Institute of Physics

Van der Waals-Zeeman Institute (WZI)

Experimental Physics Bachelor Projects

Soft Matter Group

Hard Condensed matter Group

Quantum gases & quantum information

Institute for Theoretical Physics (ITFA)

Institute for High Energy Physics (IHEF)

Dr. Noushine Shahidzadeh
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2020 Projects

Soft Matter Group
SMG

https://iop.fnwi.uva.nl/scm
Impact of electrolytes and surfactants on droplet spreading

Problem
Understanding the spreading of liquid drops on planar substrates is important in various applications (spraying, agriculture, painting and printing ...) in which the dynamics of moving contact lines plays a major role. It involves the surface energies of all interfaces and hence the wettability of the materials. Surprisingly, Droplets spreading is observed on hydrophobic surfaces when both salt and surfactant are present in the solution.

The project consists of:
• Measuring experimentally the spreading properties at different concentration
• With different surfactants and salt concentration.
• Studying the role of the wettability of the substrates
• Quantify the dynamics of moving contact line by image analysis
• Understand the role of NaCl on surfactant-surface interactions in spreading?

Place: Soft matter group, WZI-Institute of Physics - UvA
Supervisors:
Noushine Shahidzadeh, Associate professor (n.shahidzadeh@uva.nl)- C4.231 tel: 8261
Daniel Bonn, professor

Fig. 2. A liquid droplet spreading on a smooth, planar substrate.
Experimental determination of the surface energy of NaCl crystal

Problematic:
The surface energy of a solid influences the growth rate, adsorption, catalytic behavior, surface segregation and the formation of grain boundaries. Their determination is of great importance for understanding mechanisms of many physical phenomena. Despite its importance, surface energy values are very difficult to measure experimentally although computer simulation results can be found.

The Project consists of:
- Setting up an experiment for the control growth of pendant NaCl crystals at the liquid/air interface.
- Recording and Image analysis of the time evolution of the crystal growth till it falls in the solution.
- By analogy to the pendant drop method for surface tension measurement of liquids, the surface energy of the crystal will be estimated.

Place: Soft matter group, WZI-Institute of Physics -UvA

Supervisors:
Noushine Shahidzadeh, Associate (n.shahidzadeh@uva.nl) - C4.231 tel: 8261
Daily supervisor: Simon Lepinay (PhD student)
Problem
Most of the industrial / pharmaceutical products are processed, transported and stocked in a granular state. The packing density of those granular materials becomes therefore a relevant parameter for a broad range of applications in order to reduce the costs for the manipulation and transportation of such granular materials.

The project consists of:
• studying the compaction and flow of crystalline granular materials in controlled environment. The latter are grains with rough surfaces and needle like particles that can change the contact dynamics during compaction compared to spherical grains.
• We will study the case of NaCl, Gypsum (CaSO$_4$) used as plaster and calcium carbonate (CaCO$_3$) used in various applications.
• Results of 3D printed model grains will be compared with the results with real materials used in the project.

Bachelor project -2020
Compaction and flow of crystalline materials: Impact of grains (crystals) shape

Place: Soft matter group, WZI_ Institute of Physics
Supervisors:
Dr. N. Shahidzadeh-Associate Professor (n.shahidzadeh@uva.nl)
Room: C4.231- tel:8261
Daniel Bonn (professor)
Rinse Liefferink , PhD Student R.W.Liefferink@uva.nl
Crystallization: Defects & Shape

During crystallization things often go wrong and defects occur. In addition, the shape and interaction of the building blocks will influence the type of defects. To understand this on a single particle level, we use colloids, small particles with a size between 1-1000 nm, that display thermal (Brownian) motion and follow them with optical microscopy. We will perform different crystallization experiments and image the single particles. In addition, with image analysis routines we will perform quantitative investigations of the forces involved.

Available Projects:

1. How Do Defects Move and Interact?
2. Shape Matters: Crystallization of Anisotropic Colloids

If you are interested and want to know more, please contact us: j.m.meijer3@uva.nl, room: C4.232, tel: 5180 & p.schall@uva.nl, room: C4.228, tel: 6314
Project: **Damping metamaterials**

daily supervision: David Dykstra (d.m.j.dykstra@uva.nl)

supervision: Corentin Coulais (coulais@uva.nl, coulaislab.com)

Making metamaterials that absorb very efficiently shocks and vibrations

possibility to do a join project with Tata steel (IJMuiden) or ATG Europe (Noordwijk)
Theory Project: **Non-Hermitian Topology**

daily supervision: Ananya Ghatak (a.ghatak@uva.nl)
supervision: Corentin Coulais ([coulais@uva.nl](mailto:coulais@uva.nl)), Jasper van Wezel (j.vanwezel@uva.nl)

Making analogies between quantum and classical mechanics to uncover non-Hermitian topology
Project: Granular Metamaterials

daily supervision: Daan Haver
supervision: Corentin Coulais (coulais@uva.nl, coulaislab.com)

Research the mechanics of granular packings, where the grains have strange properties
Project: Non-orientable Metamaterials

daily supervision: Xiaofei Guo
supervision: Corentin Coulais (coulais@uva.nl, coulaislabs.com)

Research the topological mechanics of moebius metamaterials
Project: **Machine learning metamaterials**

daily supervision: Corentin Coulais ([coulais@uva.nl](mailto:coulais@uva.nl), coulaislab.com)

Using Machine-Learning to understand the complex mechanics of metamaterials
Contact: Peter Schall, p.schall@uva.nl
Project 3: Active Architectures

Tissue analogue  
Active particle  

Biolog. tissue  

Non-equilibrium Physics: understand biological matter

Background: Self-propelling, active particles that imitate bacteria & motor protein motion

Contact: Peter Schall, p.schall@uva.nl
Project: Quantum-dot Assembly for Photovoltaics

Quantum box

1-10nm

Electronic Wavefunctions

Build “Quantum-dot Solids”

Background: Assembled cubic perovskite nanocrystals — 10nm

Contact: Peter Schall, p.schall@uva.nl
2020 Projects

Hard Condensed Matter Group

https://iop.fnwi.uva.nl/cmp/
Optical exciton physics in monolayer 2D semiconductors

Your 2D exciton project goal:

Correlate material structure with excitonic optical properties

Methods:

- Develop correlated Raman/PL microscopy
- Commission new in-situ cryostat
- Develop model for exciton strength

BSc projects in the van de Groep Lab. QMat, IoP

Jorik van de Groep (j.vandegroep@uva.nl)
Dive into k-space: 2 ARPES projects in the Golden Lab 2020

- Black hole physics in the strange metal phase in high \( T_c \) superconductors
  - Collaboration with van Heumen lab
  - Theory: Schalm, Zaanen (U. Leiden)

- 2D semiconductors & designer Dirac materials collaborations with (new) van der Groep lab & Schall lab
  + Theory: van Wezel group

Your Dirac material project:
- Help commission X-ray monochromator
- Surface treatment of 2D materials for laserARPES

Your strange metal project:
- Help commission new cryostat
- LaserARPES of Bi-based strange metals

→ One student @AMSTEL

BSc projects in the Golden Lab: QMat, IoP
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  → one student @AMSTEL

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  → one student @AMSTEL

BSc projects in the Golden Lab, QMat, IoP
Dive into k-space: **2 ARPES projects in the Golden Lab**

**black hole physics in the strange metal phase in high T_c superconductors**

*collaboration with van Heumen lab*

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Your **Dirac material project**:

- help commission X-ray monochromator
- surface treatment of 2D materials for *laserARPES*

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Your **strange metal project**:

- help commission new **cryostat**
- **laserARPES of Bi-based strange metals**

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→ **one student @AMSTEL**
Nano-design with AFM - nano-scratching and nano-manipulation in force and conductive modes

Nanometer scaled materials are of great interest for various applications – nanosized semiconductor nanoparticles exhibit size-dependent emission, nanosized metal particles show interesting plasmonic resonances, nanosized machines can be used in micro-electronic mechanical devices (MEMS), etc. To make a complex nanosized object, one can use tip of the atomic force microscope (AFM). One can scratch materials in force mode along pre-defined path, one can push nanoparticles around with the tip in contact mode or induce oxidation in very localized volume area by use of conductive AFM mode.

In this project, student will try to replicate existing results on nano-assembly by AFM tip (see Figure below, right) and attempt to build novel structures either by direct nanomanipulation, or by scratching lines into PMMA (see Figure below, left) and then using self-assembly to build superstructures. Materials will be analyzed before and after assembling by optical micro-spectroscopy, that is correlated with the AFM.

Supervisor:
dr. K. (Katerina Dohnalova)
Newell
Faculty of Science
Van der Waals-Zeeman Instituut
k.newell@uva.nl 0205255793

Figure – Left: schematics of line scratching process using AFM tip [1]. Right: Assembly of perovskite nanocubes directly by AFM tip (result measured by our master student BSc. Menno Demmenie).

Preparation and analysis of nanomaterials prepared by laser ablation in liquid by correlated single-dot optical and atomic force microscopies

Laser ablation is one of the major techniques used nowadays for preparation of nanomaterials. When done in gas or vacuum, it is usually called PLD (pulsed laser deposition). Interest in the liquid laser ablation (or pulsed laser ablation in liquid (PLAL)) for nanostructure generation started in the early 2000s, and was first demonstrated on noble metal nanoparticles [1,2]. However, later also semiconducting nanoparticles, such as silicon nanocrystals of sizes 2-50 nm [3], were prepared, using ns-pulsed Nd:YAG laser 355 nm.

In this project, you will prepare nanomaterials from bulk semiconductor target by the use of laser ablation in liquid with ns-pulsed Nd:YAG laser at 355 nm. You will then analyze the resulting nanomaterials using correlated single-dot optical and atomic force microscopes (AFM). This will allow for size-resolved analysis of optical properties (see Figure below) of the newly made materials, such as their optical spectrum (and hence optical bandgap), luminescence lifetime (related to radiative rate) and blinking trace. After full analysis, we will know whether the new material you prepared are interesting for applications in lighting or photovoltaics.

Figure: Left – AFM scan of silicon nanoparticles; Middle – the same area scanned in optical microscope; Right – emission from interesting nanoparticle is spectrally resolved to find optical bandgap, correlated to the size. (Results were measured by PhD candidate MSc. Chia-Ching Huang)

van Heumen Lab

Possible topics

Strange metals - Quantum gravity in a crystal
Topological insulators – Geometry, topology & electrodynamics
Complex oxides – Strongly correlated electron & nano-optics

Xuanbo Feng
Stephan Bron
Erik van Heumen

2020 projects

For all these topics we are looking for students interested in optical experiments at low temperature, in magnetic fields or on nano-scale objects.

• Modelling of near field optics.
• Program & test a tunable laser for spectroscopy.
• Fabricate samples for transport experiments.

Envy a combination of difficult theory with actual experiments? We have several challenging projects available!

e.vanheumen@uva.nl
Unconventional superconductivity @ Q-mat

- Research on novel materials that show unconventional superconductivity
- Exemplary superconducting materials $\text{Sr}_x\text{Bi}_2\text{Se}_3$, $\text{PdTe}_2$, $\beta\text{-PdBi}_2$, ...
- Rotational symmetry breaking multicomponent superconducting order parameter

- Bachelor project(s)
  - specific heat measurements
  - upper critical field measurements
  - torque magnetometry
  - hydrostatic pressure
  - uniaxial pressure
  - ...

See our papers:
Y. Pan et al., Scientific Rep. 6 (2016) 28632

Supervisor: Anne de Visser, a.devisser@uva.nl, WZI-IoP, rm. C4.235
2020 Projects

Quantum gases & quantum information

http://iop.uva.nl/content/research-groups/qgqi/quantum-gases-quantum-information.html
Hybrid atom-ion Quantum Systems

Charged impurities in a Fermi sea

↑ Ion crystal

Left: Ultracold atoms

Study ionic impurities in degenerate fermi gas

Project 1
→ Build laser setup for atom precooling
→ Perform spectroscopy to characterise atoms
→ Build laser to ionize atoms

Spin-spin interactions in 2D ion crystals

Optical tweezers

SLM

Optical tweezers for pinning trapped ions

Quantum simulation of spin models

Project 2
→ Build tweezer setup for pinning ions
→ Program SLM for generating patterns
→ Perform spectroscopy on soundwaves

Contact us: www.hyqs.nl
Rene Gerritsma r.gerritsma@uva.nl
Science Park 904, room C4.246
Sr atomic source via Blu-Ray assisted Desorption

In the Strontium Quantum Gases lab, we are currently developing a state-of-the-art atom source for such a clock [1]. We are part of the European consortium iqClock [2], whose aim is two-fold: producing via our industrial members an ultracold atom optical lattice clock ready for the consumer market; generating in the lab the 1st continuous active optical clock using superradiant emission [3].

This project will focus on the generation of a source of Sr atoms through desorption [4] induced by high energy near-UV photons generated by a Blu-Ray technology diode laser. The student will setup the laser source, will couple it to the vacuum chamber, and will characterize the efficiency of this atom source for feeding a high-flux 2D magneto-optical trap. This experimental research involves laser optics, atomic physics and laser cooling.

Contacts
Shayne Bennetts (s.p.bennetts@uva.nl)
Florian Schreck (f.schreck@uva.nl)

The gas anti-laser

Equations for a laser system at threshold have time-reversal symmetry, allowing the reverse process, the anti-laser. Despite a theoretical proposal in 2010 and follow-up experimental realizations, there exist no anti-laser using a gaseous gain medium. We propose the realization of an anti-laser whose gain medium is a cell filled with strontium gas.

You will get familiar with the current understanding of anti-lasers and then build the first gas anti-laser based on a strontium spectroscopy cell surrounded by an optical cavity. If successful, the characterization this anti-laser should provide fundamental insights into the physics of anti-lasers.

Contacts
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Florian Schreck (f.schreck@uva.nl)

Figure: Experimental setup used to demonstrate the first anti-laser [2,3], using a thin Si slab as both the gain medium and the cavity.

The magneto-optical trap (MOT) is a key element, omnipresent in ultracold atom and molecule research apparatuses. In our group [1], we are building a compact MOT apparatus, with the goal of using it for outreach towards a general audience, yet versatile enough to allow further implementation of features like Bose-Einstein condensates and optical tweezers.

You will be tasked with seeing for the first time an atomic signal inside the chamber and characterizing the source efficiency. Then you will have to produce a 2D MOT, feeding a 3D MOT, and characterizing this ultracold atom source.

**Contacts**
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Florian Schreck (f.schreck@uva.nl)

[1] www.strontiumbec.com
Developing a spectroscopy lock for strontium $^{3}P_{0,2}-^{3}S_{1}$

How do you lock a laser to a transition between an excited state and an even more excited state?
(There is no population in the lower level to probe the transition!)

We need to lock lasers to transitions starting from the metastable strontium clock states of $^{3}P_{0}$ and $^{3}P_{2}$ so we need atoms in these states to probe.

In this project you will build a spectroscopy setup similar to the one in the picture, based on a hollow cathode lamp, and develop a system to lock our lasers to this transition.

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More info: www.StrontiumBEC.com

Spectroscopy setup.
Creating arbitrary light patterns with a spatial light Modulator

In the Strontium Quantum Gases lab, one of our experiments uses a grid of tightly focused laser beams, known as optical tweezers, to trap single atoms of strontium. Currently the trap array has the limitation of only being able to produce a square grid of trapped atoms. To increase the possibilities of different trap geometries, a spatial light modulator (SLM) can be used [1].

In this project you will construct the optical setup to make arbitrary light patterns, using an SLM, that will be installed in the experiment. This will involve programming the SLM to produce the proper phase on the incident laser, characterizing (and removing) any aberrations caused by the SLM or other optical elements, characterizing the performance of the SLM for creating optical tweezers, and (if time permits) installing the SLM setup onto the experiment and using it to trap strontium atoms.

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Left: Strontium atoms trapped in an array of optical tweezers. Right: Arbitrary trap patterns produced by an SLM (from left to right; phase of SLM, image of foci, and atomic signal) [1].

Example of optical setup for SLM characterization.