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DRIVE LASER SYSTEM FOR SHANGHAI SOFT X-RAY FREE ELECTRON LASER*

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Abstract

In this paper, we introduce the design and layout of the drive laser of Shanghai Soft X-ray Free Electron Laser (SXFEL). It is known that the temporal and spatial distribution of the drive laser is crucial for the high-quality electron beams. The drive laser provides the laser pulse of 266 nm wavelength for the photocathode, as well as 400 nm wavelength for the laser heater. The design specifications and measured results of this drive laser system will be detailed described.

INTRODUCTION

X-ray free electron laser (XFEL) is the fourth of generation advanced light source, is based on high brightness, high-energy free electron beam and high-gain amplification technology, resulting in ultra-high brightness, ultra-short pulse, and wavelength continuously adjustable coherent X-ray radiation. XFEL offers excellent features such as ultra-high spatial resolution, ultra-high time resolution and high energy resolution, and its applications cover cutting-edge research areas in physics, chemistry, life science, material science and many other scientific fields.

Shanghai soft X-ray free-electron laser facility (SXFEL) is the first coherent X-ray light source in China with the shortest wavelength down to 2 nm [1]. A reliable drive laser system suppling high quality laser pulses is one of the key components for the stable operation of FEL. It will strongly affect the performance of the electron beams from the photocathode RF gun, such as energy, pulse duration, distribution, and so on [2, 3]. We have established the drive laser system, which drive the photocathode to provide the high current, low emittance and low energy spread electron beam to meet the requirements of SXFEL facility.

DRIVE LASER SYSTEM

Depending on the requirements of the linear accelerator for FEL, the drive laser system's technical parameters is shown in Table 1.

The drive laser system, which is shown in Fig. 1, is mainly consisted of five parts: commercial laser system, the third harmonic generation (THG) device, temporal and spatial shaping, image transmitted system and laser optical module for laser heater.

The commercial laser system contains an oscillator, a regenerative amplifier, a first-stage multi-pass amplifier and the pumping sources. The parameters of the laser are shown in Table 2. The pulse energy from the amplifier is divided into two parts by a beam splitter: 80% for THG device generating the ultra-violet (UV) pulse to drive the photocathode, and 20% for laser heater.

Table 1: Requirements of Drive Laser System

Name	Parameters
Wavelength	260 nm ~ 270 nm
Repetition rate	1 ~ 10 Hz
Pulse energy on the photocathode	150 μJ
Energy stability in UV	<2.0% rms
Spatial profile	Gaussian
Laser spot radius on photocathode	2-4 mm (FWHM)
Laser spot diameter jitter at photocathode	2% rms radius
Pointing jitter	<2% rms radius
Pulse shape	Gaussian
Pulse duration	1-8 ps
Timing stability	< 250 fs rms

Table 2: Parameters of the Laser

Name	Parameters
Center wavelength	800 nm
Bandwidth	15 nm
Pulse duration	100 fs
Pulse energy	9.5 mJ
Repetition	10 Hz/ 50 Hz

The third harmonic generation (THG) device used to produce the 266 mm UV pulse is established based on two β-BBO crystals [2]. The 800 nm optical pulse splits into two paths of laser through the 80/20 transmission/reflection mirror. 80% of the 800 m laser pulse is converted to 400 nm by second harmonic generation in the first β-BBO crystal, which combined with the 20% 800 nm transmitted laser pulse generates 266 nm laser pulse after going through the second sum-frequency β-BBO crystal. In order to balance the conversion efficiency and horizontal distribution of the laser spot, the final conversion efficiency is closed to 13%. The schematic diagram of the THG setup is shown in Fig. 2.

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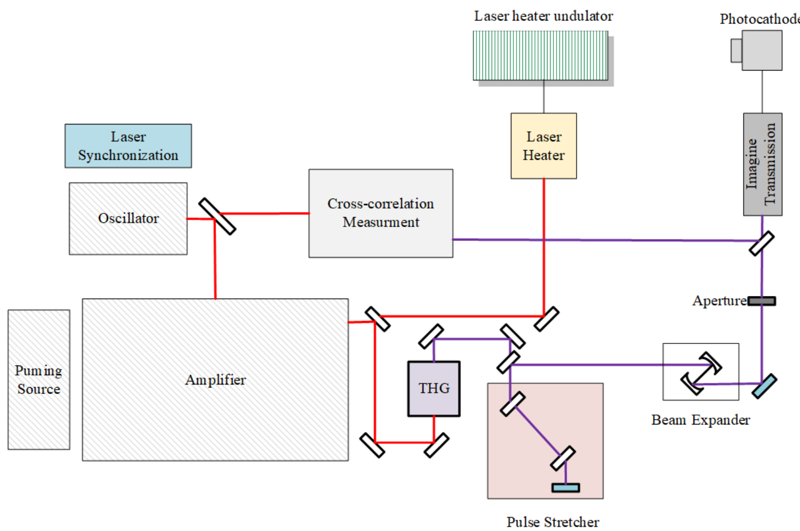

Figure 1: Schematic of SXFEL drive laser system.

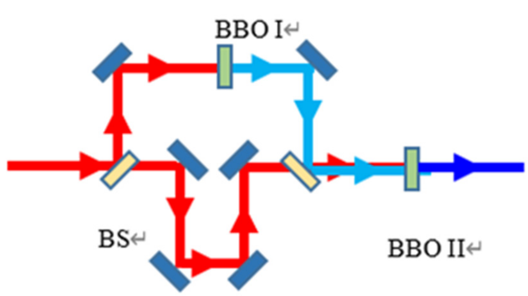

Figure 2: Schematic of the THG.

The method for using a pair of grating achieve the temporal shaping, and one aperture is used for transverse shaping. The laser distribution goes through the image transfer image transmitted system on the photocathode surface as is shown in Fig. 3. There are a pair of transmission gratings with 3846 grooves/mm to stretch the pulse from 100 fs to 7 ps. The measurement result by a cross-correlation [4] is shown in Fig. 4.

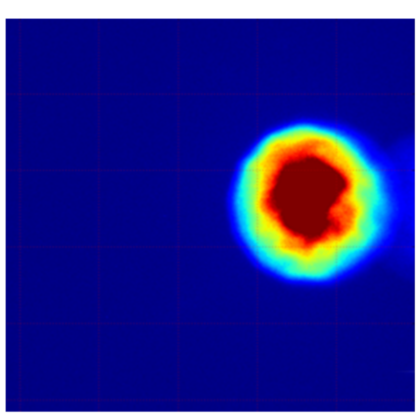

Figure 3: Laser spot image on virtual cathode.

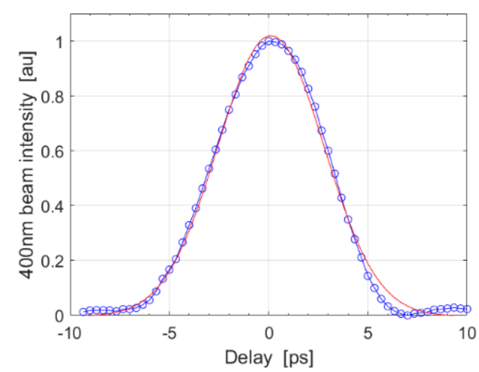

Figure 4: Measurement result for UV pulse duration.

The laser heater is expected to help in suppressing the microbunching by energy modulating for the electron beam [5]. It is played a significant role to generate and amplify for FEL. The laser used for laser heater is 400 nm wavelength, 23 ps pulse duration, and 100 µJ pulse energy in the laser heater undulator.

The laser pulse split from the main optical pulse of the amplifier is converted to 400 nm by second-harmonic generation, and a single grating with 1800 grooves/mm is used to stretch the pulse duration to 23 ps as is shown in Fig. 5.

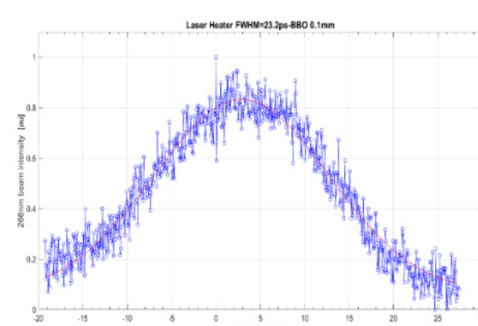

Figure 5: Measurement result for Laser heater pulse duration.

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CONCLUSION

The parameters, design and layout of the drive laser system are introduced, which provides uniform and stable laser pulse driving the photo-cathode to produce high-quality electron beam. It is critical for generation and amplification of FEL.

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