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Overview of X-ray Free-Electron Laser Science and Facilities

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The discovery of x-rays by Roentgen in 1895 is often taken as the starting point of modern physics, as x-rays, besides causing a revolution in medicine, allowed the first experimental determination of the atomic structure of matter, i.e. of the spatial arrangement of atoms in molecules and solids. Since the 1960's it became apparent that electron accelerators are the most brilliant X-ray sources on earth, leading to the enormous development of synchrotron radiation sources, based on circular accelerators and storage rings. In recent years, a further giant step was taken by sources based on linear accelerators, the Free-Electron Lasers, producing x-ray pulses with peak brilliance exceeding that of synchrotron beams by up to 9 orders of magnitude, with ultra-short duration, in the region of ~ 10 fs (10-14 s), and with a high (laser-like) degree of transverse coherence.

The partly fulfilled promises of the new sources include time-resolved studies in the sub-ps range ("molecular movies") of chemical reactions, and biochemical processes such as photosynthesis; unprecedented insights into phase transformations in condensed matter, including the physics of liquids and nucleation processes; technologically relevant solid-state processes such as the fundamental time limits of erasing and writing magnetic memory elements; the study of matter under extreme high-energy density conditions.

The attractiveness of this scientific pay-off has stimulated the construction of a number of facilities in Europe, in the US and in Japan, South Korea and China, and more are still under construction. We shall briefly review the existing facilities and their salient features: wavelength range, repetition rate, and the mode of generation of x-rays (Self-Amplified Spontaneous Emission or "Seeded"). Special attention shall be given to one of the recent additions to the handful of operating X-ray Free-Electron Lasers (XFEL's), the European XFEL, resulting from the collaboration of 12 countries and now operating in the Hamburg region in Germany.

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