

# SSRF TIMING SYSTEM

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## Abstract

In order to keep the synchronization of injection between electron emission of gun and bucket in the Boost and Storage Ring, a fast timing system with low jitter, high precise setting developed for SSRF project. Simultaneously, a slower timing system is also needed for beam diagnostic system, Top-up injection, events management system, time stamp for data processing etc. Its jitter time would be  $\mu$  s up to ms. A fast timing system consists of the revolution divider, phase shifter, high precise (2ns) counter etc. It satisfies the physical running requirement and electronics jitter time has been tested successfully. The system function and tested results are described in this paper.

## 1 The Goal of Design

### 1.1 Physical goal and target

According to the physical design, the RF frequency for SSRF project is 499.654 MHz, there are 660 buckets with 2ns interval in storage ring, the RF captured range is 1.28ns. Due to jitter and instability for gun pulser, optical fiber, The moment injected into bucket is different, however, all beam injected into RF captured range will be stabled shown in Fig.1. the total jitter time T would be as follows

$$T = \sqrt{T_a^2 + T_b^2 + T_c^2}$$

In which,  $T_a$  is jitter for electronics,  $T_b$  is jitter for fiber cable system,  $T_c$  is jitter for gun pulser. Considering the physical requirement, the total jitter time <200ps will be reasonable.

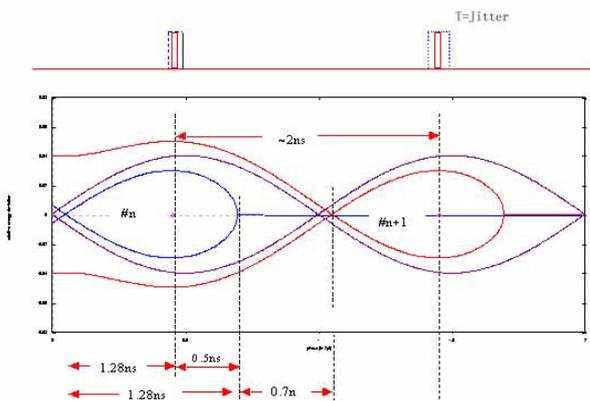


Fig.1: buckets in storage ring

### 1.2 Main performance & Running mode

- A. Main performance for timing system
  - a. RF frequency is 499.654Mhz.
  - b. Harmonic number for Ring is 660, revolution frequency is 0.7575Mhz.
  - c. Harmonic number for Booster is 264.
  - d. Synchronized frequency between Ring and Booster is 0.3787Mhz.
- B. Running mode
  - a. Multi—bunch mode, 90% running mode is multi bunches mode based on user requirement.
  - b. Single bunch mode, this mode will be used for calibration.
  - c. Mixed mode, 150 bunches distribute along the quarter of ring while a single bunch locates at the opposite point of multi bunches.
- C. Machine study mode
  - a. Injection mode, it could be used for study of injection from LINAC into the booster.
  - b. Booster is used for research of injection and extraction.
  - c. Storage mode is used for entire study of machine.

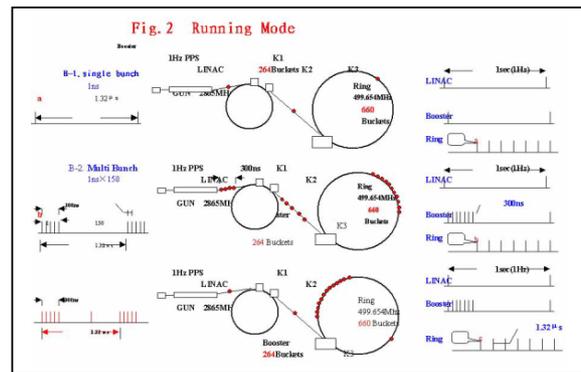


Fig.2: Running Mode

## 2 Design Principle and Consideration

Due to each facility of synchronization light source is based on various physical requirement[1], so its timing system has following characteristic:

- A. System will be more complication
 

Some facilities has different RF system used for different accelerator, so timing system should be synchronized between different RF reference signals.
- B. Application of fiber technology
 

Now the scale of accelerator is increased rapidly[2][3] so all equipment are distributed on the beam line with several hundred meters up to a few kilometers. The

EMI problem should be considered to ensure the timing system ran with reliability. Now there are many kinds of fiber products with high speed, low temperature drift in the market. This technology is widely adopted for this research field.

- C. Development of high precise low jitter modules  
According to development of high speed IC, now we have found out some modules such as TD4 with high speed (running frequency can reach 600MHz, jitter time is less than 10 ps) in the market.

### 3 The Requirement to Fast Timing System

According to physical requirement for synchronization between various equipment, the timing logic diagram is illustrated in Fig.3.

- A. Trigger signal of gun must be synchronized with dedicated bucket in storage ring.
- B. The phase between timing system and RF system could be adjusted with rang of 180 degree.
- C. The jitter time of various equipment is shown in the following table 1:

Table. 1

Item	Jitter time
Gun	<200ps
Klystron	<10ns
Kicker PS	<1ns
Magnet	<1ms
Diagnosis	5-10ns

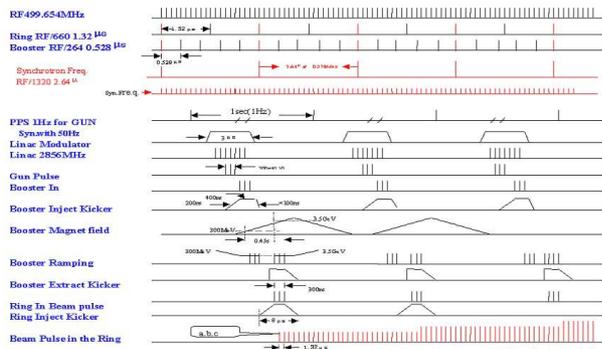


Fig3: Timing logical diagram

### 4 Main Performance

The SSRF Timing system is based on the experiments of BEPC timing system and refer to the improved timing system of many labs on the world. The system diagram is illustrated in Fig.4 It consists of various modules such as RF signals, RF phase shifter, revolution frequency generator, high precise digital delay module, high precise synchronizer, high speed transmitter and receiver for optical fiber, level converter.

#### A.RF signals:

The beam pulse extracted from gun should be synchronized with RF 499.654 MHz, its stability would

be better than 10E-8. The reference signal will be connected to timing system through isolated transformer. The signal level will be set at the 0dbm.

#### B.RF phase shifter

In order to avoid injecting into interfacing buckets based on the phase drift between gun trigger and RF signal, the phase shifter is useful for correction of phase tolerance. There are 180 degree phase shift can be adjusted by 0-10V input variant level.

#### C. Revolution frequency generator

This module will generate harmonic number for booster and storage ring (ring is 660, booster is 264). In order to synchronize booster and ring, the synchronized inject frequency should be synchronized with RF/1320, refer Fig.3. After calibration, we can get the following parameters:

- Ring revolution frequency: 0.7575MHz 1.32 μs
- Booster revolution frequency: 1.89263MHz 0.528 μs
- Synchronized frequency: 0.37853MHz 2.642 μs

#### D. High precise delay module TD4

TD2 module had developed by KEK for TRISTAN project. After improvement, TD4's performance is more powerful (maximum frequency will reach 660MHz, step of clock is 2ns/step), it can be run on the EPICS environment.[3]

#### E. High precise synchronizer

In order to keep the synchronization between RF signals (500MHz) and low frequency (1Hz), a high precise synchronizer is needed. This module is based on dedicated improvement of TD4. After testing, this module had reached expected performance.

#### F. Transmitter and receiver of optical fiber

There are lot of equipment with high power pulse source in accelerator environment. So we should pay attention to the EMI problem. The fiber system would be adopted for isolation. It has some phase shifter based on temperature variance. However some high performance fiber with low drift 1.3ps/km/C° is available in the market.

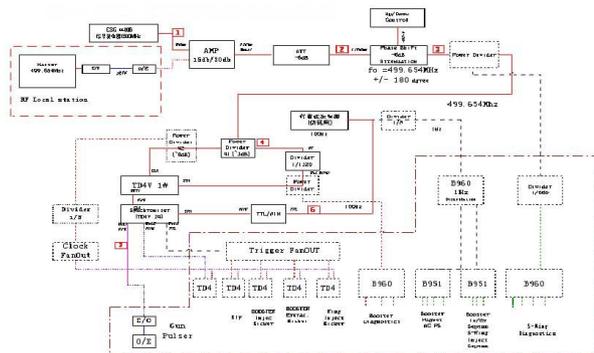


Fig.4: Block Diagram of Timing System

## 5 System Testing and Result

Due to this is a prototype, we ordered only part equipments of the whole system and we set up a testing system as Fig.4. The modules inside dotted line are not exist now. The target of testing system have checked the logic function and jitter time for main electronics loop. Whole testing was divided into two steps: modules testing and system testing.

### A. Testing Instruments

Used testing instruments are listed in the following table :

No	Item	Description	Function
1	RF signals generator	250Khz-1.0Ghz	To generate 499.654MHZ
2	Spectrum	100Khz to 1.8 GHz	To measure amplifier, shifter
3	S-parameter test set	300Khz-3.0Ghz	To measure the gain of shifter
4	Arbitrary wave generator	To generate various waveform,	Used for trigger source and Testing waveform
5	Oscilloscope	Samples rate 10GHz/s Bandwidth 3G Hz	To testing the jitter time & wave form
6	Multi-meter	High precise For testing V, I	UP/Down counter testing

### B. Modules testing

The modules testing is needed for checking each module's specification before system integration. Recently, various instruments has more powerful with digitization and high precise . We get various parameters of phase shifter, linearity of amplifier jitter time and waveform logging etc.

After testing , all of modules reach the specification.

### C. System testing

Various modules have been integrated as shown in Fig.4, the RF generator is used as RF reference signals, the output of TD4 is used for external trigger of oscilloscope then we can measure the jitter time on the oscilloscope, these data can be save into the disk and print out from computer. In order to eliminate the background jitter from final data, the jitter calculation will be as follows:

$$\sigma = \sqrt{\sigma_2^2 - \sigma_1^2}$$

in which  $\sigma_2$  is value including the back ground

$\sigma_1$  is value of background

After calculation, one  $\sigma$  is 11.ps,  $3\sigma$  will be statistics value. So 33.4ps will be jitter time for electronics. Please refer Fig.5 and Fig.6 as follows.

### D. Software testing

Whole accelerator facilities are controlled under EPICS software system. Some timing modules is installed in VME crate in which CPU board run under VxWorks real time OS and EPICS environment . The TD4 module can be controlled from a PC with LINUX OS successfully.

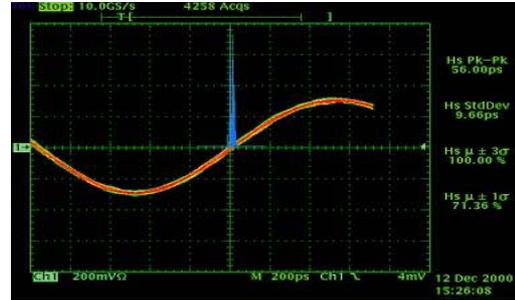


Fig.5.jitter time of back ground

So each delay setting ,bucket selection could be completed on the remote WS or console computer such as a PC with LINUX.

A set of jitter time example as follows:

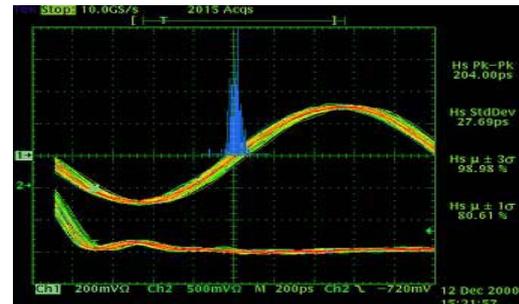


Fig.6 Jitter signal and background

## 6 Conclusion

Fast timing system is one of the most important equipments of accelerator facility. Its reliability will be considered first. So we should pay more attention to its design, fabrication and installation . The testing results showed us the selection of modules can satisfy our requirement.

## 7 Acknowledgement

During our design, we have contacted with many timing experts from KEK, APS, ALS,NLSL, TLS, they give us lots of valuable suggestion and experience ,so that we have successful prototype system . We should have appreciated for their kind support.

## Reference

- [1]. Review of Accelerator Timing System T.Korhonen, PSI, Switzerland.
- [2] Synchronization Scheme for the KEKB Accelerator T.Naito, J.Odagiri, M.Suetake,N.Yamamoto ,Proceedings of ICALEPS'97.