

ENHANCING X-RAY VISION WITH SANDPAPER PHASE PHENOMENA AND DARK(-FIELD) MAGIC

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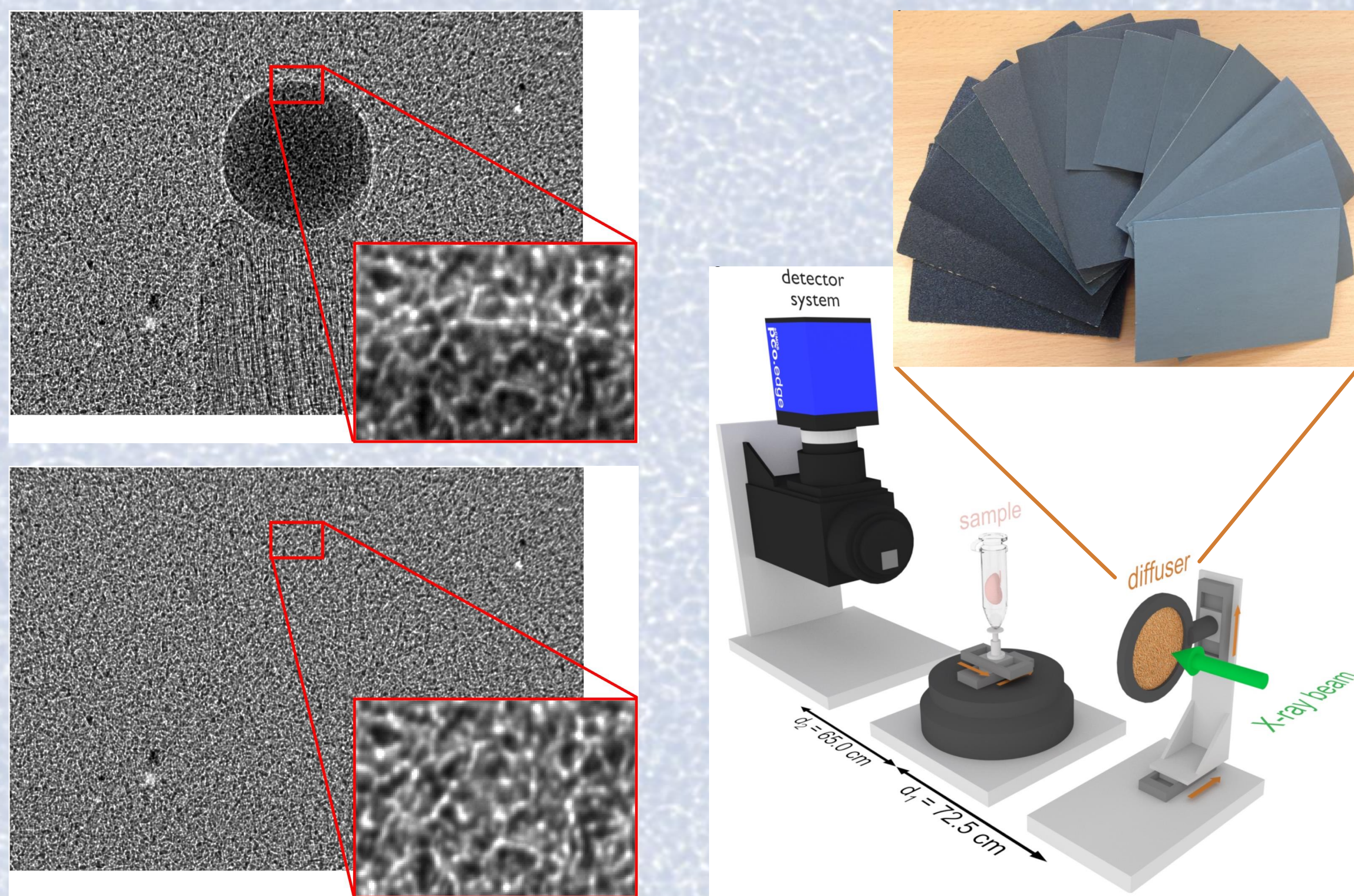
Physics of Imaging Group, School of Physics and Astronomy

Development of novel X-ray imaging methods

X-rays have been crucial for over a century in revealing the inner structure of opaque objects, advancing healthcare, industry and science. Traditional X-ray imaging provides good contrast between high- and low-density materials like bone and soft tissue but struggles to detect subtle density differences within soft tissue or sub-resolution features, such as the tiny air sacs in the lungs. In the X-ray Imaging Group, we develop novel techniques that overcome these challenges by capturing complementary phase-contrast and dark-field information.

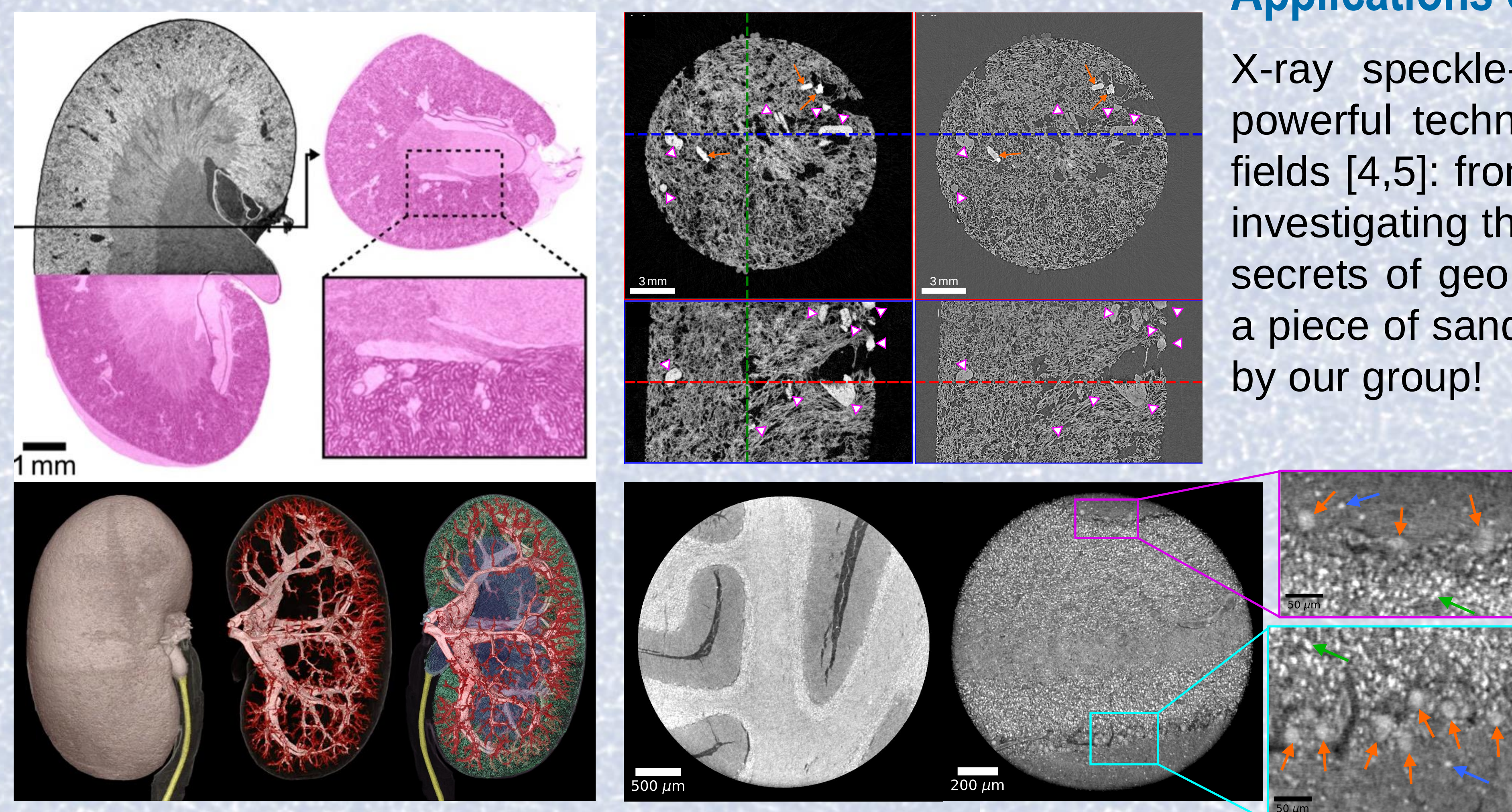
X-ray phase-contrast and dark-field imaging

While conventional X-ray imaging measures the absorption of X-rays in a sample, similar to how sunglasses absorb visible light, phase-contrast imaging analyses the phase shift or refraction, like prescription glasses redirecting light. Dark-field imaging captures the diffusion and scattering of X-rays, analogous to the way milky glass scatters and blurs light.

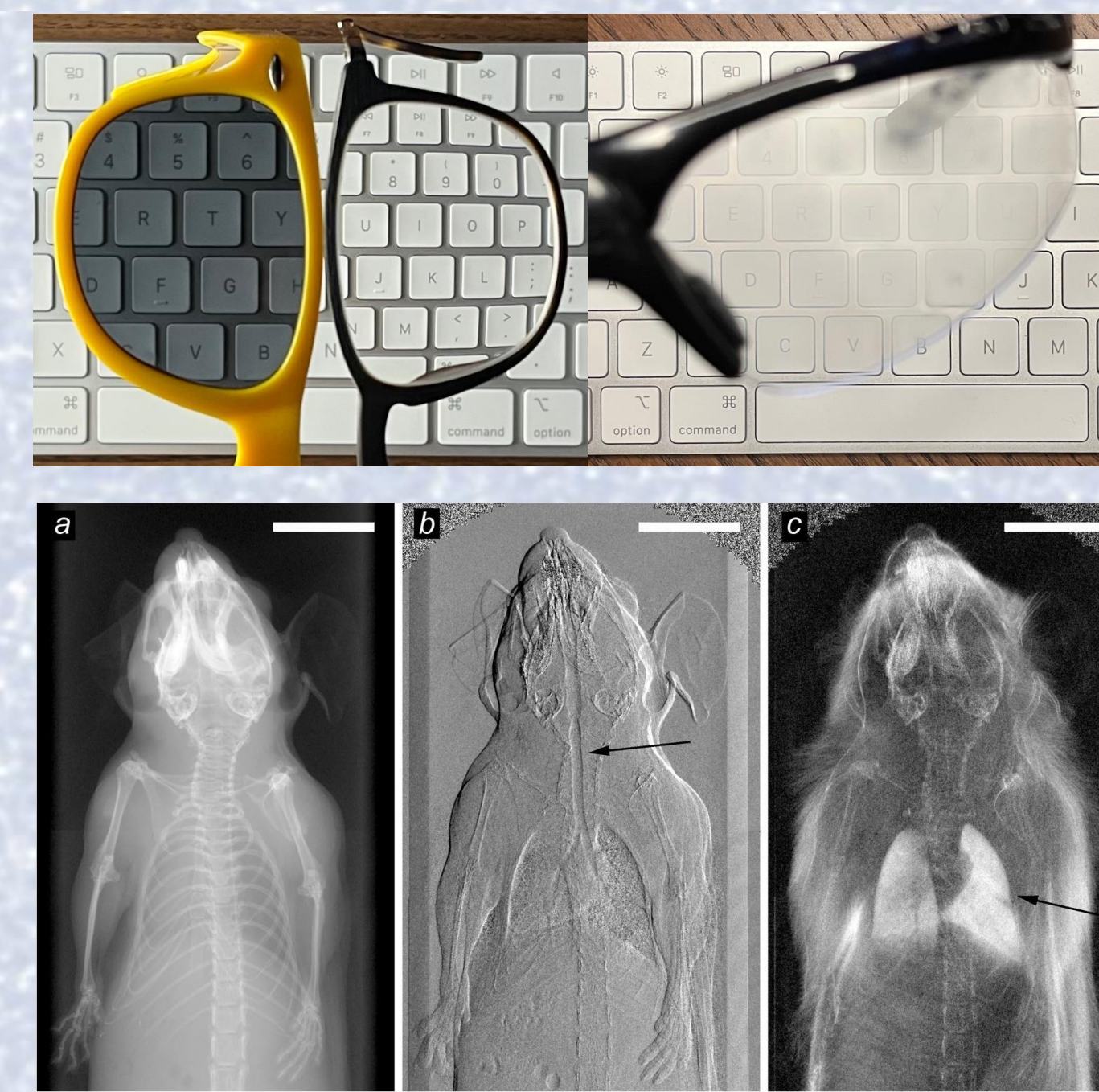


From theory to programming to X-ray experiments

Developing new X-ray imaging methods involves multiple steps: from solving the underlying mathematical problem and creating data acquisition protocols to writing computer code for extracting multi-modal signals and validating the method through simulations and experiments. We regularly conduct experiments at synchrotron facilities in worldwide, as well as in our X-ray lab at Monash.



Advanced X-ray imaging
Experiments
Programming
Mathematical models
X-ray optics
Biomedical imaging
X-ray phase-contrast and dark-field modalities
Synchrotron science
Lab sources
X-ray free-electron lasers
Virtual histology



M. Bech et al., Sci. Rep. 3, 3209 (2013).

Sandpaper X-ray optics – X-ray speckle-based imaging

How do we make these phase-contrast and dark-field effects visible? We can introduce a pattern into the X-ray beam that we can track [1,2]. A simple way to do this is by using an item found at any hardware store as an X-ray optic: sandpaper!

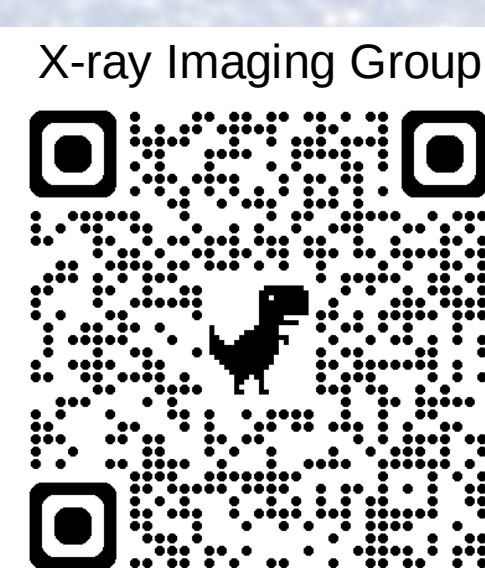
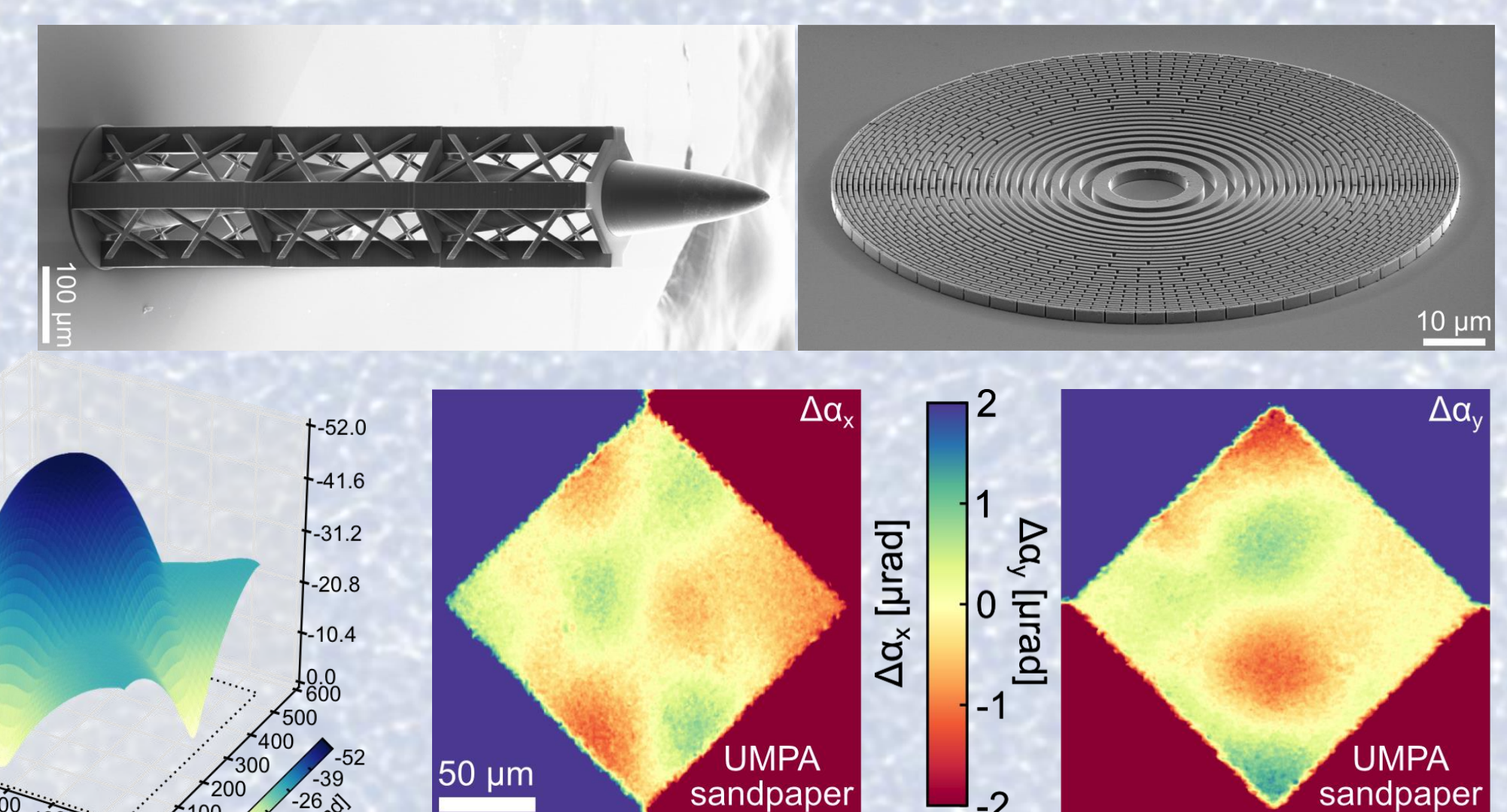
There are various ways to extract the multi-modal signals from how the sample alters the speckle pattern. One such method is the Unified Modulated Pattern Analysis (UMPA), which compares the speckle pattern with and without the sample using a least-squares minimisation approach [3]:

$$L = \sum_r \sum_j \Gamma(r - r_0) \left| I_j(r) - \underbrace{\langle I \rangle(r)}_{\text{Transmission}} \left[\underbrace{\langle I \rangle(r)}_{\text{Dark-field}} + \underbrace{\langle I \rangle(r)}_{\text{Refraction}} \left(I_{0j}(r + \underbrace{u}_{\text{Refraction}}) - \langle I \rangle \right) \right] \right|^2$$



Applications of X-ray speckle-based imaging

X-ray speckle-based imaging, particularly with UMPA, is a powerful technique with applications across a broad range of fields [4,5]: from uncovering hidden details in biological tissues, investigating the structural integrity of materials, to revealing the secrets of geological formations—all made possible by X-rays, a piece of sandpaper and the innovative approaches developed by our group!



- [1] K. S. Morgan et al., Appl. Phys. Lett. 100, 124102 (2012).
- [2] S. Berujon et al., Phys. Rev. A 86, 063813 (2012).
- [3] M. Zdora et al., Phys. Rev. Lett. 118, 203903 (2017).
- [4] M. Zdora et al., Optica 7, 1221-1227 (2020).
- [5] M. Zdora et al., Opt. Express 26, 4989-5004 (2018).