ESRF	**Experiment title:** Diffraction in planar solid-liquid-solid waveguides	**Experiment number:** SI-245
Beamline: ID10	**Date of experiment:** from: 24-6-97 to: 29-6-97	**Date of report:** 21-8-97
Shifts: 18	**Local contact(s):** D.L. Abernathy	*Received at ESRF'.* L 1 SEP. 1997

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Report:

We have developed and successfully tested the first X-ray waveguide with a tunable air gap as a guiding layer (see Figure la). In future studies, the air gap is to be used as a container of liquid samples. In this way it will be possible to perform X-ray scattering studies of ordering phenomena in confined liquid films of molecular thickness, free of background scattering from the environment. In this first experiment we investigated the mode propagation in the waveguide in the absence of a liquid (air gap). We also tested the use of a resonant beam coupler (RBC) as pre-compressor of the beam in front of the waveguide (see Figure 1 b).

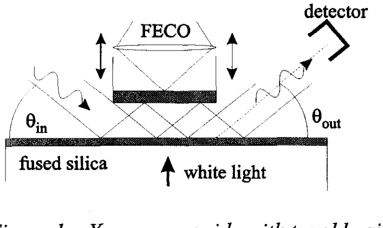

Figure 1a X-ray waveguide with tunable air gap (not to scale).

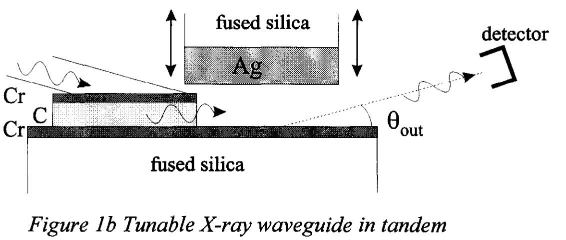

Figure 1b Tunable X-ray waveguide in tandem with a resonant beam coupler (not to scale).

The bottom waveguide surface was a chromium coated fused silica disk. The top surface was a silver coated fused-silica surface (0 4 mm) which was mounted on a tripod of piezo driven inchworm motors. Using the tripod we were able to control the gap between the chromium and the silver layer and the tilt angle of the upper surface with respect to the lower surface. During the experiment the gap size and tilt angles were continuously monitored using optical multiple beam interferometry with nanometer precision. The smallest gap size achieved was 250 nm, resulting in a gap length to width ratio as large as 1.6×10^4. The positioning and readout system can readily be adapted to yield gaps down to tens of nanometers or even less.

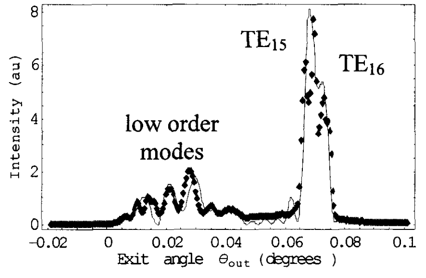

Figure 2 Example Fraunhofer diffraction pattern measured at exit of the waveguide

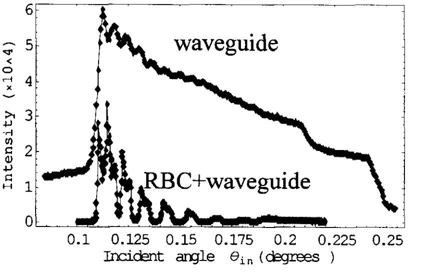

Figure 3 Transmission of RBC and waveguide in tandem compared to transmission of waveguide. Upper curve is shifted 0.1 degree to the right for clarity.

The entrance of the waveguide was illuminated by a 16.5 keV monochromatic X-ray beam. Given the small gap size, the guided beam is laterally coherent in the direction perpendicular to the surface planes. We measured the Fraunhofer patterns resulting from diffraction at the exit of the waveguide for angles of incidence ranging from 0 to 0.1 degrees with steps as small as 0.001 degree. Figure 2 shows one of these Fraunhofer patterns as an example. The peaked structure is a clear indication for the excitation of discrete guided modes in the waveguide. In the example given, the angle of incidence is such that mainly the TE_{15} mode is excited, but other modes appear as well. This is due to ' mode-mixing' induced by surface roughness and other imperfections at the entrance of the waveguide. The solid curve is the calculated Fraunhofer diffraction pattern obtained by incoherent superposition of the different modes excited within the waveguide.

We used a resonant beam coupler in front of the waveguide in order to pre-compress the beam to dimensions similar to the gap size and to eliminate scattering effects at the entrance of the waveguide. Figure 3 shows the transmission of the RBC and the waveguide in tandem and of the waveguide alone. An analysis of the transmission properties of the RBC and waveguide in tandem is in progress, along with analyses of the Fraunhofer patterns measured from the exits of the RBC and the waveguide.

[1] Y.P. Feng, H. W. Deckman and SK. Sinha, Appl. Phys. Lett. 64 (1994), 930.