ESRF	**Experiment title:** **Mode coupling induced by density variations in a liquid-filled planar X-ray waveguide**	**Experiment number:** SI-451
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Report:

We have performed static and dynamic x-ray scattering experiments on a suspension of spherical colloidal particles inside a planar x-ray waveguide [1]. A schematic drawing of the waveguide setup is shown in *figure 1*. The goal is to relate the dynamic properties of a colloidal suspension to its structural properties. The different suspensions used in the experiments consisted of monodisperse silica balls of either 25, 120 or 208 nm in diameter in various liquids. The photon energy used was 13.3 keV.

We tested several improvements to the waveguiding setup. Firstly, we were able to set the waveguiding plates to a much smaller distance because we changed the composition of the confining plates. A semitransparant metallic layer (aluminum) is used as before in order to determine the plate distance using the optical technique called fringes of equal chromatic order (FECO [2]). New is the SiO_2 spacer layer of 2-3 μm deposited on top of the metallic layer. This layer increases the distance between the metallic mirrors, while the opposing SiO_2 surfaces (3-4 Å rms roughness, AFM) serve as the guiding walls for the x-ray waveguide. Another improvement is the use of aluminum in stead of chromium. Aluminum has a higher optical reflection coefficient than chromium, resulting in sharper interference peaks which improves the accuracy of the FECO technique. We were able to go to plate distances as small as 80 nm.

Using a 2D CCD detector (Sensicam, 12 bit cooled image with 6-7 μm pixel size) we speeded up the experiments more than a factor 30, thus reducing drift in the plate distance and other time-dependent factors like x-ray beam instability and drying of the colloidal suspension. Experiments that took one complete shift in previous runs could now easily be performed in less than 15 minutes. This made possible, among others, a thourough study of mode propagation in a tapered waveguide. *Figure 2* shows a typical CCD picture. The modes exiting the waveguide can be seen as strips in the vertical direction. This is the Fraunhofer diffraction pattern of the field amplitude across the exit of the waveguide (see [1]). We have also studied mode coupling in colloid-filled waveguides. The data are currently being analyzed.

We have investigated the feasibility of dynamic x-ray photon correlation spectroscopy (XPCS) for the first time inside a waveguide filled with a colloidal suspension. From these measurements the effective diffusion

constant can be obtained. Contrary to what we expected we observed a flat time correlation function when positioning the point-detector at a mode of the waveguide. Apparently the fluctuations in the scattered intensity where too small compared to the static background. However, we did measure correlation functions when positioning the detector on the incident mode and then translating it parallel to the walls of the waveguide (scanning out in $q_{//}$). The reason for the absence of a measurable XPCS signal in the modes (for $q_{//} = 0$) is not yet clear. In the vertical scanning direction a damped 10 Hz cosine is almost always present in the correlation function. This cosine has previously been observed in bulk XPCS experiments at ID10A. Another reason may be that the colloid particles are indeed immobile or have a diffuse time outside the observable time window of the experiment (0.1- 10^4 ms). Further experimental tests are required.
An example of a correlation function is shown in fig. 3. The correlation function was measured for a suspension of 3 vol% 120 nm SiO_2 spheres in a 2 μm gap. The contrast of 2.5% is low compared to contrasts achieved normally in bulk XPCS. Measurements with gaps of 20 μm showed contrasts of 6-7%. Also shown in fig. 3 is the theoretical correlation function ($g_2 = \beta$ Exp$(-t\ D_0 q^2) + 1$) for single particle diffusion in bulk. This function does not significantly differ from the measured correlation function for diffusion parallel to the plates. The XPCS yield is very low (800 cps in fig.3). In a future experiment a factor of hundred could be gained by just using the undulator peak as energy bandpass, rather than a Si(111) monochromator. This would hardly affect the coherency.

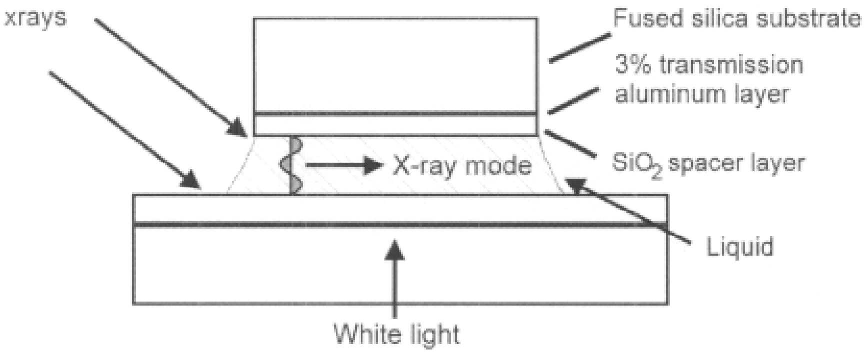

Figure 1 Schematic drawing of the x-ray waveguide setup

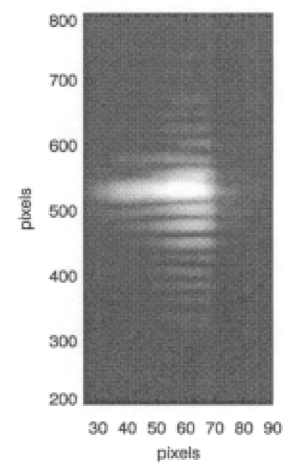

Figure 2. CCD image of modes exiting an empty waveguide for a gap width of 600 nm.

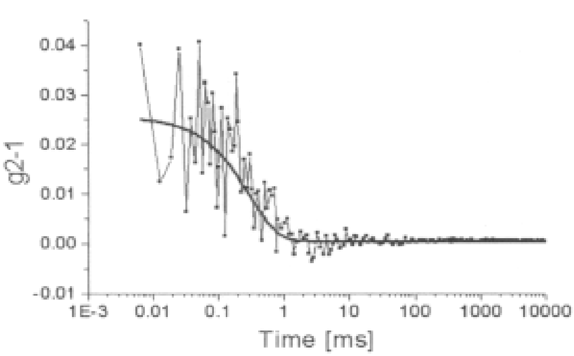

Figure 3 Time correlation function for ∅120 nm SiO_2 spheres inside a 2 micrometer wide waveguide. The solid line is the theoretical decay for single particle diffusion in bulk.

Literature
[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. Letters, Vol. 82, No. 8, 22 November 1999, p 1696.
[2] S. Tolansky, *Multiple beam interferometry of Surfaces and Films* (Oxford Univesity Press), London 1949.