VCN-SANS measurement of magnetic colloidal crystals

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Due to unforeseen lucky circumstances (success producing a certain type of magnetic samples), we decided to postpone the measurement of the electro-neutron optical effect that was actually proposed and scheduled for experiment No. 3-14-363 and did the more urgent SANS measurements on the magnetic samples before. The decision paid off and led to a successful experiment.

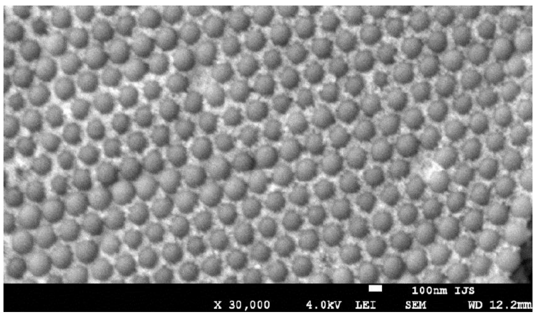

Figure 1: SEM image of a colloidal crystal structure fabricated by sedimentation on a silicon surface. Polystyrene-latex spheres were dissolved in a mixture of water and iron-oxide superparamagnetic nanoparticles with roughly 9 nm diameter. The concentration of both, spheres and nanoparticles, was 2.1 mg/ml. The scale bar corresponds to 100 nm.

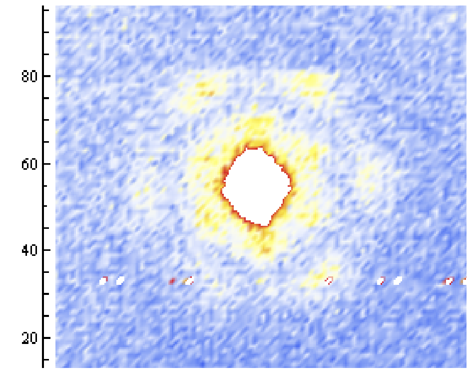

Figure 2: (a) Detector image of VCN scattering by a nanoparticle-doped colloidal crystal. Six spots within each of the two rings (rotated 30° relative to each other) due to the colloidal crystal structure are clearly visible. On top of the image unintended shielding of the detector is seen.

Light-sensitive materials combined with holographic techniques can be used to produce diffraction gratings for neutron-optics [1]. The treated materials exhibit a periodic neutron refractive-index pattern, arising from a light-induced density modulation. In recent years, we have shown that such holographic nanoparticle-polymer composite gratings can be used as 50:50 beam-splitters, mirrors or three-port beam splitters (30:30:30) for cold- and very-cold neutrons (CN and VCN) [2].
Our idea is to develop a new type of polarizers for CN and VCN, which will be based on diffractive structures made from composites of nanoparticles and polymers. Various fabrication methods are explored: holographic lithography, direct laser structuring and doping of colloidal crystals. It is the latter method that our collaboration could demonstrate successfully only recently. The refractive-index modulation for neutrons in these structures arises from periodic spatial arrangement of the nanoparticles in colloidal crystals. Such structures should best be fabricated with superparamagnetic nanoparticles. The reflectivity will become responsive to application of an external magnetic field. This can, in optimal conditions, lead to grating structures with zero reflectivity for one spin-state and 100 % reflectivity for the opposite spin state, i.e. a polarization beam splitter for neutrons can be realized [2, 3].
An example of a nanoparticle-doped colloidal crystal is shown in Fig. 1. We used a neutron beam with divergence limited – both horizontally and vertically – to 0.001 rad, collimated by two Cd slits at 2 m distance from each other to do SANS measurements with VCN at PF2. The sample-detector distance was typically about a meter to separate the diffraction spots caused by structures in the 100 nm range. An example of a detector image is shown in Fig. 2.
We also tested the magnetic field dependence of our best sample, but the results seem not to be conclusive, i.e. better samples or longer measurement time is needed.
The results will be presented in a dedicated publication [4].

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[4] M. Ličen, C. Pruner, M. Fally, L. Čoga, I. Drevenšek-Olenik, J. Klepp, U. Gasser, and G. Nagy (2016). In preparation.

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Instrument: PF2 VCN