Coherence and x-ray microscopy

Chris Jacobsen, Department of Physics & Astronomy, Stony Brook University

Microscopy with coherent x-ray beams can take many forms.

The coherent beam can be focused to a diffraction-limited spot which is then scanned through a specimen. If a large area detector is used, the resulting imaging process is incoherent, whereas if a spatially segmented detector is used one can carry out partially coherent imaging. With Brookhaven Lab and MPI Garching, our group has developed a segmented detector (*1*) that can be used for delivering both amplitude and phase contrast images from a single scan of the specimen (*2*). Absorption contrast is particularly favorable for soft x-ray spectromicroscopy studies of chemical heterogeneities in biological and environmental science specimens (in particular when clustering or pattern matching approaches are used for data analysis (*3*)), but efforts to extend chemical analysis to phase contrast imaging will also be discussed.

The coherent beam can also directly illuminate the specimen, with the exit wave carrying information about the specimen. X-ray holography provides one means for recording and reconstructing this exit wave (*4, 5*), and this can be extended to three dimensions using diffraction tomography (*6-8*), as will be discussed by Cloetens. The characteristics of holography will be compared with other approaches such as far-field diffraction reconstruction and transport of intensity equation reconstruction.

With any of these methods, the information that can be obtained about the specimen is ultimately limited by radiation damage. The effects of radiation damage can be minimized by maintaining the specimen at cryogenic temperatures. This approach works very well for preserving specimen mass and structure at larger spatial scales (*9*); however, it appears to provide less protection to near-edge absorption resonances used for chemical state imaging (*10*).

1. M. Feser *et al.*, in *X-ray micro- and nano-focusing: applications and techniques II* I. McNulty, Ed. (SPIE, Bellingham, WA, 2001), vol. 4499, pp. 117-125.
2. M. Feser, C. Jacobsen, P. Rehak, G. De Geronimo, *Journal de Physique IV* **104**, 529-534 (2003).
3. C. Jacobsen *et al.*, *Journal de Physique IV* **104**, 623-626 (2003).
4. M. Howells *et al.*, *Science* **238**, 514--517 (1987).
5. I. McNulty *et al.*, *Science* **256**, 1009--1012 (1992).
6. A. J. Devaney, *IEEE Transactions on Image Processing* **1**, 221--228 (1992).
7. W. Leitenberger, T. Weitkamp, M. Drakopoulos, I. Snigireva, A. Snigirev, *Optics Communications* **180**, 233-238 (2000).
8. T. Beetz, C. Jacobsen, A. Stein, *Journal de Physique IV* **104**, 31-34 (2003).
9. J. Maser *et al.*, *Journal Of Microscopy* **197**, 68-79 (2000).
10. T. Beetz, C. Jacobsen, *Journal of Synchrotron Radiation* **10**, 280-283 (2003).