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EXPECTED RADIATION PROPERTIES OF THE HARMONIC AFTERBURNER AT FLASH2

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Abstract

We discuss the afterburner option to upgrade the FLASH2 undulator line, at the FLASH facility at DESY in the Hamburg area, for delivering short wavelengths down to approximately 1.5 nm with variable polarization. This relatively straightforward upgrade enables us to study scientific cases involving the absorption L-edges of 3d metals. The proposed afterburner setting with an energy upgrade to 1.35 GeV will cover many of the community's requests for the short wavelength radiation and circular polarization. We also study the influence of reverse tapering on the radiation output. This contribution presents a series of simulations for the afterburner scheme and some of the technical choices made for implementation.

INTRODUCTION

FLASH delivers radiation in the fundamental wavelength down to 4 nm with the linear polarization [1]. Typical pulse energies that can be delivered are in the order of 100 µJ, depending on the exact parameters required. Many users, however, are interested in much shorter wavelength, and with variable polarization. A typical example are those users aiming at the L-edges of 3d metal metals between 1.3 and 1.6 nm. This clearly beyond the 1st harmonic wavelength range of FLASH. However, because many of these experiments do not require much pulse energy, in many cases less than a microjoule, one could offer to produce this in a harmonic at FLASH. Because the FEL produces bunching at all harmonics, one could use either 2nd or 3rd harmonic radiation. Since the 2nd harmonic is still not in the desired wavelength range, only 3rd and higher harmonics can be used. As the main undulator only delivers linearly polarized light, an afterburner with circular polarization tuned to the 3rd harmonic of the main undulator will be placed behind it.

In the afterburner, the produced circularly polarized radiation is superimposed to the linearly polarized radiation of the main undulator. Because the bunching in the afterburner does not change significantly, the pulse energy of the linear and circular contributions will be of similar magnitude. Because this is not desirable, one can either place the afterburner under an angle, thus separating linear from circular light [2], or use reverse tapering to suppress the radiation from the main undulator while keeping the bunching [3].

In this contribution, we will show results of simulations with the code GENESIS 1.3, version2 [4]. We will study at different beam parameters the wavelength range between 1.3 and 1.6 nm and check the influence of the reverse taper on pulse energy and contrast, defined as the ration between circular radiation from the afterburner and the linearly polarized light from the main undulator [5].

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SIMULATION OF STANDARD CONFIGURATION

The parameters chosen for the simulations are listed in Table 1. It assumes the energy upgrade from the present 1.25 GeV to 1.35 GeV planned in the next years and an additional bunch compressor at final energy, which should enable us to improve the electron beam quality significantly [6]. Therefore, simulations are performed for both a pessimistic set of beam parameters and the expected beam quality after the upgrade.

Table 1: FLASH2 Parameters Used for the Simulations

Electron beam	
Beam energy	1.35 GeV
Peak current	2.5 kA
Emittance, norm. (x,y)	0.7–1.4 mm mrad
Energy spread	0.2–0.5 MeV
Bunch length	15 µm
Main Undulator	**planar**
Period	31.4 mm
K_{rms}	0.87–1.05
Segment length	2.5 m
Number of segments	12
Afterburner	**APPLE III, circ.**
Period	16 mm
K	0.385–0.61
Segment length	2.5 m
Number of segments	1

The main undulator is the one already installed in FLASH2. For the afterburner undulator, we consider an APPLE III device with a *K*-value that has been obtained from Radia-simulations for the helical mode (see Table 1 and Fig. 1). The minimum undulator gap for the afterburner is 8 mm. This gives us the required tunability from about 1.3 to 1.6 nm as maximum wavelength, where for 1.3 nm, we still have $K = 0.38$.

The first set of simulation has been performed with all 12 undulators set to the same gap and the APPLE undulator to a gap corresponding to the third harmonic. The wavelength in the afterburner undulator is 1.3, 1.45 and 1.6 nm. As can be seen from Fig. 2, the pulse energy that we get from the APPLE undulator increases with increasing *K* of the undulator, as expected. Furthermore, the dependence on the beam quality is not dramatic, as the pulse energy varies

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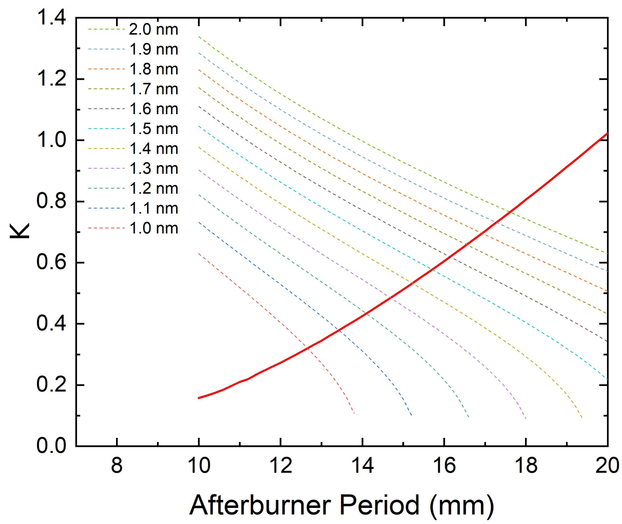

Figure 1: The characteristic radiation parameters of an APPLE III undulator for the different period. Dashed lines indicates minimum K value, required to reach the given wavelength in Table 1.

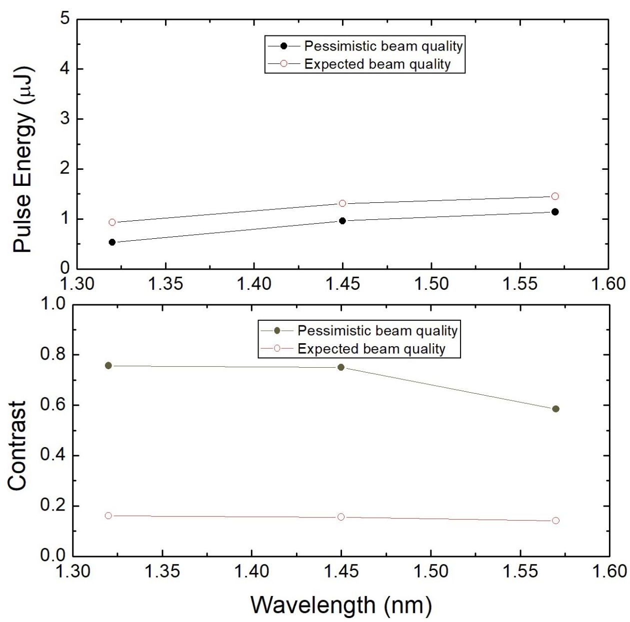

Figure 2: The pulse energy and the contrast of circular polarized radiation from the afterburner and linear radiation coming from the main undulator is shown for 3 different wavelengths and two different beam qualities, as given in Table 1. The afterburner is set to circular polarization and all 12 linear undulators are set to the fundamental.

less than a factor of two for the two parameter sets. However, the linearly polarized radiation emitted in the third harmonic from the main undulator is about an order of magnitude larger for the good beam quality. As a consequence, where the fraction of linear and circular polarization is similar for th pessimistic beam parameters, the ratio becomes around 0.1 to 0.2 for the good electron beam quality. Therefore, the radiation pulse delivered to users is completely dominated by the linear component.

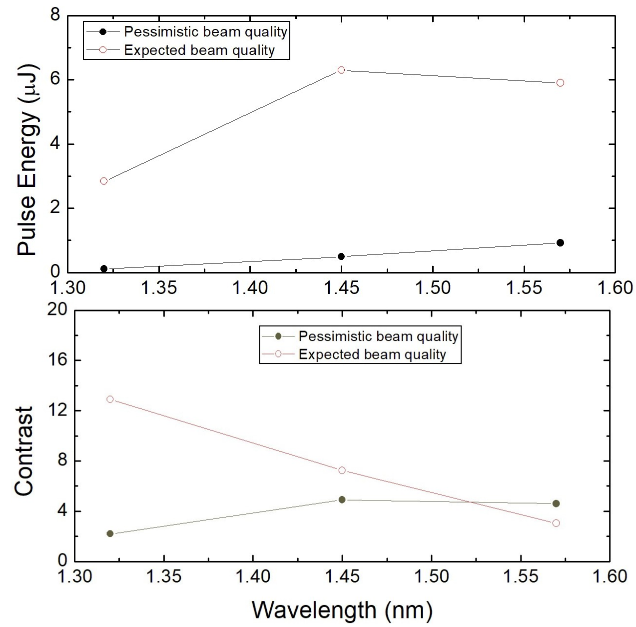

Figure 3: The pulse energy and the contrast of circular and linear coming from the main undulator is shown for 3 different wavelengths and two different beam qualities, as given in Table 1. The afterburner is set to circular polarization and an optimum number of linear undulators are set to the fundamental.

This behaviour changes when we limit the length of the main undulator by opening the gaps for those undulators before maximum bunching has been achieved. In this case, the energy spread is much smaller, the linear component is smaller and the power in the afterburner can still grow. The results are shown in Fig. 3. The pulse energy produced by the afterburner for pessimistic beam parameters is similar. But for the better beam parameters, where in the earlier simulations the energy spread increased beyond saturation in the main undulator, thus avoiding further amplification in the afterburner, now has around an order of magnitude more pulse energy. In addition, because the linearly polarized component from the main undulator is reduced, the contrast is now between 2 and 5 for the pessimistic beam parameters and 8 and 17 for the good beam parameters.

REVERSE TAPER

Although the results with optimized undulator settings seem good, especially when the beam parameters improve, the problem is, that the amplification process in the main undulator did not reach saturation. This means, that the linear background fluctuates, which is highly undesirable for the experiment. The consequence would be that the contrast fluctuates from shot to shot, but also the intensity of the radiation out of the afterburner will fluctuate.

By placing the afterburner under an angle, the linear background can be removed [2]. However, this does not avoid the large intensity fluctuation. Therefore, we study here the possibility to use reverse tapering to keep the energy spread small, but keep the bunching. It has been shown experi-

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mentally already at FLASH2 that the reverse tapering keeps bunching while suppressing the radiation intensity. This would improve the stability of the system. However, it is not easy to show experimentally that also the radiation of the harmonic is suppressed as well and therefore, the contrast improves (see Fig. 4). Therefore, we have performed several simulations to study this effect.

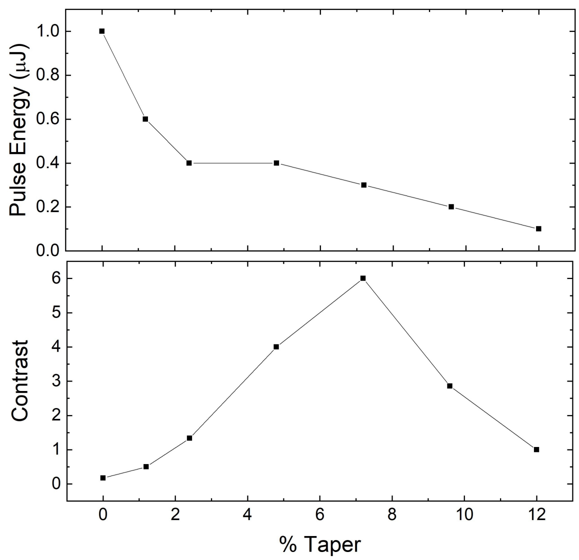

Figure 4: The pulse energy and the contrast of circular and linear coming from the main undulator is shown for 1.3 nm at the expected beam parameters as given in Table 1. The undulator is set to circular polarization and the taper taper is set over the copmplete undulator length.

As was already shown experimentally at FLASH2, a reverse taper suppresses the radiation of the fundamental. As compared to the 500 μJ for an untapered undulator, it reduces by more than two orders of magnitude when we apply a reverse taper between 5 and 10% over the complete undulator length. We have seen that also the pulse energy at the third harmonic reduces by about the same amount. Unfortunately, also the third harmonic radiation out of the afterburner reduces.

As can be seen in Fig. 5, where the reduction in bunching at the fundamental is much less than the intensity reduction, at the third harmonic these become comparable. As a consequence, the advantage of reverse taper shown in this study is much less at the harmonic.

SUMMARY AND OUTLOOK

It has been shown that we can get between 1 and 8 μJ of circular radiation out of the afterburner undulator with circular radiation, depending on wavelength and electron beam parameters used. By opening the some of the main undulators with linear polarization, the contrast of circular to linear radiation can be optimzed to a factor 10 to 60. If this contrast, which will be fluctuating from shot-to-shot, is not sufficient, the afterburner undulator can be placed under an angle or the main undulator can be reversely tapered to

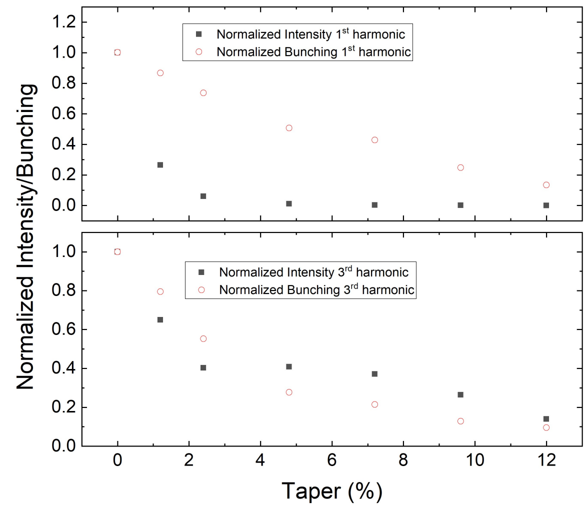

Figure 5: The normalized pulse energy and bunching for different values of tapering at the fundamental of 4 nm (top) and 3rd harmonic of 1.33 nm (bottom) coming from the main undulator at the expected beam parameters as given in Table 1. The taper is set over the complete undulator length.

suppress and stabilize the radiation from this undulator. First simulation results show that this reduces the pulse energy of the circular radiation significantly and further study is needed to optimize the system by adjusting phase shifters and tapering only part of the undulator.

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