Contribution ID: **551** Type: **Contributed talk**

Coherent Correlation Imaging for Resolving Fluctuating States of Matter

Tuesday 27 August 2024 13:00 (15 minutes)

Fluctuations and stochastic processes are ubiquitous in nanometer-scale systems, especially in the presence of disorder. Real-space access to fluctuating states is impeded by a fundamental dilemma between spatial and temporal resolution. Averaging over an extended time period (or repetitions) is key for the majority of high-resolution imaging experiments. If, by lack of better knowledge, averaging is indiscriminate, it leads to a loss of temporal resolution and motion-blurred images.
We present coherent correlation imaging (CCI) [1] –a high-resolution, full-field imaging technique that realizes multi-shot, time-resolved imaging of stochastic processes. The key idea of CCI is the classification of Fourier-space coherent scattering images (Fig. 1a) –even at a low photon count where imaging is not possible. Contrast and spatial resolution emerge by averaging selectively over same-state frames. Temporal resolution down to the single frame acquisition time arises independently from an exceptionally low misclassification rate, which we achieve by combining a correlation-based similarity metric with powerful classification algorithm.
We apply CCI to study previously inaccessible magnetic fluctuations in a highly degenerate magnetic stripe domain state with nanometer-scale resolution. Our material is a Co-based chiral ferromagnetic multilayer with magnetic pinning low enough to exhibit stochastically recurring dynamics that resemble thermally-induced Barkhausen jumps near room temperature. CCI reconstructs high-resolution real-space images of all domain states by holographically aided phase retrieval [2, 3] and, unlike previous approaches, also tracks the time when these states occur. The spatiotemporal imaging reveals an intrinsic transition network between the states and unprecedented details of the magnetic pinning landscape (Fig. 1b) allowing us to explain the dynamics on a microscopic level.
CCI massively expands the potential of emerging high-coherence X-ray sources and paves the way for addressing large fundamental questions such as the contribution of pinning and topology in phase transitions and the role of spin and charge order fluctuations in high-temperature superconductivity.

[1] C. Klose et. al., Nature 614, 256-261 (2023)
[2] S. Zayko et al., Nat. Commun. 12, 6337 (2021).
[3] R. Battistelli, et. al., Optica, DOI 10.1364/OPTICA.505999

Figure 1: a, Principle of time-resolved coherent correlation imaging. Top: Sequence of camera frames showing Fourier-space coherent scattering patterns. Coherent correlation imaging classifies scattering frames by their underlying domain state, as indicated by the colors. Bottom: Real-space images reconstructed from an informed average of same-state frames. b, Map of attractive (blue dots) and repulsive (red areas) pinning sites. The background shows the position of the domain walls and their relative occurrence.

I plan to submit also conference proceedings

No

Primary authors: KLOSE, Christopher (Max-Born-Institut); BÜTTNER, Felix (Helmholtz-Zentrum Berlin); HU, Wen (Brookhaven National Laboratory); MAZZOLI, Claudio (Brookhaven National Laboratory); PFAU, Bastian (Max-Born-Institut)

Co-authors: LITZIUS, Kai (Massachusetts Institute of Technology); BATTISTELLI, Riccardo (Helmholtz-Zentrum Berlin); LEMESH, Ivan (Massachusetts Institute of Technology); BARTELL, Jason M. (Massachusetts Institute of Technology); HUANG, Mantao (Massachusetts Institute of Technology); GÜNTHER, Christian M. (Technische Universität Berlin); SCHNEIDER, Michael (Max Born Institute); BARBOUR, Andi (Brookhaven National Laboratory); WILKINS, Stuart B. (Brookhaven National Laboratory); BEACH, Geoffrey S. D. (Massachusetts Institute of Technology); EISEBITT, Stefan (Max-Born-Institute)

Presenter: KLOSE, Christopher (Max-Born-Institut)

Session Classification: Mikrosymposium 7/1: Imaging and Cohrerence Applications

Track Classification: 7. Imaging and coherence applications