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Synchronization of Peking University THz FEL

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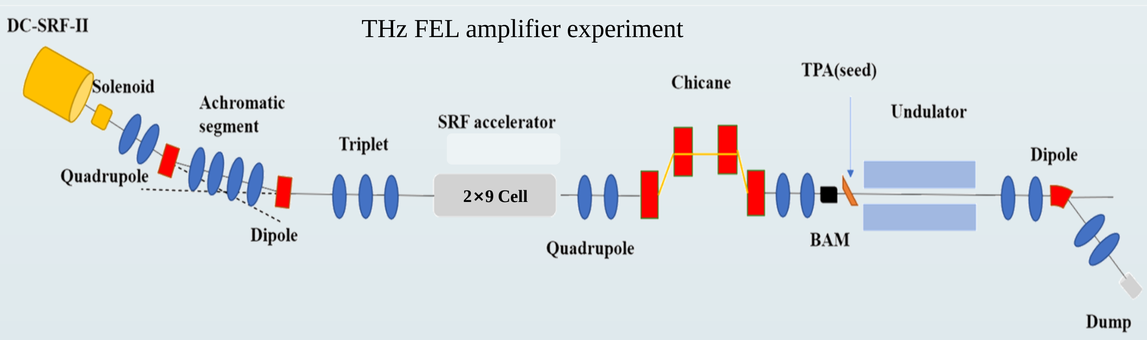
Abstract

The DC-SRF photocathode electron gun, which is capable of generating high-quality electron beams with high repetition rates and low emittance, is suitable for use in large scientific facilities such as FELs and ERLs. Peking University plans to conduct experimental research on a THz FEL (Terahertz Free Electron Laser) amplifier using a DC-SRF (Superconducting Radio Frequency) electron gun. The experimental setup of the THz FEL amplifier mainly includes a 1.3GHz DC-SRF electron gun, a 2.856GHz RF (Radio Frequency) deflection cavity, a 2.4 GHz cavity-based Beam Arrival Monitor (BAM), a 1.3 GHz 2×9 Cell superconducting accelerator module, as well as photocathode drive laser systems and THz seed light systems. The two laser systems have repetition rates of 81.25 MHz and 100 MHz, respectively. Since the operating frequencies of the components on the THz FEL amplifier device are not identical and some frequencies do not have a multiple relationship, clock generation schemes based on PLL (Phase-Locked Loop) or mixers cannot fully meet the experimental requirements. Therefore, we have employed DDS (Direct Digital Synthesis) to generate the key frequencies. Additionally, to ensure the normal operation of the BAM, signal detection and processing of the BAM signals have been implemented based on the KC705 and FMC150 platforms.

THz FEL Beamline



Main components and their frequency ranges

Component	Tunable range
Main oscillator of drive laser	81.112 ~ 81.38 MHz
RF deflecting cavity	2855.5 ~ 2856.5MHz
Main oscillator of FEL seed laser	99.9978 ~ 100.0018 MHz
2×9 cell accelerator	1300.15 ~ 1300.25 MHz
Beam arrival time monitor	2400 MHz

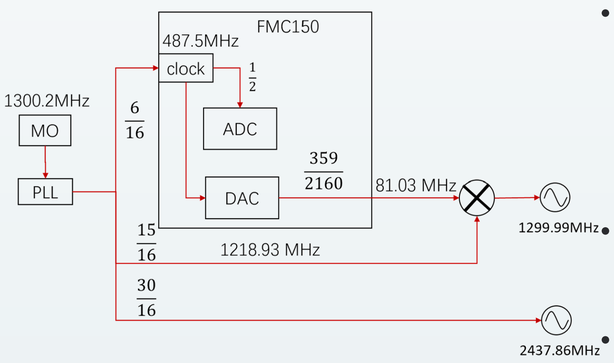
- The seed laser of the photocathode drive laser system is a Menlo Systems fiber laser with a repetition rate of 81.25 MHz, and a tunable range from 81.24 to 81.26 MHz.
- The RF deflecting cavity is used to observe the longitudinal distribution of the electron beam. For higher resolution, we selected a 2856 MHz deflecting cavity.
- The repetition rate of THz seed laser is 100 MHz, the operating frequency of the accelerator module and BAM is 1300.2 MHz and 2400MHz, respectively .

Implementation of the various frequency reference signals

The finalized frequencies of each component

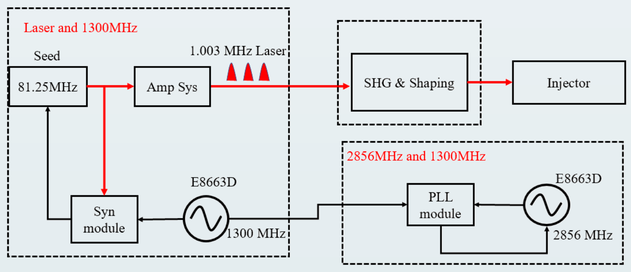
Component	Frequency	coefficient
Main oscillator	1300.215 MHz	RF
Drive laser	81.2634… MHz	FL1=RF/16
Drive laser (parameter optimization)	1.01579… MHz	FL2=FL1/80
Drive laser (THz)	112.865… kHz	FL3=FL2/9
Deflecting cavity	2856.4098… MHz	FD1=RF/320*703
THz seed	99.999174… MHz	FT1=RF/5760*443
THz pump	112.865… kHz	FT2=FT1/443/2
BAM LO	2437.8 MHz	FB=RF/16*30

Local oscillator of THz seed and BAM



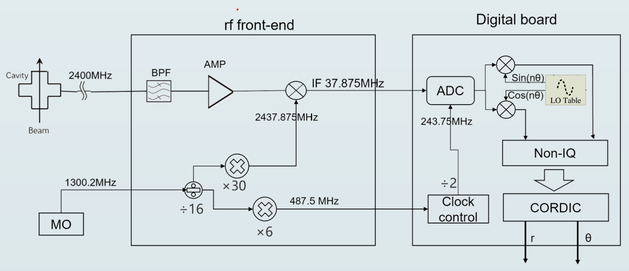
- The local oscillators for the THz seed and BAM need to be 1299.99 MHz and 2437.86 MHz, respectively, and must satisfy the corresponding relationship
- The LO of THz seed is generated by a DDS and a mixer
- The LO of BAM is generated by the PLL

Synchronization of 1300MHz and 2856MHz



- The synchronization between 1300 MHz and 2856 MHz is achieved through a PLL
- A signal generator E8663D as the external VCO
- The measured time jitter is 94.43fs.

BAM signal sample and process



- The operating frequency of the BAM is 2400 MHz
- The BAM signal is amplified and then directly down-converted with the local oscillator, the intermediate frequency (IF) is 37.875 MHz
- The KC705 is responsible for digital down-conversion and amplitude-phase analysis.

Conclusion

This work, based on the needs of the THz FEL amplifier experiment at Peking University, analyzed and determined the microwave reference signal frequencies required for various components in the experiment. Synchronization of the 1300 MHz and 2856 MHz signals was achieved using PLL and laser frequency selection. The local oscillator signals required for components such as the THz seed laser and BAM were generated using DDS and mixing methods. Additionally, based on the KC705, the signal processing framework for the BAM was designed.

Selected References

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