Timing system of the ATF

T. Naito, H. Hayano, T. Korhonen, S. Takeda, J.Urakawa,
KEK, High Energy Accelerator Organization, 1-1 Oho Tsukuba, Ibaraki, Japan 305

Abstract

A timing system was constructed for Accelerator Test Facility(ATF) for future linear collider R&D at KEK. The operation of the ATF has several features, for example, multi-bunch acceleration, delta-f energy compensation, multi-train storage, etc.. The timing system provides synchronized reference signals and trigger signals for each hardware. To keep stable phase relationships at each component, the reference signals of acceleration frequencies are transferred directly by using phase stabilized optical transfer lines. The beam timing is adjusted with the synchronized delay modules which used ECL preset counter circuits. A bucket selector circuit and a bucket matching circuit are used for manipulation of the beams in the damping ring. CAMAC interfaces and Vsystem for programming were used for control. The hardware performance and the software environment are described.

1 Introduction

The ATF consists of a 1.5GeV S-band linac, a damping ring(DR) and an extraction section for diagnostics of the damped beam characteristics. The linac accelerates multi-bunch beam which has 20 bunches of $2x10^{10}$ electrons with 2.8ns bunch spacing and the repetition rate is 25Hz. The energy spread of the multi-bunch beam is required to be less than 1% for the DR injection. The DR stores muti-train(max. 5 trains) of the multi-bunch and the damped beam is extracted sequentially after several damping time.

Device	Frequency(MHz)
Master Osc.	1428
Linac	
Acc. Structure	2856
ECS Structure	2856+/-4.32
SHB,Gun grid	357
Damping Ring	
RF cavity	714
Revolution	2.16

Table 1 Devices and the used frequencies

The timing system generates both the reference signals for each hardware which use different frequency and trigger signals for pulsed devices which use different repetition rate. The device and the used frequencies are summarized in table1. All of the reference signals and the trigger signals are required to be precisely synchronized. The accuracy and stability are significant issues in the accelerator performance. The generated signals have to be distributed to each location of over 100m, without deteriorating of the quality. An optical transfer system by using phase stabilized optical fiber was used for the delivery of signals. The operation mode, for example, the beam and the pulsed RF timing selection, the injection/extraction timing selection, the bucket selection of the DR and the number of the train selection of the DR, is manipulated by changing the phase of the timing circuits.

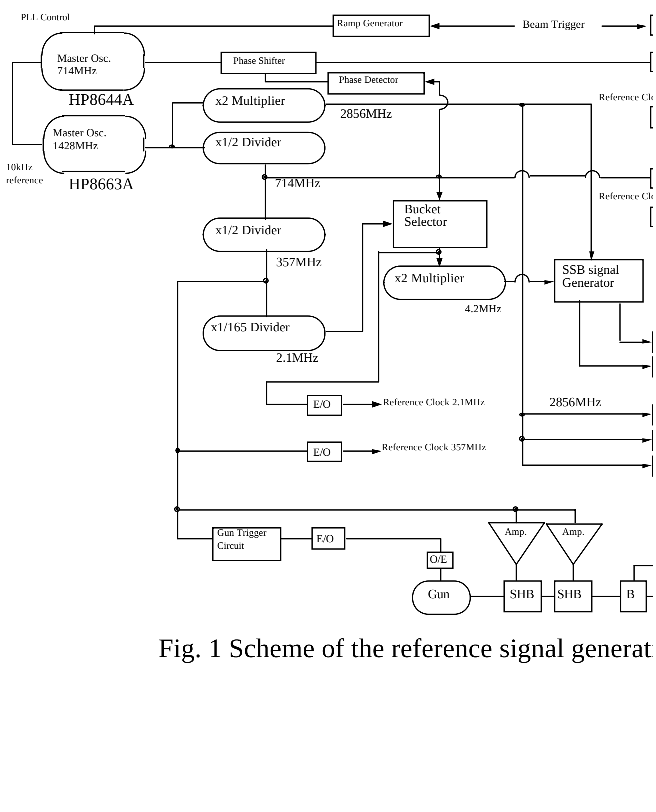

Fig. 1 Scheme of the reference signal generat

2 Hardware scheme

2.1 Reference signal generation

The scheme of the reference signal generation and distribution is shown in fig. 1. The half of the acceleration frequency(1428MHz) was selected to reduce the number of the divider and the multiplier and to use the stabilize frequency range of the master oscillator. The jitter among each frequency ought to be reduced using only several dividers and multipliers.

The linac uses 357MHz for an electron gun grid driver and two sub-harmonic bunchers, 2857MHz for a buncher and nine klystrons and 2856MHz+/-4MHz for two klystrons of the energy compensation system(delta-f ECS)[1]. In order to suppress the energy spread of the multi-bunch beam which comes from the transient beam loading effect, the slightly different cavity frequencies of 2856MHz+/-4MHz are used. The phases of the delta-f ECS are required to synchronize the revolution of the

DR. The DR operates with the cavity frequency: 714MHz, the revolution frequency: 2.16MHz and the Harmonics number: 330.

The time jitter of the multiplier/divider was measured by a sampling scope(HP54129B). The relative time jitter from 2856MHz to 714MHz and 357MHz were 0.85ps and 0.71ps, respectively. These values are enough to the linac stable operation. The time jitter of the ECS frequency(2856MHz+/-4MHz) was 0.8ps.[2]

2.2 Trigger signal generation

The trigger signals are made from the synchronized signal of AC power line(50Hz). The advantage of synchronized signal of AC power line is the reduction of the fluctuation of the high power devices. The repetition rate can be changed from 50Hz to 0.39Hz by the control computer. Different repetition rate can be selected individually for each device. The trigger signals are also synchronized by the revolution freq.(2.16MHz) and the SHB freq.(357MHz) for synchronization of the all RF devices. The time delay among the devices is created by the synchronous and delay counter module(called TD2) developed at TRISTAN timing system. The time delay can be adjustable with 2.8ns step. The improved version can count up to 1.4GHz and the time jitter is ~5ps(σ) at 714MHz clock. [3]

2.3 The optical transfer system

The drive signal of linacs have been distributed by using the coaxial cable. The down converted frequency was used for reduction of the power loss and reconverted to 2856MHz at each location. The coaxial cable is not so stable against the temperature change. At the ATF, there is no air conditioner at the klystron station. The temperature stability is one of the serious problems. The optical transfer system was used for distribution of the reference signal and the trigger signal by using the phase stabilized optical fiber cable. The optical fiber (SUMITOMO DTS) has a very low temperature coefficient(0.04ppm/°C). The temperature characteristics are shown in fig. 2. 3510A(transmitter) and 4511A(receiver) (Ortel Co.) were employed while the E/O and O/E for 2856MHz direct distribution, the temperature coefficients 0.45ps/°C and 0.85ps/°C, respectively, were measured. The phase variation at the actual station in a day was measured less than 10 degree(10ps). The time jitter of the optical transfer system, when 100m fiber cable was used, was 0.7ps.

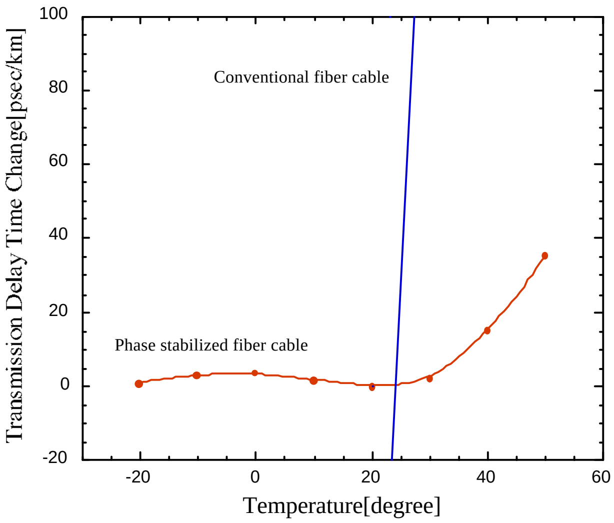

Fig.2 Temperature dependence of the phase stabilized fiber

2.4 Bucket selector

The selection of the bucket of the DR is done by changing the relative phase of the DR revolution and the beam timing of the linac. The bucket selector consists of two TD2's, one is for selection of the bucket number and the other is for the bucket matching described in the later section. The TD2's are connected cascade and shift the phase of 2.16MHz with 1.4ns step by counting 714MHz. In order to keep same phase of the delta-f of the ECS at every injection timing, the twice of the output of the bucket selector, 4.32MHz, is used. In case of 5 trains injection/extraction mode, the bucket selector has to change the timing in each injection interval of 40ms. The local control and auxiliary crate controller interface with a personal computer(LACC) are used for this purpose. The accelerator control system could not guarantee the access interval within less than 40ms. The LACC can change the value of the delay counter of the TD2 within ~1ms. The performance is not yet tested at the operation.

2.5 Bucket matching

There is a requirement to shift the frequency of the RF cavity of the DR, for example, in case of the dispersion measurement. The second oscillator is used for this purpose. The two frequencies of the master oscillator and the second oscillator are in phase locked loop(PLL) at the normal operation. The dispersion measurement procedure is following, 1)the PLL is turned off, 2)shift the frequency of the second oscillator,. 3)measure the orbit, 4)return to same frequency, 5)the PLL is turned on. The revolution phase of the DR is not same after the process. The bucket matching circuit is required to re-adjust the phase. The scheme of the bucket matching circuit is shown in fig. 3. The circuit counts both the frequency of the oscillators individually when the PLL is turned off. The difference of the counters is calculated and restore to the bucket selector after the PLL turned on. The same LACC is used for the calculation and set the data. Different scheme was used at TRISTAN by using a phase detector and a phase shifter.[4] The advantage of the ATF bucket matching circuits are no shifting the frequency of the oscillator and a simple configuration.

3 Control environment

The control system is based on CAMAC and VAX(VMS) cluster system. The data base and GUI were made by Vsystem.[5] It has many tools to ease control of the components. The some timing devices need to fine adjustment to reach the optimum timing. A convenient control windows were made by Vsystem. Several windows were already made for the timing devices, for example, the repetition rate, the delay timing of the linac, the DR, etc.. The timing control is also used as the energy feedback at the linac. The one of the klystrons is used for compensate the energy drift by controlling the timing between the pulsed RF and the beam. The energy of beam is controlled by using the different timing of the rising edge of the pulsed RF. This feedback is a operation within a few second range. A part of the timing devices like the bucket selector by using LACC is a shot by shot operation.

4 summary

The timing system of the ATF has been constructed and confirmed the performance. The stability and the easy tuning were confirmed by the commissioning of the DR with the single bunch operation.[6] The multi bunch operation is scheduled at early 1998. The optical signal distribution is promising for long distance and stable signal transfer as the linear collider reference line. The R&D of X band (11.4GHz) transfer system is in progress.

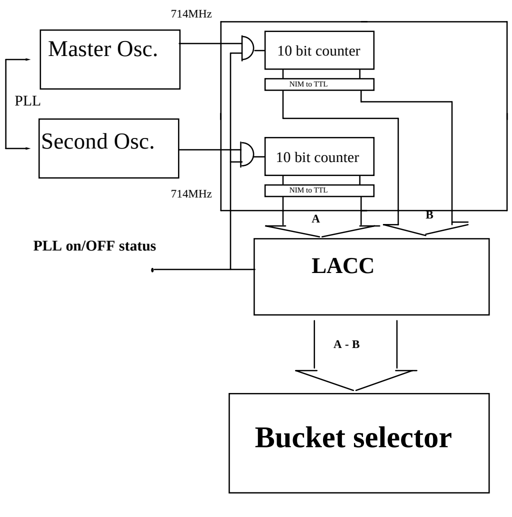

Fig. 3 Bucket matching circuit

5 ACKNOWLEDGMENTS

We would like to express our thanks to Professors M.Kihara and K.Takata for their encouragement. We also wish to thank ATF operation group for useful discussion.

REFERENCES

[1] J.Urakawa, et. al., “Gun trigger system for the ATF”, NIM A 352(1994) 207-209
[2] T.Korhonen et. al., “R&D OF THE TIMING SYSTEM”, Poc. of Linac Conf. ‘94(p831) Tsukuba Japan
[3] T.Korhonen et. al., “Performance Evaluation of a High Bandwidth Timing Module”, KEK Internal, 96-3, 1996
[4] M.Kikuchi et. al., “BUCKET SELECTOR AND TRANSFER TIMING IN TRISTAN”, Proc. of the 6th symp. of Acc. Sci. and Tec., p230 1987
[5] N.Terunuma et. al., “Status of the ATF control system” ibd.
[6] H.Hayano et. al., “ Commissioning of ATF Damping Ring”, Proc. of the 11th symp. of Acc. Sci. and Tec., p68 1997