KEK ACCELERATOR TEST FACILITY TIMING SYSTEM UPGRADE STATUS REPORT

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Abstract

The KEK ATF is the Accelerator Test Facility dedicated to survey and realize the nano-beam technology, including beam instrumentation R&D for International Linear Collider (ILC) project. The ATF facility timing system supplies trigger and gate signals for DAQ, klystrons, laser systems, interlocks etc. Before upgrade trigger signals generation and synchronization to Low-Level RF was realized using NIM and CAMAC modules and distributed via both the optical fibers with associated electro-optics transmitters, receivers and RF cables. Since 2021 it was gradually migrated to SINAP event-based timing system and signal distribution within the KEK ATF facility was switched to industrial optical fibers. This report presents KEK ATF facility timing system upgrade status.
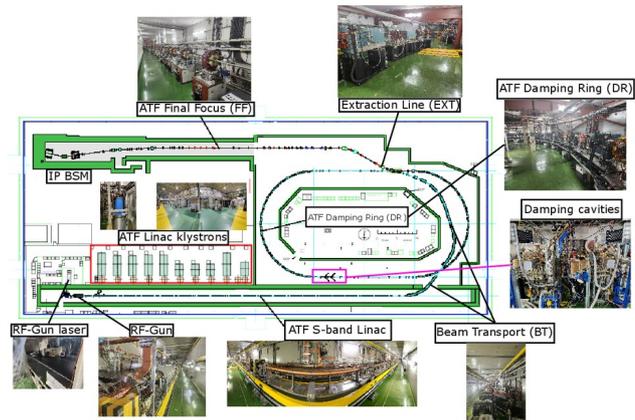
INTRODUCTION

The KEK Accelerator Test Facility (ATF) [1,2] has 8 main sections (see Fig. 1), which are laser-driven RF-Gun [3], S-band injector Linac [4], Beam Transport (BT) [5], Damping Ring (DR) [6], Extraction Line (EXT) [7, 8], Final Focus (FF) [9–13] test beamline and Interaction Point Beam Size Monitor (IP BSM) [14].

The ATF operates in pulsed mode with 3.125 Hz repetition rate, supporting both single train and two train beam operation modes. In order to control the ATF, the precise timing system synchronized to the facility Low-Level RF system [15] is vital, as well as its operation is milestone to conduct nanobeam technology study. Recently, facility timing system was migrated from CAMAC time delay modules based architecture [16] to the event generator&receiver architecture [17]. The timing system architecture based on the SINAP event generator (EVO) and receiver (EVE) modules at VME and standalone form factors [17] were chosen for the upgrade. In this upgraded timing system architecture, triggers and gate signals are transmitted over industrial-grade optical fibers, which provide robustness and reduced susceptibility to electromagnetic interference.

The SINAP EVO and EVE modules based key features are following:

1. Trigger and gate signals distribution over industrial fiber;

2. Multichannel system with independent control of every output;

3. Precise timing delay setup - 1/20 of the event clock;

4. Extra fine timing delay tuning - 5 ps;

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Figure 1: KEK ATF layout.

TIMING SYSTEM ARCHITECTURE

The timing system trigger and gate signals are synchronized with KEK ATF Low-Level, RF High-Power RF and beam arrival by clock signal and initial TTL logic pulse [15] injected into SINAP VME-EVO module inputs (see Fig. 2). The clock signal frequency is divided 4 times inside the SINAP VME-EVO module.

The input clock frequency is 357 MHz. Then, it is divided 4 times. As a result, the event clock 89.25 MHz. This event clock frequency is the 32nd subharmonic of the ATF Linac RF, the 8th subharmonic of the ATF Damping Ring RF and the 2nd subharmonic of the ATF RF-Gun laser oscillator clock. Therefore, the ambiguity between clock and trigger signals are forbidden (see Fig. 3 and 4). The trigger and gates signals timing delay setup coarse step is the event clock cycle at 11.204 ns, while the fine step is the event clock 1/20 fraction at 0.560 ns. Also, the extra fine timing delay step at 5 ps is available. The event generator (SINAP VME-EVO) realized in the VME form-factor distributes the event codes independently to the event receivers (SINAP VME-EVE and SINAP STD-EVE) over fibers. The KEK ATF 1 main section has 1 event receiver to control hardware (for example: RF-Gun laser amplifier, Pockel cells or Linac klystrons etc.) and/or supply triggers for the electron beam and/or laser pulse diagnostics DAQ.

TIMING SYSTEM SYNCHRONIZATION PRECISION MEASUREMENT RESULTS

One of the timing system operation main characteristics are the smooth accelerator operation and the synchronization precision between trigger signal and RF signal.
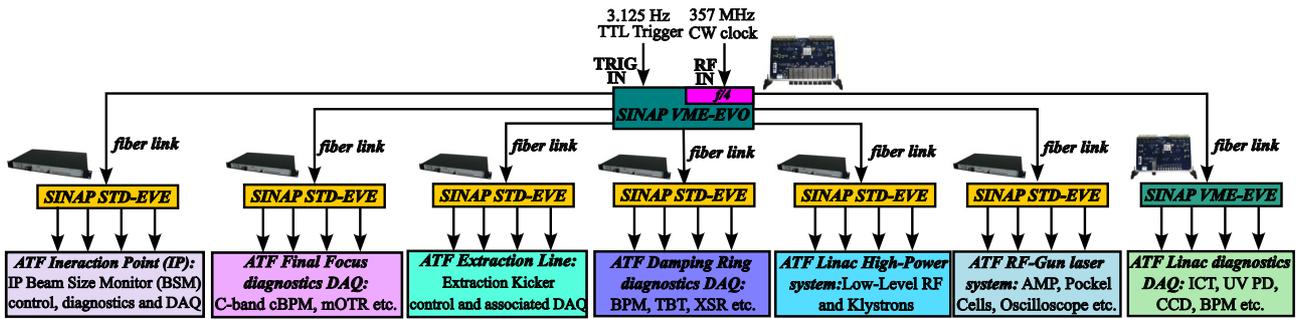
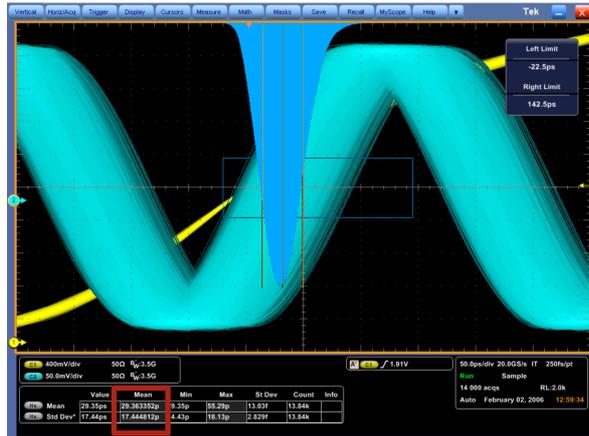Figure 2: KEK ATF timing system architecture block-diagram.

Figure 3: Synchronization precision between trigger signal and 2856 MHz RF clock over 14000 machine cycles (oscilloscope display screenshot).

Figure 4: Synchronization precision between trigger signal and 2856 MHz RF clock over 14000 machine cycles (histogram).

It was chosen to be the KEK ATF Linac RF. The Tektronix DPO 7354 oscilloscope with DPX option [18] was utilized to measure the synchronization precision. The oscilloscope configuration was following:

1. DPX function;

2. Interpolation measurement mode;

3. Infinite persistency;

4. Histogram measurement;

5. 40 GSa/s sampling rate;

6. 3.5 GHz input bandwidth;

7. 50 ps per 1 horizontal division;

8. 250 fs distance between points;

The TTL standard trigger pulse was injected into the oscilloscope input 1, while input 2 was fed with 2856 MHz RF clock (see Fig. 3). Also, the oscilloscope was synchronized to external 10 MHz reference signal taken from KEK ATF Low-Level RF system [15]. As can be seen on the Fig. 3, the input 1 was saturated in order to neglect the amplitude
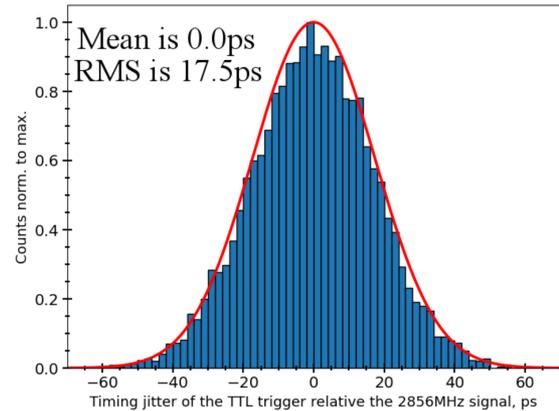
jitter effect on the synchronization precision measurement results.

The histogram data separated from accumulated waveforms are shown on the Fig. 4. The histogram peak value was normalized to 1 in sake of visibility. The synchronization precision between the TTL standard trigger signal and 2856 MHz RF clock is equal to 17.5 ps (RMS) over 14000 machine cycles. The data was acquired at KEK ATF RF-Gun section test start up on July 2025.

Figure 5: RF-Gun status display with its laser system parameters strip-charts (screenshot).

As a result, the stable operation of the RF-Gun laser system, particularly laser pulse arrival timing, and KEK ATF RF-Gun section [3] itself was confirmed (see Fig. 5).

CONCLUSION

KEK ATF timing system upgrade is on the final stage in 2025. Its event clock, event codes and timing distribution architecture demonstrate stable and precise operation. The long-term synchronization precision between trigger and RF clock signal is 17.5 ps (RMS). There is not sign of the synchronization drift and/or drift. Moreover, trigger timing jumps and/or ambiguity were not detected during the KEK ATF RF-Gun section test start-up on July 2025. The RF-Gun laser UV pulse arrival time data does not demonstrates several nanoseconds timing jumps too. The KEK ATF timing system nominal and stable operation will be fully confirmed during the autumn operation in 2025.

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