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HIGH RESOLUTION ARRIVAL TIME MEASUREMENT OF THE SEED LASER*

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Abstract

The Shanghai soft X-ray Free-Electron Laser facility (SXFEL) is a fourth-generation linac-based light source [1], capable of producing X-ray pulses with duration of tens of femtosecond. The seed laser for external seeding FEL therefore have tight requirements for relative arrival time to the electron bunch. To reach required energy and wavelength for external seeding FEL, further optical amplification and frequency conversion is needed. These include reflection and propagation in different material and in air, in addition, also include the long laser transport beamline to the undulator, make the laser pulses arrival time influenced by environmental variation. To reach required specification, high resolution measurement of the laser arrival time is necessary. In this paper, we present a general concept for the measurement of the laser arrival time.

INTRODUCTION

Table 1 shows the seed laser parameters and the pulsed reference laser parameters of the SXFEL. The seed laser system is seeded by Vitara-T Oscillator, operating at 800 nm. The repetition rate of the oscillator is at 79.33 MHz and pulses are amplified in Legend Elite Duo HE+ amplifier, which is operating at up to 50 Hz repetition rate. The system has a UV output.

The pulsed reference laser is delivered by Onefive Inc, operating at 1562 nm, with 0.5 nJ energy, delivering 140 fs pulses in stabilized fiber links. The repetition rate of the optical master oscillator is at 238 MHz, which is triple of the seed oscillators, used for the seed laser system. It is expected that the added timing jitter of the stabilized fiber link is below 5 fs rms integrated from 10 Hz to 10 MHz.

Table 1: Laser Specifications

Parameter	**Seed Laser**	**Unit**
Wavelength	240-360	nm
Repetition rate	1-50	Hz
Pulse duration	~100	fs
Reference	1562	nm
Pulse duration	140	fs
Pulse energy	0.5	nJ

Next generation light sources like SXFEL and the upcoming SHINE generate x-ray pulses of tens femtosecond duration. To fully exploit these short pulses in pump-probe experiments or for the operation of an FEL with EEHG or cascaded EEHG scheme [2, 3] by the external seed laser, a pulsed optical synchronization system has been proposed and is being testing at SXFEL. The pulsed optical synchronization system distributes stabilized optical pulse train with femtosecond precision via stabilized fiber links. The ultralow noise pulses are generated by an optical master oscillator (OMO), a passively mode-locked laser, which is phase-locked to the RF master oscillator (RMO).

LASER ARRIVAL TIME MEASUREMENT CONCEPT

The oscillators of the seed laser are phase-locked to the pulsed reference laser that is distributed via stabilized fiber links. However, the following laser chain (stretcher, amplification, compression, frequency conversion, roundtrips and propagation) may introduce timing jitter due to vibration and electromagnetic noise or timing drift due to changes in environmental factors, such as temperature, humidity, atmospheric pressure and airflow [4]. The laser arrival time monitor will provide precise measurement of timing jitter and timing drift along the laser chain. The arrival time information can be used to identify the drifts and additional jitter sources and thus allowing to compensate for observed timing drifts and to reduce timing jitter. To engage the high-resolution laser arrival time measurement, timing overlap between the seed laser output and the stabilized fiber link output is required. This is achieved by a motorized variable optical delay line.

For the seed laser it is important to compensate for the drift up to the inlet of the undulator and therefore arrival time measurement has to take place in the ultraviolet pulses. Figure 1 shows the layout of the seed laser system, and the seed laser arrival time measurement needs to be as closed to the undulator as possible. Here, a similar principle to the bunch arrival time measurement (BAM) developed at SXFEL will be used [5]. Figure 2 shows the general concept for the seed laser arrival time measurement. The modulation signal is generated by a high-speed photodiode based on photovoltaic effect and then it is filtered and amplified to drive an electro-optical intensity modulator (EOM). By means of the EOM the seed laser arrival time information is finally encoded into the amplitude of the pulsed reference pulses that are then read out and data processing by a readout electronics.

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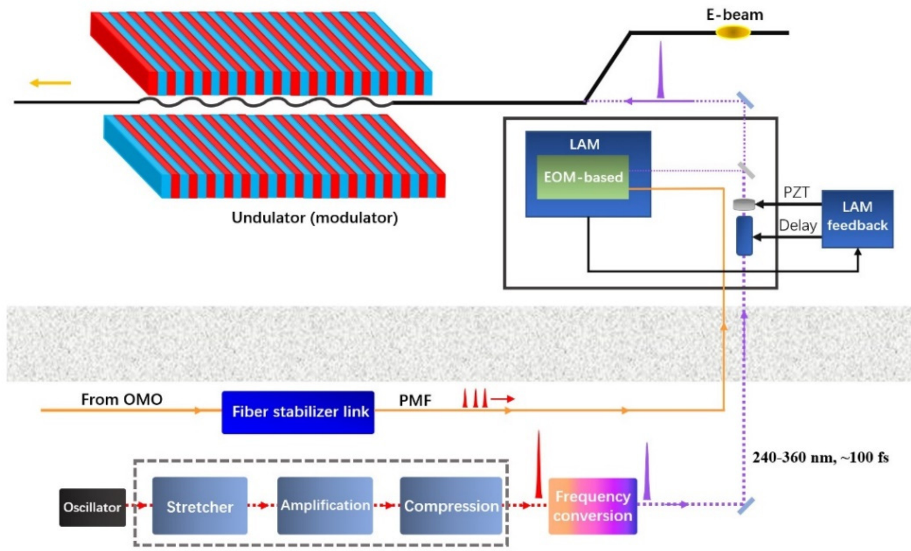

Figure 1: Shows the layout of the seed laser system and the position of the seed LAM.

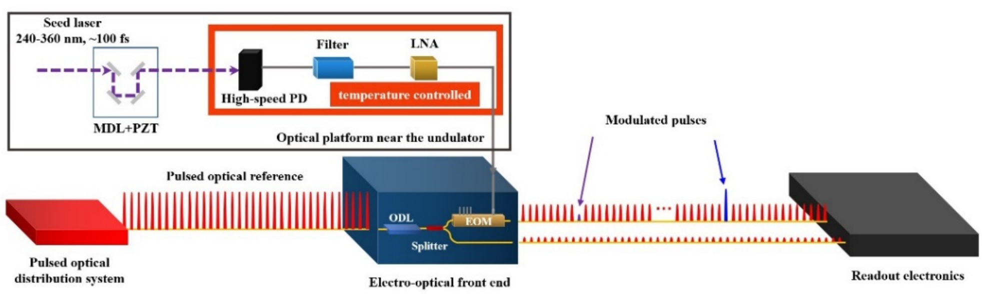

Figure 2: General concept of the seed laser arrival time measurement.

The amplitude noise of the laser pulses has been evaluated with instantaneous measurements using the readout electronics. As shown in Fig. 3, the standard deviation of the normalized instantaneous amplitude noise is calculated to be approximately 0.28% [6]. From the EOM-based laser arrival time measurement 10 fs resolution is expected.

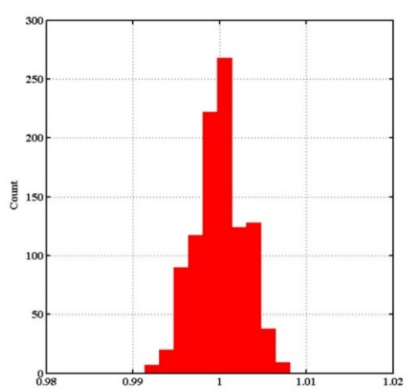

Figure 3: The standard deviation of the normalized instantaneous amplitude noise is calculated to be approximately 0.28%.

OUTLOOK

A dedicated Laser Arrival time Monitor is expected for the photocathode laser system, for the seed laser system and for the experimental lasers of the future SXFEL. The previous two will measure jitters and compensate drifts of the relative time of arrival between the pulsed output of the stabilized fiber links of the SXFEL precise synchronization system and the UV pulses as close as possible to the photocathode and the modulator respectively. The latter will measure and correct the jitter and drift of the experimental laser, such as for pump-probe experiment. The balanced optical cross-correlation technique has been verified that it has <10 fs resolution and enough sensitivity to measure the relative time of arrival. By complementing with the electro-optical modulation approach, an integrated scheme both wide dynamic range and sub-10 fs resolution is expected.

CONCLUSION

The strict requirements of less than 20 fs arrival time of the seed laser near the undulator. Furthermore, the passive

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stabilization and active control of the laser arrival time is foreseen for the seed laser and the experimental laser.

The currently used Ti:sapphire laser systems at SXFEL reach <10 fs integrated residual jitter performance at the output of oscillators. These are achieved by balanced optical cross-correlation. In order to reach required energy for seeded mode of EEHG or its cascade, further amplification is needed. However, regenerative amplifier system, pulses temporal shaping system and long transport paths make the output pulse arrival influenced by environmental changes.

In the future, the arrival time information from the development of wide dynamic range, high resolution laser arrival time monitors will be used to characterize the laser systems and help to find the jitter and the drift sources at different stages. Besides, the error signal provided by these devices can also be used to compensate and eliminate the long-term drift. As for jitter, it is main degraded by vibration and electromagnetic noise, which will be solved by passive stabilization.

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