Seeded X-Ray Free-Electron Laser Simulations

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Until today synchrotron based light sources represented the best candidate to provide x-ray radiation characterized by a broad spectrum of tunability, high flux and high brilliance. In order to go a step forward a different approach has to be taken, for this purpose a new kind of machine is being developed: Free-Electron Lasers. In contrast to traditional synchrotron light source, Free-Electron Lasers permit the generation of higher radiation flux with much shorter duration and a good degree of coherence.
Free-Electron Lasers have been successfully operated in a self amplified spontaneous emission (SASE) regime, with ultra high brightness and excellent transverse coherency at x-ray wavelengths. But due to the inherent nature of the spontaneous emission process only partial temporal coherence can be achieved. The SASE process rely on the initial emission of spontaneous radiation by electrons in an undulator. The radiation, reinteracting with electrons, forces the beam to get bunched in a periodic structure resulting then in a coherent emission, that still enhances the bunching process. Since this amplification process starts from an initial uncoherent emission, due to the random local charge fluctuation in the electron beam, full longitudinal coherence cannot be achieved. To achieve a high grade of coherence various schemes of external seeding have been studied. Common to all these kind of schemes is the use of an external coherent seed, actually produced by a conventional laser, that interacts with electrons imprinting to the beam a periodic structure with the same periodicity of the radiation that has to be generated. If such imprinting is predominant over the intrinsic noise, due to the electron density fluctuations, than it will drive the Free-Electron Laser process ending with a full temporal coherent emission. Since no coherent seed is available at the x-ray wavelength, some more complex schemes have to be used in order to be able to employ a conventional laser to produce a periodic modulation at the target x-ray wavelength.
Among these schemes Echo Enabled Harmonic Generation (EEHG) is a promising candidate. EEHG acts on the beam in several non trivial steps that must be carefully tuned in order to get the desired results. In order to understand the required working conditions and the reliability of the EEHG seeding scheme an extensive study, by means of numerical simulations, has been done. Different scenarios has been tested trying to verify the most probable working conditions, and all possible problems that can emerge when driving the Free-Electron Laser with a typical accelerator. The work has been carried out in the context of the SwissFEL facility, where the construction of the Athos soft x-ray beamline, is foreseen in the next years. For such reason all the simulations has been run taking as reference the Athos beamline parameters and the SwissFEL linear accelerator.

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