequency of the dimers

(3) Accurately control the motion of the magnetic particles using computational trajectories

(4) Test different kinds of magnetic-electric field combinations in order to manufacture unique motion

Apparatus



Results

Determining critical rotation frequency for magnetic fields

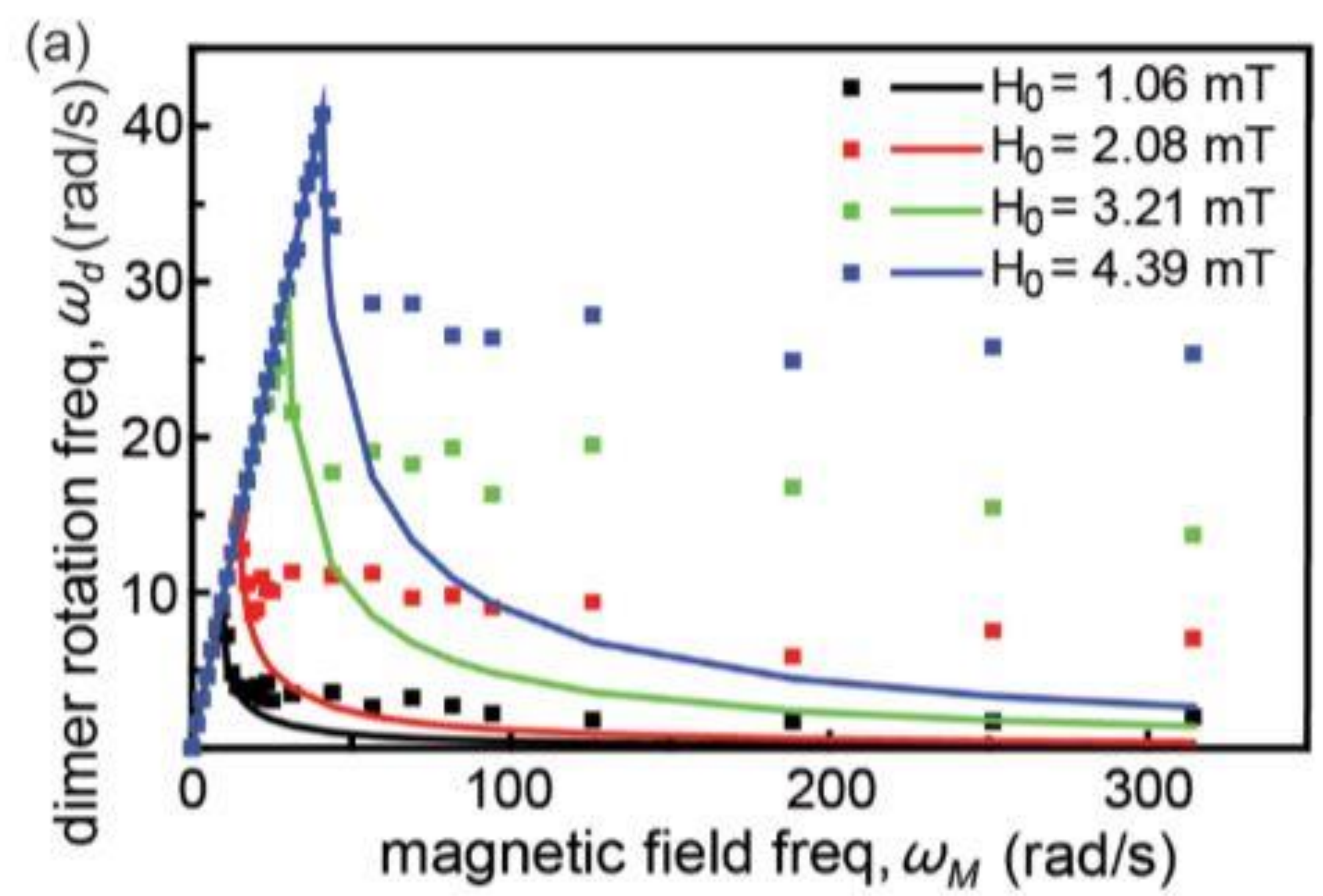


Figure 2: Rotational frequency of dimers versus the frequency and strength of the applied magnetic field. Note the different in theoretical versus experimental rotation speed at high magnetic frequencies, caused by the phase lag between the induced dipoles.

Trajectory-tracing using dynamic electric/magnetic fields

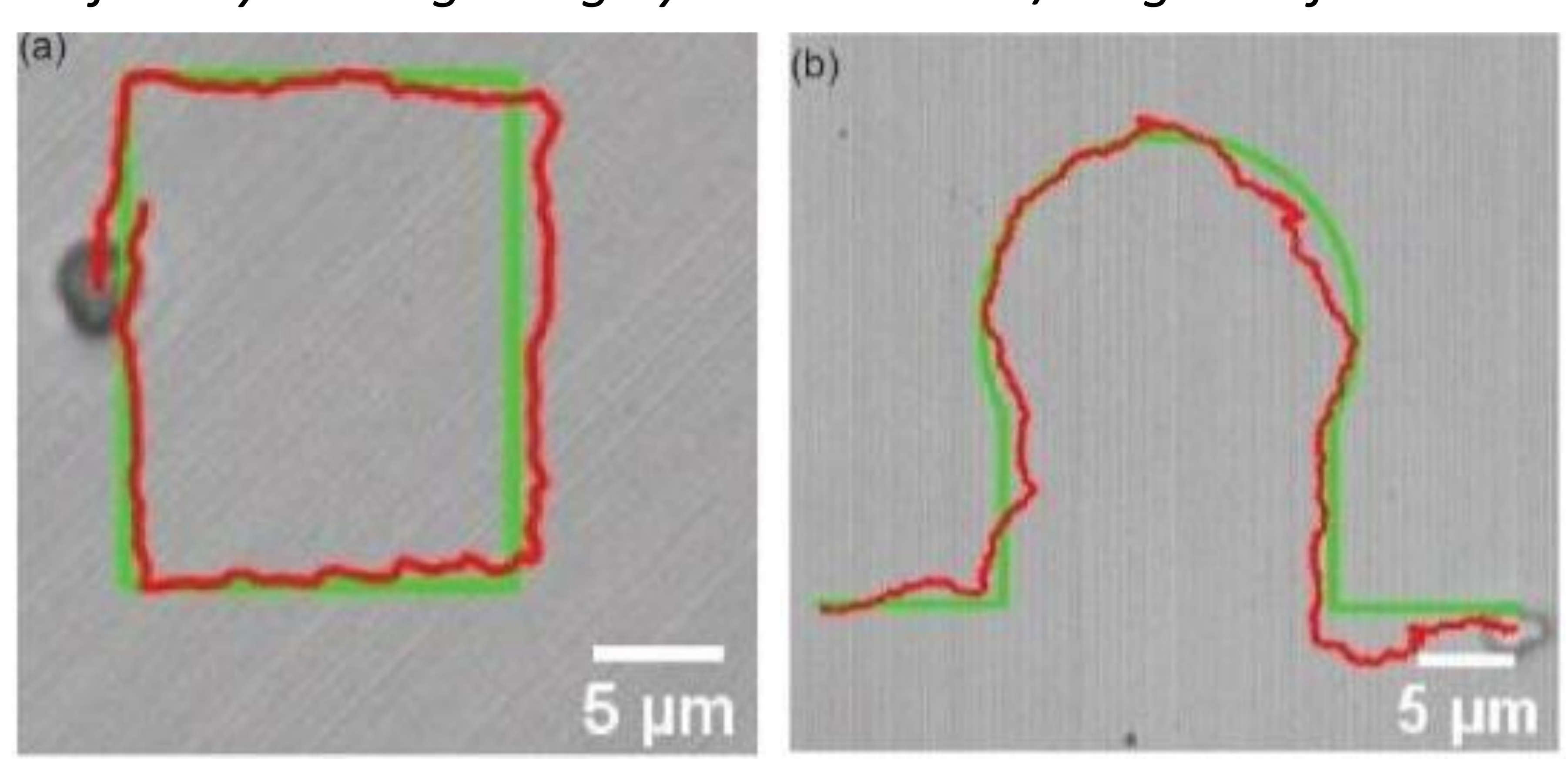


Figure 3: (a) The rectangular-shaped trajectory of a dimer drawn by combined fields (8 V pp , 400 Hz electric field and 1.1 mT DC magnetic field).
(b) The omega-shaped trajectory of a dimer drawn by combined fields (12 V pp , 1,000 Hz electric field and 1.1 mT DC magnetic field). The red lines are the particle's actual trajectory, and the green line is the trajectory intended by the programmed magnetic and electric field.

Conclusions

- Our method for synthesizing magnetic dimers return particles that repeatedly respond to magnetic and electric field manipulation
- Our experimental results for the critical rotational frequency of the dimers matched the expected models we ran prior to testing.
- We have demonstrated a method for controlling the motion of anisotropic particles in a precise and accurate manner
- Using these methods, the dimers could be used for colloidal assembly, micromachines, and cargo delivery.

Future Work

- Synthesize magnetic dimers with fewer impurities in a repeatable process
- Continue testing different electric/magnetic field combinations in order to find unique motion
- Use methods from this project and apply them to creating crystalline structure inside of wedge device using PS particles and Dynabeads

Selected References

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[2] Ma, F.; Wang, S.; Wu, D. T.; Wu, N. Electric-Field-Induced Assembly and Propulsion of Chiral Colloidal Clusters. Proceedings of the National Academy of Sciences of the United States of America 2015, 112, 6307–6312.

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