

Supplementary Information

Optimising 4D imaging of fast-oscillating structures using X-ray microtomography with retrospective gating

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In addition to the information presented in this document, video clips are provided as Supplementary Materials:

- [Supplementary Video – C1_Sphere_100Hz_MR.gif](#)
- [Supplementary Video – C2_Sphere_100Hz_MR.gif](#)
- [Supplementary Video – C3_Sphere_100Hz_MR.gif](#)
- [Supplementary Video – Sphere_400Hz_MR.gif](#)
- [Supplementary Video – Fibre_100Hz_MR.gif](#)
- [Supplementary Video – Sphere_100Hz_HR.gif](#)

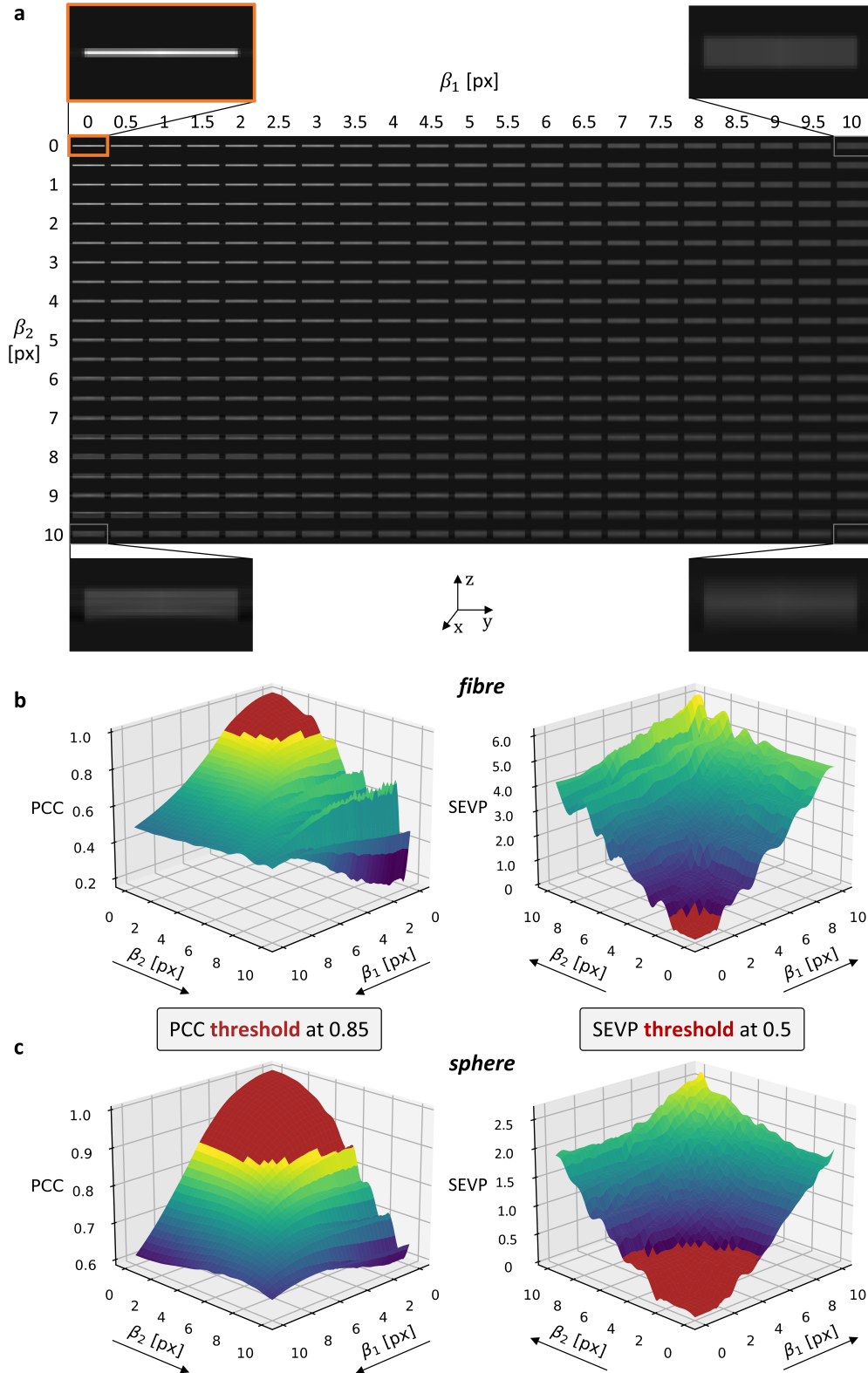


Figure S1. **a.** Same as for Figure 5a for the fibre-like phantom described in section *Methods – Tomography simulation with motion artefacts*. **b.** (left) 3D surface plot of the PCC computed between each blurred simulation of the fibre phantom and the static one. The red region gives maximum β_1 and β_2 to not exceed a PCC threshold at 0.85. (right) Idem for the SEVP with switched axis for better illustration, and a threshold at 50%. **c.** Same panel layout, with the spherical phantom data already described in Figure 5.

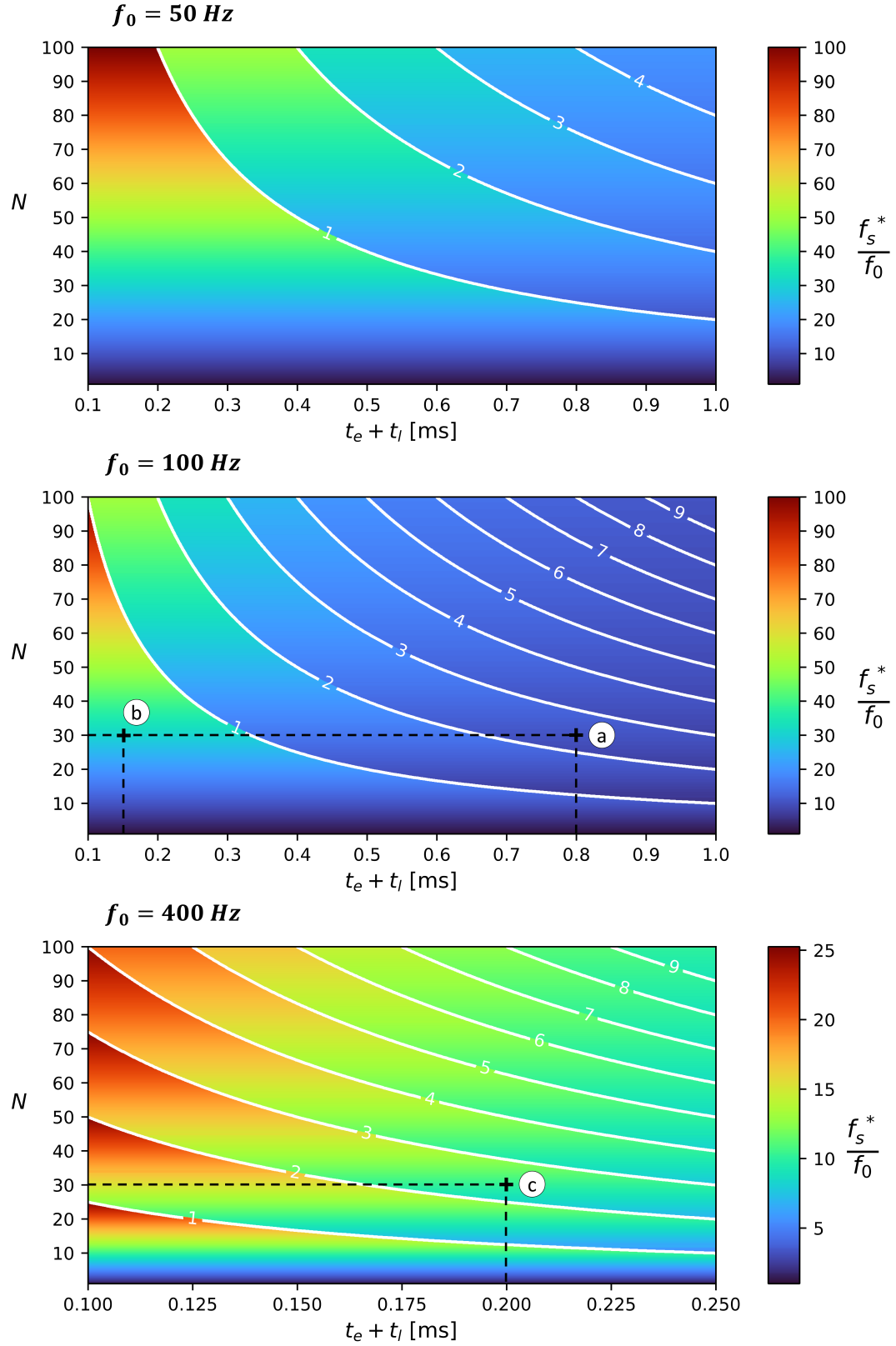


Figure S2. Same as for Figure 6 for f_0 equal to 50 Hz, 100 Hz and 400 Hz. Black crosses highlight the value of f_s^*/f_0 for the presented experimental cases: (a) cases **Ci** at $f_0 = 100 \text{ Hz}$ and $L_{vx} = 9.58 \text{ }\mu\text{m}$; (b) case at $f_0 = 100 \text{ Hz}$ and $L_{vx} = 2.17 \text{ }\mu\text{m}$ (see Fig. S5-d) ; (c) case at $f_0 = 400 \text{ Hz}$ and $L_{vx} = 9.58 \text{ }\mu\text{m}$ (see Fig. S5-b).

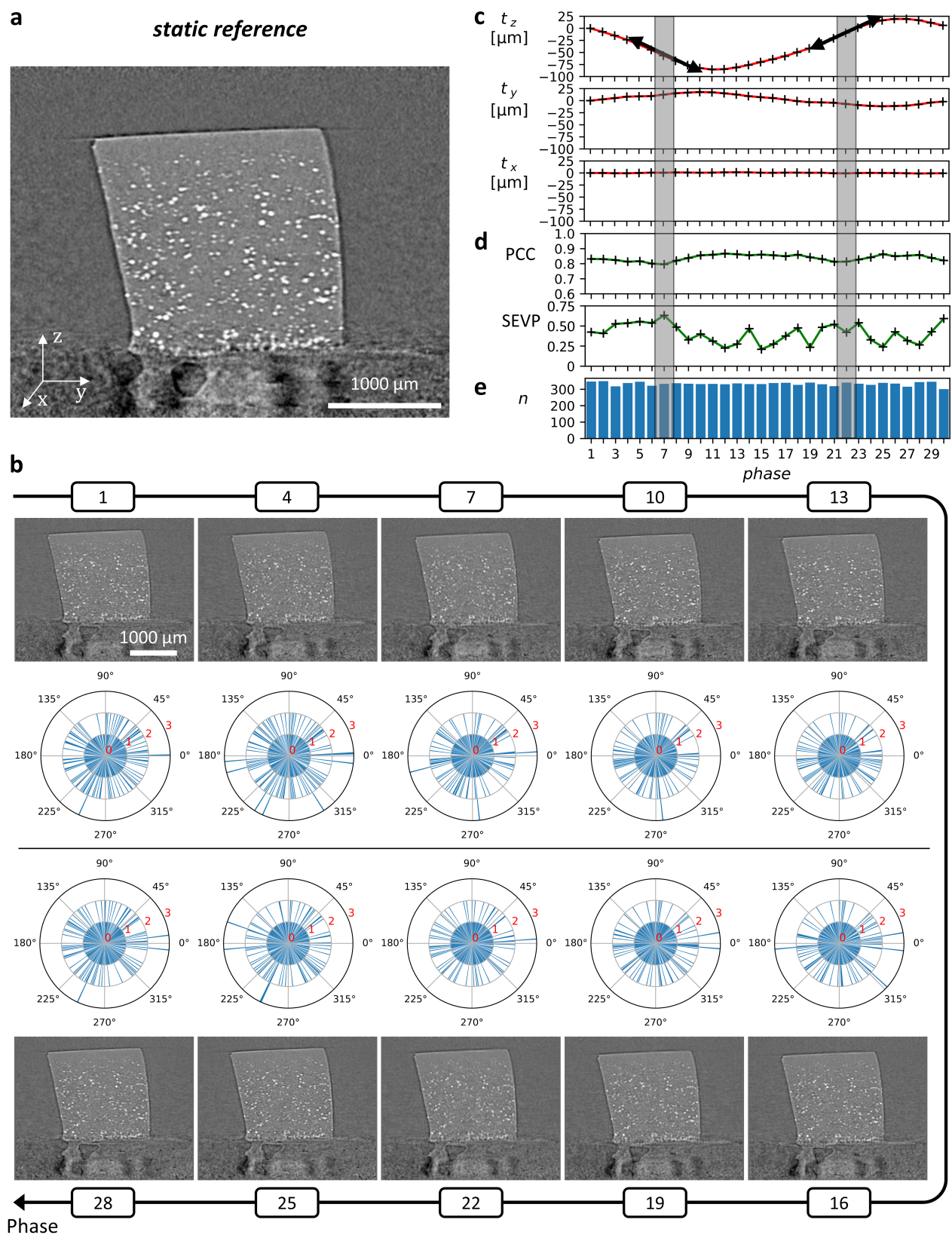


Figure S3. Same as Figure 7 for case study C1. Supplementary Video C1_Sphere_100Hz_MR.gif provides dynamic version of the vertical slices.

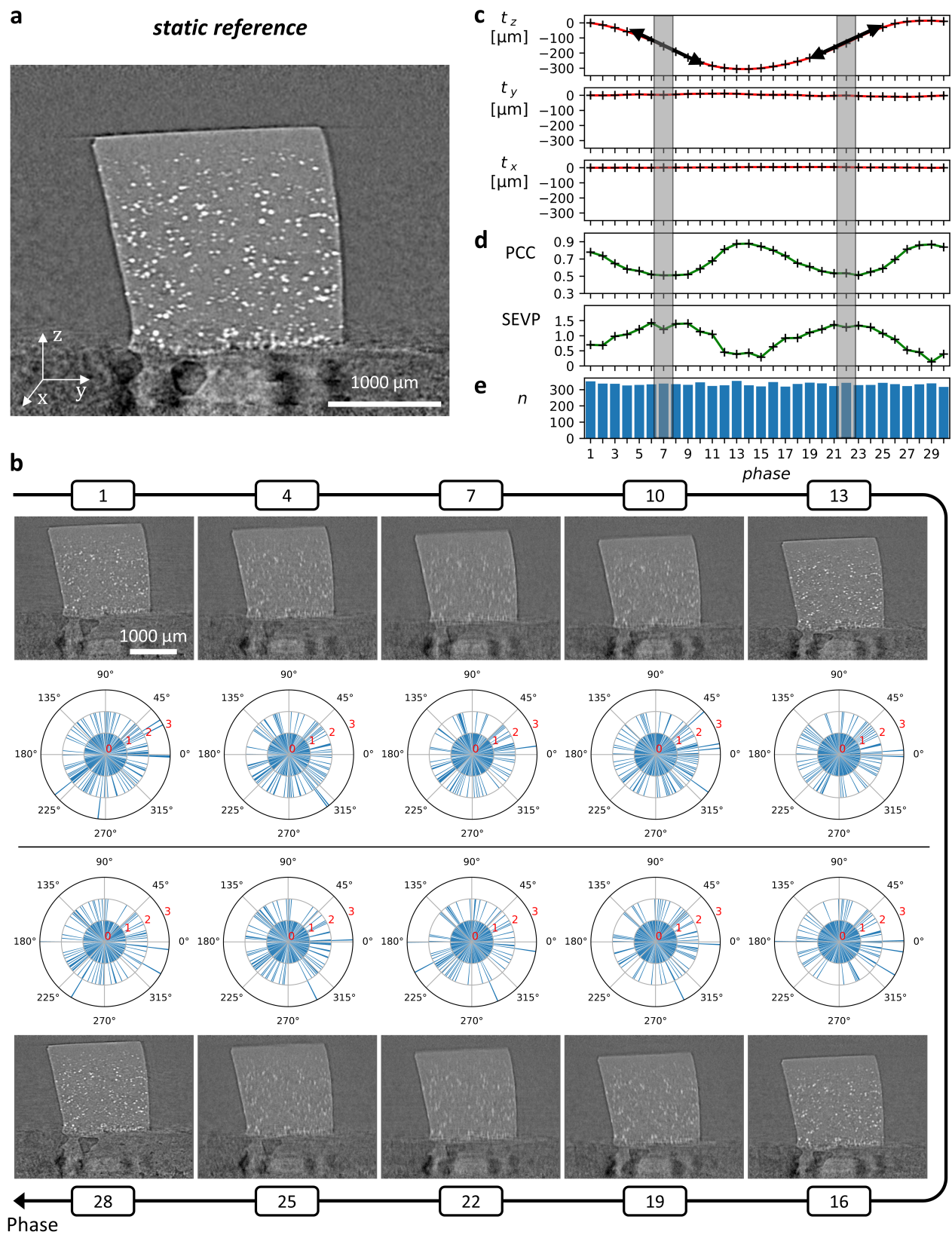


Figure S4. Same as Figure 7 for case study **C3**. Supplementary Video C3_Sphere_100Hz_MR.gif provides dynamic version of the vertical slices.

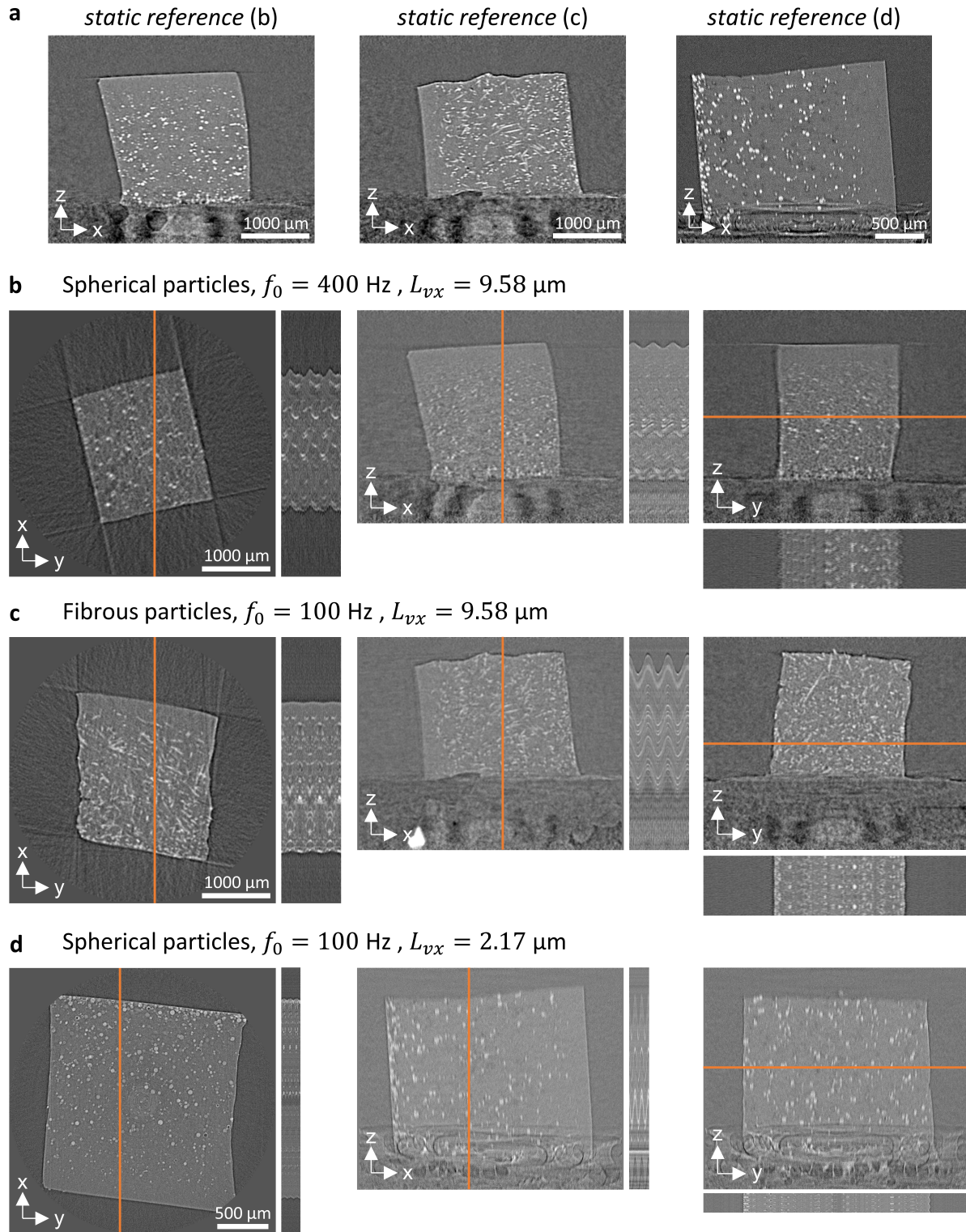


Figure S5. Overview of other acquired gated-CT varying the oscillation frequency, the heterogeneity type and the pixel size. **a.** Vertical slices of the *static reference* of each following case. **b.** Sample oscillating at $f_0 = 400 \text{ Hz}$. Orthogonal slices of the first phase in each direction and its associated kymograms (repeated 3 times) drawn along the orange axis over the 30 phases. Supplementary Video *Sphere_400Hz_MR.gif* provides dynamic version of the vertical slices. **c.** Same panel layout for a sample containing fibreglass (Supplementary Video: *Fibre_100Hz_MR.gif*). **d.** Same panel layout for a sample imaged at high resolution with a pixel size $L_{vx} = 2.17 \mu\text{m}$ (Supplementary Video: *Sphere_100Hz_HR.gif*).

Supplementary Methods – For the high resolution configuration ($L_{vx} = 2.17 \mu\text{m}$, $\text{FOV} = 1200 \times 1200 \times 1000 \text{ vx}$), t_e was set to $\approx 0.15 \text{ ms}$. The flux was increased at $87 \cdot 10^{12} \text{ photon mm}^{-2} \text{ s}^{-1}$ (3 mm Al and 0.177 mm Sn filters) for a photon energy close to the initial configuration ($E = 31.9 \text{ keV}$, wavelength = $0.389 \text{ \AA}$). The scintillator was switched for a 250 μm -thick LuAG, the propagation distance was reduced to 110 mm, and a 5×0.21 Mitutoyo long working distance objective was mounted on the camera. A kernel length of 15 px was used for Paganin’s method for phase retrieval.

Supplementary Note – We note in Supplementary Fig. S5-b that the discussed translation in the (x, y) plane is even more distinct for $f_0 = 400 \text{ Hz}$. Moreover, an overlay artefact is visible at the bottom of the vertical slices in Supplementary Fig. S5-d. This is due to the unintentional presence of the translation plateau in the FOV of the reference projections used for the flat-field correction when imaging at $L_{vx} = 2.17 \mu\text{m}$.

Authors	Year	Link	Scanning strategy	Source type	$L_{vx} [\mu\text{m}]$	$f_0 [\text{Hz}]$	N	$t_p [\text{s}]$
Drangova <i>et al.</i>	2007	DOI	retrospective	medical CT	150.00	6.00	14	$1.19 \cdot 10^{-2}$
Guo <i>et al.</i>	2012	DOI	prospective	medical CT	88.00	10.00	10	$1.00 \cdot 10^{-2}$
Murrie <i>et al.</i>	2020	DOI	prospective	lab	20.00	2.00	15	$3.33 \cdot 10^{-2}$
Schuler <i>et al.</i>	2021	DOI	retrospective	lab	12.00	0.80	24	$5.21 \cdot 10^{-2}$
Dubsky <i>et al.</i>	2012	DOI	prospective	synchrotron	20.00	1.11	50	$1.80 \cdot 10^{-2}$
Walker <i>et al.</i>	2014	DOI	retrospective	synchrotron	3.30	145.00	10	$6.90 \cdot 10^{-4}$
Mokso <i>et al.</i>	2015	DOI	retrospective	synchrotron	3.30	150.00	20	$3.33 \cdot 10^{-4}$
Hoshino <i>et al.</i>	2016	DOI	stroboscopic	synchrotron	13.00	0.14	40	$1.75 \cdot 10^{-1}$
Hoshino <i>et al.</i>	2018	DOI	stroboscopic	synchrotron	7.80	0.50	40	$5.00 \cdot 10^{-2}$
Tekawade <i>et al.</i>	2020	DOI	stroboscopic	synchrotron	2.10	714.29	14	$1.00 \cdot 10^{-4}$
Wu <i>et al.</i>	2021	DOI	stroboscopic	synchrotron	11.20	24.00	12	$3.47 \cdot 10^{-3}$
Fardin <i>et al.</i>	2021	DOI	retrospective	synchrotron	22.60	0.67	10	$1.50 \cdot 10^{-1}$
Maiditsch <i>et al.</i>	2022	DOI	retrospective	synchrotron	2.75	450.00	16	$1.39 \cdot 10^{-4}$
					2.75	350.00	20	$1.43 \cdot 10^{-4}$
					2.75	200.00	10	$5.00 \cdot 10^{-4}$
Matsubara <i>et al.</i>	2022	DOI	stroboscopic	synchrotron	0.50	1.00	10	$1.00 \cdot 10^{-1}$
Dejea <i>et al.</i>	2022	DOI	retrospective	synchrotron	2.75	5.00	200	$1.00 \cdot 10^{-3}$
Schmeltz <i>et al.</i>	2024	DOI	retrospective	synchrotron	2.75	128.00	10	$7.81 \cdot 10^{-4}$
					9.58	100.00	30	$3.33 \cdot 10^{-4}$
Our study – Klos <i>et al.</i>			retrospective	synchrotron	2.17	100.00	30	$3.33 \cdot 10^{-4}$
					9.58	400.00	30	$8.33 \cdot 10^{-5}$

Table S1. State of the art of X-ray microtomography applied to the imaging of periodic systems. Figure 9 was based on this database.