A workflow to reconstruct grating-based X-ray phase contrast CT images: application to CFRP samples

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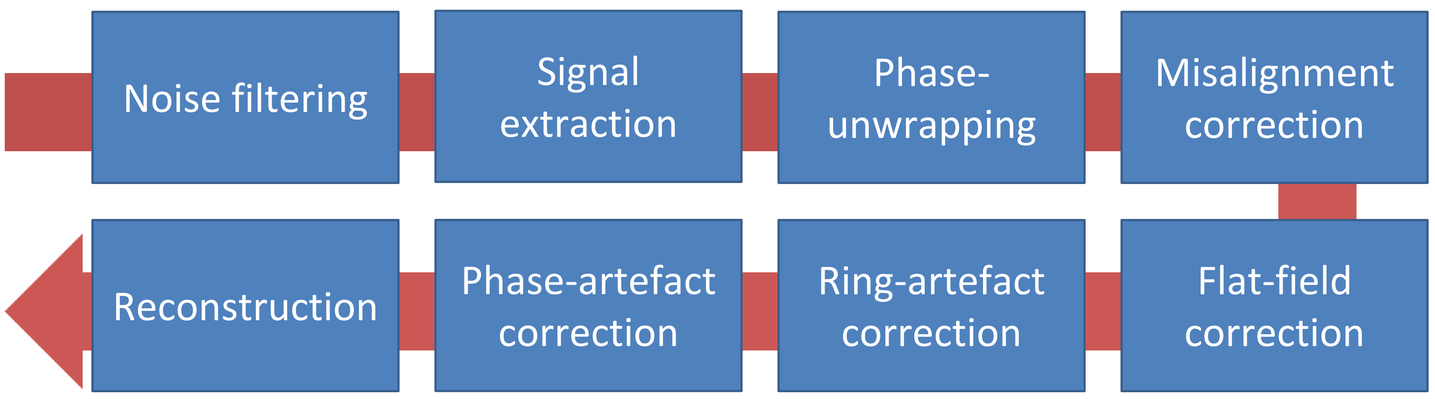
Introduction

Carbon fiber reinforced polymers (CFRPs) outperform conventional materials such as aluminum, steel or alloys in terms of strength, elasticity, durability, energy efficiency, and weight [1]. To design optimal components, detailed investigations of, for example, the fiber orientations in CFRP materials are vital. To visualize the fibers and fiber bundles inside the samples, phase contrast X-ray computed tomography (PCCT) can be applied. This technique allows reconstructing 3D images of CFRP samples from projection data, acquired with, for example, a grating based interferometer (GBI) through a phase-stepping procedure [2]. Many processing steps are involved in such a GBI-PCCT reconstruction pipeline, each of which significantly affects the final image quality.

Methods and experiments

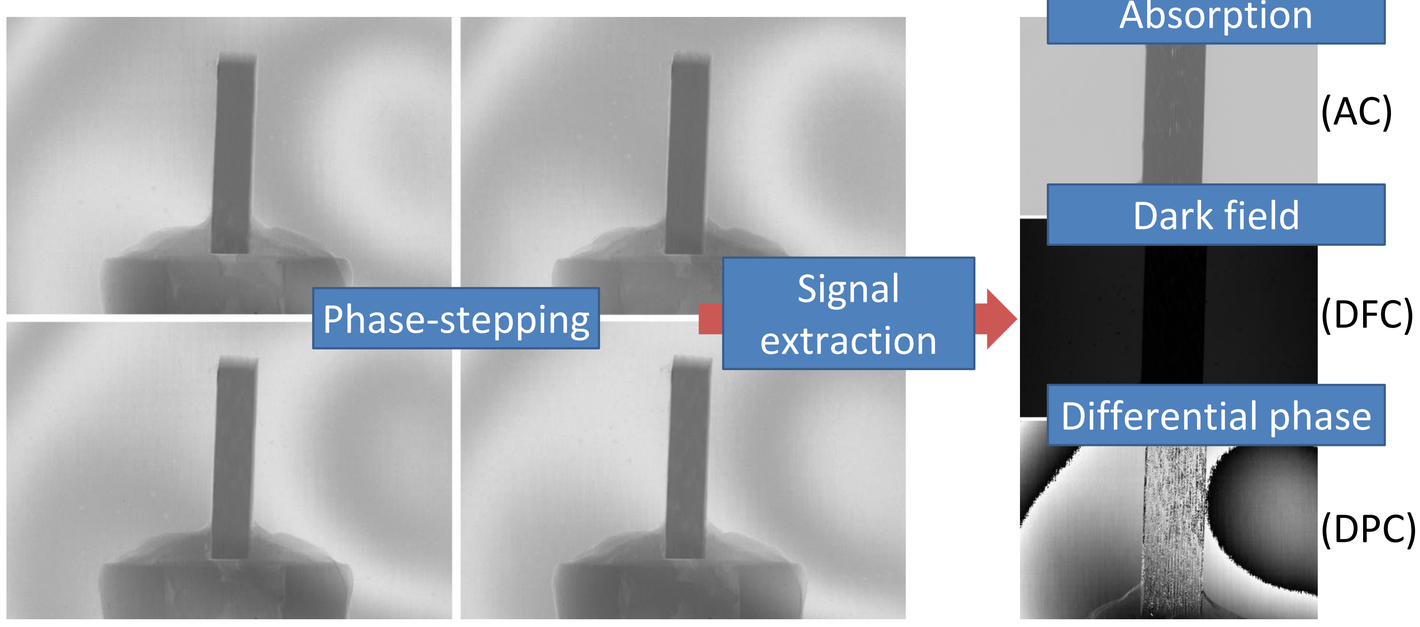
We present a workflow to process GBI-PCCT data and reconstruct 3D images of CFRP samples, starting from the raw phase-stepping data up until the final reconstruction step:

- **Noise filtering:** collaborative filtering with block-matching for grouping similar image segments [3]
- **Signal extraction:** Fourier fitting procedure [2]
- **Phase-unwrapping:** accelerated multi-scale phase unwrapping with modulo wavelet transform[4]
- Rotation axis **misalignment correction:** matching of projections acquired at angles α and α + π.
- **Flat-field correction:** [2] (s: sample, r: reference)
  - $T = a_0^s / a_0^r$ (AC)
  - $V = V^s / V^r$ (DFC)
  - $\nabla_x \varphi = \nabla_x \varphi^s - \nabla_x \varphi^r$ (DPC)
- **Ring-artefact correction**: artefacts visible as lines in sinogram, use post-reconstruction line-based artefact removal method [5] as preprocessing technique
- **Phase-artefact correction**: modified from [6]:
  - if $x_{DFC}(i,j) > threshold$
  - do $x_{DPC}(i,j) = \frac{\phi_{lin}}{\mu} \cdot \frac{x_{AC}(i,j-1) - x_{AC}(i,j+1)}{2}$
- **Reconstruction** with open source **ASTRA-toolbox** [7]



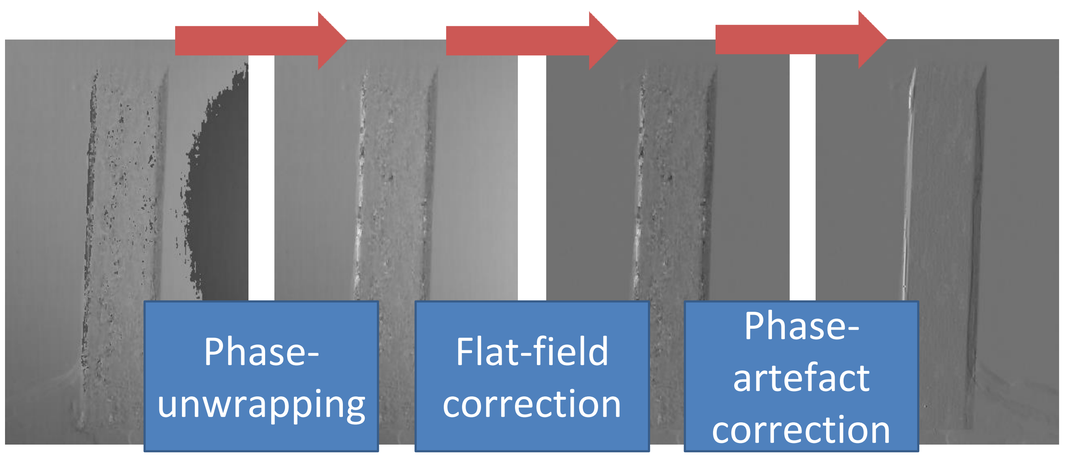
CFRP data acquired at FH-Wels:

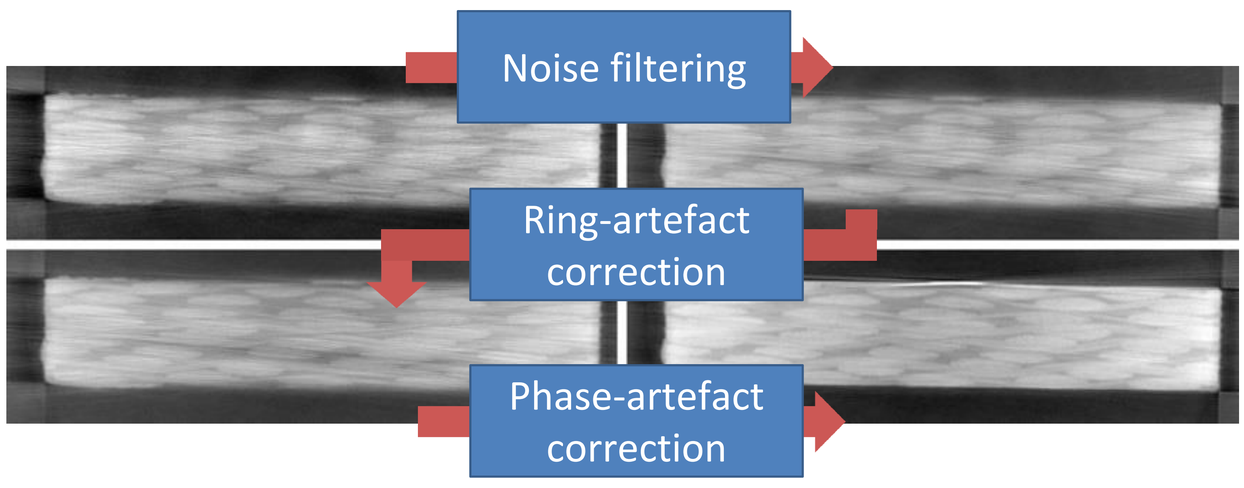
- Scanner: Bruker SkyScan 1294
- Exposure time: 650 ms
- 1200 projections
- Total scan time: 8h 16m 6s
- Pixel size: 22.8 µm
- 4 phase-steps



Results

Overview of the effects of preprocessing steps on differential phase contrast (DPC) projections (left) and the final phase contrast reconstruction (right).





Conclusion

Adequate preprocessing of the GBI-PCCT projection data before the reconstruction step improves the reconstruction quality.

References

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Future work

- Simulations for numerical validation
- Investigation of reconstruction algorithms

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