DY 26: Ferrofluids / Liquid crystals

Time: Thursday 10:30–13:00 Location: H3

DY 26.1 Thu 10:30 H3

Localized and Decomposable States at the Rosensweig Instability — •Reinhard Richter — Experimentalphysik 5, Universität Bayreuth, D-95444 Bayreuth

Recently it was demonstrated in experiment [1] and numerics [2] that two-dimensional static localized structures can be generated in the bistable regime of the Rosensweig instability by means of a local perturbation. Here we investigate whether these *ferrosolitons* are decomposable [3], in the sense that packets of bumps or holes can be created at will. Moreover we show for the first time that information can be stored in the decomposable pattern without any extrinsic grid, as suggested by [4].

- [1] R. Richter, I.V. Barashenkov, Phys. Rev. Lett **94** , 184503 (2005).
- [2] O. Lavrova, G Matthies, T. Mitkova, V. Polevikov and L. Tobiska, J. Phys.: Condens. Matter **18**, S2657 (2006).
- [3] P. Coullet, C. Riera, C. Tresser, Phys. Rev. Lett. **84**, 3069 (2000).
- [4] P. Coullet, C. Toniolo, C. Tresser, Chaos, **84** 193 (2004).

DY 26.2 Thu 10:45 H3

Structure formation in ferrofluid monolayers-I: Simulations. — •Juan J. Cerda[1], Sofia Kantorovich[2,3], and Christian Holm[1,2] — [1]FIAS, Frankfurt am Main, Germany — [2]MPI-P, Mainz, Germany — [3]Ural State Univ., Ekaterinburg, Russia

Molecular dynamics (MD) is used to study thoroughly the microstructure formation of monodisperse and bidisperse ferrofluid monolayers. Long-range dipolar interactions are computed using a recently developed dipolar-P3M-layer correction algorithm. In comparison to the traditional Ewald sum methods, this approach allows to handle and characterize larger systems. An extensive comparison with theoretical density functional theory, and experimental results from in situ cryogenic tansmission electron microscopy [Klokkenburg et al., PRL 97,185702,(2006)] will be also presented.

DY 26.3 Thu 11:00 H3

Structure formation in ferrofluid monolayers-II: Theory. — •Sofia Kantorovich[1,3], Joan Cerda[2], and Christian Holm[2,3] — [1]Ural State University, Ekaterinburg, Russia — [2]Frankfurt Institute for Advanced Studies, Frankfurt, Germany — [3]Max Planck Institute for Polymer Research, Mainz, Germany

Due to specific interactions inherent to single domain ferroparticles in magnetic fluids complex nanostructures might exist in ferrocolloids. Unfortunately the particle size and the optical properties of carrier liquids make the natural studies of the aggregation processes in 3D samples difficult, but it is possible to use cryo-TEM in 2D (in monolayers) [Klokkenburg et al., PRL 97, 185702, (2006)].

Here we present theoretical investigation of the mono- and bidisperse ferrofluid monolayers. We allow for the probability of chains and rings coexistence in the thermodynamic equilibrium at room temperatures. Predictions obtained via the theoretical density functional approach are extensively compared to simulation data and experimental results of Klokkenburg et al.

DY 26.4 Thu 11:15 H3

Maximal growth rate at the Rosensweig instability — •Adrian Lange[1], Holger Knieling[2], Gunar Matthies[3], Ingo Rehberg[2], and Reinhard Richter[2] — [1]Fraunhofer Institut für Werkstoff- und Strahltechnologie, Winterbergstraße 28, D-1277 Dresden — [2]Experimentalphysik V, Universität Bayreuth, D-95440 Bayreuth — [3]Ruhr-Universität Bochum, Universitätsstraße 150, D-44780 Bochum

Instabilities in magnetic fluids (MFs) have had a long history with the most eye-catching phenomenon being the Rosensweig instability [1]. When a critical value B_c of the vertical magnetic induction is surpassed, static liquid peaks arranged in a hexagonal pattern are rising on the free surface of the fluid. A linear description of the Rosensweig instability is amenable in theory, but restricted to small amplitudes. In experiments they can be observed only for a very short time during the increase of the pattern of ridges, which bifurcate supercritically. Thus a new pulse technique has been developed and applied [2,3]. It is assumed that in the linear state of the pattern forming process the wave number with the largest growth rate will prevail. This contribution is devoted to present theoretical, experimental, and numerical results for the maximal growth rate for two different MFs. The results show that the experimental and numerical data agree satisfyingly whereas the theoretical data show a sizeable disagreement.

[1] M. D. Cowley, R. E. Rosensweig, J. Fluid Mech. **30**, 671 (1967).
[2] A. Lange, B. Reimann, R. Richter, Phys. Rev. E **61**, 5528 (2000).
[3] B. Reimann, R. Richter, I. Rehberg, A. Lange, Phys. Rev. E **68**, 036220 (2003).

DY 26.5 Thu 11:30 H3

Pattern Formation in Isotropic Ferrogels - Nonlinear Analysis Using the Energy Method — •Stefan Bohlius[1], Harald Pleiner[1], and Helmut Brand[2] — [1]Max Planck Institute for Polymer Research, 55021 Mainz, Germany — [2]Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth, Germany

Ferrogels are chemically cross-linked polymer networks that are generated using a ferrofluid as a solvent. Just as ferrofluids, ferrogels undergo an instability from an initially flat surface to a stationary spike structure, if an external magnetic field applied perpendicular to the surface exceeds a certain critical value. In the case of isotropic ferrogels this critical magnetic field is enhanced by the shear modulus of the network. The wavelength of the critical mode, however, does not change with respect to usual ferrofluids at the onset of the instability.

For a nonlinear discussion of this instability, we extend the previous discussions for magnetic fluids of Gailitis and Friedrichs and Engel, who used an energy minimizing method, to media with elastic degrees of freedom. In addition to the known surface energy density of ferrofluids we add the contribution due to elasticity.

Stripes turn out to be never stable with respect to one of the other two regular patterns. At the linear threshold the flat surface transforms into hexagons. This hysteretic region of this transition shrinks with increasing shear modulus. For higher magnetic fields the hexagonal pattern becomes unstable in favor of squares. Also this transition shows a hysteresis for the back transformation to hexagons. With increasing shear modulus this hysteretic region shrinks.

DY 26.6 Thu 11:45 H3

The deformation of a ferrogel in uniform magnetic fields — •Christian Gollwitzer[1], Alexander Turanov[2], Marina Krekhova[3], Ingo Rehberg[1], Günter Lattermann[3], and Reinhard Richter[1] — [1]Experimentalphysik V, Universität Bayreuth — [2]Zavoisky Physical-Technical Institute. KSC, RAS, Kazan, Russia — [3]Makromolekulare Chemie I, Universität Bayreuth

Ferrogels are an interesting new class of materials that enhance the properties of magnetic fluids by elastic components. Ferrogels are able to exert forces when exposed to magnetic field gradients [1]. But also in homogeneous fields there can be shape changes, albeit much smaller ones. This has been predicted already by Landau [2] for the case of a sphere. We expose a sphere of a thermoreversible magnetoelastic material [3] to a homogeneous magnetic field and observe the elongation laterally with a highspeed camera. To compensate the deformation of the sample under gravity, we immerse it into water. We compare the outcome of this magnetic stress experiment to mechanical creep experiments and to the theoretical predictions by Landau [2] and Raikher [4].

[1] Zrinyi, M., Barsi, L., Szabo, D. & Kilian, H.-G. 1997 *The Journal of Chemical Physics* **106** (13), 5685–5692.
[2]Landau, L. D. & Lifschitz, E. M. 1960 *Electrodynamics of Continuous Media*, 3rd edn., vol. 8. Oxford: Pergamon.
[3]Lattermann, G. & Krekhova, M. 2006 *Macromol. Rapid Commun.* **27**, 1373–1379.
[4]Raikher, Y. & Stolbov, O. 2005 *Journal of Applied Mechanics and Technical Physics* **46** (3), 434–443.

DY 26.7 Thu 12:00 H3

Role of interactions in ferroluid thermal ratchets — •Volker Becker — Charite, Augustenburger Platz 1, 13353 Berlin

Orientational fluctuations of colloidal particles with magnetic moments may be rectified with the help of external magnetic fields with suitably chosen time dependence [1]. As a result a noise-driven rotation of particles occours giving rise to a macroscopic torque per volume of the

carrier liquid. We have theoretically analyzed the influence of mutual interactions between the particles on this ratchet effect by studying a model system with mean-field interactions. The stochastic dynamik may be described by a nonlinear Fokker-Planck equation for the collective orientation of the particles which we have solved aproximately. We have found that interactions favouring the parallel alignment of the magnetization of the ferrofluid particles reinforce the ratchet effect. Morover we have determined an intevall for the ratio between coupling strength and noise intensity for which a self-sustained rectification of fluctuations can be observed. The ratchet effect then operates under conditions for which it where impossible in the absence of fluctuations.

[1] A. Engel, H. W. Müller, P. Reimann, A. Jung, *Phys. Rev. Lett.* **91**, 060602(2003); A. Engel, P. Reimann, *Phys. Rev. E* **70**, 051107 (2004)

[2] V. Becker, A.Engel, *cond. Mat.*/0609546

DY 26.8 Thu 12:15 H3

Rheological investigations of ferrofluids with a shear stress controlled rheometer — •Hamid Shahnazian and Stefan Odenbach — Lehrstuhl für Magnetofluiddynamik, Technische Universität Dresden, 01062 Dresden

Ferrofluids, suspensions of magnetic nanoparticles with a mean diameter of about 10 nm in appropriate carrier liquids, show normal liquid behaviour coupled with superparamagnetic properties. This enables to influence significantly their flow behaviour by moderate magnetic field strengths, giving rise to numerous technical and biomedical applications. One of the major attributes of ferrofluids is the change of viscosity (magnetoviscous effect) and the appearance of viscoelastic effects caused by applied magnetic fields. Different theoretical approaches have been developed to explain these effects. The predictions of these models differ in a point, which comes into a question of an appearance and field dependence of yield stress in ferrofluids. For the investigations concerning yield stress a shear stress controlled rheometer for magnetic fluids has been designed. For different kind of ferrofluids, a dependence of the yield stress on magnetic field strength is observed. In order to get information on the size of the structures, formed by the particles under magnetic field influence, and its dependence on field strength as well as on interparticle interaction, variation of geometry - cone/plate or plate/plate - and distance of the walls in plate/plate geometry of the shear cell have been used.

DY 26.9 Thu 12:30 H3

Parametric modulation of thermal and thermomagnetic convection in magnetic fluids — •Harald Engler and Stefan Odenbach — Lehrstuhl für Magnetofluiddynamik, Technische Universität Dresden, 01062 Dresden

Former theoretical investigations of the behaviour of thermal convection under the influence of a time modulated driving force have shown that the threshold where heat flux converts from diffusion to convective flow depends on the frequency of the driving force. However experimental setups to generate thermal convection with a time modulated driving force fails due to the immense technical problems. Recent research activities on heat and mass transfer phenomena in ferrofluids - superparametric suspensions of magnetic particles with an average diameter of 10 nm in appropriate carrier liquids - are focused on the influence of time modulated driving force on the critical temperature difference of thermomagnetic convection. The driving force in convection in ferrofluids, so called thermomagnetic convection, depends on temperature difference, geometric boundary and the additional magnetic force provided by an external magnetic field. A time modulated magnetic field that provides the required time dependent driving force with frequencies in the order of 1 Hz can easily be realized. The experimental setup designed for the investigation of thermomagnetic convection under the influence of time varying magnetic force as well as the first results will be presented.

DY 26.10 Thu 12:45 H3

Synthesis and magnetoviscosity of nanotube/nanorod ferrofluids — •Zhenyu Wu[1], Dörte Junk[2], Xiong Liu[3], Alexander Bittner[3], Christina Wege[4], and Carl Krill[1] — [1]Institute of Micro and Nanomaterials, Ulm University, D-89081 Ulm — [2]Technical Physics, University of the Saarland, D-66123 Saarbrücken — [3]Max Planck Institute for Solid State Research, D-70569 Stuttgart — [4]Institute of Molecular Biology and Virology of Plants, D-70550 Stuttgart

As colloidal suspensions of ferromagnetic nanoparticles in a carrier liquid, ferrofluids combine the magnetic properties of solids with the flow properties of liquids. Their viscosity increases dramatically in the presence of an externally applied magnetic field; however, this magnetoviscosity is lost when the ferrofluid is subjected to shear forces. One strategy to suppress such shear thinning is to replace the spherical nanoparticles of a conventional ferrofluid with nanotubes or nanorods. We report the synthesis of nanotube ferrofluids based on the metallization of the tobacco mosaic virus (TMV) with Co. The magnetoviscous properties of these samples were studied using a squeeze-flow viscometer at magnetic fields up to 150 mT and frequencies up to 400 Hz. The measured viscosity behavior is compared to that of conventional ferrofluids and to suspensions of Fe nanorods prepared by aerosol condensation.