Combined Differential Phase Contrast Imaging and Fluorescence Trace Element Mapping at the Advanced Photon Source

B. Hornberger[1], C. Jacobsen[1], M. Feser[1], S. Vogt[2], P. Rehak[3]

[1]*Dept. of Physics and Astronomy, Stony Brook University, Stony Brook, NY 11794-3800, USA*
[2]*Advanced Photon Source, Argonne National Laboratory, Argonne, IL 60439, USA*
[3]*Instrumentation Division, Brookhaven National Laboratory, Upton, NY 11973, USA*

Hard x-ray microprobes excel at fluorescence mapping and quantification of trace metals in biological cells. They are less good at putting these elements in structural context: where are they in the cell? The reason is that biological ultrastructure is absorbing only weakly at the multi-keV energies required for the excitation of fluorescence from biologically interesting metals. We describe here a solution involving the use of phase contrast imaging integrated into an x-ray microprobe.

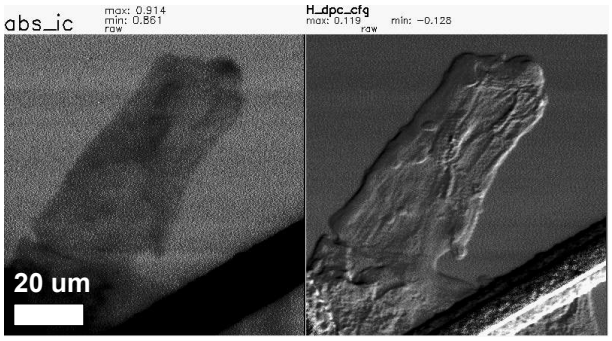

Fig. 1: Cardiac myocyte (heart muscle cell). Collaboration with B. Palmer, U. Vermont. While absorption contrast shows only an outline of the cell, differential phase contrast shows subcellular structures.

Phase effects in the specimen lead to a modification of the intensity distribution following the specimen. We have previously used a segmented silicon detector with rapid analog signal readout, and a Fourier filtering image reconstruction approach, to obtain quantitative soft x-ray phase contrast images of microfabricated test patterns [1]. We have modified this detector for differential phase contrast imaging at multi-keV x rays. While a second generation detector optimized for operation in this energy range is now under construction, experiments with the existing detector at beamline 2-ID-E of the Advanced Photon Source (APS) show the utility of phase contrast. Fig. 1 shows images of a cardiac myocyte investigated by Palmer *et al*. While these cells are thick enough to show some absorption contrast at 10 keV incident x-ray energy, a simple difference signal between opposing segments of our detector shows ultrastructural components of the cell to provide the information necessary to understand the physiological role of trace elemental concentration variations.

We describe the use of phase contrast in a variety of microprobe studies, and the characteristics expected for the new detectors optimized for present APS zone plate microprobes, as well as the Nanoprobe system presently being built for installation at the APS. When the new detectors become available, we also hope to measure phase shift quantitatively to obtain specimen thickness and therefore concentrations rather than absolute amounts of trace elements.

[1] M. Feser, C. Jacobsen, P. Rehak *et al.*, "Scanning transmission x-ray microscopy with a segmented detector," Journal de Physique IV **104**, 529-534 (2003).