component of the polarization vector is collinear with the ± [-110]$_{pc}$ shear direction of the pseudocubic (pc) unit cell of the film and periodically changes by 180° in adjacent domains.

A structural variant of a 90° rotated M_A domain pattern, where the monoclinic distortion of the pseudocubic unit cells occurs along ± [110]$_{pc}$ is also observed (Fig.1b). However, this variant appears with significantly lower probability in agreement with energy considerations based on linear elasticity theory and cannot be independently resolved in a conventional X-ray diffraction experiment as shown in Fig.1c. Nevertheless, a 100 nm-focus experiment recently carried out at ID01 beamline (ESRF) could be used to individually investigate the two domain variants. Distinct differences between the 0° variant and the 90° variant were observed and will be discussed.

1. J. Schwarzkopf, D. Braun, M. Hanke, A. Kwasniewski, J. Sellmann, M. Schmidbauer, *J. Appl. Cryst.* **49**, (2016), 375.

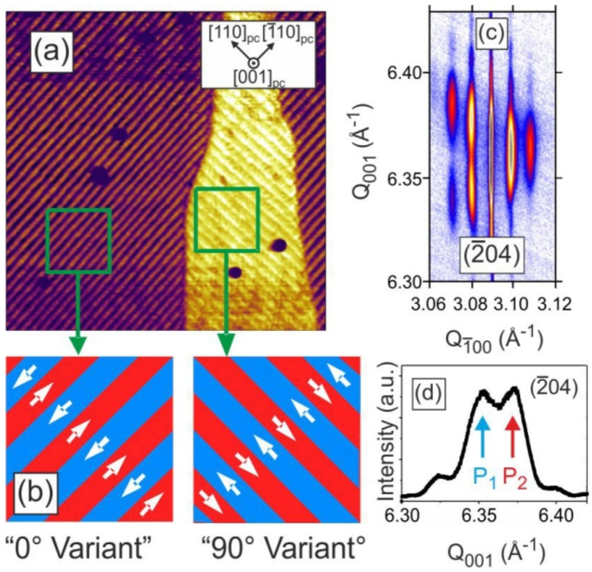

Figure 1. (a) Lateral PFM image (2 m x 2 m) of a 30 nm $K_{0.75}Na_{0.25}NbO_3$ film grown on (110) $TbScO_3$, (b) models of 0° and 90° variants (white arrows indicate the in-plane component of the polarization vector), (c) out-of-plane x-ray diffraction and, (d) section along the CTR at Q_{-100} = 3.09 Å^{-1} (adapted from [1]).

Session II

Monday, September 4 - afternoon

I2

X-RAY PHASE-CONTRAST IN VIVO TOMOGRAPHY

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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 African clawed frog (Xenopus laevis), an important vertebrate model organism, over the course of time and in 3D. Early developmental stages of the Xenopus frog are optically opaque and lack conventional X-ray absorption contrast. For hard X-rays such embryos essentially are pure-phase objects. The probing wave front is thus characterised by a 2D phase map representing the projection of the object along the X-ray beam. Employing quasi-monochromatic and spatially coherent X-rays, we thus use propagation-based phase-contrast.

In Fresnel theory, the formation of 2D intensity contrast upon free-space propagation from a given phase map is studied and how linear approximations to the inverse problem of phase retrieval from a single-distance intensity measurement break down for large propagation distances and strong phase variations. Important properties of linear contrast transfer, which are conserved for a wide range of phase variations and propagation distances, are exploited in order to devise a phase-retrieval method which exhibits a high spatial resolution and contrast at low photon statistics.

Constraints imposed by in vivo imaging are discussed and results from experiments on living Xenopus embryos are presented.

C5

STATUS AND PERSPECTIVES OF SYNCHROTRON-BASED COHERENT X-RAY DIFFRACTION IMAGING

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After the first demonstration experiment [1], Coherent X-ray Diffraction Imaging (CXDI) attracted a lot of interest because of its promise of imaging isolated microscopic objects at high resolution which is beyond the values achieved with standard lens-based microscopy techniques. In spite of the huge potential [2-4] technical challenges have delayed the exploitation of the method for a regular application in science. Only recently CXDI turned out to be a reliable technique for high resolution 3D imaging [5].

In this work we report and discuss the opportunities and challenges of CXDI by showing examples of reconstructions of *Deinococcus radiodurans* bacteria in 2D Fig. 1(a), of a vaterite core-shell particle Fig. 1(b), a polymer microsphere coated with metallic multi-layers Fig. 1(c) and a gold test sample Fig. 1(d) in 3D. The high quality of the reconstructed images proves the power of CXDI: high sensitivity, full 3D capability, imaging the internal structure and high resolution. The improvement in the biological sample preparation and the development of large 2D (pixel) detectors remain the key elements for achieving the full potential of the technique.

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2. H.N. Chapman, and K.A. Nugent, *Nature Photonics*, **4**, (2010), 833.
3. J. Miao, T. Ishikawa, B. Johnson, E.H. Anderson, B. Lai, K.O. Hodgson, *Phys. Rev. Letters*, **89**, (2002), 088303.
4. H.M. Chapman *et al, J. Opt. Soc. Am. A*, **23**, (2006), 1179.
5. Y. Chushkin *et al*, *J. Synchrotron Rad.,* **21**, (2014), 594.

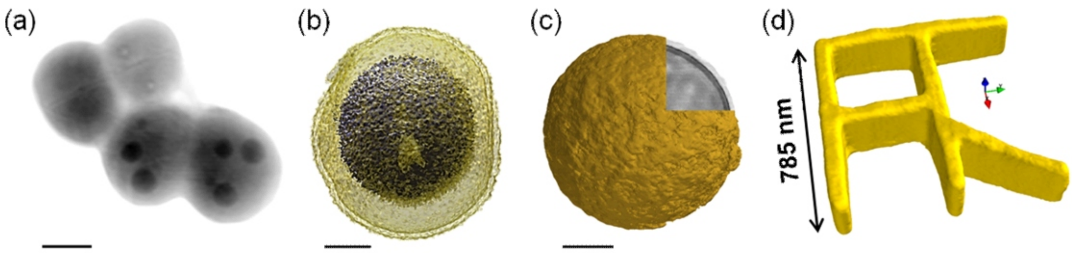

Figure 1. Reconstructed images: (a) *Deinococcus radiodurans* bacteria; (b) Vaterite core-shell particle (semitransparent iso-surface rendering); (c) Polymer microsphere with 3 coating layers (shown in a cut); (d) Tiny gold test sample. The scale bars are 1 m.

C6

STRUCTURAL INVESTIGATIONS OF SINGLE HETEROSTRUCTURE NANOWIRES

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GaAs/InGaAs/GaAs heterostructure nanowires (NWs) with 140nm GaAs core-10nm $In_{0.15}Ga_{0.85}As$ quantum well-30nm GaAs outer shell have been studied using Coherent X-ray diffraction imaging (CXDI) technique at ID1 beamline at ESRF. CXDI probes the structure of the wire by mapping the reciprocal space for example around the symmetric GaAs (333) (see Fig. 1 a,b) and asymmetric GaAs (331) (not shown here). In the direction of perpendicular to the NW growth axis the CDXI pattern shows a complex diffraction pattern as a result of the core-shell structure (Fig. 1a). Along the truncation rod the CXDI pattern shows displaced peaks indicating that coherently illuminated segment of the NW is composed from wurzite and zinc-blende segments (Fig. 1b). The electron density distribution in real space can be inverted from the diffraction patterns by means of dual space phase retrieval iterative algorithms. We demonstrate the feasibility of phase retrieval algorithms in case of symmetric and asymmetric reflections in 2D. Inverting the 2D diffraction pattern shown in Fig. 1a leads to the phase pattern (see Fig. 1c,d) where the phase anomalies are appearing at the corners of the hexagonal shaped nanowire indicating higher strain accumulation at the corners and strain relaxation towards the side facets of the NW. Fig.1d shows sensitivity of the phase to the presence of the InGaAs shell with phase shifts at the position of the embedded quantum well. Interpretation of these results by means of Finite Element Method simulations as well as 3D phase retrieval analysis are currently on the way in order to investigate the impact of strain caused by InGaAs inner shell and retrieve the 3D nanowire structure.

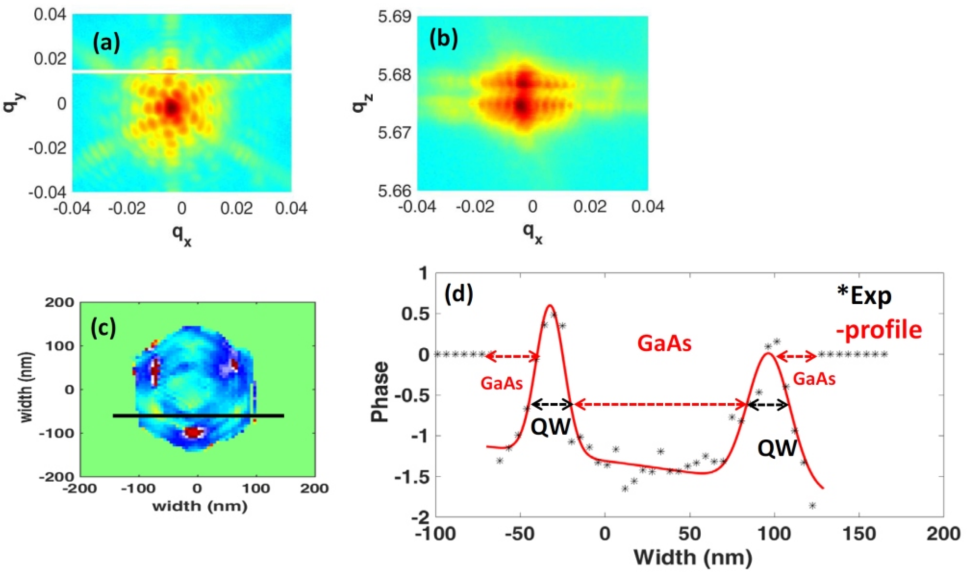

Figure 1. (a,b) Projections of the experimentally recorded 3D CXDI pattern from single NW around the GaAs (333) reflection.(c) Retrieved phase pattern of the nanowire. (d) Line cut from the phase shown in (c) black line.