ESRF	**Experiment title:** Ordering of liquids confined in planar waveguides	**Experiment number:** SI-346
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Report:

We performed X-ray scattering studies of ordering phenomena in confined colloids. As a sample container we used an improved version of our tuneable X-ray waveguide (see Figure 1).

The waveguide surfaces were fused silica disks coated with a chromium layer and had a final rms roughness of about 0.4 nm as was confirmed by X-ray reflectivity measurements. The upper surface (0 5.2 mm) was mounted on a piezoelement which in turn was mounted on a tripod of piezo-driven inchworm motors. The inchworms were used for a coarse approach to the lower plate and for tilt adjustments. The additional piezo-element was used for fine tuning of the gap which is necessary to correct for tiny mechanical and thermal drifts of the system. During the experiment the gap width and the tilt of the upper surface was continuously monitored using fringes of equal chromatic order (FECO)[2] with nanometer precision.

The entrance of the waveguide was illuminated with a 16.5 keV monochromatic X-ray beam. The guided beam is laterally coherent because the -500 mn gap width is much smaller than the transverse coherence length of the incident beam. The longitudinal coherence length is much larger than the maximum path length difference possible in our experiment. Hence, the non-zero bandwidth of the monochromator does not affect the coherent phase relation between different guided modes.

The undisturbed propagation of modes in the empty waveguide can be observed from the Fraunhofer diffraction patterns (FDP's) from the waveguide exit. These reveal which modes are excited in the waveguide for a given angle of incidence θ_i. We measured FDP's for values of θ_i ranging from 0 to 0.05° in steps of 0.001° using a NaI scintillation detector. Figure 2 shows a contour plot of the diffracted intensity as function of θ_i and θ_o.

The maxima in the plot at angles of incidence $\theta_i=(m+1)\lambda/2W$, as indicated by the crosses, are the guided modes supported by the empty waveguide. Their angular spacing corresponds to gap width W of 486 nm, which confirms the interferometrically measured gap width. The surfaces have a r.m.s. roughness of 0.4 nm and no off-diagonal peaks due to roughness-induced mode-mixing are observed. However, we do observe subsidiary diffraction maxima from the exit plane of the waveguide. We note that the waveguide performs much better than the one used in run SI-245 in June 1997. The improvement lies in much better control of the gap distance (~2 nm positioning accuracy) and in a smoother upper surface.

At angles of incidence in between two modes the incident field does not match the field distribution of a mode and the intensity is distributed mainly over the two neighbouring modes. The superperiod in the intensity variations along the diagonal is a direct consequence of multimode interference. Hence, the phase relation between the different modes, as given by their propagation constants, is preserved over the entire length of the waveguide.

Our waveguide is designed to serve as a sample container of fluids. We filled the waveguide with a suspension of silica particles (0 120 nm) in dimethylformamide and set the gap distance to ~500 nm. The experiment was aimed at investigating the ordering of the particles in the gap. One intuitively expects ordering in layers parallel to the confining walls. The layering sets up a modulated refractive index profile across the gap and one should be able to observe selective mode coupling as a result of that. Indeed this is what we appear to see in our experiment. The mode excitation spectrum was determined by measuring FDP's for various incident modes. Figure 3 shows a FDP from the exit of the filled waveguide for a TE_4 mode launched at the entrance. An analysis using couple mode theory[4] is in progress, see preliminary fit.

[1]M.J. Zwanenburg *et al.*, submitted.
[2]S.Tolansky, *Multiple beam interferometry of Surfaces and Films* (Oxford University Press, London, 1949).
[3]Y.P. Feng *et al.*, Appl. Phys. Lett. 64 (1994) 930.
[4]D.Marcuse, *Theory of Dielectric Waveguide* (Academic Press, San Diego, 1991).

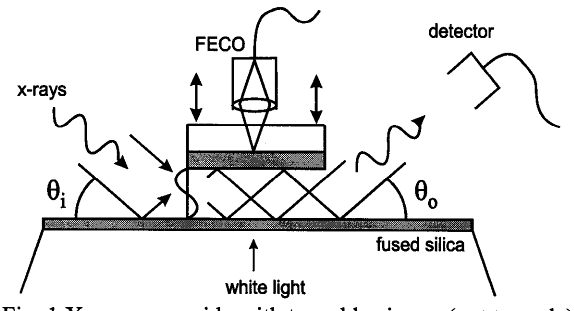

Fig. 1 X-ray waveguide with tuneable air gap (not to scale)

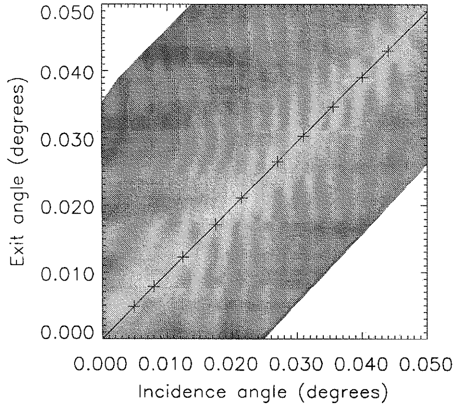

Fig. 2. Contour plot of diffracted intensity as a function of θ_i and θ_o, measured with *W=486 nm.* The crosses indicate the TE-modes excited in the waveguide.

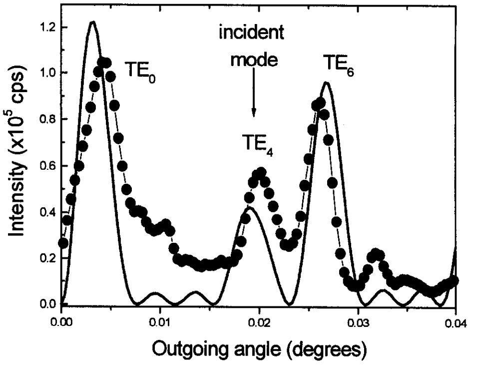

Fig. 3. Fraunhofer diffraction pattern from waveguide exit for incident TE_4 mode (circles). The solid curve represents a calculation based on mode-coupling theory.