ESRF	**Experiment title:** The structure of photonic colloidal crystals	**Experiment number:** SC216
Beamline: BL4/ID02	**Date of experiment:** from: 02-Sep-1996 07:OO to: 04-Sep-1996 07:OO	**Date of report:** 26-Feb- 1997
Shifts: 6	**Local contact(s):** Dr. Peter Bosecke and Dr. Olivier Diat	*Received at ESRF:* 28 FEV. 1997

Names and affiliations of applicants (* indicates experimentalists):

Willem L. Vos*, Mischa Megens*, and Mark Kroon*.
van der Waals-Zeeman Instituut
Universiteit van Amsterdam
Valckenierstraat 65
1018 XE Amsterdam
The Netherlands

Report:

On September 2-4, 1996, we have done a small angle x-ray scattering (SAXS) study of colloidal crystals with lattice parameters on the order of optical wavelengths. Our research interest is to use these crystals as so-called photonic crystals [l], and they are optically as multiply scattering as possible. Our main results are [3-7] i) we have managed to do SAXS on a single crystal, ii) we have succeeded in resolving the crystal structure of dense charge stabilized crystals, iii) the data from our experiments are essential for the interpretation of optical experiments, and iv) the form factors of the particles reveal a wealth of information on the internal structure of the colloids. Thus, synchrotron SAXS is a very powerful tool to study colloids, even at optical length scales.

We emphasize the necessity of using SAXS on BL4/ID2: Optical techniques probe too little reciprocal space to determine the structure of the colloidal crystals. Moreover, the large optical multiple scattering effects seriously impede structure determination [2]. The high brilliance of BL4/ID2 allows to study samples that are weakly scattering, e.g. latex particles in water. The narrow focus of the beam allows us to for the first time study single crystals. This is an important advantage over small angle neutron scattering.

- We have found reflections from a single crystal of charge stabilized latex spheres in water (see figure below). The structure is fcc, with the close packed planes parallel to the cell wall. This result reproduces a crystal with a much higher particle density, that was studied in a previous run.
- Common wisdom in colloid science has it that crystals order with close packed planes parallel to cell walls (windows), i.e. the 111 planes of fcc. Interestingly, we have observed single crystals of charge screened particles in water that have a different orientation. It is not yet clear whether the new orientation is parallel to a particular set of symmetry planes.
- We have studied charge stabilized crystals of silica particles in water. At the lowest density (- 8 vol%), we find ordered crystals. At higher densities, there are hardly anymore crystalline features. This appears similar to earlier experiments by Sirota et al (PRL 62, 1524 (1989)), who observed vitrification in dense charge stabilized samples.
- We have studied formfactors of the Colloids. The radii of particles with a NIST certificate agree very well with our results. It has been observed that at high scattering vectors, the intensities have an increasing tail in a Porod plot (intensity times s^4 vs. s). This has also been seen earlier by Diat. It is possibly an effect of saturation of the gas-filled detector, and warrants a closer look at the detection system.

[l] see e.g. E. Yablonovitch & D. Sievenpiper, Nature 383, 665 (1995).
[2] W.L. Vos, R. Sprik, A. van Blaaderen, A. Imhof, A. Lagendijk & G.H. Wegdam, Phys. Rev. B 53, 16231 (1996).
[3] W.L. Vos, M. Megens, C.M. van Kats & P. Bosecke, J. Phys. Cond. Matter 8,9503-9507 (1996).
[4] M. Megens, C.M. van Kats, P. Bösecke & W. L. Vos, J. Appl. Cryst. (1997, at press).
[5] M. Megens, C.M. van Kats, P. Bösecke & W. L. Vos, Langmuir (submitted).
[6] W.L. Vos, M. Megens, C.M. van Kats & P. Bosecke, Nature (submitted).
[7] W. L. Vos, M. Megens, C.M. van Kats & P. Bösecke, Conference *on Lasers and Electra Optics* (IEEE, Piscataway, 1996) p. 309.

Diffraction pattern of a single colloidal crystal, taken during run SC216 on ID2/BL4. The sample consists of r=101 nm polystyrene spheres in water. The spheres are charge stabilized at a density of 27 vol%. The sample has been rotated by 34 degrees away from normal incidence. The pattern clearly shows the Bragg peaks, which are those of an fcc crystal with lattice parameter 400 nm, viewed along the 110 axis.