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Basic parameters of an experimental set-up using a microfocus x-ray source

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Introduction

Recent developments of x-ray imaging techniques at synchrotrons such as phase cotrast imaging[1,2] present a strong driving force for the development of laboratory x-ray imaging techniques [3]. The brilliance of new micro-focus sources combined with suitable source-side optics gives the possibility to transfer some demanding experiments from synchrotrons to laboratories. Concerning detection side, new approaches include single photon counting with semiconductor radiation detectors and the so called “colour” imaging allowing evaluation in a pre-selected photon energy window [4]. These new techniques substantially improve overall diagnostic performance of new generation x-ray systems [5].

The basic parameters of an experimental set-up using microfocus x-ray source like a focus size and spatial resolution are presnted. To asses the coherence character of imaging a Fraunhofer diffraction is simulated. Transverse spatial coherence is generated by using a small focus size of the x-ray source and phase contrast images are observed by appropriate settings of imaging geometry.

Experimental Setup

Based on our experience in x-ray crystal optics, in semiconductor detectors and in x-ray imaging we are developing a variable x-ray optical bench to study some of modern imaging techniques [6].

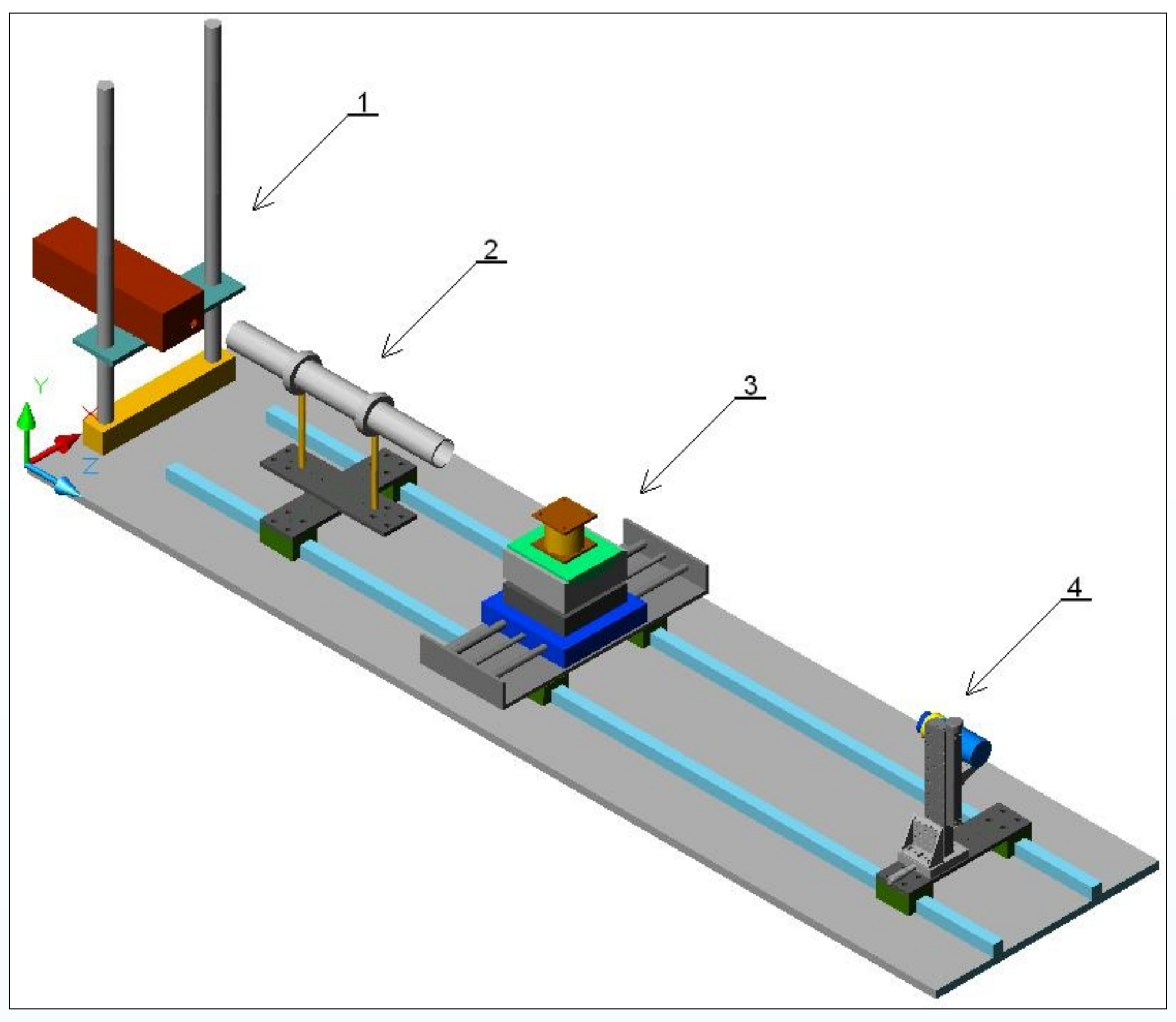


Fig. 1.

(1)Hamamatsu microfocus x-ray source (L6731-01 type)
(2)Collimator ø50x500 [mm](option)
(3)Newport goniometer to adjust and rotate the object or optics
(4)x-ray Mini FDI camera, Photonic Science, Ltd.

The enclosed radiation leak protected optical bench 2,6 m long contains a vertical stand for a Hamamatsu microfocus x-ray source (L6731-01 type), longitudinal slides for changing geometrical magnification and moving various components, a Newport goniometer to adjust and rotate the object or optics, and another stand for detector or camera slides [6, 8].

We have started in running the new x-ray camera recently. We use a CCD x-ray MiniFDI camera with 1392 (h) x 1040 (v) pixels, 6.45 microns square for imaging purposes. The high quantum efficiency interline transfer CCD is optically bonded to a coherent straight fiberoptic of input diameter approximately 11,3 mm, on the front of which a gadolinium oxysufphide x-ray scintillator has been deposited [9].

Testing of focal spot size of x-ray source

The focus size of the x-ray source with a transmission tungsten anode (declared as of 8 μm) has been measured using the technique of imaging a tungsten crossed wires according to EN 12543-3 [8]. At the full power of 80 kV and 100 μA the technique has given focus size of 8.6 μm in horizontal and 6.2 μm in vertical direction [6].

Dependence of x-ray tube spot size (FWHM) on tube voltage

The measurements were performed with three tools: grid mesh-1000, grid mesh-2000 and a slit, edges of which were used as "knife edges". Though differences are larger than estimated error bars, the results seem to be consistent between the three sets.

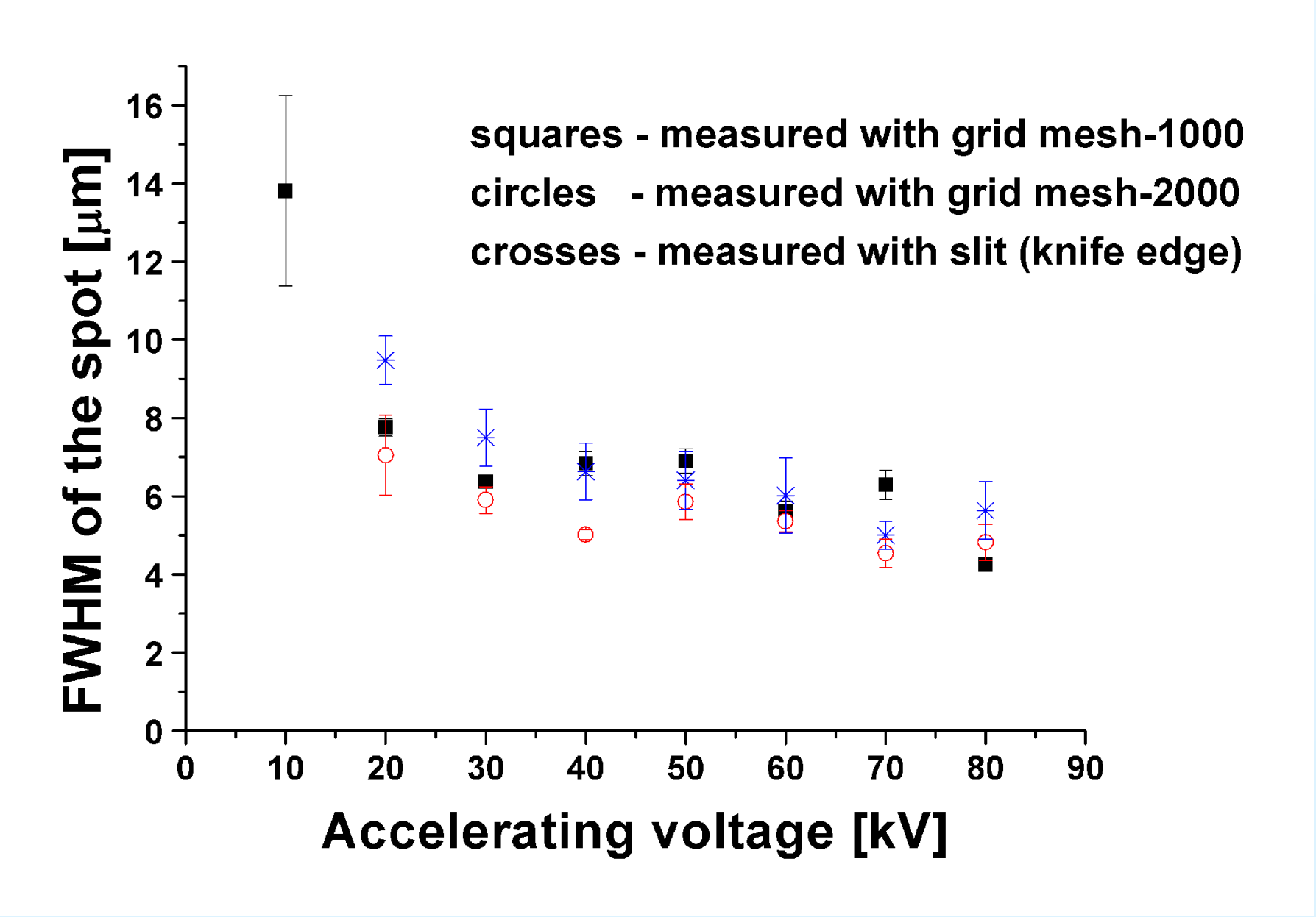


***Fig.2.** Dependence of the FWHM of the spot on the accelerating voltage.*

Measurement of spatial resolution

One of the most important imaging parameters is spatial resolution. A technique using full width at half maximum (FWHM) of the absolute derivative of transmission function of a gold grid has been used for the purpose. The distance between the source and the sample was 27 mm and between sample and camera 219 mm. Magnification was 9.1.

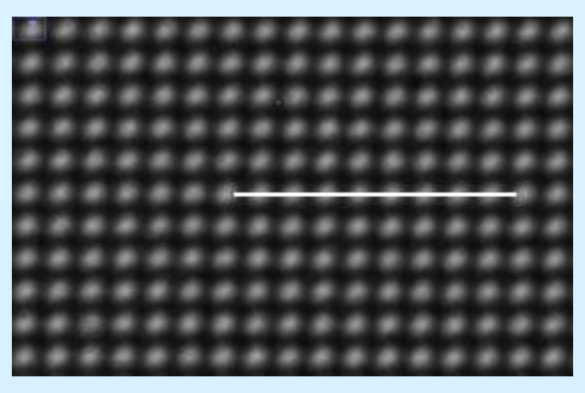
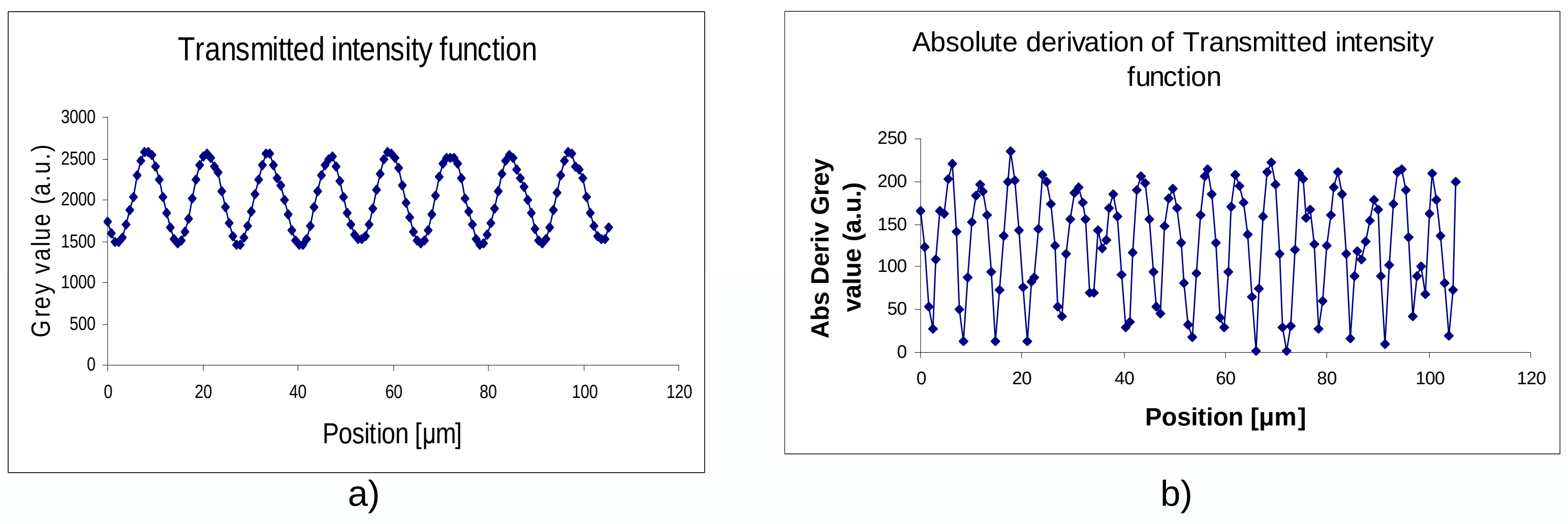


***Fig. 3.** X-ray image of a gold microscopic grid with 4÷5 μm stripes, 12.5 μm period taken with the geometrical magnification of 9.1, accelerating voltage 40kV,current 100 μA, exposure time 10 s.*

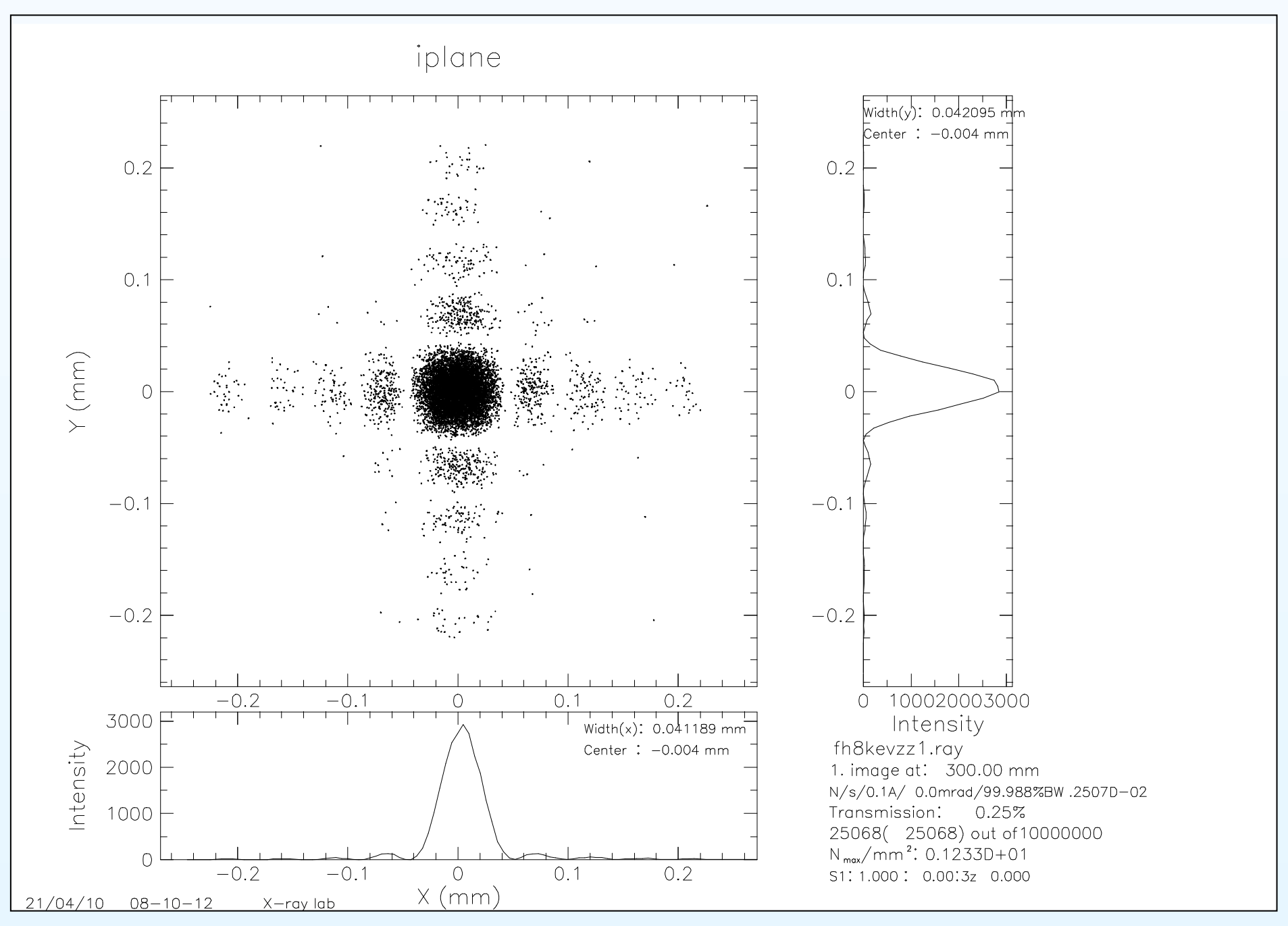


a) b)

***Fig. 4.** a) Transmitted intensity function from the white horizontal region indicated in Fig.3., b) Absolute value of the first derivative of the transmitted intensity profile and calculated FWHM of 3÷5.2 μm.*

Simulation of Fraunhofer diffraction

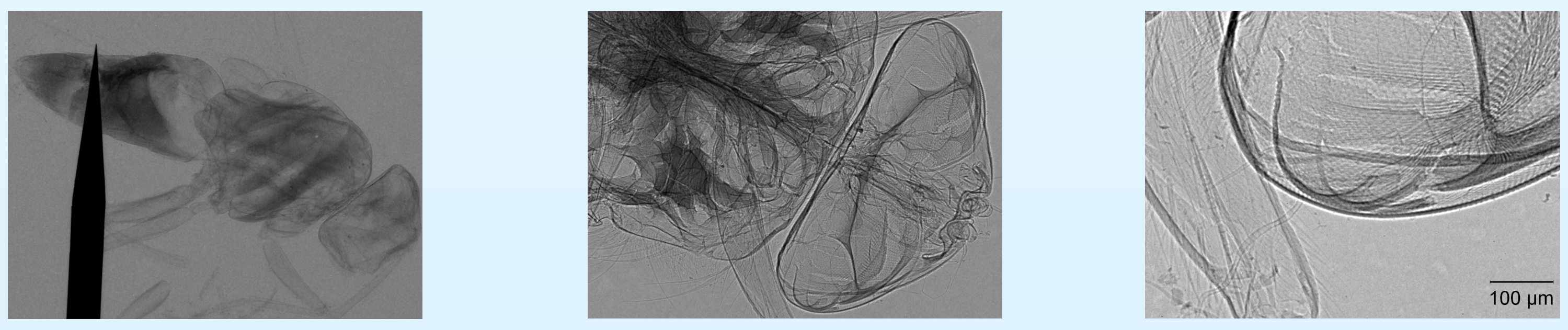
To assess the coherence character of imaging we are simulating the Fraunhofer diffraction at a rectangular aperture using the BESSY raytracing program RAY [10]. Preliminary results show that ripples up to 100 μm distance from the edges are observable (see Fig. 5).



Parameters of simulation:
Number of rays: 10 000 000
Source: (w x h x d) = 0.008 x 0.008 x 0.008 [mm]
Energy of photons:
E_0 = 8039,960 eV, (λ = 0,1542 nm)
ΔE = 4000-12000 [eV]
One optical element: slit (w x h) = 0.001 x 0.001 [mm]
Source-slit distance: 20 mm
Slit-image plane distance: 300 mm

***Fig. 5.** Fraunhofer diffraction at a rectangular slit as simulated by the ray tracing program RAY.*

The images done with the built-up imaging system



a) M=1.02
SDD = 508.8 mm
SOD = 500 mm

a) M=2.29
SDD = 370.8 mm
SOD = 162 mm

a) M=9.09
SDD = 290.8 mm
SOD = 32 mm

M – geometrical magnification, SDD – source-detector distance, SOD – source-object distance

M = SDD/SOD

***Fig. 6.** Radiographs of a fly using accelerating voltage 80kV, current 100μA, exposure time 20 s. **a)** the absorption contrast is dominating, **b)** phase contrast is starting to be seen, **c)** phase contrast is clearly observable as dark-bright contrast on the edges due to the beam deflection induced by the change of refractive index.*

Conclusion

Basic parameters and options of the current set-up of the imaging system were defined. A first experience shows that with the present set-up it is possible to achieve the spatial resolution down to 3 micrometers. The system in this establishment is suitable for small samples, because of using camera with a relatively small input active area approximately 10x8 mm. The high resolution rotation stage for the sample holder allowed us to take sequential computer tomography pictures which are now being reconstructed into 3D tomographs.

Acknowledgement

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