Towards 0.1-meV-Resolution Inelastic X-ray Scattering

Yuri Shvyd'ko*[1]

[1]Argonne National Laboratory

Photon and neutron inelastic scattering spectrometers are microscopes for imaging condensed matter dynamics on very small length and time scales. Inelastic x-ray scattering permitted the first quantitative studies of picosecond nanoscale dynamics in disordered systems almost 20 years ago. However, the nature of the liquid-glass transition still remains one of the great unsolved problems in condensed matter physics. It calls for studies at hitherto inaccessible time and length scales, and therefore for substantial improvements in the spectral and momentum resolution of the inelastic x-ray scattering spectrometers, down to 0.1-meV and 0.02-nm^{-1}, respectively, along with major enhancements in spectral contrast and count-rates.

In approaching this goal we have developed a conceptually new inelastic x-ray scattering spectrometer, based on new principles of x-ray monochromatization and spectral analysis [1]. Combination of novel angular-dispersive optical components allowed us to create an ultra-high-resolution inelastic X-ray scattering (UHRIX) spectrometer with unmatched performance in terms of energy, momentum resolution, and spectral contrast. The UHRIX spectrometer features a spectral resolution function with steep, almost Gaussian tails, sub-meV (0.62 meV) bandwidth and improved momentum resolution. We have successfully verified the new spectrometer concept by carrying out measurements on liquid glycerol in previously inaccessible regions of energy and momentum transfer, and achieved very promising results.

UHRIX opened up uncharted space on the dynamics landscape. However, further improvements are needed to achieve the required 0.1-meV resolution, and simultaneously to overcome the low-count-rate limitations in IXS experiments. For this purpose, we propose to adopt a new strategy by replacing scanning IXS spectrometers with imaging spectrographs [2], and by using high-repetition-rate self-seeded x-ray free-electron lasers [3] as x-ray sources, which will deliver three orders of magnitude more spectral flux than what is possible with storage-ring based radiation sources [3].

References

[1] Yu. Shvyd'ko, S. Stoupin, D. Shu, S. P. Collins, K. Mundboth, J. Sutter and M. Tolkiehn, *Nature Communications*, **5**:4219 doi: 10.1038/ncomms5219 (2014).

[2] Yu. Shvyd'ko, *Phys. Rev. A*, **91**, 053817 (2015)

[3] O. Chubar, G. Geloni, V. Kocharyan, A. Madsen, E. Saldin, S. Serkez, Yu. Shvyd'ko, and J. Sutter. *arXiv:*1508.02632, 8 Aug 2015

*Corresponding author: shvydko@aps.anl.gov