Development of synchrotron-based x-ray scatter projection imaging

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In medical x-ray imaging a major challenge is to obtain adequate soft tissue contrast. The goal of our research is to develop a high soft-tissue contrast x-ray technique based on the detection of low-angle scattered photons. Scattered photons comprise up to 90% of the radiation downstream of the patient and can provide information in addition to that of the transmitted primary x rays. In particular, the cross section for coherent x-ray scattering, the basis of x-ray diffraction, varies with angle and photon energy in a material-specific manner, even for amorphous materials, and thus it can provide good soft tissue contrast. At the photon energies of medical radiology coherent scatter is a minority of all photon interactions, but its forward nature at these energies makes it relatively easy to detect. For example, in abdominal radiography coherent single scatter is 10% of the total scatter and 26% of the primary fluence.

We are developing x-ray scatter imaging at the BioMedical Imaging & Therapy (BMIT) facility of the Canadian Light Source (CLS) synchrotron in Saskatoon, Canada. The BMIT facility provides an excellent development environment with the availability of monoenergetic x-ray beams, flat-panel x-ray imagers and automated sample positioning stages. The best images are obtained using step-and-shoot scanning with a pencil beam and area detector to capture sequentially the scatter pattern for each primary beam location on the sample. Primary x-ray transmission is recorded simultaneously using photodiodes. Our beam energy is 33.2 keV and the pencil beam area is about 2.5 mm^2. The technological challenge is to acquire the scatter data in a reasonable time. Our aim is to acquire images on a time scale similar to that of nuclear medicine, e.g., under 15 minutes. Geometries using multiple pencil beams producing partially-overlapping scatter patterns reduce acquisition time but increase the complexity due to the need for a disentangling algorithm to extract the data. Continuous sample motion, rather than step-and-shoot, also reduces acquisition time at the expense of introducing motion blur and is the subject of our latest investigation. Our recent work with plastic phantoms and animal tissues is described.

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