Coherent X-ray Scattering and Lenseless Imaging at XFEL Facilities

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Coherent X-ray Diffraction Imaging (CXDI) is a rapidly advancing form of lenseless microscopy. The phase information of the diffraction pattern is embedded in a sufficiently oversampled coherent diffraction pattern. Using advanced computational methods this diffraction pattern can be inverted to produce an image of a sample with diffraction limited resolution.

In that respect future X-ray Free Electron Lasers (XFEL) based on Self-Amplified Spontaneous Emission (SASE) provide the best opportunity for the future development of CXDI methods and its applications to material science and biology. Several similar XFEL sources are at the moment at its construction and planning stage. These are LCLS (Linac Coherent Light Source) in the USA [1], SCSS (Spring-8 Compact SASE Source) in Japan [2] and European XFEL Facility in Germany [3]. Comparing to other projects the European XFEL Facility is unique due to its time structure. It will produce 30 000 pulses per second, to be compared to 120 of the LCLS and 60 of the SCSS.

Lenseless imaging is particularly well suited to the unique capabilities of the XFEL Facilities. As it is expected from theoretical calculations [4] the incoming beam will have nearly full transverse coherence (80% transverse coherence, with a beam of a few mm^2 section). Other unique properties of the XFEL, such as the high peak brilliance (we expect 10^{12} coherent photons in a single pulse) and ultrashort pulse time structure (100 fs pulses separated by 200 ns at European XFEL), allow us to consider applications of CXDI to structural analysis of nanometer-scale particles, inaccessible using third-generation undulator sources. The possibility to study dynamics at such resolutions and on the sub-picosecond time scale with the XFEL opens up entirely new research horizons.

In this talk we will present the scientific case, requirements and the possible realisation of the coherent x-ray diffraction experiments at XFEL Facilities.

[1] J. Arthur et al. Linac Coherent Light Source (LCLS) Conceptual Design Report. http://www-ssrl.slac.stanford.edu/LCLS/CDR/.

[2] SCSS X-FEL Conceptual Design Report, SCSS XFEL, R&D Group RIKEN Harima Institute/SPring-8, Edited by Takashi Tanaka and Tsumoru Shintake, Japan, May 2005. http://www-xfel.spring8.or.jp/SCSSCDR.pdf.

[3] XFEL The European X-ray Free-Electron Laser. Technical Design Report, M. Altarelli et al. (Eds.), DESY 2006-097 (2006). http://xfel.desy.de/tdr/index_eng.html.

[4] E.L. Saldin, E.A. Schneidmiller, and M.V. Yurkov "Coherence properties of the radiation from X-ray free electron laser", DESY Preprint, DESY 06-137 (2006).