Correlation Spectroscopy in Disordered Systems

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One of the outstanding properties of third generation synchrotron radiation sources is their capability of producing coherent x-ray beams several orders of magnitude more intense than previously available. The access to coherent x-rays opens up a variety of possibilities for new techniques such as x-ray photon correlation spectroscopy (XPCS), static x-ray speckle analysis and metrology and has major impact on imaging techniques such as topography, phase-contrast and holographic imaging. XPCS probes the dynamic properties of matter by analyzing the temporal correlations among photons scattered by the studied material. It can measure the low frequency dynamics (10^6 Hz to 10^{-3} Hz) in a Q range from typically $1 \cdot 10^{-3}$ Å^{-1} up to several Å^{-1}. X-ray photon correlation spectroscopy is in particular complementary to Dynamic Light Scattering (DLS) or Photon Correlation Spectroscopy (PCS) with visible coherent light which probes also slow dynamics ($\omega<10^6$ Hz) but can cover only the long wavelength $Q<4 \cdot 10^{-3}$ Å^{-1} regime. XPCS is furthermore not subject to multiple scattering, a phenomenon frequently complicating the analysis of PCS data in optically opaque systems. Neutron based techniques (inelastic and quasi-elastic neutron scattering, neutron spin-echo) on the other hand can access the same Q range but probe the dynamic properties of matter at high frequencies from typically 10^{14} Hz down to about 10^8 Hz.

XPCS is a young technique but has already shown the potential to impact many areas of statistical physics and provide access to a variety of important dynamic phenomena. Among them are the time-dependence of equilibrium critical fluctuations and the low frequency dynamics in disordered hard (e.g. non-equilibrium dynamics in phase separating alloys or glasses, domain wall dynamics) and soft condensed matter materials, in particular complex fluids (e.g. hydrodynamic modes in concentrated colloidal suspensions, liquids in confined geometry, internal conformational dynamics in polymer systems, capillary wave dynamics).