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PULSE ENERGY MEASUREMENT AT THE SXFEL

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Abstract

The test facility will generate 8.8 nm FEL radiation by using an 840 MeV electron linac passing through the two-stage cascaded HGHG-HGHG or EEHG-HGHG (high-gain harmonic generation, echo-enabled harmonic generation) scheme. Several methods have been developed to measure the power of pulse. The responsivity of silicon photodiode having no loss in the entrance window. Silicon photodiode reach saturates at the SXFEL. In this work, we simulated the attenuator transmittance for different thicknesses. We also show the preparations of the experiment results at the SXFEL.

INTRODUCTION

The Shanghai soft X-ray Free-Electron Laser Facility (SXFEL) is a phased project, including the SXFEL test facility (SXFEL-TF), and the SXFEL user facility (SXFEL-UF). SXFEL-TF is mainly used for the study of the external seeding FEL operation mode, including High-gain Harmonic Generation (HGHG) and Echo-enabled Harmonic Generation (EEHG) schemes. And various cascade combinations of HGHG and EEHG. The upgrading of the test facility to the water window user facility, SXFEL-UF, has been undertaken by the collaboration between the Shanghai Institute of Applied Physics (SINAP) and Shanghai-Tech University. Shanghai-Tech University is in charge of developing science cases and experimental end-stations, and SINAP is responsible for the remaining parts of facility development, including upgrading the linac energy to 1.5 GeV, building a second undulator line, facility integration, and constructing the utility and SXFEL-UF buildings. The civil construction was started in November 2016.

The SXFEL-TF

The SXFEL-TF is composed of an 840 MeV electron linac and a two-stage cascaded seeding scheme-based undulator system. The initial proposal of the SXFEL-TF project in 2016 was to test the cascaded HGHG scheme [1]. In the following years, it was gradually optimized and more contents of the EEHG were added to the project when the construction started in 2014. A new cascaded EEHG-HGHG operation scheme was incorporated into the SXFEL-TF to further improve the ultra-high harmonic up-conversion efficiency.

The main parameters of SXFEL-TF are shown in Table 1. The first stage uses a seeded laser with a wavelength of 265 nm. The first stage output radiation wavelength is about 44nm. An 8.8 nm radiation pulse is generated in the second stage based on the HGHG scheme.

Table 1: The Main Parameters of SXFEL-TF [2]

Undulator	Stage 1	Stage 2
Seed laser wavelength	265 nm	*
FEL output wavelength	44 nm	8.8 nm
Modulator undulator period	80 mm	40 mm
Modulator undulator K value	5.81	2.22
Radiator undulator period	40 mm	22.5 mm
Radiator undulator K value	2.22	1.43

Pin Photodiode

The principle of a silicon diode is similar to that of an ionization chamber, absorption of a photon in a silicon crystal creates separations of charge, which are called electron–hole pairs and require an average energy, ", of 3.66±0.03 eV [3,4] Silicon photodiodes (AXUV series) are being used as absolute devices for 50 eV to 1500 eV photons because of their wellknown device parameters, mainly the Internal Quantum Efficiency (IQE). The IQE is 100% from 270 to 800 nm and higher at shorter wavelengths due to the creation of multiple electron-hole pairs by a single high energy photon [5]. IQE is defined as the percentage of internal charge generated in the diode per incident photon. Figure 1 shows the cross-section of the photodiode investigated. The diode is not suitable for high pulse energy measurement at the SXFEL.

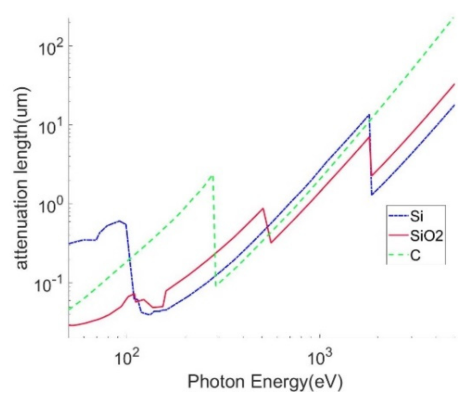

Figure 1: Photodiode absorption attenuation lengths used to calculate soft x-ray responsivity from the model and parameters described in the text. The sources of the data are references [6-8].

Attenuators

A solution to this problem would be to place an absorber in the beam to reduce the flux to a manageable value. Using

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Geant 4(G4) to simulate photon attenuation of different energies passing through aluminium foil, compared with Henke data, the corresponding situation of 150nm aluminium foil is shown in Figure 2. Comparison is consistent.

The measurement steps are shown in Figure 3. The experimental data (42%) of testing 150 nm aluminium foil at the output value of 44 nm of the first stage of SXFEL-TF have little difference from the simulation results (59%). We put the attenuation film in front of the first stage. A movable motor is set to control the film. It is assumed that filtering can completely shield background noise. When the device works normally, the total output signal of the device is composed of FEL signal and undulator radiation ($I_{FEL} + I_B$). When the aluminium foil is placed in the optical path, the attenuated FEL signal (T× I_{FEL}) output is measured. When the undulator is detuned, the measured signal is zero (which

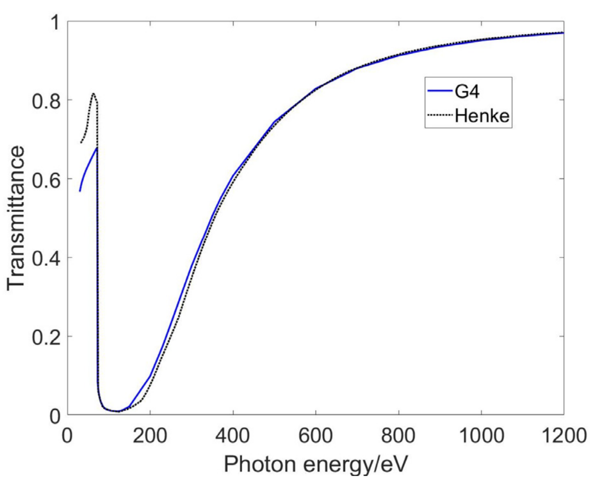

Figure 2: 150nm Aluminum foil transmittance

proves that the aluminium foil can completely shield the undulator radiation). When the aluminium foil is withdrawn, the undulator is still in detuning state, and the intensity of undulator radiation (I_B) is measured. In the latter test, the undulator radiation is almost 0. It depends on the stability of the facility. Long wave signals are difficult to reflect and are detected by photodiode. The attenuation coefficient T can be obtained by calculation. There is little difference between the experimental data and the simulated data.

The SXFEL User Facility

The SXFEL-UF is upgraded from SXFEL-TF, and it covers the water window band by increasing the electron beam energy to 1.5 GeV. The peak current increase to 700A. By adding a radiator undulator in the first and second stage, the seed FEL energy is brought to 3 nm. FEL peak output power up to hundreds of MW, pulse length of about 50fs. The SASE undulator line of the SXFEL-UF is based on in-vacuum planar-type undulators. Its final output wavelength is 2nm at 1.5GeV beam, and the pulse energy at 2nm is about 100 μJ. The main parameters are shown in Table 2.

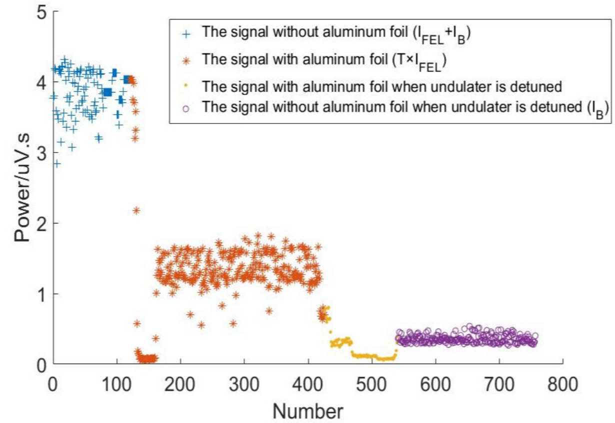

Figure 3: The measurement steps at SXFEL-TF

Table 2: The main parameters of SXFEL-UF

Undulator	Line 1	Line 2
FEL operation mode	SASE	External seeding
FEL output wavelength	~2 nm	~3 nm
FEL output pulse peak power	⩾100 MW	⩾100 MW

The Simulation of User Facility

The SXFEL-UF also faces the problem of saturation of the photodiode. The measuring device is not able to react accurately to the continuously increasing pulse energy. Therefore, we also use an attenuator to reduce the pulse energy to a linear region.[9] We need to reduce the pulse energy to below 10% or even lower. The attenuation at 2 nm and 3 nm was simulated and foils of different thicknesses were selected. The 1980 nm, 2580 nm, and 740 nm, 965 nm were used to reduce the pulse energy of the 2 nm and 3 nm wavelengths to 1/10 and 1/20, respectively. The design uses a three-in-one plug-in design that includes a filter and two attenuators.

CONCLUSIONS

This paper introducess the current situation of SXFEL-TF and the research conducted, simulates the energy measurement of x-rays in the test device, and results is 59%, the average experimental data is 42%. It demonstrates that it is feasible to measure pulse energy with this way at the SXFEL-TF. Simulation results show that this method is feasible on SXFEL-UF.

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