Instrumentation advances with the new X-ray microscopes at BESSY II

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Abstract

A new X-ray microscopic area is going to be established at the undulator U41 at BESSY II. This undulator provides an X-ray source of high brilliance in the energy range from 163 to 595 eV in the first harmonic. The microscopic area will comprise a transmission X-ray microscope, a scanning transmission X-ray microscope, and an X-ray test chamber. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

X-ray microscopy is a well established method to study especially samples in their natural wet environment with a higher resolution than with light microscopes. Structures as small as 30 nm in size have been made visible. To visualize smaller structures higher photon densities are required [1]. These photon densities are available at third generation electron storage rings like BESSY II. The undulator U41 at this facility is well suited for X-ray microscopy because the so-called water window wavelength region (2.34–4.38 nm) is within the first harmonic [2]. Half of the available beamtime at this undulator will be reserved for X-ray microscopy experiments. Therefore, a switching mirror unit equipped with a water cooled, nickel coated plane mirror is installed in front of the beamline. The X-ray microscopy beamline [3] splits into separate beamlines for three instruments described in the following. The optical layout is shown in Fig. 1. A preparation laboratory equipped with different light microscopes and several instruments which will be necessary for the applications of X-ray microscopy in the fields of e.g. biology, colloidal physics, environmental and soil sciences will be available directly at the X-ray microscopy area (see Fig. 2).

2. Transmission X-ray microscope (TXM)

A second switching mirror unit is used to direct the beam via a water cooled, nickel coated
plane mirror into the TXM-beamline. The conventional zone plate linear monochromator cannot be used with the highly collimated X-ray beam of the undulator. Therefore, a new condenser concept is incorporated. To obtain best lateral resolution with a TXM, the aperture of the condenser should be matched to that of the objective. This is done with a dynamical aperture synthesis using a rotating condenser [4]. The monochromaticity will be improved considerably and the contrast in the images will be better. For imaging a micro-zone plate and a thinned, back-side illuminated CCD is used. The TXM [3] will provide high lateral resolution of down to about 20 nm at a spectral resolution in the range of one thousand. Due to the higher flux of about a factor of 60 compared to BESSY I shorter exposure times will be possible. Besides X-ray microscopy at room temperature cryo X-ray microscopy and X-ray tomography will be possible. Fig. 3 shows the TXM installed at BESSY II.

3. Scanning transmission X-ray microscope (STXM)

The STXM [5] will allow investigations with higher energy resolution compared to the TXM. Therefore, quantitative analysis and elemental mapping will be done with the STXM whereas structural studies will be done with the TXM. In the first step a lateral resolution of 40–50 nm is envisaged. In this setup the zone plate is illuminated with spatially coherent radiation. Due to the higher brilliance of BESSY II compared to BESSY I a gain in spatially coherent photons/s in the scan spot of a factor $10^4$ is achievable. To obtain the necessary monochromaticity a plane grating in combination with a plane mirror is used as a monochromator [6]. The water cooled plane mirror will be movable perpendicular to the beam to adjust different coatings optimized for the suppression of higher order radiation. For working near the carbon-K-absorption edge e.g. chromium will be a suitable coating whereas for...
working near the oxygen-K-absorption edge nickel will be chosen. To correct astigmatism, a plane grating with variable line density is used. With this monochromator a monochromaticity of several thousand will be obtained. The sample in the STXM is located in air as well as in the TXM and will have the same specimen holder. Therefore, investigations in both instruments from the same specimen or specimen detail will be possible.

4. X-ray test chamber (XTC)

The XTC will be used mainly for the characterization of X-ray optical elements, e.g. zone plates.

Fig. 2. The status of the X-ray microscopy area at BESSY II. (a) Transmission X-ray microscope (TXM) beamline with the TXM, (b) scanning transmission X-ray microscope (STXM) beamline, (c) X-ray test chamber (XTC) beamline with the XTC transferred from BESSY I, (d) preparation laboratory for X-ray microscopy experiments.

Fig. 3. The transmission X-ray microscope at BESSY II. The light microscope (a) can be used to adjust and prefocus the specimen (b) which is kept under normal air pressure. For this purpose, the rotating condenser (c) can be moved to the left side and the light microscope (a) can be moved down. The micro zone plate (d) is inside the vacuum chamber. The CCD camera (e) can be moved to adjust the magnification.
built in our institute. The monochromator of the STXM will be used for this instrument, too. A plane mirror in the second switching mirror unit (see Fig. 1) will direct the beam into the XTC-beamline. Several types of detectors are available and switching between them can be done without venting the system [3]. For the radially resolved determination of zone plate efficiencies a thinned, back-side illuminated CCD camera can be utilized.

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References


