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THE SYNCHRONIZATION AND TIMING SYSTEM UPDATING AT CTFEL FACILITY*

Shuai Ma, Weijun Wang, Ziru Sang, Hanxun Xu, Dexin Xiao, Peng Li, Kui Zhou†, Xingfan Yang, Dai Wu, Ming Li
Institute of Applied Electronics, China Academy of Engineering Physics, Mianyang, China
Chongxian Yin, Ming Liu
Shanghai Advanced Research Institute, Chinese Academy of Sciences, Shanghai, China

Abstract

Chinese Academy of Engineering Physics terahertz free electron laser facility (CTFEL) is a superconducting linac-based user facility. It provides laser pulses with frequencies from 0.1 THz to 4.2 THz. CTFEL works in pulsed mode with a repetition of 10 Hz where up to about 54000 bunches at a bunch spacing of 18.5 ns are accelerated in one macro-pulse. To satisfy the high-precision synchronization requirement from user experiments, the synchronization system based on coaxial line is updated to a continuous laser carrier and Michelson interferometer-based system. The timing system is updated to event system.

INTRODUCTION

The user experiments performed at CTFEL facility require beam stability. Especially the pump-probe experiments need high precision synchronization at samples to obtain the low possibility interaction. In these experiments pump pulses activate the sample microparticles to high energy state and the probe pulses interact with the sample microparticles to detect the relaxation dynamic of core-excited atoms. The temporal resolution of these experiments are limited by the synchronization between the pump pulses and the probe pulses[1]. The beam arriving time jitter will transfer to pump or probe pulses jitter by the interaction between the beam and light pulse in the undulator or resonator[2]. The trigger signal from the event system to user laser will also affect temporal resolution. Several sources result in beam arriving time jitter, such as superconducting cavities' phase and amplitude jitter, magnet compressors and beam trajectory jitter. These reasons are coupled with phase reference signal distribution from master oscillator to driving laser system, RF cavity LLRF et.al. The coaxial cable based and fiber optic cable based are two main methods of phase reference signal distribution. The coaxial cable based solutions include with and without feedback control method[3, 4]. The fiber optic cable based includes the continuous laser carrier based method and the balanced optical pulse laser cross-corelated method[5–7]. A general composition of these four methods performance is shown in Table 1.

Table 1: Comparison of two methods of phase reference signal

Methods	Jitter/fs	Drift/fs
Coaxial cable based without feedback[3]	Hundreds fs @2856MHz	±500 fs @2 days,200m
Coaxial cable based with feedback[8]	54 fs @2856MHz	158 fs, p-p @14 days,30m
Fiber optic cable based CW laser carrier based[9]	< 1 fs @2856MHz	< 70 fs @2 months, 2 km
Fiber optic cable based balanced optical pulse laser cross-corelated[10]	< 1 fs @1.3GHz	0.6 fs @16 days,1.2km

Figure 1 illustrates the layout of CTFEL facility after update in 2025. At present, the acceleration part is consists of a DC injector with 320 kV and one L-band 2*4 cell superconducting cavity cryomodule. A L-band buncher is located between the DC injector and the 2*4 cell superconducting cavity cryomodule. One undulator with a period of 58 mm is in the downstream after several quadrupoles. The other undulator with a period of 38 mm and a resonator locates after a dog-leg transfer section. The new section includes two 2*9 cell superconducting cavities, two undulators with period of 35 mm and 48 mm respectively and a X-ray FLASH lab. This circular beamline is also the main part of energy recovery linac (ERL)[11] in the future. During this construction of new facility section, the synchronization and timing system is updating from the coaxial cable based without feedback to the fiber optic cable based with continues laser and Michelson intervened system. This paper presents a updating design and construction of synchronization and timing system for CTFEL. The first test results in CTFEL about the phase reference signal distribution jitter is given.

SYNCHRONIZATION AND TIMING SYSTEM DESIGN

In the new facility based on CTFEL, eight parts need synchronization signal including the driven laser, one buncher cavity LLRF, two 2*4 cell superconducting cavity LLRF and four 2*9 cell superconducting cavity LLRF. The above parts, 23 BPMs, 2 BAMs and some user facilities require trigger signal from timing system. We construct the fiber optic cable based with continues laser and Michelson intervened synchronization and event timing system, as shown in Fig. 2. The master oscillator generates 1.3 GHz reference signal in the laser room and the signal is modulated by the

* Work supported by National Key Research and Development Projects (2011YQ130018)
† zhoudakui@163.com

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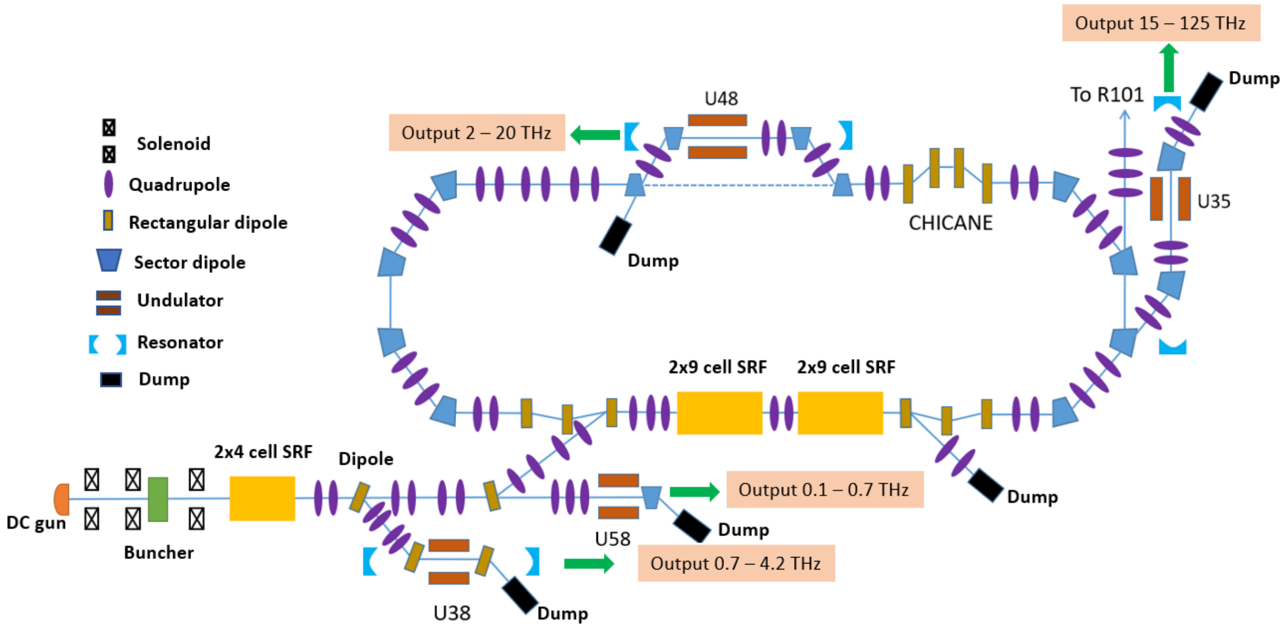

Figure 1: Beamline layout of future CTFEL facility.

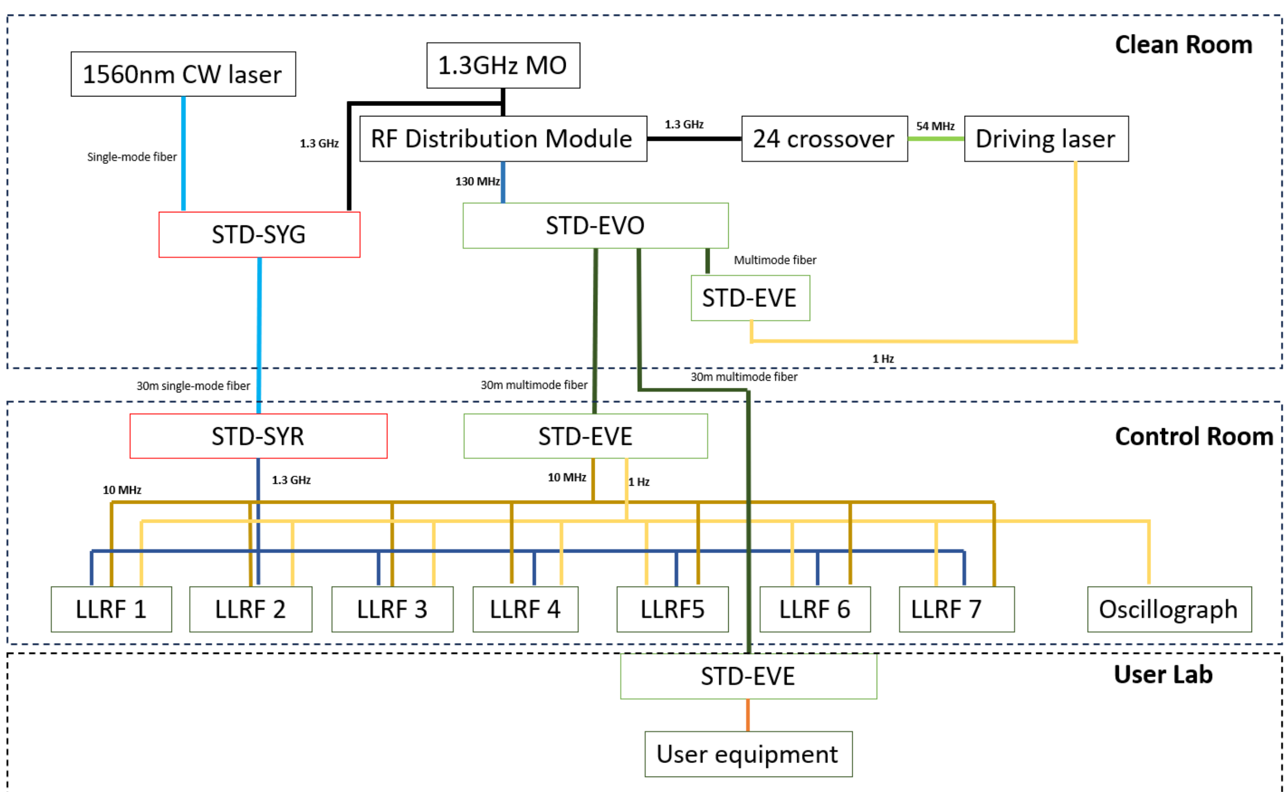

Figure 2: Skeleton of new facility synchronization and timing system.

infrared continue laser with a wavelength of 1560 nm locked with the Rb absorption line in the synchronization generator. Through the 30 meters single-mode fiber the signal transfer to the synchronization receiver in the center control room where seven LLRFs are located. The heterodyne fiber optic Michelson interferometer is used to detect the laser phase movement in the fiber. Then a fiber stretcher compensates the phase error result the distribution, shown as Fig. 3.

The trigger system based on a event system is consists of an event generator, an event receiver and a fiber network. After 10 time down conversion in a RF distribution module, the 130 MHz reference signal is transferred to event genera-

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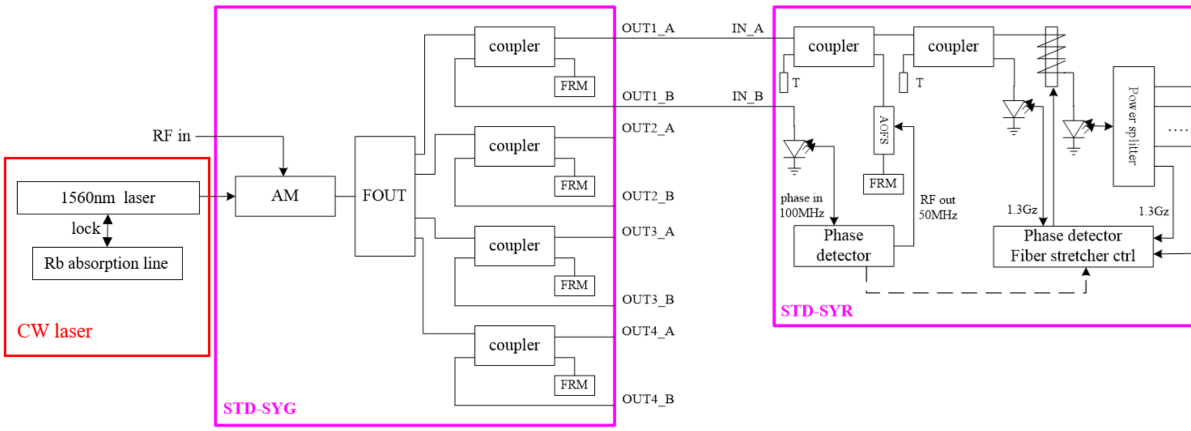

Figure 3: Skeleton of continues laser and Michelson intervened synchronization system.

tor in the laser room. Then the trigger signal is transferred to the event receiver in the center control room by the 30 meters multi-mode fiber and event receiver in user room. The period and pulse length of trigger signals from the event receiver can be changed independently as requirements.

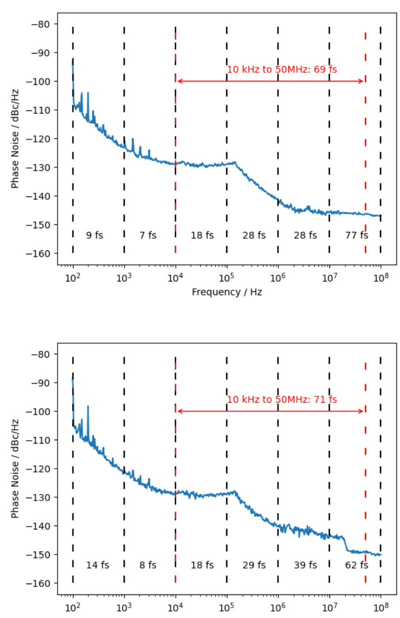

Figure 4: Phase nose of synchronization signal in the laser room and the control room.

TEST RESULTS AT CTFEL

The synchronization and timing system has been completed in the early of this year. We analyze the short time jitter of phase reference signal from the synchronization system. The 1.3 GHz reference signal from a master oscillator has 69 fs time jitter with integrated scale from 10 kHz to 50 MHz, shown as Fig. 4 a. After modulated in the infrared laser and transferred by 30 meter fiber, the reference signal from the synchronization receiver has 72 fs time jitter, shown as Fig. 4 b. The phase noise at terminal station decreases from about 15 MHz to 50 MHz due to a low band filter installed in the synchronization signal receiver. Then the RMS jitter of the synchronization system is about 16.7 fs.

The jitter of the timing signal from a EVE relative to the reference signal is measured by an oscilloscope. The RMS jitter is 3.6 ps. At the same time the resolution of a delay step is 5 ps from the measurements.

CONCLUSION

The synchronization based on continues laser and the timing system based on events distribution have been completed at CTFEL. The test shows that the jitter of reference signal distribution is about 16.7 fs which is satisfied with the requirements from all sections in the facility. The trigger signal's jitter is down to 3.6 ps and the step of delay is 5 ps as designed. Further test is the long time drift of the phase reference signal which is critical to the stability of CTFEL and the facility in the future.

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