Keynote Lecture

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The potential of future light sources to explore the structure and function of matter

E. Weckert[1]

[1] *DESY, Photon Science, Hamburg, Germany*

Structural studies in general and in particular in crystallography have benefited and still do benefit dramatically from the use of synchrotron radiation. Its tuneability is mandatory for multi or single anomalous diffraction experiments, still one of the main methods for solving new crystal structures. Its tuneability is also a key for spectroscopy techniques for the determination of the local atomic environment around and the oxidation state of an absorbing atom. These techniques are powerful tools e.g. in chemistry to study reactions, and can be applied not only to crystalline matter. Low emittance storage rings of the third generation with their highly brilliant X-ray beams enable us to focus beams down to the micrometer range intense enough for the investigation of weakly scattering crystals down to the size of several micrometers. Considering these highly intense beams, if it comes to structural studies using X-ray, what are still the limitations of the most modern storage ring sources? The length of individual X-ray pulses is in the order of 100 ps, which is sufficient to trace structural changes of larger groups or the diffusion of atoms over larger atomic distances. However, fast processes as they occur e.g. during vision or photosynthesis are not accessible by these means. Also the coherent fraction of the radiation of present day storage rings in the X-ray regime is rather low (i.g. < 1 %). This limits on one hand our ability to study the structure and dynamic of non-crystalline materials by methods exploiting the coherence properties of the beam like coherent diffractive imaging and X-ray correlation spectroscopy, respectively. On the other hand the flux in an ultra small diffraction-limited focus is limited as well. Upcoming linac driven free electron laser (FEL) sources with extremely short (sub 100 fs) and intense pulse (~10^12 ph) of very high coherence circumvent some of the limitations of present day storage rings. It has been demonstrated that their individual pulses are short enough to outrun radiation damage for single pulse exposures. First structures from sub micrometer crystals using an X-ray FEL (LCLS, Stanford) have already been published. These ultra short pulses also enable time resolved studies 1000 times faster than at standard storage ring sources. Meanwhile new storage rings with more aggressive lattice designs are under construction or under consideration with significantly smaller emittances. These sources target towards the diffraction limit in the X-ray regime and will provide roughly one to two orders of magnitude higher brilliance and coherence. They will be especially suited to those experiments exploiting the coherence properties of the beams and to ultra small focal spot sizes in the several nm regime. Developments at various places are ongoing for a totally new type of X-ray source combining a linac with a storage ring. This so called energy recovery linacs (ERL) promise to provide pulses almost as short as at an FEL with brilliances and multi-user capabilities comparable to a diffraction limited storage ring. The contribution will try to give an overview of the stage of development of the various source projects and their possible impact on structural studies in future.

Keywords: free electron laser, diffraction limited synchrotron radiation storage ring, energy recovery linac