Using a Photoelectron Emission Microscope as an Image Detector for Hard X-rays

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Introduction

Photoelectron emission microscopes (PEEMs) can be used as x-ray detectors to produce x-ray images with excellent lateral resolution. The use of PEEMs as detectors offers several advantages, in particular high lateral resolution: the resolution can reach the 20 nm level when soft-x-ray photons are used.[1-3] Although configuring a PEEM as a x-ray detector was proposed and tested by various groups, it was mainly used for soft-x-rays.[4-5] In the present work, we achieved a resolution ~0.3 µm with no indication that we reached the lower limit.

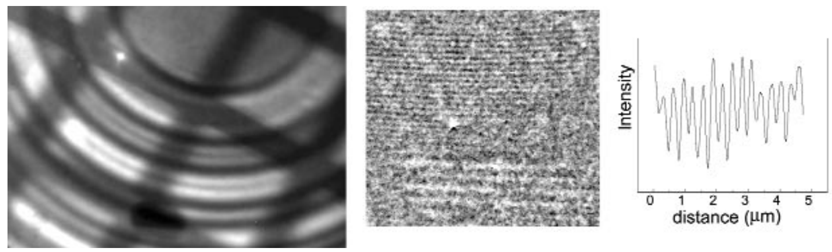

FIG. 1. Images taken in the PEEM "transmission" geometry: a Fresnel zone plate consisting of circular zones (Au) on a silicon nitride substrate. Note in (a) the edge-enhancing fringes typical of phase-contrast radiography. The underlying shadow is from a metal mesh with 25 µm pitch. (b) Image taken at the outer zones of ~0.3 µm pitch. The area in the lower part of the images is from those "collapsed/damaged" zones. (c) The corresponding line scans of the intensity taken from the area indicated in (b).

Methods and Materials

The experimental geometry is what we call the "transmission" mode of PEEM. In this case, x-ray photons from the other side of the screen (acting as a photocathode as well as a vacuum window separating the PEEM chamber from air), with respect to the PEEM, travel through the screen, and some of them can stimulate the emission of photoelectrons from the PEEM side.[6] The photoelectrons are processed by the PEEM and form detectable images on the multichannel plate (MCP). In our test, we used an Au-coated Si wafer to serve as the screen and a vacuum window, which separates the PEEM ultrahigh vacuum chamber from air.

Results and discussion

Figure 1 presents phase-contrast images taken with the PEEM. The sample is a Fresnel zone plate consisting of circular zones (3.2-µm-thick Au) on a silicon nitride substrate. In this case, both the edge-enhancing fringes typical of phase-contrast radiography[7-12] and the direct absorption image of the object are easily visible. Note that the edge-enhancing fringes typical of phase-contrast radiography are clearly visible, even for a fairly wide energy band x-ray beam. From the smallest detectable zones, we concluded that the lateral resolution of the PEEM-based detection reached the planned level of ~0.3 µm.

Discussion

High lateral resolution is particularly critical for coherence-based image enhancement schemes like phase contrast radiography. This point is discussed in detail in Ref. 13: basically, high lateral resolution allows precise measurements of all fringes with small sample-to-detector distances. The maximum source size required for phase-contrast radiography is proportional to the reciprocal square root of the sample-detector distance.[11-13] Thus, a decreased sample-detector distance means that a source of limited lateral coherence can be used. This point appears crucial for extending phase-contrast radiography from third-generation synchrotron sources to other synchrotron sources and conventional sources.

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References

[1] Th. Schmid, S. Heun, K.C. Prince and and E. Bauer, unpublished.

[2] G. De Stasio et al., Rev. Sci. Instrum. **70**, 1740 (1999).

[3] Ch. Ziethen et al., J. Elect. Spectrosc. Rel. Phen. **88-91**, 983 (1998).

[4] G. De Stasio et al., Rev. Sci. Instrum. **69**, 3106 (1998).

[5] R.N. Watts et al., Rev. Sci. Instrum. **68**, 3464 (1997).

[6] Y. Hwu, et al., Nucl. Instrum. Meth. A **437**, 516 (1999).

[7] For a recent short review see: G. Margaritondo, Physics World **11**, 28 (1998).

[8] A. Snigirev, I. Snigireva, V. Kohn, S. Kuznetsov and I. Schelokov, Rev. Sci. Instrum. **66**, 5486 (1995).

[9] F. Arfelli et al., Physics in Medicine & Biology **43**, 2845 (1998).

[10] A. Pogany, D. Gao and S.W. Wilkins, Rev. Sci. Instrum. **68**, 2774 (1997).

[11] S.W. Wilkins et al., Nature **384**, 335 (1996).

[12] K.A. Nugent et al., Phys. Rev. Lett. **77**, 2961 (1996).

[13] G. Margaritondo and G. Tromba, J. Appl. Phys. **85**, 3406 (1999).