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*Editorial*

# Special Issue on Trends in Sub-Microsecond X-ray Science with Coherent Beams

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Large increases in synchrotron brightness have brought notable breakthroughs in measurement techniques that exploit transverse coherence, such as X-ray photon correlation spectroscopy (XPCS), coherent diffraction imaging (CDI), diffraction microscopy, and ptychography. The pulsed nature of synchrotron X-ray radiation combined with cutting-edge timing and detection technologies has enabled time-domain science that probes dynamics in a wide range of chemical, biological, and condensed matter systems.

Diffraction-limited light sources that will increase the spatial coherence of hard X-rays nearly 1000-fold, while delivering X-ray pulses at repetition rates of tens to hundreds of MHz, are planned worldwide. These new machines will make possible investigations of real-world materials at both atomic length- and timescales by extending the techniques of XPCS and CDI to the nanosecond timescale and below. Improving source coherence by three orders of magnitude puts equal demands on light sources, X-ray optics, detectors, data processing, and storage, as well as data analysis and modeling. There has been some acknowledgement that X-ray optics need development in order to preserve this new level of coherence and that the detector frame rate may become the ultimate limit of time resolution. However, several additional issues remain undiscussed related to the practical difficulties of performing measurements with high-coherence beams: parasitic speckle, unwanted spatio-temporal correlations from the source, and handling an impending 1000-fold explosion of data rates. It remains to be seen what exemplary systems can be used as standards and benchmarks in this regime.

This Special Issue aimed to address topics in all these areas, as well as reviews of diffraction-limited light sources and their applications at sub-microsecond timescales. A total of six papers (five research papers and one review paper) are published, which elaborate on the designs and capabilities of emerging storage ring-based synchrotrons, novel X-ray instrumentation, analysis techniques, and measurement protocols. Shin et al. presented the characteristics of photon beams expected at Korea's fourth-generation storage ring that employs a multi-bend achromat lattice concept [1]. Dallari et al. discussed solutions for acquiring and analyzing an enormous stream of data from 2D detectors that operate at MHz frame rate, which poses a great challenge for performing XPCS experiments at sub-microsecond temporal resolution [2]. Lee at al. reported on the technical realization of a high-speed hard X-ray single photon detection scheme at a synchrotron that delivers X-ray pulses at a repetition rate of 500 MHz [3]. Sung et al. reported on the development of a single-shot coherent X-ray imaging instrument at Pohang Accelerator Laboratory that is optimized to perform XPCS, CDI, and coherent X-ray scattering experiments for pursuing ultrafast phenomena of nanoparticles [4]. Sun et al. proposed a novel X-ray speckle contrast calibration protocol and its practical implementation in computer algorithms for high-speed correlation evaluation using pixelated 2D detectors [5]. Finally, Lehmkühler et al. reviewed the concept and latest development of XPCS and relevant X-ray measurement methods as well as their future opportunities at upcoming X-ray sources that will enable the study of over more than 18 orders of temporal dynamics range [6]. These studies explore the dramatically increased brightness of the source that will potentially lead to groundbreaking opportunities and applications in quantum X-ray optics, nanosecond X-ray ptychography, artificial intelligence for data analysis, and other novel approaches.

Although submissions for this Special Issue have been closed, the arrival of diffraction-limited light sources and their applications at sub-microsecond timescales will have a major impact on a broad spectrum of disciplines, such as physics, chemistry, biology, materials, and accelerator sciences.

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