**Abstract**

**X-ray phase-contrast in vivo tomography**

Four-dimensional imaging techniques are essential tools in biology to understand the behaviour of cells during embryonic development. Here, we apply X-ray phase-contrast microtomography to capture the early development of the optically opaque African clawed frog (Xenopus laevis) over the course of time and in 3D. Xenopus embryos lack conventional X-ray absorption contrast and act as pure-phase objects for hard X-rays. The wave front exiting the sample is thus characterised by a 2D phase map representing the projection of the object along the X-ray beam. Employing quasi-monochromatic and sufficiently spatially coherent X-rays, we make use of propagation-based phase-contrast.

In Fresnel theory, we study the formation of 2D intensity contrast upon free-space propagation from a given phase map and how phase retrieval based on linear contrast transfer breaks down at strong phase variations. Using a single-distance intensity measurement only, we devise a phase-retrieval method for moderately strong phase variations which, due to large propagation distances, exhibits high spatial resolution and contrast at low photon statistics.

We discuss constraints imposed by in vivo imaging and present results from experiments on living Xenopus embryos.

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