Single shot spectral characterisation of a SASE free electron laser

M. Martins, M. Wellhöfer, J.T. Hoeft, W. Wurth

Application Note

Introduction

Free electron lasers (FEL) are novel, extremely powerful ligth sources which will deliver laser like radiation from the soft up to the hard x-ray regime. FEL's are plused sources and will deliver the same flux of about 10^{13} photons, which a third generation synchrotron radiation sources deliver in 1 s, in only 100 fs. The first FEL user facility in the soft x-ray regime FLASH at DESY in Hamburg has started its operation in summer 2005. FLASH is based on the so called SASE principle. Synchrotron radiation, which is created from noise is amplified in a 30 m long periodic, magnetic structure (undulator) up to a saturation level. However, because the amplification starts from noise, each FEL pulse will be different from each other. Thus, a characterization of every single pulse is mandatory.

Experimental setup

To record the SASE FEL spectra an Andor iStar ICCD detector DH740-18F-63 is used at the FLASH plane grating monochromator (PG) beamline, which has been setup by the University of Hamburg. In figure 1 the principle setup of the PG beamline at FLASH is shown. Via two mirrors M_0 and M_1 the FEL beam is steered into the PG branch. The monochromator itself (M_2 and G) is setup as a standard SX700 beamline using collimated light.

The FLASH PG-beamline has a special option, to use the 0. and the 1. order of the grating simultaneously. The 1. order dispersed light from the grating is focused by a further mirror M_3 onto the exit slit. However, at the exit slit position a Ce-YAG crystal can be moved and the monochromator can be used in a spectrographic mode. The fluorescence radiation from the Ce-YAG crystal with a decay time of $\approx$80 ns is monitored on a single shot basis with the Andor DH740 camera with a gating time of 100 ns.

In parallel in 0. order FEL radiation can be used in the PG_0 branch, to perform photoionization experiments on atoms and molecules. The data is later evaluated and synchronized. FLASH is currently delivering bunch trains with a 5 Hz repetion rate; every bunch train can contain several hundred bunches with a time separation of 1 µs. Due to the fast shutter capability and the digital delay generator of the Andor ICCD every single bunch can be easily selected. Within one 12 hour shift of FLASH with this setup several 100 GB of data can be recorded.

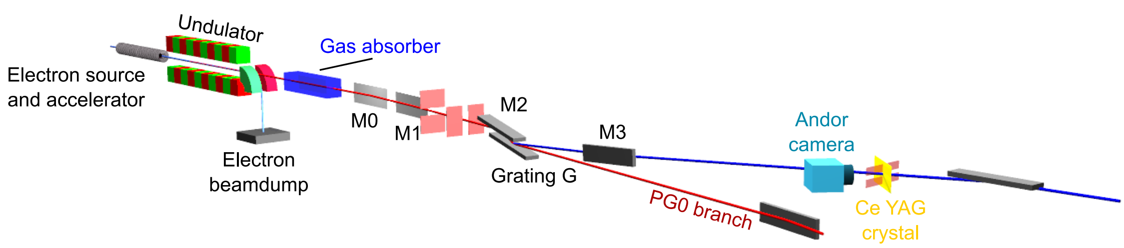

Figure 1: Principle setup to record the single-shot SASE FEL spectra at the plane-grating monochromator beamline at FLASH.

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Properties of the FLASH radiation

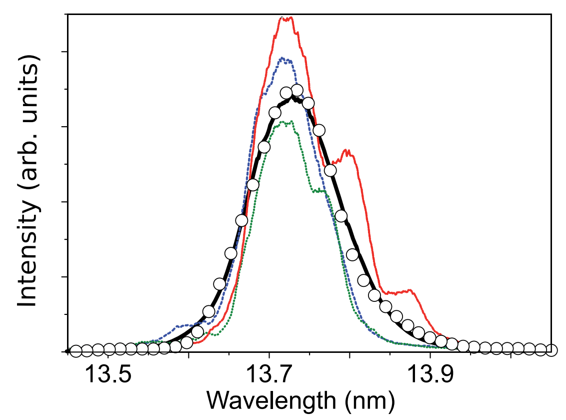
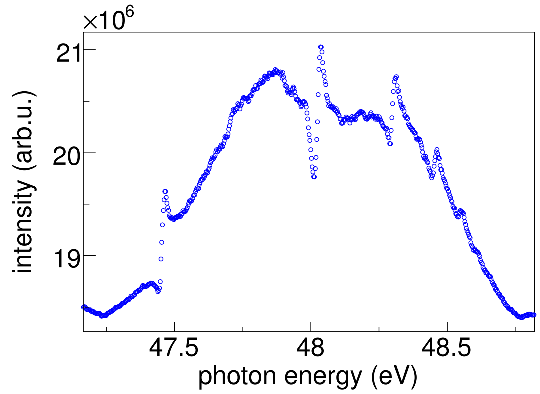


Figure 2 (a) Typical single shot SASE FEL spectra recorded with the ICCD camera at the position of the exit slit. The solid black line is an average over several single shots



(b) Averaged SASE spectra with a neon filled gas absorber. The core level ne resonances can be used to monitor the resolution of the monochromator beamline.

In figure 2a several single shot SASE spectra record with the Ce-YAG and the ICCD camera are shown. The spectra are strongly varying in intensity and in their spectra distribution. These spectra and the statistics of them contain important information about several properties of FLASH. E.g., from the spectral distribution one can estimate the time duration of the FEL pulses. This can be done either by a Fourier transformation of the spectral distribution or by evaluating the number of modes, which are present in the spectrum. For the pulse duration both methods give a value of 10 – 20 fs.

The camera setup is furthermore an essential tool to align the monochromator beamline. Integrated into the FEL beamline is a large gas absorber, which can be filled with different gases to attenuate the FEL beam. By filling this absorber with neon gas and setting the FLASH photon energy to 48 eV, Ne resonances can be observed when the monochromator is operated in the spectrographic mode (see figure 2b). This mode allows us to take absorption spectra within 1 – 2 minutes and optimize the alignment of the beamline quite efficiently.

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