Status of Hard X-ray FELs

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In the past, every new generation of analysis tools has immediately given new insights into our understanding of the structure and the dynamics of matter with enhanced spatial and temporal resolution. For radiation sources the transition from the second to the present day state-of-the-art third-generation sources brought a substantial progress for the achievable spatial resolution in the hard x-ray regime, this being limited now more by the quality of the x-ray optical components than by the source properties.

In the temporal domain, storage ring technology has its limitations determined by the equilibrium length of the electron bunch packets that is in the order of some tens of ps. This resolution still allows for the direct investigation of phenomena at time scales lower than 100-200 ps, which has allowed many groundbreaking experiments to be carried out. On the other hand, very new opportunities to deliver shorter x-ray pulses have opened by the advent of linear accelerator driven free-electron-lasers (FELs), a development that is taking place at different places worldwide.

With photon pulse lengths of a few fs to 100s of fs, wavelengths in the x-ray regime, and with single-pulse intensities equivalent to those produced by traditional storage rings over 0.1-1.0 sec, these facilities will allow the direct and simultaneous study of both the structure and the dynamics of matter at atomic length- and time-scales for the first time. This will provide a direct route for detailed studies and understanding of fast non-equilibrium phenomena at the route of the evolution of complexity in matter.

Two FEL-facilities are already in user operation, FLASH at DESY in the soft x-ray regime and LCLS at Stanford for the soft and hard X-ray regime. FERMI at ELETTRA (Trieste, Italy) for soft x-rays and SCCS at SPring8 for hard x-rays will become operational within the next one or two years. The European x-FEL being just under construction is expected to start commissioning / user-operation by 2014 / 2015. For the operation of FELs two technologies are being applied, normal and super conducting acceleration structures. While the normal conducting structures provide in general a higher acceleration gradient and in time, equally space photon bunches up to 50 - 400 Hz, the superconducting technology is capable of providing up to 30000 bunches / s in bunch trains with repetition rates of 10 - 30 Hz. All present day FEL-facilities rely on the self amplified spontaneous emission (SASE) principle, which shows some random fluctuation of pulse energy and photon energy spectrum, as well as jitter in pulse arrival time. Present and future developments target for external- (soft X-rays) or self-seeding (hard x-rays) schemes for a better control of the above-mentioned parameters. The talk will report on the status of (hard-) x-ray-FEL developments and envisaged scientific applications.