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Coherent x-ray studies of spontaneous fluctuations in correlated systems

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Rare-earth nickelates ($RNiO_3$) exhibit a rich interplay of electronic, magnetic, and structural phase transitions, including a metal-to-insulator transition (MIT). While these transitions have been widely studied, spontaneous fluctuations across the phase transition are mostly unexplored. Such fluctuations are increasingly recognized for enabling stochastic functionality in neuromorphic computing. Here, we employ X-ray photon correlation spectroscopy (XPCS) to directly probe structural and magnetic fluctuations in $NdNiO_3$ and $SmNiO_3$ thin films. For $NdNiO_3$, we observe a pronounced slowdown in fluctuation timescales—by an order of magnitude—near the Néel temperature, highlighting strong coupling between structural and magnetic order parameters, independent of epitaxial strain. In contrast, $SmNiO_3$ shows no such slowdown. Unexpectedly, wavevector-dependent measurements reveal that short-range structural fluctuations are significantly slower (by a factor of 3–5) than long-range fluctuations. Our results demonstrate the power of coherent X-ray techniques in capturing nanoscale fluctuation dynamics and provide new insight into the role of fluctuations in complex oxides.

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