UNIVERSITY OF LATVIA

77th SCIENTIFIC CONFERENCE

FACULTY OF PHYSICS, MATHEMATICS AND OPTOMETRY

MAGNETIC SOFT MATTER

Book of Abstracts

House of Science, Jelgavas 3

Riga, February 1st, 2019

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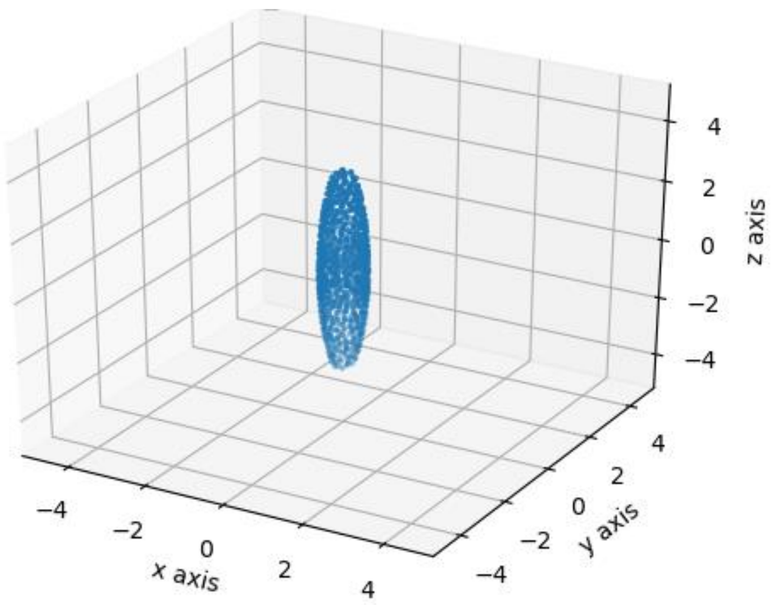
UNIVERSITY OF LATVIA
ANNO 1919

Magnētisku Mīkstu Materiālu Laboratorija
LAB OF MAGNETIC SOFT MATERIALS

Asymptotic analysis of magnetic droplet configurations

Aigars Langins, Andrejs Cēbers
MMML lab, Faculty of Physics, Mathematics and Optometry, University of Latvia

Magnetic fluid droplets in external magnetic fields may be deformed in ways where complete mathematical modelling is no longer feasible, due to prohibitive computing costs. These deformations include highly stretched droplets in homogeneous fields or droplets on the verge of breaking up in rotating fields. In these cases, one may resort to approximations like the slender body theory or asymptotical series to simplify the underlying boundary integral integrations. This presentation outlines described situations in detail, as well as possible solutions.

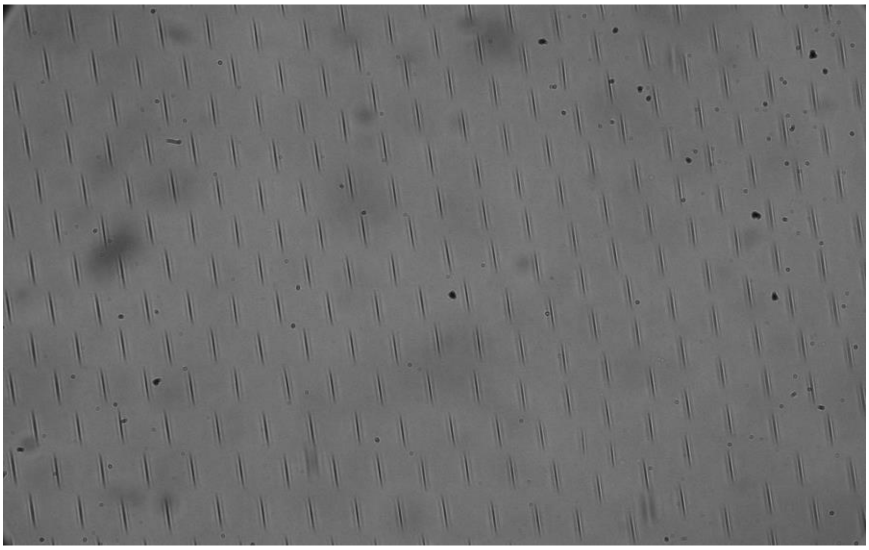


MSCA ITN project MaMi (EU H2020 Grant agreement No. 766007)

The dynamics of magnetic droplets subjected to a rotating magnetic field

Andris Pāvils Stikuts[1], Guntars Kitenbergs[1], Regine Perzynski[2], Andrejs Cēbers[1]
[1] *MMML lab, Faculty of Physics, Mathematics and Optometry, University of Latvia*
[2] *PHENIX lab, Sorbonne University, CNRS*

Phase separated magnetic droplets subjected to a rotating magnetic field spontaneously form regular structures akin to a hexagonal lattice. The droplets are relatively uniform in size, elongated and rotating along with the magnetic field. In this presentation various physical parameters are described under which the phenomenon was observed to take place.

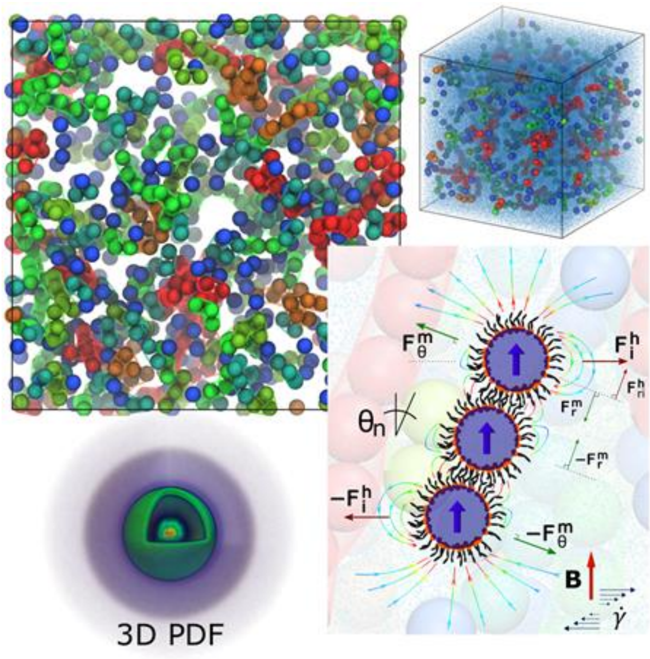


French embassy in Latvia scholarship for cotutelle studies, SIA "Mikrotīkls" scholarship for PhD students (administered by the University of Latvia Foundation)

Micromechanics of self-assembled chain-fluids

Dmitrijs Zablockis
Institute of Physics, University of Latvia

Emerging materials technologies require advanced self-assembly strategies that can be amalgamated into an entirely solution-based low temperature processing. Deterministic assembly via a colloidal route is a core platform for exploiting the potential for variable property design/fabrication and deployment of mesoscale architectures with structural hierarchy, multi-functionality and programmed response to mechanical stress or external field, harnessing the physical properties originating from both the individual nanocrystals and collective interactions. Here we will report the results of theoretical and experimental investigations of the microstructure and flowing behaviour of chain-forming dipolar colloids. Using hybrid molecular dynamics and multi-particle collision dynamics we describe the self-assembly of dipolar particles in various aligned mesostructures and their destruction by the shear flow. We will present quantitative comparison of our theoretical studies and micromechanical models with recent experimental data, showing evidence of the universality of the structural behaviour governed by the competition between the bonding and erosive stresses. The results display pronounced chain-fluid anisotropy and induced magnetoviscosity across several orders of magnitude in fair quantitative agreement with experiments.

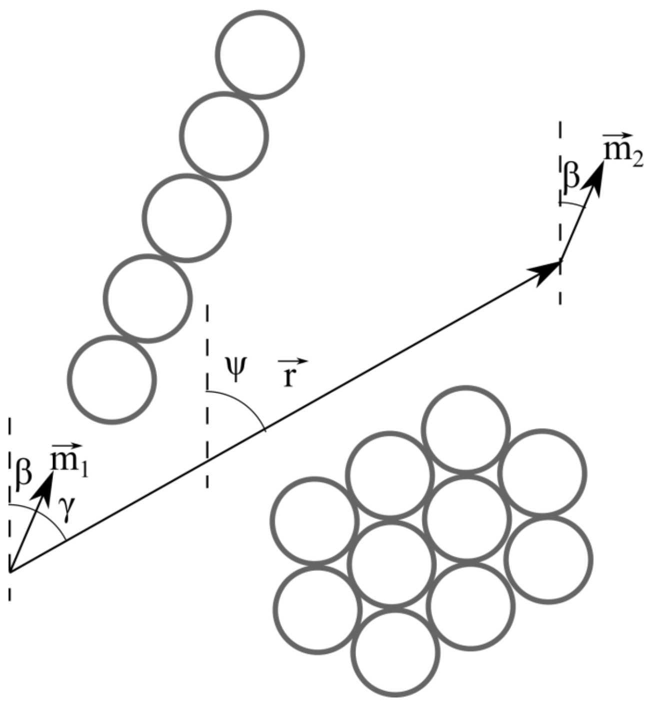


PostDoc Latvia (project no.1.1.1.2/VIAA/1/16/072)

Stable structures of paramagnetic particles in precessing field

Jānis Cīmurs, Jānis Užulis
MMML lab, Faculty of Physics, Mathematics and Optometry, University of Latvia

Paramagnetic particles magnetizes in external magnetic field. Magnetization of the particle depends on external magnetic field and particle anisotropy axis direction. If such particles is exposed to stationary field they form chains, but if these particles is exposed to rotating field they form planes of particles. If we combine these two fields, we obtain precessing field which consists of stationary field which is perpendicular to rotation plane of rotating field. In this research it is found how structures (chain or plane) depend on precessing field parameters. Results are obtained theoretically and numerically. This talk will give insight how theoretical and numerical results are obtained and will show when you would obtain chain and when plane of particles in precessing field.



PostDoc Latvia (Project no. 1.1.1.2/VIAA/1/16/060)

Deformation of flexible ferromagnetic filaments under rotating field

Abdelqader Zaben, Andrejs Cēbers, Guntars Kitenbergs
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Magnetic driven micro robots are becoming an increasingly active research topic due to the promising applications as targeted drug delivery, bio-sensing and imaging, and environmental remediation in which their advantage of on demand motion control, long lifetime and safe bio-compatibility are used [1]. One type of micro robots are made by flexible magnetic filaments [2]. Here we investigate filaments, which are formed using ferromagnetic particles with DNA strands as a linking agent. The experiments were conducted under different magnetic field strengths and frequencies while observing the shape deformation with a microscope and a camera. We present an overview of the experimental procedures, as well as the data and its analysis from the initial experiments. It has been shown that longer filaments tend to deform more compared with shorter ones and that deformations increase with the increase of the field. An example of filament deformation can be seen in figure 1. Once the frequency becomes too high, the filament moves out of the plane of rotation as shown in figure 2 and breaks. Additionally, we discuss the challenges associated with filament synthesis and upgrade of the experimental setup.

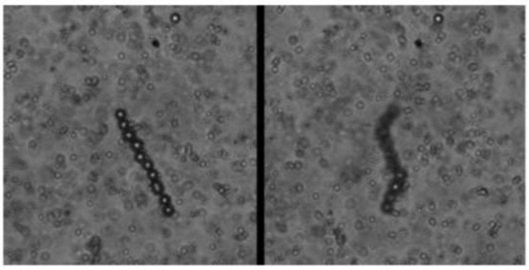


Figure 1 *Flexible ferromagnetic filaments (formed by 4µm particles) behaviour with the addition of tracer particles (1µm) under rotating field producing an S like shape (Left – no field applied, right – rotating magnetic field)*

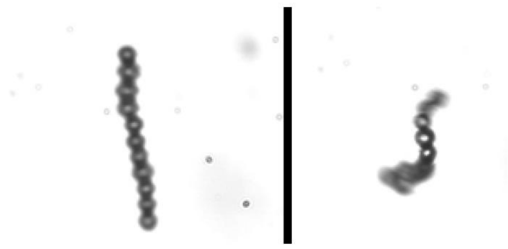


Figure 2 *Flexible ferromagnetic filaments (formed by 4µm particles) behaviour under rotating field operating under relatively high frequency resulting in out of plane of rotation. (Left – no field applied, right – rotating magnetic field)*

[1] - Yu, H., Tang, W., Mu, G., Wang, H., Chang, X., Dong, H., Qi, L., Zhang, G. and Li, T. (2018). Micro-/Nanorobots Propelled by Oscillating Magnetic Fields. Micromachines, 9(11), p.540.

[2] - A. Cēbers, K. Ērglis (2016) Flexible Magnetic Filaments and their Applications. Advanced Functional Materials, 26, p.3783

MSCA ITN project MaMi (EU H2020 Grant agreement No. 766007)

Coupled lattice Boltzmann and Langevin dynamics simulation of microscopic particle suspensions

Rūdolfs Livanovičs, Andrejs Cēbers
MMML lab, Faculty of Physics, Mathematics and Optometry, University of Latvia

Three dimensional simulations of microscopic particle suspensions are commonly forced to utilize very fine grids to resolve fluid motion around the particles or else employ one of a small number of semi-analytic approximations based on fundamental solutions to the Stokes equations. Neither approach scales well to large numbers of particles or complex geometries, thereby severely limiting the applicability of these techniques. In this talk I will describe an implementation of a novel algorithm recently introduced by Liu et al, which consists of a stochastic Langevin dynamics solver that is two-way coupled to a lattice Boltzmann method which resolves the full Navier-Stokes equations in 3D. Sub-lattice techniques are used to implement the coupling, obviating the constraint on the grid size. Initial attempts to accelerate the algorithm using GPU hardware have been made, with promising results.

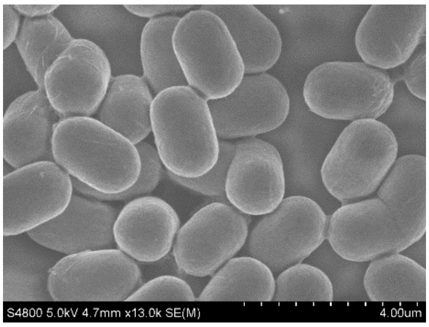
ERA-NET project „Flexible Magnetic Filaments: Properties and Applications” (Project no. 1.1.1.5/ERANET/18/04)

Synthesis and properties of hematite (α-Fe_2O_3) particles

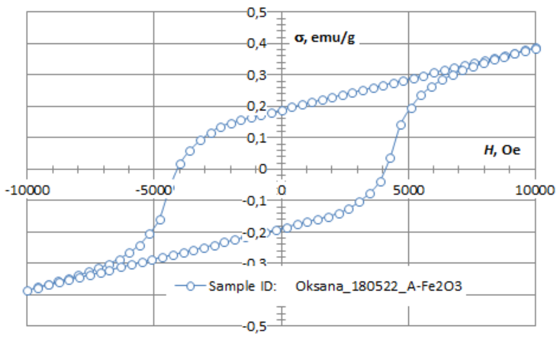
Oksana Petričenko

MMML lab, Faculty of Physics, Mathematics and Optometry, University of Latvia

Hematite micron-sized particles have been synthesized by the gel-sol method proposed by T. Sugimoto et al. By changing some parameters of the synthesis, particles with ellipsoid, cubic and peanut shapes were synthesized. The sizes and shape were observed by optical (OM) and scanning electron microscopy (SEM). By X-ray powder diffraction of the samples the formation of the α-Fe_2O_3 phase was found. Magnetic measurements were made using a vibration sample magnetometer (VSM).



Ellipsoid shape hematite particles (SEM). Sizes 1.1 x 2.5 μm.



Magnetic hysteresis curve of the ellipsoid shape hematite particles (VSM).

PostDoc project Synthesis of new magneto-active functional nanomaterials (1.1.1.2/VIAA/1/16/018))

Experimental observation of hematite cube swarming under rotating magnetic field

Guntars Kitenbergs[1], Oksana Petričenko[1], Emmanuelle Dubois[2], Regine Perzynski[2], Andrejs Cēbers[1]

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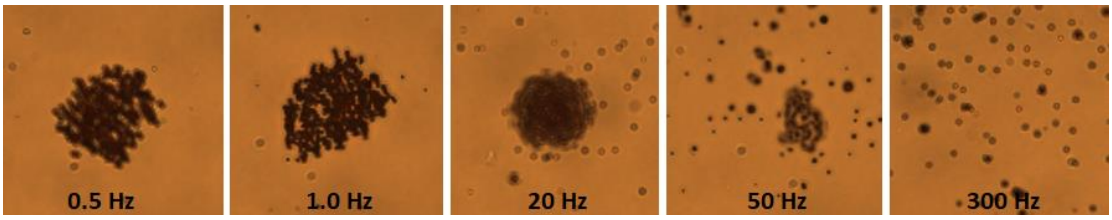
Miniaturization of various processes demands new types of actuation, manipulation and control. Collective effects in microscopic scale can be very helpful for that. Here we report experimental observation of swarming of microscopic hematite cubes, when exposed to a rotating magnetic field. When no field is applied, cubes form connected structures due to a small permanent magnetic moment. Slow rotating field splits these structures and creates islands of rotating cube agglomerates. When field frequency is increased, agglomerates split in short chains or individual cubes that are rotating in a swarm like structure. Above a critical frequency swarms dissolve into individual cubes. We characterize this behaviour and quantify the size and motion of swarms in order to compare it with a theoretical model.

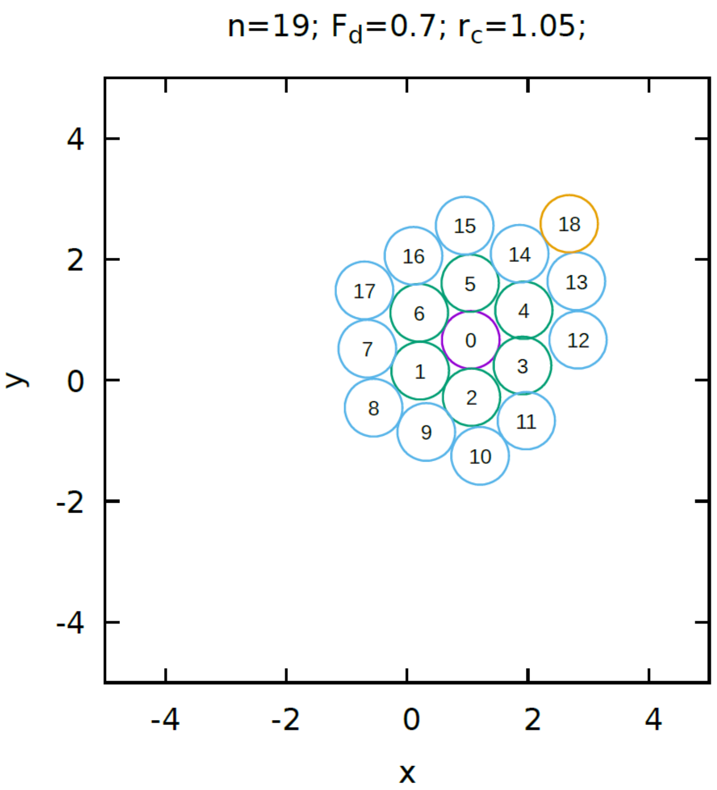


PostDoc Latvia (project no.1.1.1.2/VIAA/1/16/197)

Hematite cubes in rotating magnetic fields

Mārtiņš Brics, Andrejs Cēbers
MMML lab, Faculty of Physics, Mathematics and Optometry, University of Latvia

At room temperature hematite is weakly ferromagnetic and has spontaneous magnetization of $M_{hem} = 2.2 \cdot 10^3$ A/m which is two orders smaller than that of other magnetic materials such as magnetite. However, it's domain size is much larger, i.e. hematite maintains a permanent dipole moment even at large sizes up to 15 µm. The consequence of this is micron-sized hematite colloids which display a fixed and permanent magnetic dipole moment that is strong enough to allow for the formation of dipolar chains thus making it an interesting system for study. Recently by our experimental part of group were performed an experiment with such hematite colloids in rotating magnetic field. The colloid consisted of approx. 1 µm large cube shaped hematite particles. At high enough concentration hematite cubes form relatively large agglomerates which then by applying slowly rotating external field started to rotate around its center of mass. This talk then tries to explain this effect from theoretical point of view.



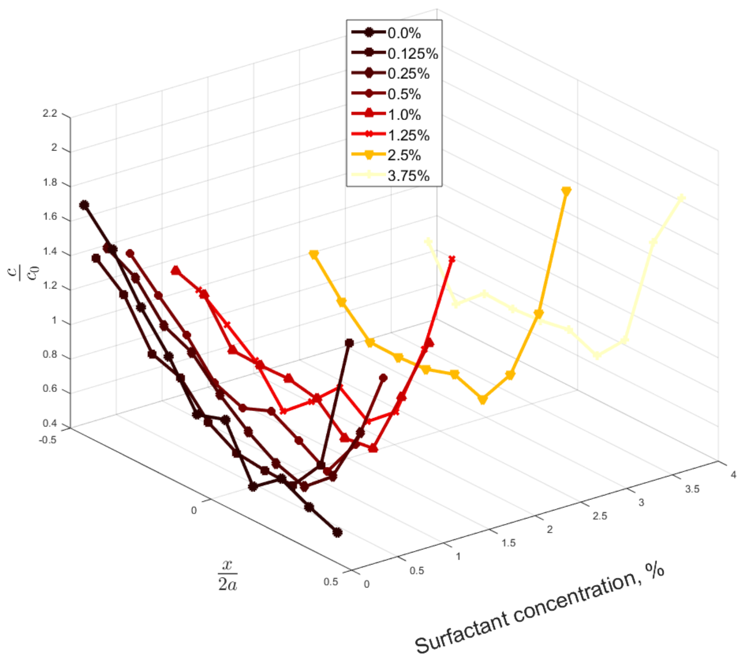
ERA-NET project „Flexible Magnetic Filaments: Properties and Applications" (Project no. 1.1.1.5/ERANET/18/04)

Influence of surfactant on surfaced nanoparticle thermophoresis in a porous medium

Viesturs Šints[1], Gunars Kronkalns[1], Elmars Blums[1], Mikhail M. Maiorov[1], Mitradeep Sarkar[2], Jesse Riedl[2], Gilles Demouchy[2,3], Regine Perzynski[2], Emmanuelle Dubois[2]

[1] Institute of Physics, University of Latvia, [2] PHENIX lab, Sorbonne University, CNRS,
[3] Dpt de Physique - Univ. Cergy-Pontoise

Experimental research on thermally induced transport of surfactant-coated magnetic nanoparticles has revealed unexpected effects of excess surfactant on surfaced nanoparticle thermal transport in a porous medium – Soret coefficient is decreased, compared to a free fluid. With sufficient surfactant concentration, particle transport direction is inverted, Soret coefficient changing from positive to negative. Dependance of Soret coefficient on temperature also appears to depend on surfactant concentration. The effects are observed within a porous layer subjected to a temperature difference but isolated to mass transport. We use a ferrofluid with magnetite nanoparticles surfaced with oleic acid, with varying amounts of excess oleic acid, unbound to the particles, added to the colloid. Carrier fluid is tetradecane. In order to isolate the effects of a porous environment, nanoparticle thermophoresis in a free fluid outside of a porous environment is measured using Forced Rayleigh scattering. Thermophoretic flow of carrier fluid and surfactant mixture has been investigated. Investigation of ferrofluid flow with various surfactant concentrations through a porous layer – allowing for mass transport to and from the layer – has also been started. As a possible conclusion, it could be suggested that the mechanism through which this phenomena works is related to surfactant thermal transport, likely induced by interaction with pore walls, forming a gradient of surfactant concentration. Thermally induced transport of the nanoparticles in such a system would then be driven by thermophoresis within the surfactant gradient.

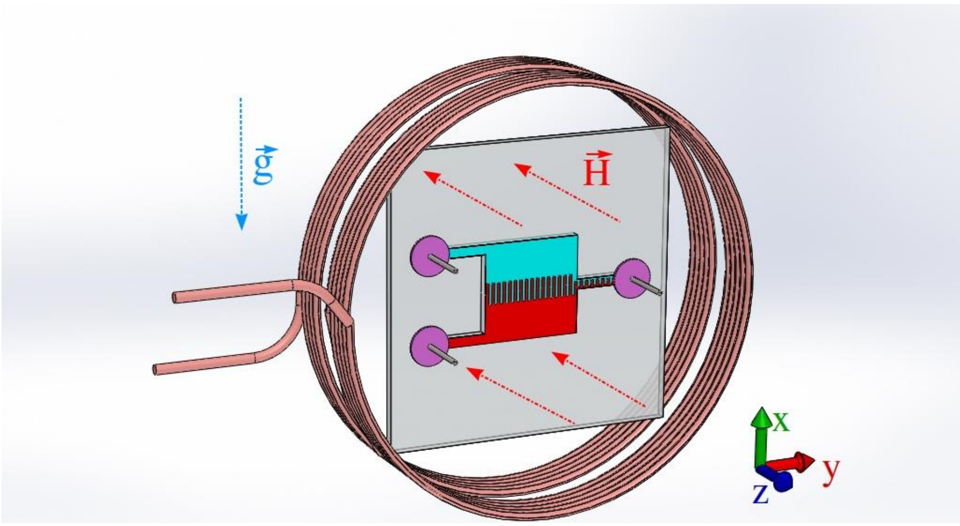


Experimental investigation of how gravity stabilizes instability due to magnetic microconvection

Lāsma Puķina, Andrejs Tatuļčenkovs, Guntars Kitenbergs

MMML lab, Faculty of Physics, Mathematics and Optometry, University of Latvia

The effect of magnetic microconvection in mixing between two fluids in cases of various differences between the densities of the fluids is studied. Water based magnetic colloid and a water are filled in a vertical Hele-Shaw cell like microfluidics chip. Colloids with different magnetic particle concentration are used in the experiments. An external magnetic field is applied perpendicularly to the cell and the interface between the two fluids is observed. In addition to the diffusion that happens between the two fluids a fingering instability arises on the interface between fluids, due to the ponderomotive forces of the non-homogeneous self-magnetic field. The mixing length of both fluids obtained from the change of concentration distribution in the cell is analyzed over time in a context of the strength of the external magnetic field and initial magnetic particle concentration of the used colloids.



PostDoc Latvia (project no.1.1.1.2/VIAA/1/16/197)