TITLE: Ultrafast imaging beyond "Uncertainty Principle": Unveiling hidden orders in phase transitions

ABSTRACT: Evolution of imaging technologies has now entered both space and time domains, aiming to capture the most elementary chemical processes, such as breaking and forming chemical bonds in molecules or spontaneous symmetry breaking in phase transitions of complex materials down to the atomic details. However, in pushing for greater space and time resolutions, the fundamental limits set by quantum mechanics emerge. For example, under an electron microscope the particle-wave duality imposes a constraint in the time resolution due to Uncertainty Principle, when a specific energy resolution is set to maintain phase coherence for imaging. Here we show such limitations should only exist due to our poor understanding of the phase space evolution as part of the imaging processes. By establishing the precise correlations between energy and time, or likewise between momentum and position, pertaining to the phase space of the probing electron pulses, the resolution may go beyond the limits set by the scalar form of Uncertainty Principle, and the ultimate limitations lie primarily in the statistics of measurement or so-called brightness. Using a newly developed high-brightness electron beamline, we demonstrate that the hidden orders during the phase transitions of unconventional semiconductors can be visualized directly in space and time. Such physical processes follow a new scaling law and are relevant for understanding the emergence of high-temperature superconductivity. The strategy for improving resolution through correlations may be incorporated into various forms of imaging technologies, and promises to revolutionize the future electron microscope development.