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Advancements in Ptychography through the Alternating Amplitude Flow algorithm

High-resolution transmission electron microscopy (HRTEM) is a powerful technique for resolving the atomic structure of materials. However, it fails to retain the phase information of the exit wave. To address this limitation, advanced 4D-STEM techniques, such as electron ptychography, have been developed to retrieve phase information and enhance resolution. Conventional electron ptychography methods typically require high electron doses on the order of 106 e-/A2 [1] to achieve reliable reconstructions with atomic resolution. Reducing the dose while maintaining the resolution power poses a fundamental challenge due to increased noise.

This study represents a new approach to achieve high noise resistance in atomically resolved electron ptychography using the Alternating Amplitude Flow (AAF). Our method enables high resolution reconstructions at doses 10% of conventional levels, while maintaining this dose across different elements. By using a larger step size and at reduced overlap area of around 25-50%, our approach allows for effective phase retrieval at lower doses and higher scan speeds.

To demonstrate the effectiveness of AAF, we applied it to SrTiO3 (STO) and PrScO3 (PSO). In the first figure vacancies remain visible, and differences between light elements (O), medium elements (Sr, Ti), and heavy elements (Pb) in the phase are observable.

Additionally, we have extended the applicability of electron ptychography to thicker samples, up to 10 nm, without relying on multi-slice methods. As shown in the reconstruction of a 10 nm SrTiO3 (STO) sample, atomic resolution is preserved with only the Pb columns showing phase errors due to their high atomic weight in figure 2.

By providing a detailed analysis of the noise resistance and resolution capabilities of the AAF method, we aim to improve the boundaries of low dose high-resolution imaging. The ability to achieve high noise resistance with minimal dose rates opens up new possibilities for understanding the fundamental properties of materials and their applications in advanced technologies.

[1] Zhen Chen et al., Electron ptychography achieves atomic-resolution limits set by lattice vibrations. Science372,826-831(2021).DOI:10.1126/science.abg2533

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