Polychromatic Cone-Beam Phase-Contrast Tomography

G.R. Myers[1], S.C. Mayo,[2] P.R. Miller,[3] D.M. Paganin,[1] T.E. Gureyev,[2] S.W. Wilkins[2]

[1]School of Physics, Monash University, VIC 3800, Australia, [2]CSIRO Manufacturing and Materials Technology, PB 33, Clayton South, VIC 3169, Australia, [3]Monash Centre for Electron Microscopy, Monash University, VIC 3800, Australia

We have developed and experimentally implemented an algorithm for propagation-based phase-contrast cone-beam computed tomography of non-absorbing or weak monomorphous objects, which are illuminated using partially coherent radiation from a small polychromatic source. In the case of non-absorbing objects and sufficiently short propagation distances between the object and the detector, the propagation-based phase-contrast tomography (PCT) is "achromatic", thus allowing quantitative cone-beam PCT to be realized using unfiltered divergent radiation from laboratory-based X-ray microfocus sources, as well as small polyenergetic sources of cold or thermal neutrons. The method may also be applied to point-projection optical tomography using a thermal light source, and to the minimally-destructive three-dimensional imaging of cold atom clouds.

The three-dimensional distribution of complex refractive index is reconstructed from a single projection image at each view angle, on the basis of phase contrast introduced by free-space propagation from the object to the detector. A tomographic dataset for a Polyethylene Terephthalate fibre scaffold was acquired on a point-projection X-ray Ultra Microscope (XUM) based on an FEI XL-30 scanning electron microscope. Using these data, a numerical implementation of our method was used for the tomographic reconstruction.

Where applicable, our approach provides a powerful and convenient alternative to working with highly-coherent sources, such as third-generation X-ray synchrotrons or filtered reactor neutron sources. Of particular note is the stability with respect to noise of our algorithm in the case of monomorphous objects, due to the complementary nature of the phase-contrast and amplitude-contrast transfer functions.