Coherent soft x-ray imaging at BL07LSU

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We have developed a coherent soft x-ray imaging system at BL07LSU of SPring-8. We measured a spatial coherence length of soft x-rays from BL07LSU with the wavelength of 1 nm and 3 nm using pinholes and double pinholes. We have also performed test experiments for coherent x-ray diffraction imaging.

Recent development of soft x-ray microscopy reaches the spatial resolution down to 10 nm with the use of Fresnel Zone Plates, since the smallest length scales that can be achieved with these techniques are set by the outermost width of FZP. The motivation for using coherent x-ray sources is to extend the spatial resolution from 10 nm scales to the molecular and atomic length scales.

The undulator beamlines at third-generation synchrotron sources provide dramatic increases in the coherence of x-rays. The principal advantage of BL07LSU is its highly coherent x-rays for high resolution and high coherence experiments from the 27 m undulator. The coherence properties of x-rays are frequently indicated as the spatial coherence length, or the coherent fraction of the light. However, in order to understand the sources of changes in diffracted intensity, fringe visibility and speckle structure for experiments involving diffraction or speckle interferometry, more detailed information concerning the coherence properties of the light is required. The standard method of measuring spatial coherence is to determine the visibility of interference fringes that result from diffraction patterns of radiation incident on double pinhole masks of varying pinhole separations. The fringe visibility is directly proportional to the mutual coherence function with a proportionality constant that depends on the uniformity of the intensities incident on the two pinholes.

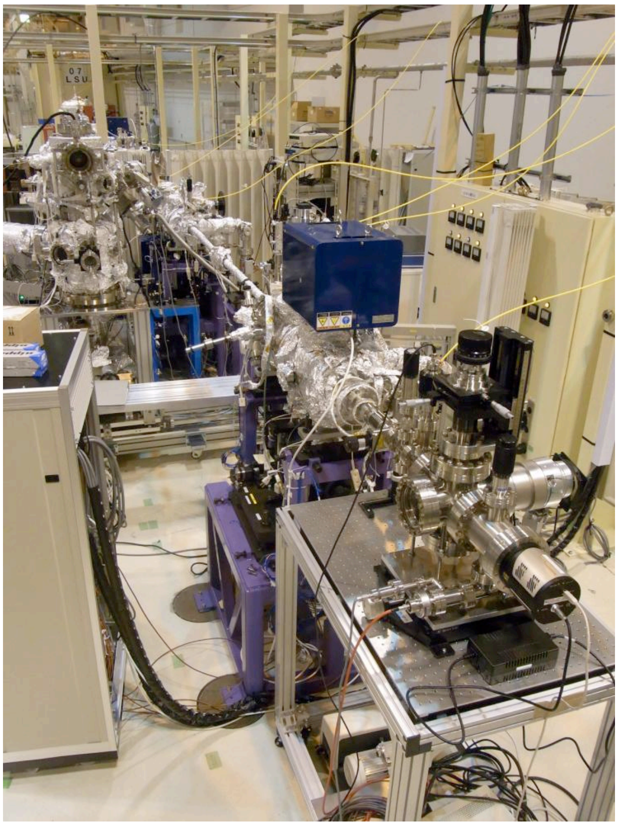

Figure 1. Coherent x-ray imaging system at BL07LSU

The coherence properties of soft x-ray synchrotron radiation at BL07LSU were studied by observing the visibility of interference fringes produced by diffraction at the apertures of double pinhole. Figure 1 shows our coherent soft x-ray imaging system at the free port of BL07LSU. The coherent soft x-ray imaging system consists of mechanical shutter, beam monitor, sample manipulator, beam stopper and x-ray CCD camera. The CCD camera (Roper PIXIX-XO) uses a backside illumination chip for maximum quantum efficiency and uses thermoelectric cooling in order to minimize dark noise. The CCD is composed of a 2048 x 2048 array of 13 μm pitch pixels and the distance between the sample and the detector is 30 cm. Absorption films were prepared by depositing a 360 nm thick layer of Au onto a 150 nm thick Si3N4 membrane. In order to achieve the requisite aspect ratio, a Focused Ion Beam (FIB) was used to mill double pinhole masks with center-to-center distances of 3 and 9 μm and pinhole diameters ranging from 170 to 700 nm shown in Fig. 2. The divergence of the beam was controlled by manipulating sets of movable horizontal and vertical exit slits.

Double pinhole fringe visibilities were determined by taking horizontal line cuts from 2-dimensional images and sampling maximum-minimum pairs from each line cut to apply the visibility formula.

Figure 3 shows the double pinhole fringes with the pinhole separation of 9 μm taken at the wavelength of 3 nm. Even with the 9 μm separation, the visibility is nearly 100%, which satisfies the spatial coherence for coherent imaging experiments.

The limited spatial resolution of the CCD had the effect of producing systematically lowered visibility measurements, because minima values are raised and maxima values are lowered. This error is more pronounced for larger pinhole separation distances where the fringes are more tightly spaced. There was no significant variation in visibility between line cuts for a given image.

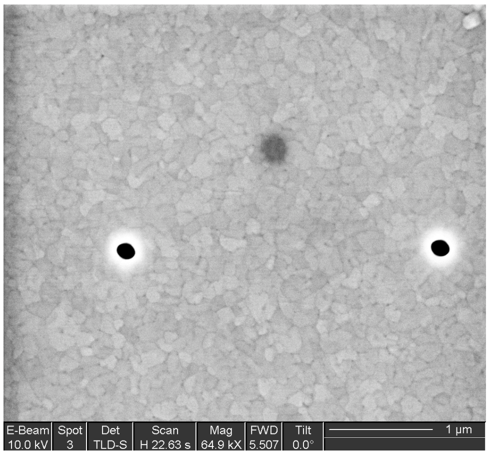

Figure 2. Double pinhole mask with center-to-center distance of 3 μm and the diameter of 170 nm.

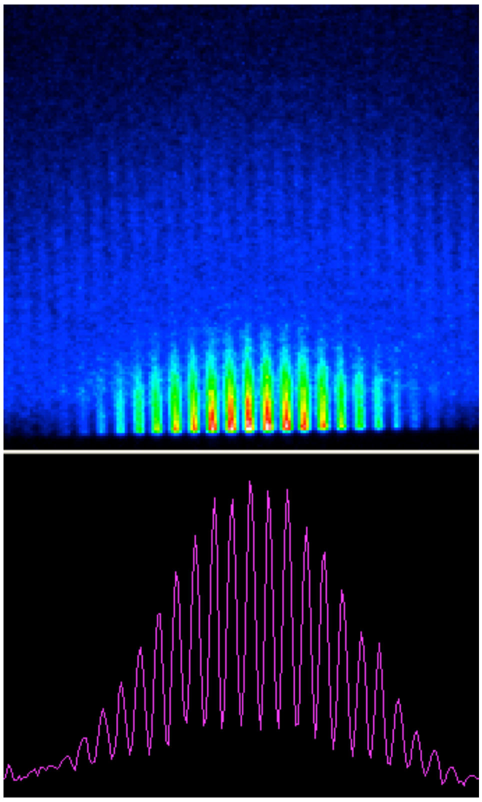

Figure 3. (upper) CCD image from double pinhole with 9 μm separation distance. (lower) Horizontal line cut plot of intensity vs position from upper CCD image.