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From femtoseconds to hours – measuring dynamics of complex liquids over 18 orders of magnitude with coherent X-rays

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Abstract: X-ray photon correlation spectroscopy (XPCS) and X-ray speckle visibility spectroscopy (XSVS) enables the study of dynamics of liquids and soft matter between micrometer and atomic length scales. Typically, time scales of (sub-)milliseconds to hours can be accessed with these techniques at synchrotron radiation sources such as PETRA III. Therefore, dynamics studies are typically limited to slow dynamics in soft and hard condensed matter, e.g., probing glasses and gels. Thanks to advances in detector technology and the increase of brilliance at the next-generation synchrotron radiation sources (e.g. PETRA IV), this time limit is currently being reduced by many orders of magnitude. Together with XSVS applications at Free-Electron Laser (FEL) sources, as the European XFEL, soon dynamics can be probed over more than 18 orders of magnitude with these coherent scattering techniques.

In this talk I will introduce coherent scattering techniques at modern X-ray sources. XPCS concepts and the latest developments will be reviewed with special attention on the extension of accessible time scales to sub-µs and the application of XPCS at FELs [1]. I will focus first on our recent results on understanding structure and dynamics of PNIPAM-based nanogels [2-5]. By combining static structure from small-angle X-ray scattering with dynamics we explored the whole phase diagram, covering repulsive and attractive fluids, glasses and gels over a wide range of particle concentration. Second, I will discuss relation between dynamics and higher-order structure in hard spheres [6]. Third, the results of MHz XPCS and its application in a pump-probe scheme, allowing e.g. obtaining superheated water states, will be presented [7,8]. I will end with an outlook on future possibilities of XPCS and XSVS at diffraction-limited storage rings and FEL sources.

References

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