Single-Shot Mössbauer Spectroscopy at X-Ray Free Electron Lasers

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Mössbauer nuclei form a rich platform for the exploration of X-ray quantum optics and dynamics [1-3]. However, theory and experiment so far are focused on the linear low-excitation regime with on average less than one resonant exciting photon per incident X-ray pulse, owing to a restriction of the experimentally available resonant photon flux due to the narrow nuclear linewidths. This situation has changed with the availability of X-ray free electron lasers, which may provide a large number of photons within the nuclear linewidth - either on average, or per pulse. A first experiment demonstrated superradiance with up to 70 signal photons per X-ray pulse [4]. Further progress towards the high-excitation regime recently became possible with high-repetition-rate self-seeded hard X-ray free electron lasers, and is expected to open up several qualitatively new lines of research with Mössbauer nuclei. One of them is the exploration of ultra-narrow Mössbauer resonances, which has already been realized with the recent direct resonant X-ray excitation of the Mössbauer clock transition in ^{45}Sc [5], and which is based on the high average number of resonant photons.

In this talk, I will discuss single-shot Mössbauer spectroscopy as a second application, relying on the high number of resonant photons per pulse [6]. First, I will introduce our approach, which also allows one to make use of shots with lower photon number for the single-shot analysis. Next, I will demonstrate its feasibility using data from recent experiments on the archetype Mössbauer isotope ^{57}Fe at the European X-ray free electron laser (EuXFEL).

References

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