ESRF	**Experiment title:** The structure of photonic colloidal crystals	**Experiment number:** SC-341
Beamline: BL4/ID02	**Date of experiment:** from: 18-Jul-1997 07:OO to: 21-Jul-1997 07:OO	**Date of report:** 26-Aug- 1997
Shifts: 9	**Local contact(s):** Dr. Olivier Diat	*Received at ESRF:* 1 SEP. 1997

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Report:

We have done a small angle x-ray scattering (SAXS) study of colloidal crystals. The main reason is to use the crystals as “photonic” crystals: three-dimensional dielectric composites with a with lattice parameters on the order of optical wavelengths [l]. These crystals are pursued with the goal to achieve novel optical phenomena. To achieve this, they should be optically as multiply scattering as possible, which precludes optical probes [2]. In addition, we are interested in the mesoscopic ordering of dense colloids[3]. Colloids are often viewed as an enlarged and slowed down analogy of atomic condensed matter, yet important differences exist. Our experiments have shown that synchrotron SAXS is a powerful probe of Colloids [3-8]. Yet, this technique is surprisingly hardly applied in this field.
In collaboration with Dr. Diat, the first day of the experiment was basically spent testing the CCD camera, which had its “maiden run”. The advantage over the usual gas-filled detector is that the smaller pixels result in a higher resolving power and that the photon count rate can be much higher, whereas its dynamic range is lower. The system is linear over 3.5 decades in intensity, which isan improvement over previous experiments. Unfortunately, the control software was still in an early version and there was way too little data storage space. Therefore, we often had to wait for backups. Fortunately, we still obtained exciting results:
The SAXS data have elucidated optical experiments: several crystals had a low optical transmission at frequencies beyond the first Bragg reflection [4]. This was surprising, since the crystals appeared as large single crystals to the naked eye, and the Bragg reflections had

flat Darwin-like shapes, suggestive of high quality crystals. In the SAXS experiments ***on the*** same ***samples,*** it turned out that the crystals revealed only few Bragg reflections, hinting at disorder. Moreover, crystals with a high optical transmission revealed many SAXS reflections over a wide range in reciprocal space, indicative of well-ordered crystals. Thus, the conclusion is that highly ordered crystals correlate with a high optical transmission, whereas optical reflection is apparently less sensitive to order.

In all of our SAXS experiments, we have only found evidence for the fcc structure, which is desirable for photonic crystals. On the other hand, others often find random stacks of hexagonal close-packed planes (rscp). In the present run, we have at several instances recorded diffraction patterns with a cubic symmetry (see figure), which has never been observed before on colloids. This firmly supports our other observations of fcc. It is known that shear induces rscp, but this probably does not explain recent spacecraft experiments.

We have obtained reliable intensity measurements on single crystals. The goal is to obtain Debye-Waller factors, and to determine the excursions of the particles about their lattice sites. This should yield constraints on the many body interactions between the colloids, which are fundamentally different from atomic condensed matter, on account of hydrodynamic interactions, but which are currently subject to debate. The single crystal data should be a major improvement over the powder data, that we obtained in a previous run [5].

[l] See e.g. J.D. Joannopoulos, P.R. Villeneuve & S. Fan, Nature 386, 143 (1997).
[2] W.L. Vos, ***et al,*** Phys. Rev. B 53, 16231 (1996).
[3] M. Kroon, W.L. Vos & G.H. Wegdam, Phys. Rev. E (accepted, 1997).
[4] W.L. Vos, M. Megens, C. van Kats & P. Bosecke, J. Phys.:Cond. Matt. 8,9503 (1996).
[5] M. Megens, C.M. van Kats, P. Bosecke & W. L. Vos, J. Appl. Cryst. (1997, at press).
[6] M. Megens, C.M. van Kats, P. Bosecke & W. L. Vos, Langmuir (accepted, 1997).
[7] W.L. Vos, M. Megens, C.M. van Kats & P. Bosecke, Langmuir 13 (Nov. 12), with front cover. See also ESRF Newsletter, No. 29, 8 (July 1997).
[8] W. Vos, ***"Photonic Colloidal Crystals",*** ESRF seminar 07/01/97, invited by M. Altarelli.

Diffraction pattern of a single colloidal crystal, taken during run SC341 on ID2/BL4. The sample consists of r=101 nm silica spheres in water. The spheres are charge stabilized at a density of ~40 vol%. The sample has been rotated by 50 degrees away from normal incidence. The pattern clearly reveals many Bragg peaks, which are those of an fcc crystal viewed along the cubic 100 axis. This has never been seen before.