PROPAGATION-BASED PHASE CONTRAST IMAGING WITH A LAB-BASED CT SYSTEM USING HELICAL TRAJECTORY

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Summary: In this work, the use of lab-based X-ray computed tomography (CT) system HeliScan for propagation-based phase contrast imaging (PBI) is presented. The system allows to employ helical trajectories (double helix, space filling) to measure long, thin samples. Investigation of feasibility with this system is conducted via several measurements of polymeric samples.

1. INTRODUCTION

In recent years, significant progress has been made in phase contrast imaging modalities with laboratory-based X-ray computed tomography (CT) devices. This work focuses on propagation-based imaging (PBI). It does not require any additional hardware components, only the distance between sample and detector has to be larger than with usual absorption imaging. X-rays deviating on edges and structures of the sample propagate through this distance and form interference fringes. This is detected as edge enhancement (Fig. 1).

Laboratory X-ray sources have several specifics which have to be evaluated when using PBI [1]. In order for interference fringes to occur, the X-rays must have a sufficiently high degree of coherence. Tomographic PBI is usually performed in near field regime (for very large sample–detector distances, the direct information about morphology is lost due to multiple fringes). The X-rays are emitted from a finite focal spot and the size of this spot limits the maximum distance between sample and detector. Considering these factors, it is possible to estimate suitability of a CT device for PBI and theoretically predict its capabilities [2].

One of the limitations in CT imaging is the sample size. A given machine has some obvious dimension limits for the sample. However, there are several ways of extending the field of view while maintaining the voxel resolution. Merging methods allow to combine several X-ray projections into one or to merge reconstructed datasets from different places of the sample. This approach requires long acquisition times, and it is prone to misalignment errors. Moreover, the usage with cone beam geometry is not easy to implement, and the reconstruction process is quite complex [3]. Redundancy data rebin methods utilise scanning with the offset detector, which increases the field of view, but they are only available with parallel beam scanning geometry [4].

Use of helical trajectory (Fig. 1a) is a standard solution in medical CT imaging. In microCT, scanning with helical trajectory can be applied to long samples such as bones, rods with polymeric reinforcements etc. The sample movement consists of rotation and translation along one dimension. The main advantage is a considerable low scanning time compared to other methods [5]. Several variants of helical trajectories are available. Besides single helix, also double helix or space-filling [6] trajectories can be used to obtain more data or to save measurement time.

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2. EXPERIMENTAL METHOD

We perform the experiments with the CT system Thermo Fisher HeliScan with space-filling trajectory. The system employs cone-beam geometry, and it can reach sub-micron voxel size down to 0.2 µm. We show measurements of a polymer rod with carbon fibres, where edge enhancement is visible (Fig. 1b). This measurement was made with 50 kV tube voltage, 4 s exposure time and 0.8 µm voxel size. A phase-retrieval algorithm is used to enhance data quality (Fig. 1c). Several CT scans will be made (e.g. at several effective propagation distances $Z_{\mathrm{eff}} = R_1 R_2/(R_1 + R_2)$, where R_1 is source–sample distance and R_2 is sample–detector distance) to record and evaluate the edge enhancement. Image quality parameters such as absorption and phase contrast [2] and signal to noise ratio will be used for evaluation of results.

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References

[1] P. M. Bidola, I. Zanette, K. Achterhold, Ch. Holzner & F. Pfeiffer. Optimization of propagation-based phase-contrast imaging at a laboratory setup, *Optics Express*, 23, 2015.

[2] D. Kalasova, T. Zikkmund, L. Pina, Y. Takeda, M. Horvath, K. Omote & J. Kaiser. Characterization of a laboratory-based X-ray computed nanotomography system for propagation-based method of phase contrast imaging, *manuscript to be published in 2019.*

[3] A. Kyrieleis, M. Ibison, V. Titarenko & P. J. Withers. Image stitching strategies for tomographic imaging of large objects at high resolution at synchrotron sources, *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 607, 677–684, 2009.

[4] F. Jian, L. Hongnian, L. Bing, Z. Lei & S. Jingjing. X-CT imaging method for large objects using double offset scan mode, *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 575, 519–523, 2007.

[5] T. Varslot, A. Kingston, G. Meyers & A. Sheppard. High-resolution helical cone-beam micro-CT with theoretically-exact reconstruction from experimental data, *Medical Physics*, 38, 5459–5476, 2011.

[6] A. M. Kingston, G. R. Myers, S. J. Latham, B. Recur, H. Li & A. P. Sheppard. Space-filling X-ray source trajectories for efficient scanning in large-angle cone-beam computed tomography, *IEEE Transactions on Computational Imaging*, 4, 447–458, 2018.

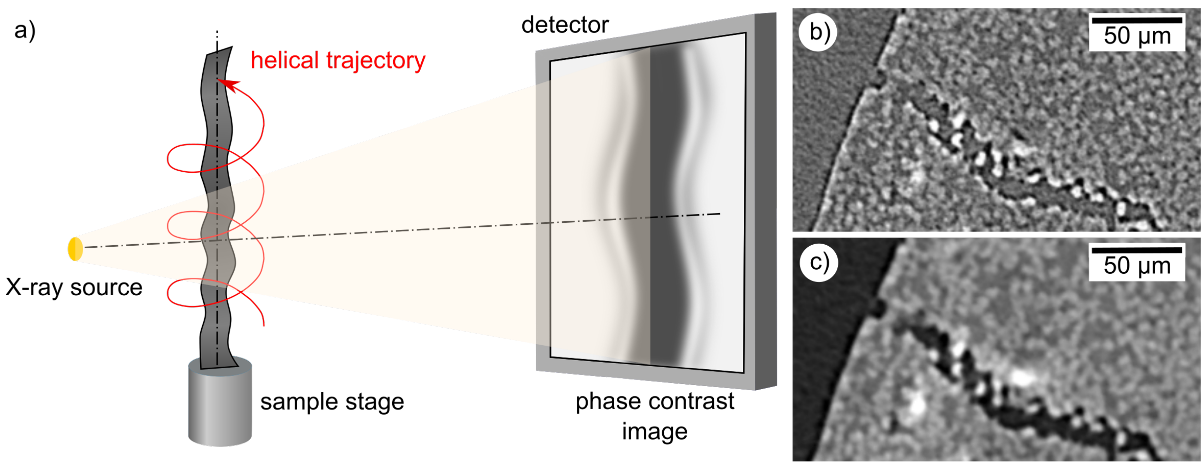

Figure 1: a) Schematic diagram of propagation-based imaging with lab-based helical CT system. CT slice of a polymer with carbon fibres, b) original slice, c) phase retrieved slice.