ESRF	Nanometer hard x-ray focussing by reflective off-axis zone plates	**number:** MI-873
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Names and affiliations of applicants (* indicates experimentalists):
Tim Salditt*, Sebastian Kalbfleisch*, Klaus Giewekemeyer*, Sven Krüger*,
Institut für Röntgenphysik
Universität Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen (Germany)

Report:

The aim of this experiment was to demonstrate heterodyne photon correlation spectroscopy on colloidal suspensions using a pair of lithographic Y-shapes channel waveguides, with an expected sensitivity down to single colloid dynamics. The conception of the experiment was based on an dynamic extension of a recent reference beam holography experiment [1]. The experiment was carried out at ID10c after installation of our dedicated waveguide imaging stage. The photon energy was set to $E = 10.44$kev by a double bounce $Si(111)$ monochromator. Higher harmonics were suppressed by double bounce silicon mirrors inclined at 0.16° incidence angle. The flux density of the unfocused primary beam was $I_0 = 5 \times 10^{13} cps$ at 150 mA ring current. Two different optics were used as pre-focusing elemts necessary to generate a high flux density at the front side (entrance) of the waveguide: (i) A Fresnel zone plate (FZP) made from W zones deposited on a SiN foil with diameter $D = 295\mu$m, outermost zone width of $\Delta r_n = 400$nm, producing a focal length of $f = 994.3$mm at $E =$ 10.44kev. (ii) Crossed linear compound refractive lenses fabricated by lithography in SU8 (SU8-CRL) resist. Note that Si nanolenses do not operate efficiently in this energy range, so that lenses structured in polymer offer an attractive alternative. Out of the several lenses on the chip, row number 2 with 88(horz) × 50(vert) lenses with radius of curvature $R = 16.125$ and effective geometric acceptance of 129μm were selected, resulting in a calculated 18.000 fold gain (flux density) and a focal spot of 540(horz)×90(vert)nm^2. Unfortunately, with none of the two above optics, we were able to achieve the calculated focal spots and the high gain necessary to couple a sufficient number of photons into the waveguide channels for photon correlation spectroscopy. Previous 2D waveguide experiments had benefited from the high gain of the ESRF KB-focusing system in the range of $10^4 - 10^5$ (ID22,depending on the beamline parameters). The FZP resulted in a 8μm (vertical focus, FWHM, determined from knife edge scans) and thus about ten times larger than the calculated 700nm demagnified image of the 30μm source. The measured focus of the CRL in the vertical direction yielded a FWHM of 600nm (measured by translating a planar waveguide through the focus). However, the gain was not sufficient. Thus, heterodyne photon correlation with the waveguide beams was not possible as planned.

Therefore we decided to couple the unfocused undulator beam into the waveguide, which was possible given the comparably high flux density at ID10, and to record static images on test objects. To this end, a novel generation of lithographic channel (2D) waveguides fabricated by wafer bonding was characterized (Hillmann at al., to be published). Fig. 1 (left)shows SEM micrographs of the entrance side of these structures. The waveguides exhibit shapes of rounded triangles, with a base length of roughly 4μm and were cut to a length of $l = 5$mm. The coherent beam impinging on the waveguide then generates multimodal beam propagation. Fig. 2 (right) shows the coherent farfield pattern recorded with a back illuminated CCD (Princeton , SX1300) placed at a distance of 2700mm behind the waveguide, along with vertical and horizontal projections which show the speckeled nature of the beam. Gaussian lineshapes are shown for comparison as enveloppes of the farfield patterns.

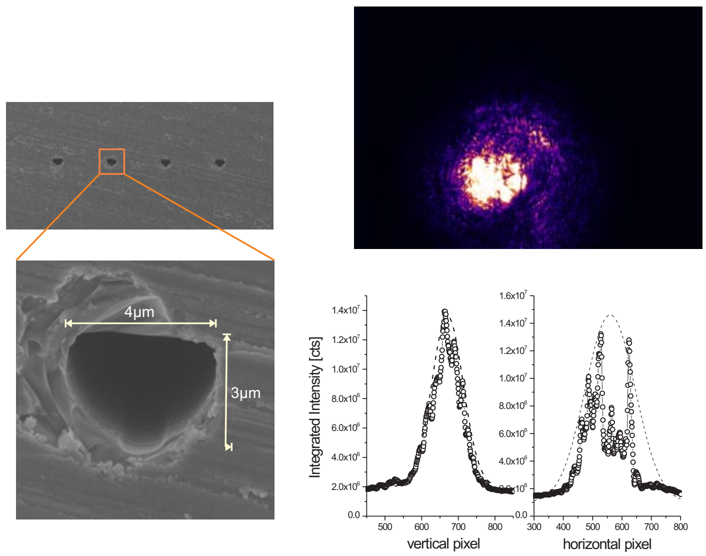

Fig. 1: *Lithographic channels etched in silicon and covered by wafer bonding. (left) SEM micrographs of the channels. (right, top) 2D coherent farfield pattern with (right, bottom) vertical and horizontal projection. Due to the lack of high gain pre-focussing, only very large multimodal waveguides could be used.*

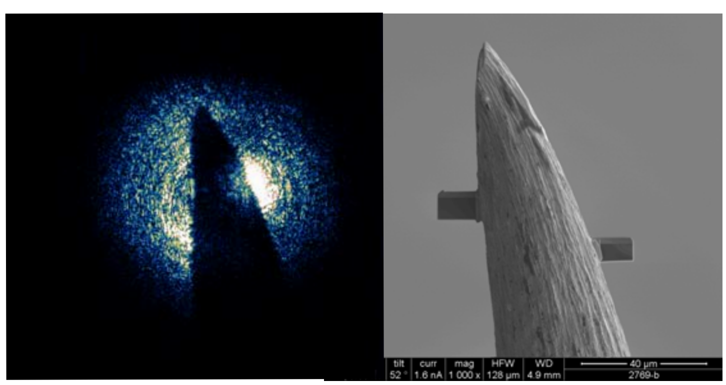

Fig. 2: *(left) Far-field image of the W-tip in the multimodal waveguide beam, and (right) SEM image. Reference samples (TEM lamellae) were attached to the tip. Data analysis is in progress.*

[1] C. Fuhse, C. Ollinger, T. Salditt, Phys.Rev.Lett. 97, 254801 (2006).