Dual axis Dark Field Contrast Tomography for visualisation of scattering directions in a CFRP sample

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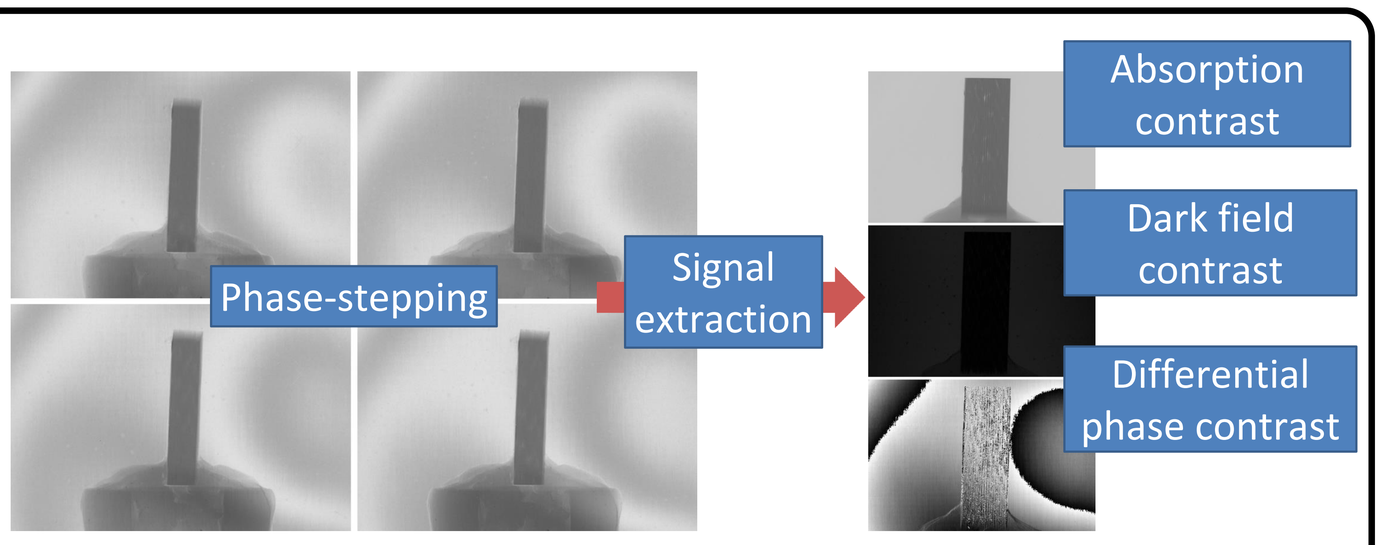
Introduction

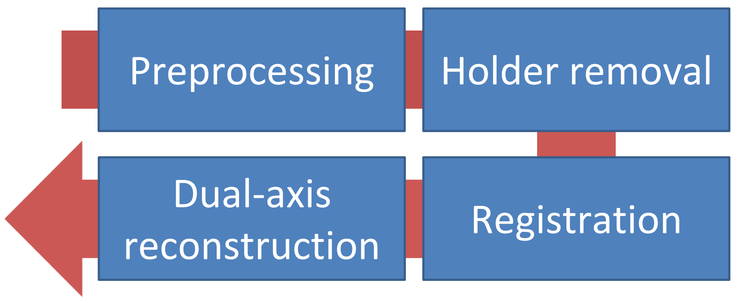
The success of carbon fiber reinforced polymers (CFRPs) in different industries is due to the distribution of carbon fibers throughout the resin matrix, which provides their strong material qualities. To visualize the fiber bundles, CFRP samples can be scanned with phase contrast computed tomography (PCCT) using a grating based interferometer (GBI) through a phase-stepping procedure [1]. This procedure allows to acquire three different images: an absorption image, a refraction image and a dark field image. In CFRPs, the carbon fibers cause scattering when inspected with X-rays. This scattering is captured within the dark field signal. The main disadvantage is, however, that due to the orientation of the gratings not all directional scattering is captured [2]. By scanning the sample twice, with a 90 degrees rotation of the sample in between, information from two different scattering directions can be combined into one 3D reconstruction volume.

Methods and experiments

We propose to use a dual axis scan and a combined 3D reconstruction approach :

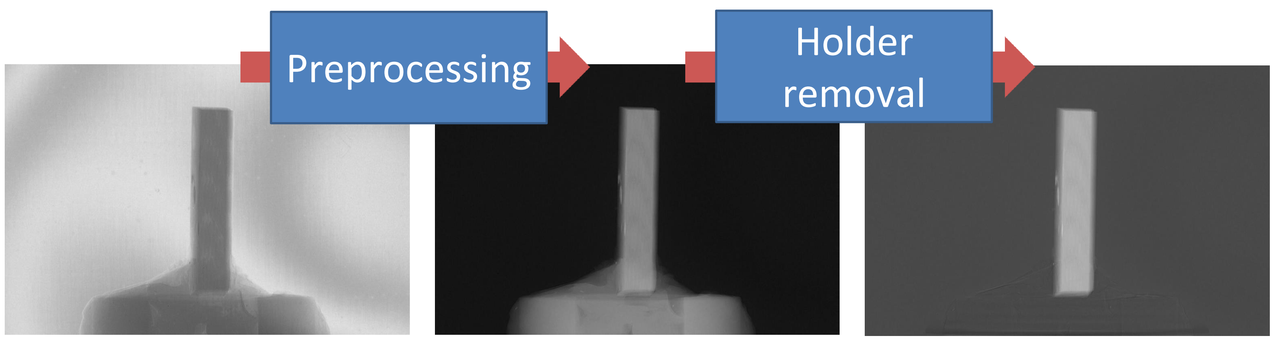
1. **Preprocessing [3]:**
   - Noise filtering
   - Signal extraction
   - Rotation axis misalignment correction
   - Flat field correction
2. **Sample holder removal with ASTRA toolbox [4]:**
   - Sample is rotated 90 degrees and placed in the same holder → sample holder at different position relative to sample
   - Remove holder from data through segmentation and forward projection to avoid registration errors and reconstruction artifacts
3. **Registration with ASTRA toolbox [4]:**
   - 3D dual axis alignment
   - As few parameters as possible:
     - Free 3D detector and source position
     - Free 3D rotation of detector
   - GPU accelerated with the ASTRA toolbox
4. **Dual-axis reconstruction with ASTRA toolbox [4]:**
   - Flexible vector geometry
   - Iterative SIRT algorithm
   - GPU accelerated





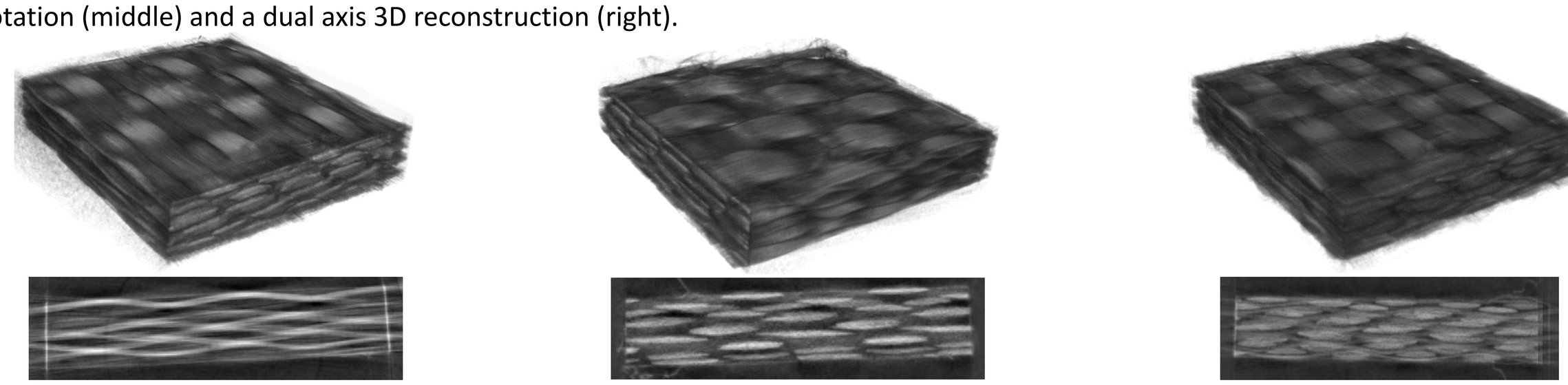
CFRP data acquired at FH-Wels:

- Scanner: Bruker SkyScan 1294
- Exposure time: 650 ms
- 2 rotation axes
- **2x** 1200 projections
- Total scan time: 8h 16m 6s
- Pixel size: 22.8 µm
- 4 phase-steps



Results

3D SIRT rendered reconstructions and slices of the scattering in the sample (dark field) scanned at zero degrees rotation (left), at 90 degrees rotation (middle) and a dual axis 3D reconstruction (right).



Conclusion

For visualization of the fiber structure inside a CFRP sample, it is beneficial to scan the sample twice, with a 90 degrees rotation in between, and use both sets of projection data to make one 3D reconstruction. This way, fiber bundles with different orientations are visualized in one reconstruction. In this work, SIRT was used as a reconstruction algorithm. It should however be noted that the forward and back projection model used in the SIRT algorithm does not give a complete description of the scattering physics.

References

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