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A novel Approach to separate Absorption, Refraction and Scattering in Analyzer Based Lung Imaging

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One of the advantages of phase contrast x-ray imaging with respect to conventional x-ray attenuation is its capability of extracting complementary and useful physical properties of the sample under investigation. Different phase contrast methods have been developed and extensively applied at synchrotron radiation sources, one of them being Analyzer Based x-ray Imaging (ABI) [1] which utilizes perfect crystals exploring the x-ray deviation by their interaction with the sample. Owing to the narrow angular acceptance of the analyzer crystals, ABI is an excellent tool for highlighting x-ray scattering.

A single image acquisition is sufficient to obtain qualitative and high signal to background radiographs, however, it requires multiple image acquisition schemes to assess quantitative metrics.

ABI may yield three parametric output images [2,3], which assess different physical properties namely absorption, refraction and scattering linked to dark field images, when a minimum of three input images are acquired and dedicated image processing on a pixel basis is applied. These modalities can be extended from planar images to computed tomography and allow quantitatively retrieving of scattering even for wide scattering distribution. Linking the (sub) micro-structure to morphological changes in soft tissues at biocompatible radiation doses is a yet challenging problem due to the lack of quantitative characterization tools possessing sufficient structural sensitivity at this length scale. In this view dark field or scattering based images yielded by ABI possess additional valuable information on the microscopic range without necessarily employing a high-resolution imaging detector. ABI enables to qualitatively assess such scattering in a wide angular validity range.

For biological samples this in turn might yield information on biological function in micrometer sized particulate systems as found for instance in lungs. Scattering can be efficiently separated from refraction and absorption effects acquiring only three images of the sample with the associated dose reduction with respect to multiple images approaches. While the potential benefits of dark field and scattering images in lung imaging yielded with different phase contrast modalities are generally acknowledged, it is still in question for ABI, which image (single shot images, a linear combination of those or parametric images (i.e. the scatter image)) would provide the highest diagnostic value and what are the role of the x-ray energy and the spatial resolution of the image receptor.

For this purpose contrast and signal to noise ratio have been evaluated in post mortem AB images of mice lungs, acquired at the SYRMEP beamline of the ELETTRA synchrotron in Trieste (Italy), for different x-ray energies and pixel sizes in several regions of interest. In this presentation some of the aforementioned image processing algorithms will be presented and the yielded parametric images, which have been analyzed in terms of contrast and signal-to-noise ratio will be discussed.

References

- [1] Chapman D. et al., Diffraction enhanced x-ray imaging. *Phys. Med. Biol.* 42, 2015-2025 (1997).
- [2] Rigon, L., Arfelli F. & Menk R.H. Three-image diffraction enhanced imaging algorithm to extract absorption, refraction, and ultras-small-angle scattering. *Appl. Phys. Lett.* 90, (2007).
- [3] Arfelli F., Astolfo A., Rigon L. & Menk R.H., A Gaussian extension for Diffraction Enhanced Imaging. *Scientific Reports* 8, art. no. 362, 1-14 (2018).

Authors: Prof. ARFELLI, Fulvia (University of Trieste and INFN); Dr RIGON, Luigi (University of Trieste and INFN); Dr MENK, Ralf-Hendrik (ELETTRA Sincrotrone Trieste)

Presenter: Dr MENK, Ralf-Hendrik (ELETTRA Sincrotrone Trieste)

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