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New dimensions for imaging and diffraction research at European XFEL

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European X-ray Free-Electron Laser (European XFEL) is a unique facility under construction near Hamburg, Germany, where the Russsian Federation is the second shareholder after Germany with 25% of shares . The scientific possibilities opened up due to the start of European XFEL in the middle of 2017 are briefly described, together with the current instrumental developments (in optics, detectors, lasers, etc.).
X-ray bunches will be delivered (see Figure 1) within electron bunch trains, each train 600 μs long, and containing up to 2700 bunches. There is also a basic 10 Hz repetition rate of RF system providing the separation of successive trains by ~100 ms, whereas, inside each train, consecutive bunches are spaced by ~222 ns, corresponding to an effective repetition rate, during each train, of ~4.5 MHz.
One of the important fields of experiments is connected with ultrafast coherent diffraction visualization of single particles, clusters and biomolecules, viruses and cages.
Coherent x-ray Diffraction Imaging (CXDI) is in fact a lensless microscopy, one of the methods for oversampled diffraction patterns to be inverted to obtain real-space images, as it was demonstrated in 1999 by Miao et al. [1]. It is well known that phase information of the diffraction pattern is lost as far as detectors record just an intensity (square of amplitude), [2]. Nevertheless phase information in sufficiently oversampled diffraction patterns is "embedded" in complex image which is Fourier transform of the complex sample.
Lensless coherent x-rays imaging competes with high resolution electron microscopy, though of course the cost of electron microscope (capable to see the virus with diameter 100 nm) and XFEL facility are incomparable. Advantages of XFEL are connected with better penetration of the electromagnetic waves in materials; neglected multiple scattering effects, x-rays are less damaging, the collection of diffraction patterns is inherently more efficient. The holographic method based on combining signal and reference wave is an alternative way to perform the inversion.
The XFEL beam will have nearly full transverse coherence (~80%), with a beam of a few mm2 section on sample, [15]. High peak brilliance (1012 coherent photons in a single pulse) and ultra-short pulse time structure (100 fs pulses separated by ~200 ns), allows an application of CXDI to structural analysis of nanometer particles with time resolution (sub-picosecond timescale with XFEL photons).

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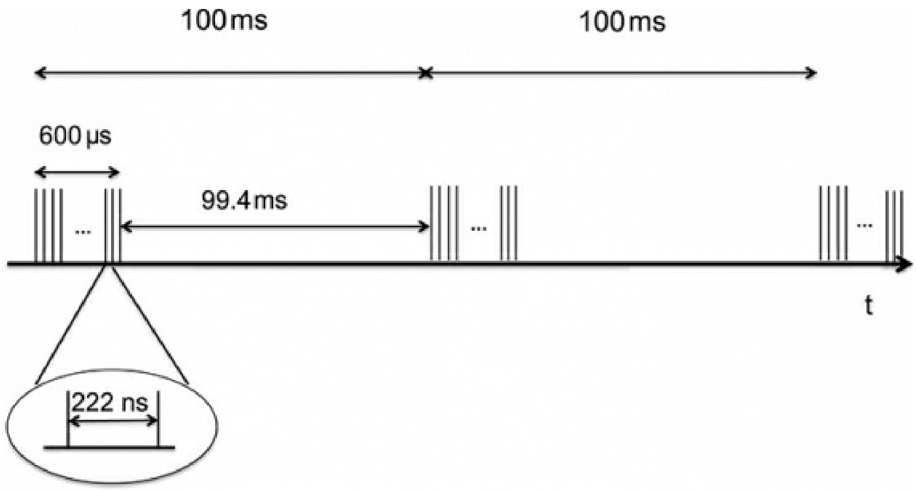

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