Approaches and Prospects for VUV and Soft X-ray Free-Electron Lasers

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In the Free-Electron Laser (FEL) radiation is produced by oscillating ‘free electrons’ as they pass through an undulator or wiggler. As such it strongly resembles an Insertion Device (ID) of a modern light-source. Similar to IDs the spectral tuning range of the FEL is determined by the undulator properties and the energy of the electron beam and is not, like conventional laser systems, impeded by fundamental limitations of the gain medium. The output of the FEL is similar to other laser systems, i.e., a source of intense transverse an longitudinal coherent light.

For a laser, the FEL is a relatively recent development. Lasing was observed for he first time in 1975 [1]. Since then the technology has matured which resulted in several FEL user-facilities, most of them addressing the (far) infrared spectral range [2]. Generation of shorter wavelengths, specifically in the VUV and X-ray spectral range, proved to be more difficult since it requires more sophisticated optics and accelerator technology.

The first of these type of devices to access the UV were the so-called Storage Ring FELs (SRFEL) where the electron beam of the storage ring is used to drive the lasing process. SRFELs have a combination of characteristics that make them attractive as a light-source in the UV: e.g., high-power ps pulses with excellent optical properties and tunable wavelength at a MHz repetition rate [3]. Unfortunately the SRFEL requires high-reflective normal-incidence mirrors which has, until now, inhibited access to wavelengths below 190 nm.

As an alternative it is possible to sustain the lasing process in a scheme of so-called Self-Amplified Spontaneous Emission (SASE) [4]. Here an electron beam with extreme high density is passed through a long undulator which forces the spontaneous radiation of the undulator to be amplified up to nine orders of magnitude in a single pass. The SASE FEL has the advantage that it does not require mirrors and can cover a larger spectral range. However, it also puts higher demands on the electron beam. Only recent pilot experiments at the UCLA [5], ANL [6] and at the DESY TESLA Test Facility [7] demonstrated the practical feasibility to construct such light-source in the VUV and X-ray spectral range. Several laboratories around the world are now pursuing this scheme as a light-source user-facility for the VUV and/or X-ray spectral range, e.g., DESY (Hamburg, Germany) [8], SLAC (Stanford, USA) [9], Spring8 (Japan) [10], and BESSY (Berlin, Germany) [11]. The goal is to create a new generation of light-sources which surpasses the performance of modern synchrotron light-sources: six to eight orders of magnitude higher peak-power in combination with up to three orders of magnitude shorter pulses.

The presentation gives details on-going and proposed SRFEL and SASE FEL projects and their (expected) performance as a light-source in the UV to X-ray spectral range. Emphasis is given to the characteristics of SASE FELs and the ideas to enhance the output of such devices, both in terms of an improvement of the spectral purity and a reduction of the pulse-duration down into the fs range.

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