Shape matters: crystallization of colloidal cubes with critical Casimir forces

Supervisor: Dr. Janne-Mieke Meijer (janne-mieke.meijer@uva.nl, www.janne-miekemeijer.com)
Co-supervisor: Prof. Peter Schall (p.schall@uva.nl)

One of the most fascinating things in nature is the spontaneous organization of building blocks into ordered structures. Everyday examples are the freezing of water into ice or the formation of salt crystals when sea water evaporates. During these crystallization processes the shape and the interactions of the atoms and molecules, play a key role in the crystal structure that forms. Particles with a spherical interaction potential, such as metal atoms, form close-packing configurations, while rod-like molecules form liquid crystalline phases and depending of the complexity of the building blocks, proteins have been observed to form a rich variety of crystal structures.

In order to understand the crystallization process, we study the crystallization on a single particle level using colloids. Colloids are small solid particles with a size between 1 to 1000 nm. When dispersed in a liquid, colloids display thermal (Brownian) motion and because they are governed by the same statistical physics, colloids show similar phase transitions as atoms and molecules. However, due to their size and the processes occur at much longer timescales and we can easily visualize the phase transitions on a single particle level with an optical microscope. Today, thanks to advances in synthesis, colloidal particles can be synthesized with many different shapes, making them almost as complex as their atomic and molecular counterparts. In addition, due to their size and the possibility to make colloids out of many different materials, the structures formed by the self-assembly of colloids are also of interest as materials themselves, with applications in photonics, solar cells, catalysis and biomimicry. However, the biggest challenge is to assemble the particles in a controllable way and avoid mistakes, i.e. defects, in the crystal structures. Therefore, understanding of the effect of shape on the assembly process is needed.

In this project we will study the crystallization process of a novel type of colloids, those with a cubic shape (Figure 1). To induce their assembly, we will make use of critical Casimir forces. These attractive forces arise between the colloids due to the de-mixing of 2 solvents close to the critical temperature, and can be conveniently tuned with temperature. The goal is to understand how shape influences the crystallization process. For this you will study the crystallization of the colloidal cubes induced by the attractive critical Casimir forces with the confocal microscope. You will follow the crystallization process and investigate the crystal structures and defect structures that form. Further investigations will use image analysis techniques to track and trace each single particle to completely quantify the crystallization process.

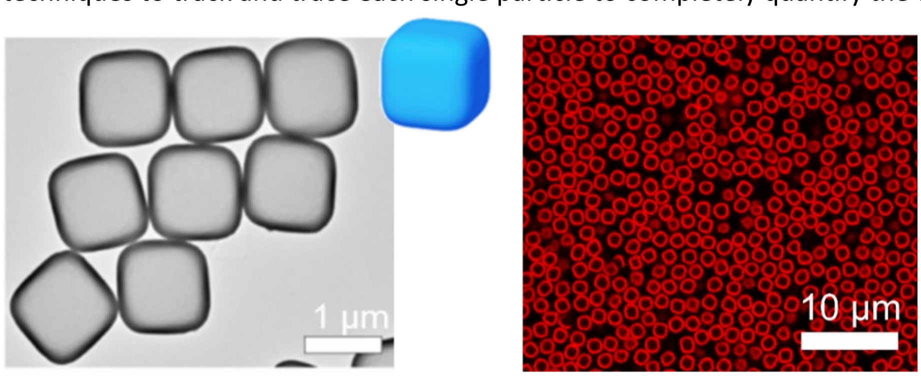

Figure 1. (left) Transmission electron microscope image of hollow silica cubes (right) Confocal microscope image of hollow silica cubes labeled with a fluorescent dye.