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Coherent X-rays Reveals Radiation-Induced Dynamics in Hydrated Proteins

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Radiation damage remains a central challenge in structural biology, particularly when probing soft, disordered materials like hydrated proteins. In this presentation, I will discuss recent advances using X-ray Photon Correlation Spectroscopy (XPCS) to study radiation-driven dynamics in both hydrated protein powders [1] and dense protein solutions [2,3]. At cryogenic temperatures, we investigate lysozyme powders and find that X-ray exposure induces nanoscale stress relaxation, revealing a temperature-dependent transition around 227 K associated with enhanced dynamical heterogeneity. These results highlight how radiation can stimulate out-of-equilibrium processes in supercooled, granular biomaterials. At ambient temperatures, using megahertz XPCS at the European XFEL, we probe antibody and ferritin solutions as a function of X-ray dose and dose rate. Our measurements capture anomalous diffusion and aggregation dynamics, which are influenced by both hydrodynamic and direct protein interactions. Modeling these effects allows us to disentangle intrinsic molecular behavior from radiation-induced perturbations. Together, these studies underscore the dual role of coherent X-rays as both probe and stimulus, offering critical insights into how radiation impacts biological materials under experimentally relevant conditions. This understanding is essential for optimizing measurement strategies in next-generation X-ray facilities and for minimizing radiation effects in XPCS studies of biological samples.

References

[1] M. Bin et al., Coherent X-ray Scattering Reveals Nanoscale Fluctuations in Hydrated Proteins, J. Phys. Chem. B 127, 4922 (2023).

[2] M. Reiser et al., Resolving molecular diffusion and aggregation of antibody proteins with megahertz X-ray free-electron laser pulses, Nat. Commun. 13, 1 (2022).

[3] A. Girelli et al., Coherent X-Rays Reveal Anomalous Molecular Diffusion and Cage Effects in Crowded Protein Solutions, arXiv:2410.08873.

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Session Classification: Radiation Damage in Complementary Fields including Biological Imaging