X-ray Echo Spectroscopy

Yuri Shvyd’ko

Advanced Photon Source, Argonne National Laboratory, Illinois, 60439, USA

X-ray echo spectroscopy, a space-domain counterpart of neutron spin-echo, has been introduced [1,2] to overcome limitations in spectral resolution and weak signals of the traditional inelastic hard x-ray scattering (IXS) probes.

An image of a point-like x-ray source is defocused by a dispersing system comprised of asymmetrically cut Bragg diffracting crystals. The defocused image is refocused into a point (echo) in a time-reversal refocusing dispersing system [Fig.1(a)]. If the defocused beam is inelastically scattered from a sample, the echo signal acquires a spatial distribution, which is a map of the inelastic scattering spectrum [Fig.1(b)].

The spectral resolution of the echo spectroscopy does not rely on the monochromaticity of the x-rays, thus ensuring strong signals along with a very high spectral resolution. Particular schemes of x-ray echo spectrometers for 0.1-meV ultra-high-resolution IXS applications (resolving power $\simeq 10^8$) with broadband $\simeq 10$ meV dispersing systems are introduced featuring more than $10^3$ signal enhancement. The technique is general, applicable in different photon frequency domains.

[1.] Yu. Shvyd’ko, “X-ray echo spectroscopy” Phys. Rev. Lett. 116, 080801 (2016)
[2.] Yu. Shvyd’ko, “Theory and optical design of x-ray echo spectrometers”, Phys.Rev.A 96, 023804 (2017)

Figure 1: Optical scheme of an x-ray echo spectrometer, comprised of the defocusing $\hat{O}_D$ and refocusing $\hat{O}_R$ dispersing systems; an x-ray source in reference plane 0; a sample in 1; and a position-sensitive detector in 2. (a) Elastic scattering from the sample. (b) X-ray photons scattered inelastically from the sample with an energy transfer $\epsilon$ are refocused with a spatial shift $G_R \epsilon$, where $G_R$ is a linear dispersion rate of the refocusing system.