

KI4D4E: Artificial Intelligence for Synchrotron-radiation 4D Tomography Data



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KI4D4E: An AI-based framework for the visualization and evaluation of 4D tomography data for beamline end-users

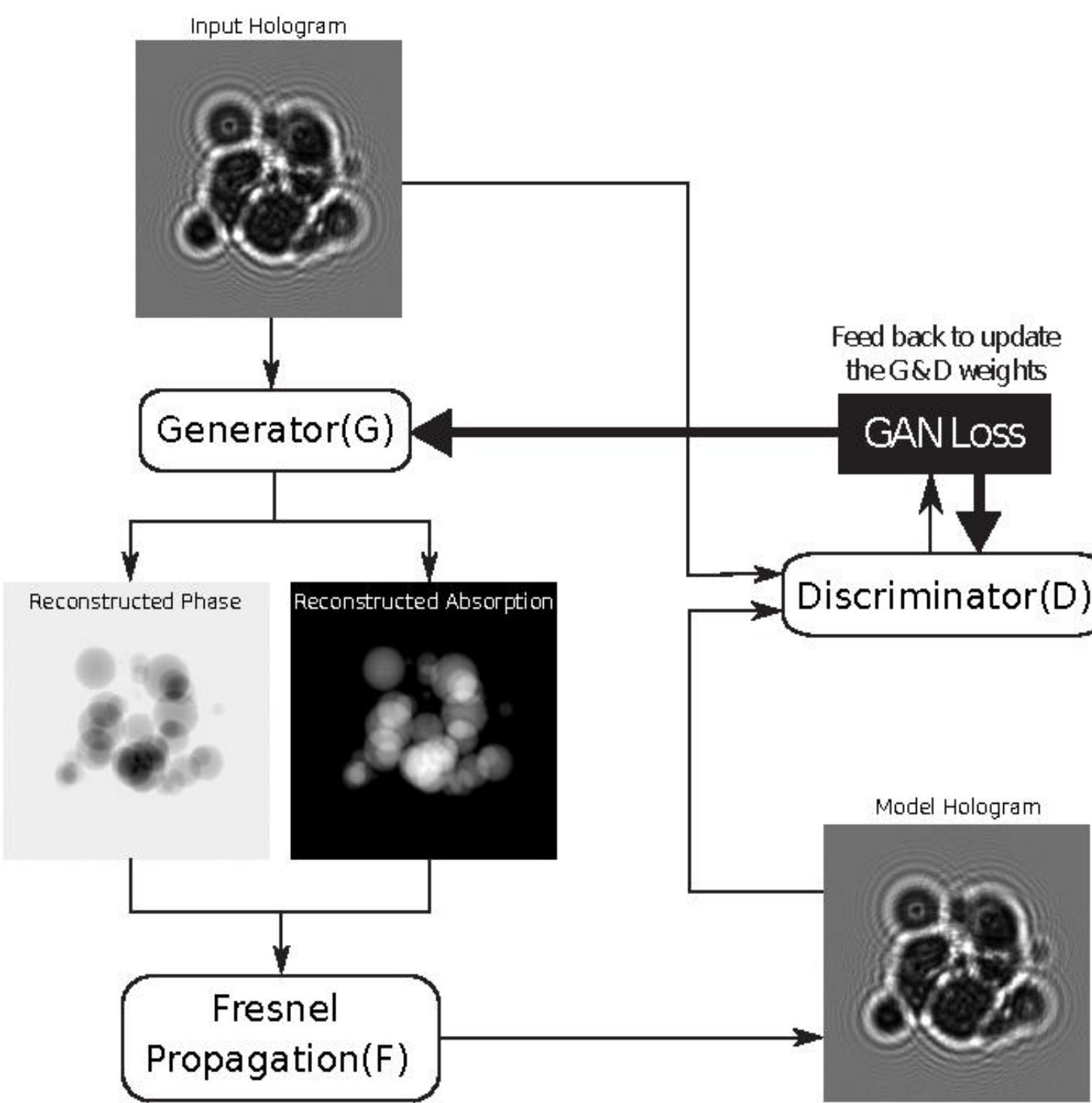
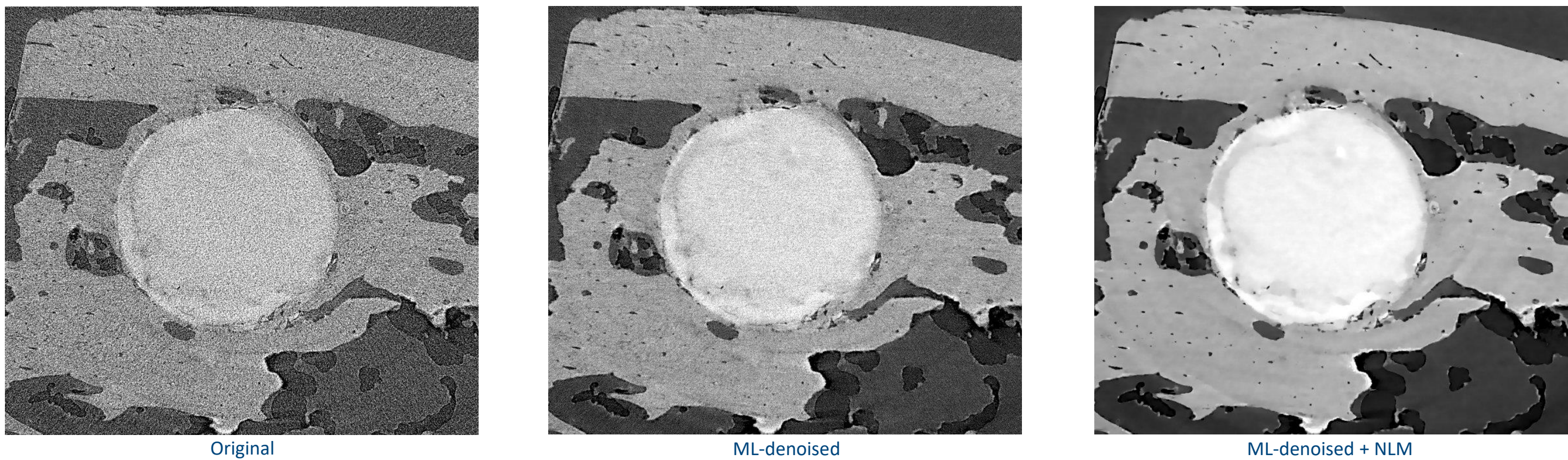
- Utilize modern machine learning (ML) methods for the data processing of synchrotron-radiation tomography experiments
- Example: segmentation, denoising, multi-modal imaging, phase retrieval, and digital volume correlation
- Apply to the data analysis of biodegradable implant materials.

Bio-degradable Bone Implant Materials

- Study the degradation of bio-degradable bone implants (e.g. Magnesium alloy)
- Almost always required time-consuming labeling by domain experts
- Hundreds of large volumetric datasets
- Classical iterative approaches often fail

Denoising

- Combine ML-based and non-local mean (NLM) approaches [3]
- Train by self-supervised approach

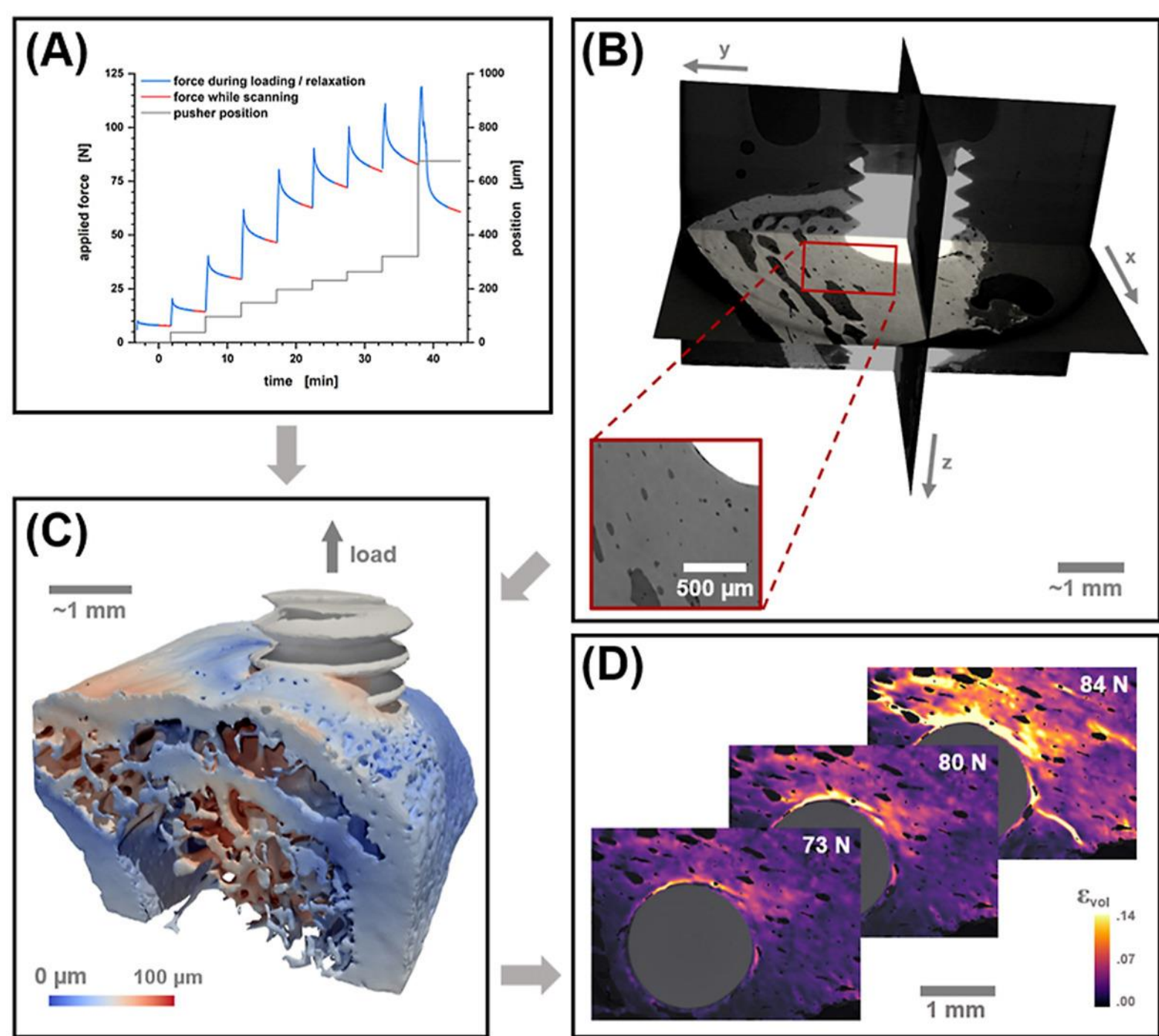


Phase Retrieval

- Reconstruct amplitude and phase from a single intensity measurement
- Use GAN and Fresnel Propagation (i.e. physics informed learning) to construct the hologram

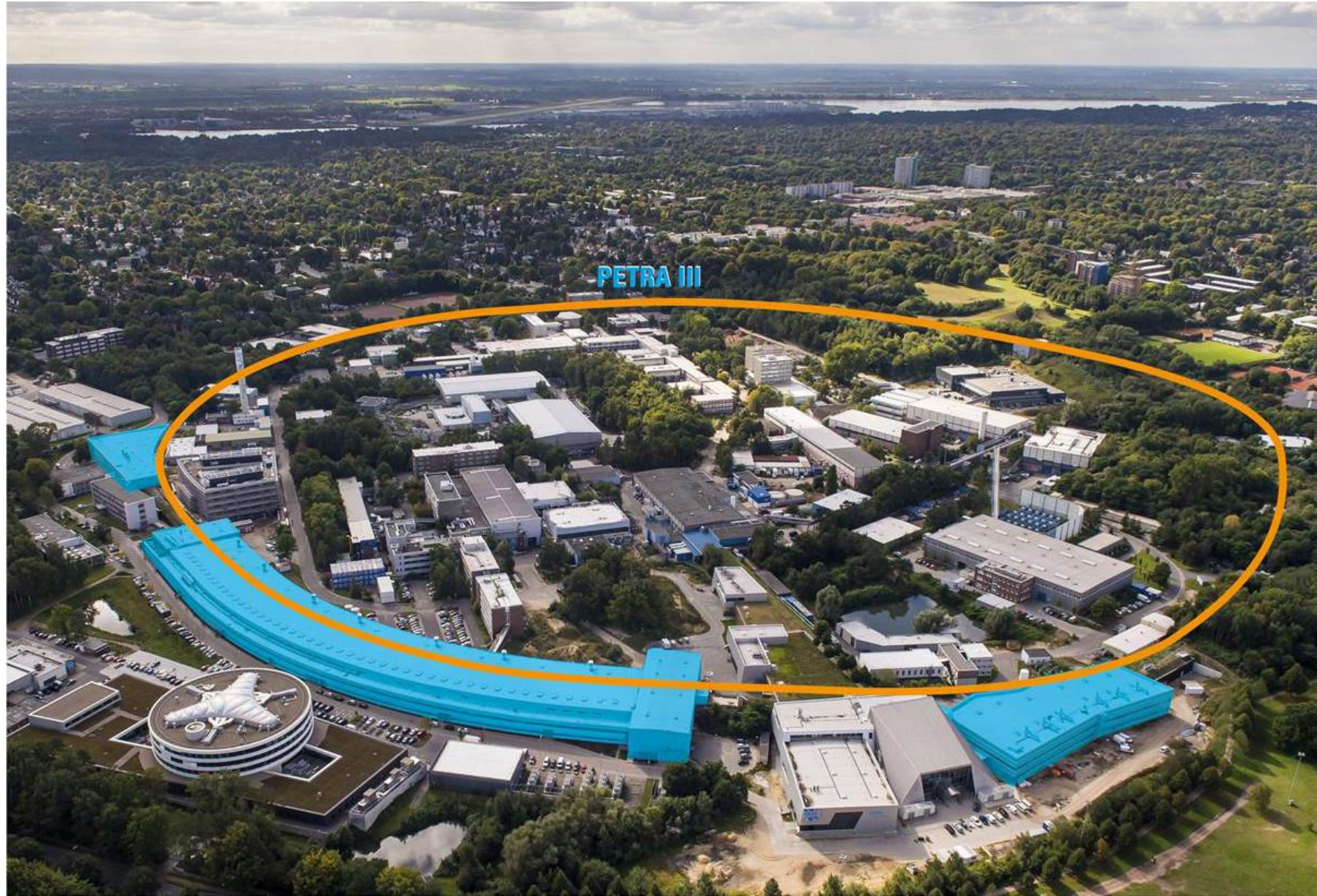
Digital Volume Correlation

- Estimate local volume correlation to track bone deformation and strains [4]
- Dense optical-flow based approach: compute the 3D flow field based on the reference volume and the deformed volume

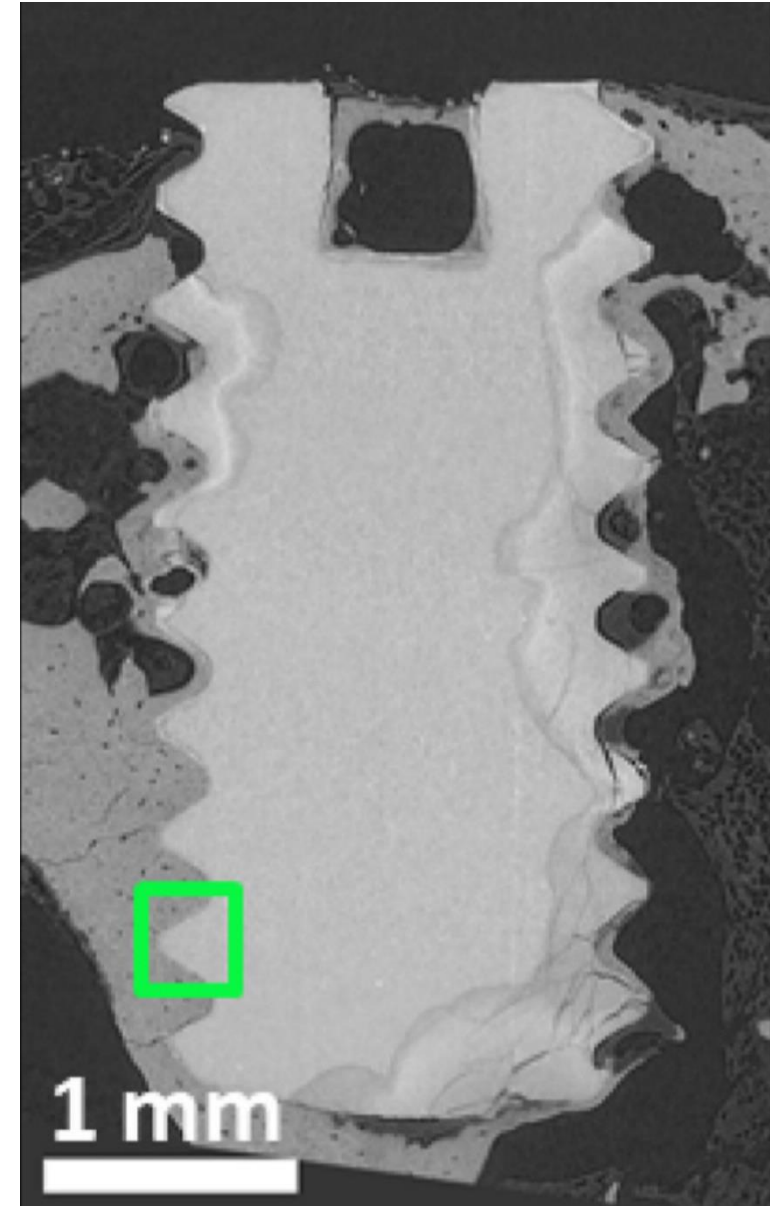


Reference

- Courtesy of DESY https://photon-science.desy.de/facilities/petra_iii/index_eng.html
- Krüger, Diana, et al. "High-resolution ex vivo analysis of the degradation and osseointegration of Mg-xGd implant screws in 3D." Bioactive Materials 13 (2022): 37-52.
- Flenner, Silja, et al. "Machine learning denoising of high-resolution X-ray nanotomography data." Journal of synchrotron radiation 29.1 (2022): 230-238.
- Bruns, Stefan, et al. "On the material dependency of peri-implant morphology and stability in healing bone." Bioactive Materials 28 (2023): 155-166.



PETRA III at DESY: The Helmholtz-Zentrum Hereon is operating imaging beamlines for X-ray tomography for academic and industrial users at the synchrotron radiation source PETRA III. [1]



Tomogram of bone implant: ex vivo SRμCT Mg-10Gd screw, 12 weeks after implantation [2].

Synchrotron-radiation (SR) 4D Tomography Data

- The high X-ray flux density and coherence of synchrotron radiation enable high-resolution in situ/operando/vivo tomography experiments.
- Large amounts of 4D data are collected from a wide variety of samples, which is challenging to reconstruct, process, and analyze.

Experimental result of 3D Displacement Vector for DVC					
Position	MSE Error by	Grad. Mag.	dx	dy	dz
z = 250	ML	32.9	41.2	40.1	17.4
	Iterative [6]	53.0	57.0	57.9	44.0
x = 320	ML	41.6	44.8	41.9	38.0
	Iterative [6]	69.6	58.9	51.6	98.2
y = 330	ML	42.1	56.4	26.5	43.5
	Iterative [6]	58.6	68.3	19.0	88.5

