Status of sFLASH, the seeding experiment at FLASH

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Due to its stochastic nature, the Self Amplified Spontaneous Emission (SASE) of a Free Electron Laser (FEL) is characterized by spikes in the temporal/spectral pulse profiles. To improve the pulse properties for user experiments, in particular the synchronization to an external laser source for time-resolved studies, several different configurations have been suggested in the past and are currently tested in many laboratories worldwide. One possibility is to seed the electron beam with an external laser that transfers its coherence properties to the electrons. The external seed can be provided either by an optical laser or by a High-Harmonic Generation (HHG) source[1]. In both cases it is possible to reach even shorter wavelength with a cascade configuration if the initial energy is high enough.
During the shutdown in 2009-2010 the Free-electron LASer in Hamburg (FLASH)[2] has been upgraded with several new installations in order to achieve shorter wavelength and to control the electron beam phase-space[3]. The new RF module allows longer electron bunch duration (≈200 fs) with a peak current of few kA. The seeding experiment at FLASH (sFLASH) relies on the relaxed timing condition in order to overlap the electron bunch with HHG pulses of ≈40 fs duration, that are generated by focusing Ti:Sa drive laser pulses into a noble gas target. By means of multilayer mirrors the seed is transported into the tunnel and injected into the electron beam pipe. A 40 m long section of FLASH (see Fig. 1) has been completely redesigned to accommodate the 10 m variable-gap undulators for the sFLASH experiment, consisting of three 2 m-long undulators (PETRA III type, 31.4 mm period) and one 4 m-long undulator (period 33 mm) previously used at the PETRA II synchrotron light source. The radiation produced by these undulators is extracted with carbon-coated mirrors at grazing incidence that can be inserted into a magnetic chicane where the electron beam is vertically displaced. A photon beamline with dedicated diagnostics in order to characterize spectral properties and photon flux is located inside the accelerator tunnel. The photon beamline is extended toward the outside of the FLASH tunnel for temporal and timing characterization of the seeded radiation [5]. The diagnostics (MCP-based monitor and XUV spectrometer) are designed to span several orders of magnitude in flux, i.e. from the spontaneous emission up to the seeded FEL radiation at Gigawatt power level. These diagnostics exhibit single shot capabilities [4]. The aim of the sFLASH project is to demonstrate direct seeding at 38 and 13 nm and synchronization to the optical drive laser pulses on the fs level.

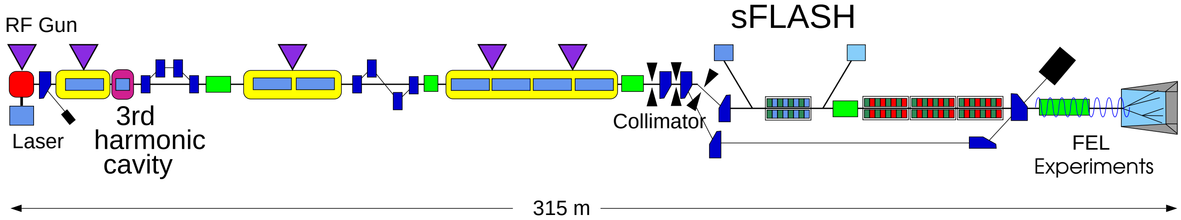

Figure 1: Layout of the FLASH facility after the shutdown.

In order to seed the electron beam one needs to control the transverse, longitudinal and frequency overlap. For the first purpose beam position monitors for electrons and XUV photons are installed between the undulators. A straight trajectory through the undulators is defined by the seed laser. By means of a slow orbit feedback the electron beam is forced to follow the same path along the undulators. The drive laser of the HHG source is locked to the electron beam using an optical cross correlator [6] with a relative timing jitter of less than 50 fs rms. The coarse ($\approx$1 ps) temporal overlap is monitored by sending the infrared drive laser and the synchrotron light generated in a short undulator located in front of the sFLASH section to to a streak camera [7]. For matching the amplification bandwidth, the HHG spectrum is measured online and used as a reference while the undulator gaps are adjusted accordingly (see Fig. 2).

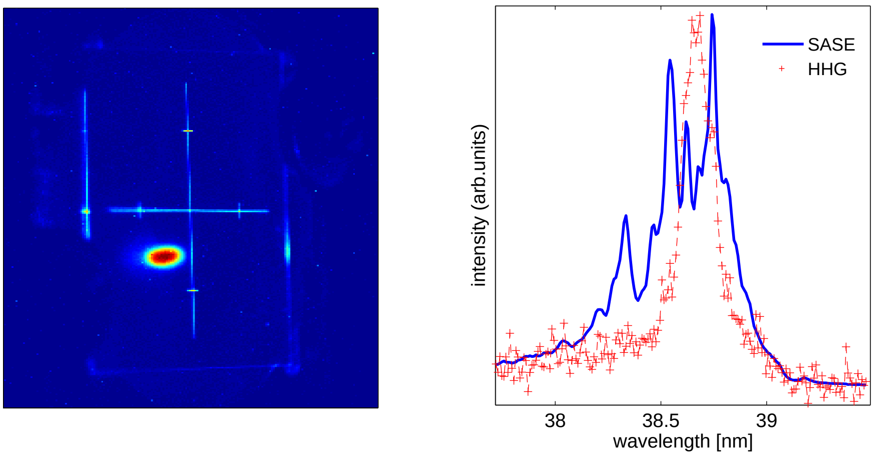

Figure 2: Left: sFLASH SASE spot on a YAG screen installed in the photon beamline. Right: integrated HHG seed and single shot sFLASH SASE spectrum.

The commissioning of sFLASH started last summer with dedicated machine shifts after successful testing of all the components. Meanwhile, we could establish SASE operation using the sFLASH undulators in a standard procedure (see Fig. 2). However, there is not yet strong evidence of seeding. It is expected that current efforts to enhance the seed power and to improve the spatial overlap of the seed with the electron bunch will allow us to reach the next milestone that is demonstration of seeding at FLASH.

References

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