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Time and Length Scales in X-Ray Science

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Abstract

My talk will first discuss the production and characteristics of x-rays. I will start with the basic concept of the energy contained in the electric and magnetic fields associated with relativistic electrons and how these “virtual photons” that are the carriers of the electro-magnetic (EM) force can be shaken off as ”real photons” = EM radiation. The time scales associated with the shake-off or emission processes naturally provide the familiar x-ray spectra for synchrotron and X-ray free electron laser (X-FEL) sources. I will then discuss the importance of source (electron beam) brightness, which completely determines the x-ray coherence properties. The ultimate synchrotron source is laterally coherent (diffraction limited), while the ultimate X-FEL source is both diffraction limited and longitudinally coherent (transform limited).

The second part focusses on the fundamental interactions of x-rays with matter. I will discuss why the interaction is dominated by the electric field of the x-rays, and distinguish first order (absorption, emission, Thomson scattering) and second order (resonant scattering) x-ray interactions and their quantum mechanical calculation, including their polarization dependence (x-ray dichroism). Finally, I will discuss characteristic x-ray interaction times, in particular, the fundamental atomic decay clock. It determines whether a decay is *spontaneously* driven by the zero-point field as in all synchrotron radiation experiments or is *stimulated* which is possible for X-FEL sources. The latter case is the foundation for the entirely new field of non-linear x-ray science.