ESRF	**Experiment title:** **Ordering and dynamical properties of colloidal particles in a planar X-ray waveguide**	**Experiment number:** SI-498
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Names and affiliations of applicants (* indicates experimentalists):

M.J. Zwanenburg*, J.H.H. Bongaerts*, N.Q. Vinh*, J.F. van der Veen*

Van der Waals-Zeeman Institute, University of Amsterdam, The Netherlands

Report:

We have performed X-ray scattering experiments on suspensions of colloidal particles confined in a planar x-ray waveguide [1,2]. We studied colloidal suspensions of monodisperse SiO_2 particles, having a diameter of 25, 120 and 200 nm, suspended in various liquids. The photon energy was 13.3 keV.

Prior to the experiments on confined colloids we investigated mode propagation the empty waveguide. In the previous experiment (SI-451, June 1999) we added SiO_2 layers (see Fig. 1) as spacer layers to improve the accuracy of setting the plate distance. The effect of these layers were characterised by measuring the far-field angular intensity distributions using a 2D CCD detector (Sensicam, 12 bit cooled image with 6-7 μm pixel size) for values of θ_i and θ_e up to 0.15° as shown in Fig. 2. The intensity for $\theta_e > 0.13°$ or for $\theta_i > 0.13°$ is due to the excitation of modes which extend into the SiO_2 layers. Good agreement between the calculations and the data demonstrates that we now fully comprehend the propagation of x-rays in our complex waveguiding geometry.

We confined a colloidal suspension of 120 nm diameter SiO_2 particles (1 vol. %) in dimethylformamide (DMF) in a gap of 310 nm. The resulting far-field angular intensity distributions as a function of the angle of incidence are shown in Fig. 3a. The intensity observed away from the diagonal ($\theta_i=\theta_e$) is due to a modulation of the density (refractive index) induced by the colloidal particles. Since a cross-diagonal crosses the diagonal at mode 2 (θ_i =0.022°), the density profile perpendicular to the surfaces has approximately the same spatial frequency as mode 2. This means the colloidal particles are ordered in two layers across the gap. Fig. 3b shows calculations of the far-field intensity distributions assuming a z-independent density profile across the gap as shown in the inset. The observed asymmetry in the measured intensity with respect to the diagonal is due to inhomogenieties in the density along the z-direction.

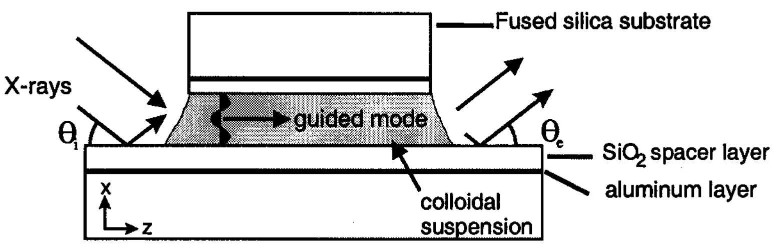

Fig. 1 Schematic of waveguiding geometry.

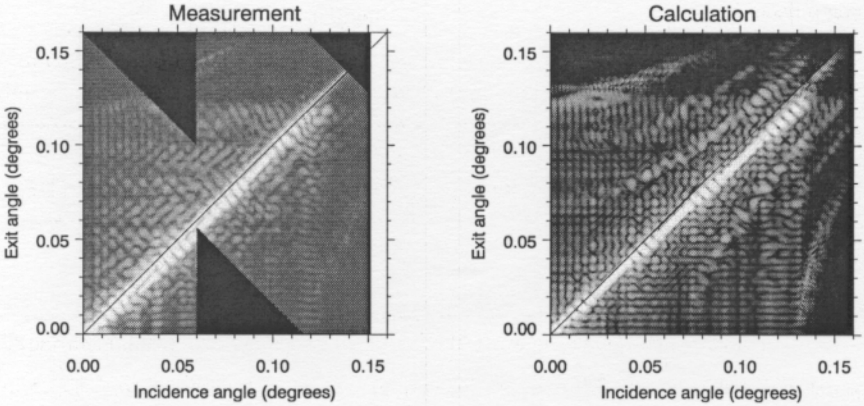

Fig. 2 Logarithmic contourplot of measured (left) and calculated (right) far-field angular intensity distributions as a function of the incidence and exit angle for an empty waveguide. The calculations take into account the presence of the SiO_2 and aluminium layers.

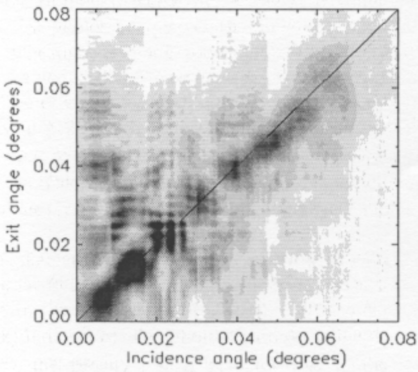

Fig.3a Linear contourplot of measured far-field angular intensity distribution as a function of the incidence and exit angle for a waveguide filled with colloidal particles.

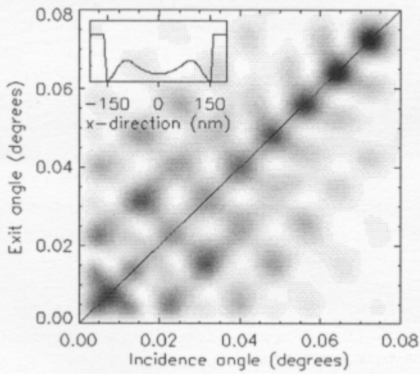

Fig.3b Linear contourplot of calculated far-field angular intensity distribution assuming a z-independent density profile across the gap as shown in the inset.

In order to further explore the possibilities of our waveguiding method, we filled the air gap with a suspension of 25 nm SiO_2 particles in dimethylformamide (DMF) and reduced the gap width down to approximately 250 nm. We observed, by means of optical interferometry [2], a confinement induced crystallisation of the confined fluid for gaps settings <1 μm. To remove residual colloidal particles in front of the waveguide, which may affect the measurements, we retracted the upper surface and replaced the lower surface. For several plate distances we measured far-field angular intensity distributions as a function of the angle of incidence. Recent calculations and AFM measurements confirmed that the asymmetry in the measured intensity with respect to the diagonal is due to an asymmetry of the refractive index profile along the z-direction. Further analysis of these measurements is in progress.

[1] M.J. Zwanenburg, J.F. Peters, J.H.H. Bongaerts, S.A. de Vries, D.L. Abernathy, and J.F. van der Veen, Phys. Rev. Lett. 82 (1999) 1696.
[2] M.J. Zwanenburg, J.F. van der Veen, H.G. Ficke, H. Neerings, Rev. Sci. Instr.71, no.4 (2000)