New properties and exotic quantum phenomena can arise due to periodic nanotextures of co-existing materials, including metal-insulator transitions and negative differential capacitance. Here, **users of PARADIM and their collaborators** combine conventional iterative phase retrieval with unsupervised machine learning to extract high-resolution images of nanotextured materials from diffuse diffraction intensities using a conventional, partially coherent synchrotron beam. The method solves a long-standing problem and achieves a direct, model-independent inversion of x-ray diffraction data. Using the technique, a previously unreported nanotexture in a film undergoing a metal-insulator transition (Ca$_2$RuO$_4$) is discovered and confirmed by PARADIM’s cryo-STEM capabilities. The method is relevant to modulated structures in ferroics and topological quantum materials.


**X-ray imaging:** Nanotextures calculated to be present in a strained Ca$_2$RuO$_4$ film measured at 7 K. (A) Measured and (B) reconstructed diffraction pattern. Four characteristic structural motifs (SMs) labelled normal strain (NS) and crystal-plane inclination (CI) are identified. **Electron Microscopy:** Cryo-STEM map of the interplanar spacing along [001] of the cross-section of a ~34-nm-thick Ca$_2$RuO$_4$ film at ~100 K. The features seen in STEM corroborate the nanotextures calculated from X-ray diffraction data, including the average stripe angle (48°).