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Single-Shot Temporal Characterization of XUV FEL Pulses

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The free-electron laser in Hamburg (FLASH) operates in the extreme ultraviolet (XUV) and soft X-ray region, providing photon pulses of few femtosecond (fs) duration and unprecedented intensity [1]. FLASH operates in the self-amplified spontaneous emission (SASE) regime, meaning that every pulse has a unique combination of energy, spectrum, arrival time and pulse duration. Therefore, it is critical to be able to determine these parameters for each individual pulse. The THz field-driven streaking technique has the potential to deliver single-shot pulse duration information, as well as the XUV arrival time, basically wavelength-independent and over a large dynamic range (in pulse duration and FEL energy) [2, 3].

We present the results of several campaigns measuring the single-shot pulse duration over a wide range from 10 fs to 350 fs (FWHM) [3]. Here we focus on the particular difficulties in the different pulse duration regimes. Furthermore, correlations between the pulse duration and other radiation parameters as pulse energy and spectrum are compared on a single-shot and average level as well as being compared to simulations [4]. The variable gap undulators at FLASH2 also allow to study the evolution of the XUV pulse duration for the fundamental as well as for the 3rd harmonic radiation pulse as function of contributing undulators. The best agreement between measurement and simulation was found when modeling the SASE process using an energy chirped electron pulse.
Finally, a comparison of the pulse duration determined by THz streaking with an alternative pulse duration diagnostic, a transverse deflecting structure (TDS) measuring the modulation of the electron bunch (analog to [5]) is shown and the advantages, as well as limitations of both techniques, are discussed.

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[4] I. Bermudez et al., Opt. Express 29, 10491 (2021)
[5] C. Behrens et al., Nat. Commun. 5, 3762 (2014)

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