Scaled-Up Optical Simulation of X-Ray Diffraction Microscopy

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This project is to develop a technique that can non-destructively inspect state-of-the-art integrated circuits with <20nm resolution. Thus we need a technique that combines such resolution with penetration of the sample (e.g. 70 microns of Si for operation in transmission). One candidate technique is X-ray diffraction microscopy, which converts the diffraction pattern, which is the Fourier transform of the sample, into spatial domain using computational methods. This technique was initially developed by Jianwei Miao *et al.*, giving a reconstruction of an isolated sample with appreciable resolution [1].

However, the X-ray experiment can be costly and time-consuming, and since the Fourier transform is linear, we can linearly scale everything from ~0.2 nm wavelength up to the visible range such as 632-nm red laser; i.e. a scaling factor of about 3000. Our optical arrangement is similar to that of Pierre Thibault *et al.*, who also carried out diffraction microscopy in the optical range [2].

Our source of radiation is a 632 nm-HeNe laser, and we use a starlight SXV-M7 CCD camera to capture the diffraction pattern from our sample. The sample is rotated by approximately 45 degree so that the higher order diffraction can be captured on the corners of the CCD sensor. After reconstruction, therefore, we need to rescale and rotate the reconstruction to obtain the result shown in figure 2. Furthermore, because diffraction microscopy requires a higher dynamic range than that of our camera, we need to combine measurements of the same diffraction pattern at 10 different exposure times to obtain diffraction data with the required dynamic range. We then apply a Difference Map algorithm to the data to obtain the spatial reconstruction of the sample [3]. We demonstrate 50um resolution, corresponding to approximately 15nm for an X-ray wavelength of 0.18nm.

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[1] Miao, J. et.al. “High Resolution 3D X-Ray Diffraction Microscopy.” *Phys. Rev. Lett*. **89**, 088303 (2002)

[2] Thibault, P. and I.C. Rankenburg. “Optical diffraction microscopy in a teaching laboratory.” *Am. J. Phys.*, **75** (9) 827–832 (2007)

[3] Baghaei Rad, L. “X-ray diffraction microscopy: Reconstruction with partial magnitude and spatial a priori information.” *J. Vac. Sci. Technol. B*, **26**(6), 2362-2366 (2008)

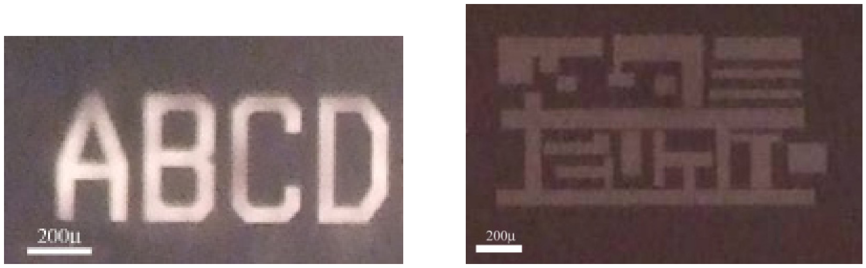

Figure 1 a) The objects are patterns etched in 200nm thick chromium on a glass substrate

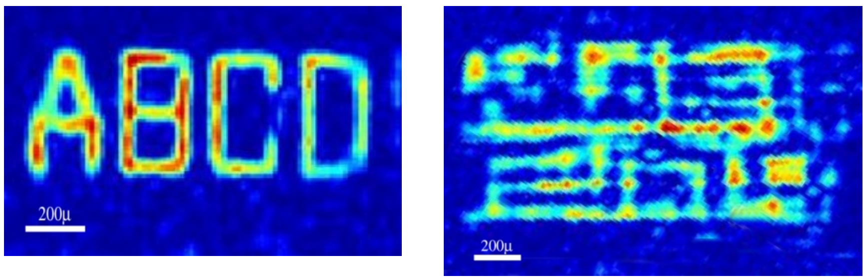

Figure 2 The reconstructed images obtained from diffraction microscopy, all taken in one shot. The second image shows that our resolution can be as small as 50µm corresponding to about 15nm at 0.18nm X-ray wavelength.

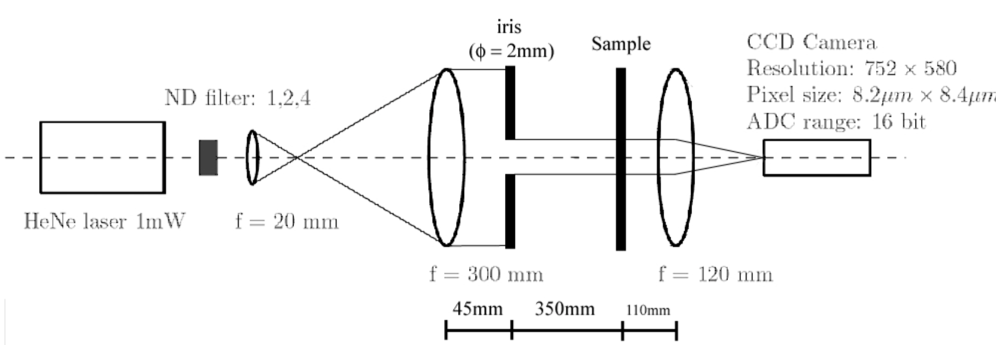

Figure 3 Experimental Arrangement.