Complex Magnetic Fields Breathe Life into Fluids

James E. Martin and Kyle J. Solis

Sandia National Laboratories, Albuquerque, New Mexico, USA

jmartin@sandia.gov

There are many areas of science and technology where being able to generate vigorous, *noncontact* flow would be desirable. We have discovered that three dimensional, time-dependent electric or magnetic fields having key symmetries can be used to generate controlled fluid motion, Fig. 1, by the continuous injection of energy [1-7]. Unlike natural convection, this approach does not require a thermal gradient as an energy source, nor does it require gravity, so space applications are feasible. The result is a highly active material we call a *vortex* fluid. The homogeneous torque density of this fluid enables it to climb walls, induce ballistic droplet motion, mix vigorously, even in such complex geometries as porous media, and effect highly efficient heat transfer. This vortex fluid can also exhibit a *negative* viscosity, which can immeasurably extend the control range of the "smart fluids" used in electro- and magnetorheological devices and can thus significantly increase their performance. Because the applied fields are uniform and modest in strength, vortex fluids of any scale can be created, making applications of any size, from directing microdroplet motion to controlling damping in magneto-rheological dampers that protect bridges and buildings from earthquakes, feasible. Finally, we will demonstrate that such fields can animate fluids in remarkable ways that resemble living systems.
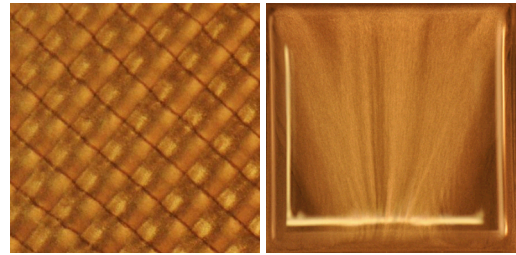

Figure 1. A vortex lattice and fluid vorticity created by multiaxial fields.

Acknowledgments

References

[1]   Martin, J. E. (2009) *Phys. Rev. E* **79** 011503.

[2]   Martin, J. E., Shea-Rohwer, L., Solis, K. J., (2009) *Phys. Rev. E* **80** 016312.

[3]   Solis, K. J., Bell, R. C., Martin, J. E., (2010) *J. Appl. Phys.* **107** 114911.

[4]   Solis, K. J., Martin, J. E., (2010) Appl. Phys. Lett. **97**, 034101.

[5]   Solis, K. J., Martin, J. E., (2012) Soft Matter **8**, 11989.

[6]   Solis, K. J., Martin, J. E., (2012) *J. Appl. Phys.* **112**, 049912-7.

[7]   Solis, K. J., Martin, J. E., (2013) Soft Matter **9**, 9182-9188.

[8]   Martin, J. E., Solis, K. J., (2014) Soft Matter **X**, XXXX.