Timing system for multi-bunch/multi-train operation at ATF-DR

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Abstract

A timing system for manipulating muti-bunch/multi-train beams has been installed for Accelerator Test Facility Damping Ring(ATF-DR). The ATF-DR has 330 rf buckets with 1.4ns spacing. The ATF linac accelerates multi-bunch beam which has 20bunches with 2.8ns spacing. 5 trains of muti-bunch beam can be stored to the ATF-DR, sequentially. The timing system is required to make a precise trigger signals and to make a flexible bucket selection scheme. This paper describes the ATF-DR operation mode, the hardware to realize the operation mode and the result of the preliminary test of the sequential bucket change operation.

1 Introduction

ATF-DR has been constructed for developing the low emittance multi-bunch beam as a future linear collider(LC) technology. Muti-bunch beam operation is a key issue to increase the luminosity of the LC. The ATF-DR was designed to circulate multi-bunch beam, 20 bunches with 2.8ns spacing, and multi-train beam of maximum 5 trains[1]. The future LC will be operated at 150Hz or more. The damping time of the DR is insufficient comparing the injection period. The sequential multi-train operation is required at the DR in order to keep sufficient storage time. The multi-train operation at the ATF-DR is a quite similar to future LC operation. The timing system of the ATF-DR is also required to make flexible injection/extraction sequence for various studies. The one of the problem to design the timing system is to make injection/extraction trigger signals flexible in order to keep the ambient radiation revel low, for example, 5 trains injection with a half minute interval. We could realize the requirement by using the combination of the trigger control hardware and the personal computer(PC) control.

2 ATF-DR operation modes

2.1 Multi-bunch, Multi-train operation

The ATF linac accelerates multi-bunch beam which has 20 bunches with 2.8ns spacing. The single bunch has 2 x 10^{10} electrons. An energy compensation system is used for the multi-bunch acceleration[2]. A single turn injection/extraction kicker system is used for the multi-bunch injection/extraction. The pulse characteristics of the injection kicker system was already confirmed[3] which has 60ns flat top within 0.2%. It is sufficient for the multi-bunch injection. The improvement

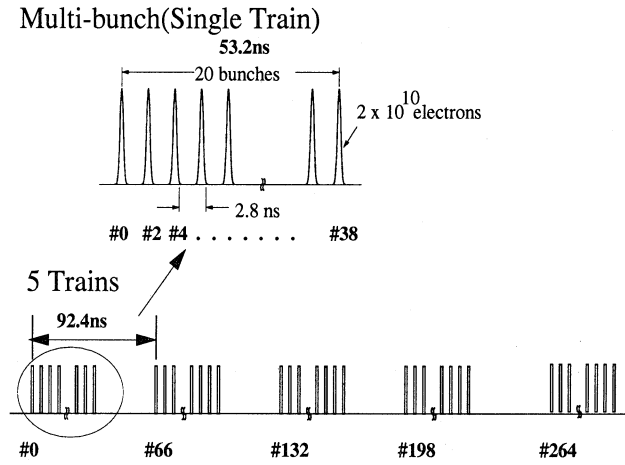

Fig. 1 Beam structure in ATF-DR

of the extraction kicker for multi-bunch beam is in progress. The kicker pulses are required to have sufficiently flat, no pulse tail and fast rise/fall time.

The injected beam from 0th number of bucket occupies every even number of the bucket, like #0,#2,#4,..#38. (see Fig.1) 5 trains of the multi-bunch beam which have 92.4ns spacing can be injected to the ATF-DR by changing the injection timing. At the continuous operation, the sequential injection/extraction of the beam train is executed to keep sufficient storage time. The beam trains are injected with 40ms interval and stay 200ms in the DR then extracted just before next injection to the same bucket.(see Fig.2)

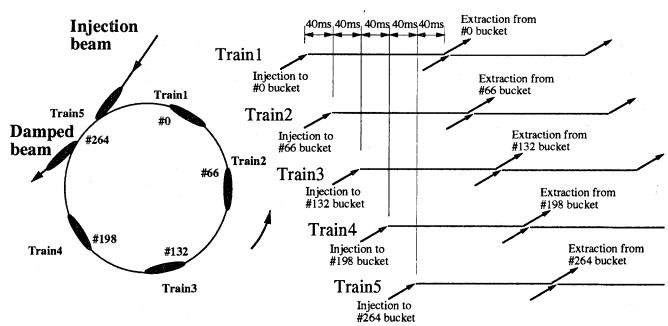

Fig. 2 5 train operation at ATF-DR

2.2 operation mode for various studies

The ATF-DR has been required to have various operation modes in order to make various beam studies besides the normal multi-train operation. Especially, the function of

the injection cycle control is necessary to reduce the ambient radiation level which comes from the injection beam loss. The operation modes are as follows.

2.2.1 Single bunch injection/extraction

The single bunch beam is injected to ATF-DR and extracted to the extraction line after the arbitrary storage time. The extraction is executed before the next injection. The repetition rate of the injection can be changed from 25Hz to 0.39Hz by the hardware setting and more large intervals can be set by the software control.

2.2.2 Multi-bunch injection/extraction

This mode is the same as 2.2.1 except for using multi-bunch beam. The first bunch of the 20 bunches is injected to the same bucket of the case of the single bunch. In this mode, the repetition rate of the injection can be reduced to keep the same ambient radiation level as the single bunch.

2.2.3 Multi-bunch/multi-train injection/extraction

This mode will be used as a most realistic LC operation. The DR is filled by the successive pules in n(n=1 to 5) injection cycles. For the following some period there is no injection in order to keep the low ambient radiation revel. The trains are extracted just as the restart of the next injection cycle. The period of no injection cycle should be controllable . When the period can be kept minimum, this mode will be correspond to the normal LC operation.

2.2.4 Storage mode

The storage mode is made by stopping the injection and extraction kicker magnets just after the beam injection. This mode is used for studying the DR performance with the stored beam.

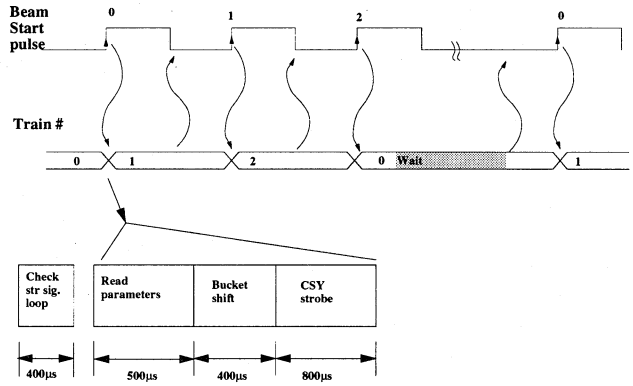

Fig. 4 Timing chart of the bucket controller

3 Hardware

The layout of the timing control system is shown in Fig.3. The line sync module generates all the trigger signals of the linac and injection/extraction kickers. The repetition rate can be selected individually from 25Hz to 0.39 which is synchronized to the commercial AC line. The advantage of the synchronized signal of the commercial AC line is the reduction of the fluctuation of the high power devices. The trigger signals are also synchronized by the revolution frequency(2.16MHz) and the 357MHz reference clock. TD2 CAMAC modules are used to make the synchronization and the time delay for each device. The TD2 is a digital delay used preset counter which can delay the start signal while the

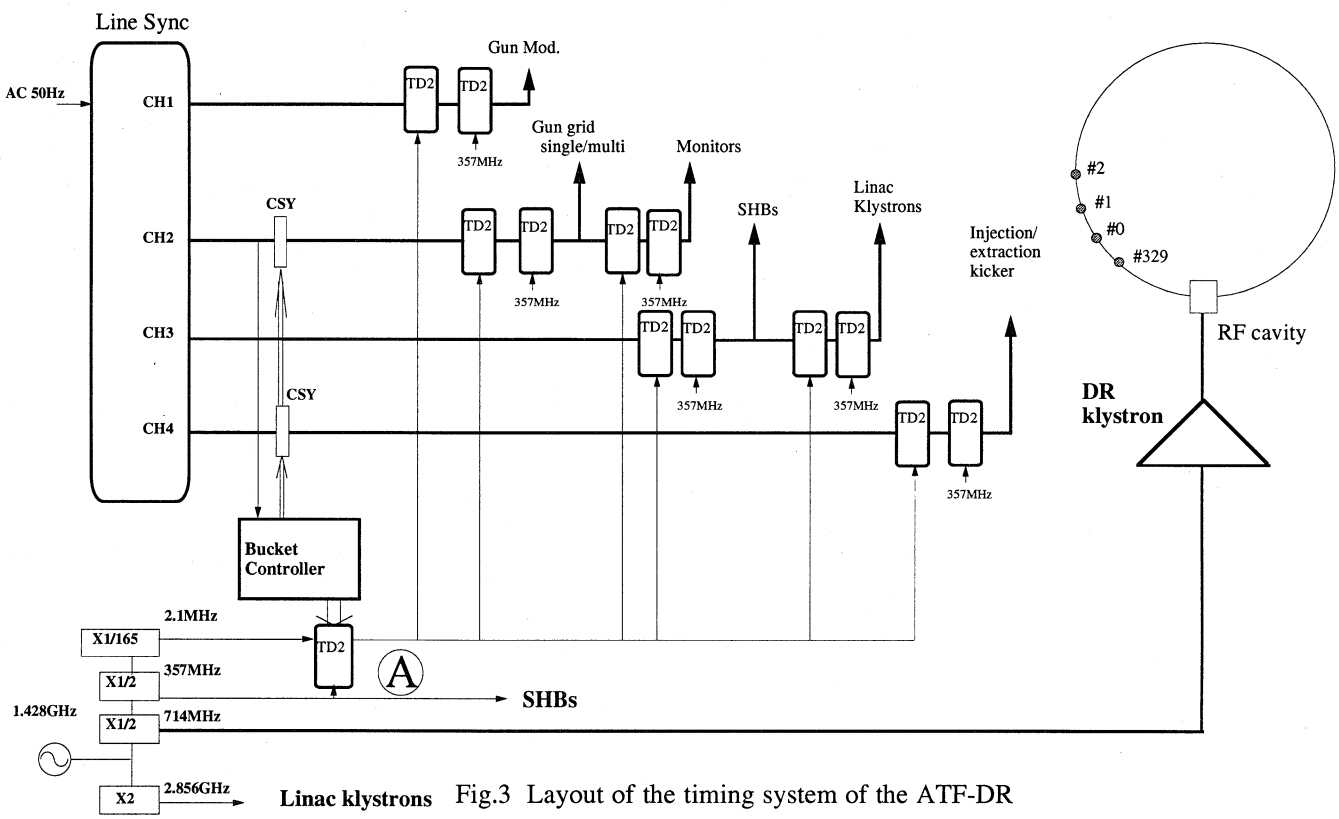

Fig.3 Layout of the timing system of the ATF-DR

programmed counting period. The time jitter between the output and the clock signal is ~7ps(σ) at the 357MHz clock[4]. The selection of the bucket number of the DR is done by changing the relative phase of the DR revolution and the beam timing of the linac and kickers. The one of the TD2 marked A in Fig.3 defines the bucket number. The revolution clock is delayed with 2.8ns step. The delayed revolution clock is used to synchronization of the linac and the kickers. So, the injection beam timing for the fixed DR bucket is shifted by the delayed revolution clock. Consequently, the arbitrary bucket number can be selected by the set value of the bucket selection TD2.

3.1 Bucket selector for multi-train operation

At the multi-train operation, the set value of the bucket selection TD2 has to be changed within less than 40ms. The accelerator control computer and CAMAC system can not work so quickly because of the multi-task operation. We prepare a hardware for the bucket change which is called bucket controller. The bucket controller consists of a personal computer with an auxiliary crate controller interface, digital input module for checking beam start timing and memory box module for reading the parameter of the operation mode. The function of the bucket controller is as follows, 1)check the rising edge of the start pulse, 2)If the start pulse(previous beam injection) is sensed, read parameters which are set by the control computer through the memory box module and execute bucket shift, then give a permission of the next pulse to the clear and synchronize module(CSY), 3)If the shot is final shot of the multi-train, wait for the set time, then give a permission of the next pulse to the CSY. Only one input pulse of the CSY goes through to output after accepting the software command. Thus, the CSY can make the start pulse with software control. The all of the procedure finishes within 2ms except for the wait time. The timing chart of the bucket selector is shown in Fig. 4, as and example of 3train operation. The Train number can be set from 1to 5 and the wait time can be set to 0 to 4095sec.

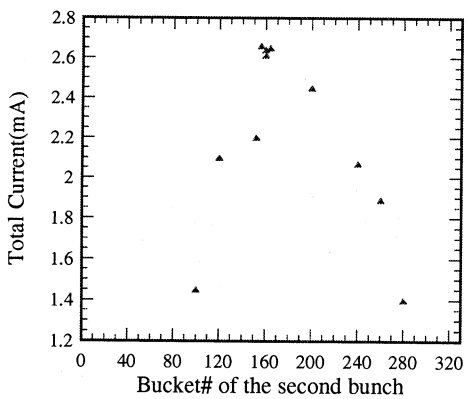

Fig.5 Stored current at the two bunch injection

4 Multi-beam injection test

A preliminary test of the multi-beam injection was done by using the single bunch beam. The purpose of the test is to confirm the behavior of the bucket selection and to check the effect of the kicker pulse to the other stored beam. In order to store the two bunch beams in the DR, the beam is injected by following sequence. 1)The first beam is injected to #0 bucket. 2)The beam trigger is stopped and the injection/extraction kickers are stopped. 3)The set value of the bucket select TD2 changes to #n(n=100~280) bucket. 4)The injection kicker is triggered and the second beam is injected. 5)The beam is stopped and the injection kicker is stopped. These controls were done by the main control computer.

The stored current of the first bunch is 1.4mA. If the second bunch is stored as well as the first bunch and no effect on the first bunch, the stored current should be 2.8mA. The stored current vs. the bucket number of the second injection beam is shown in Fig.5. The data show that the injection efficiency of the #165 bucket(opposite side of the ring) is almost 100%, but the other positions are not good efficiency. It is assumed mainly it come from the effect of the pulse tail of the injection kicker .

5 Summary

A timing system for muti-bunch/multi-train beams has been installed to the ATF-DR. A precise trigger signals and a flexible bucket selection scheme were made by the combination of the hardware and PC control. A preliminary test of the multi-beam injection was done by using the single bunch beam. We confirmed the behavior of the bucket selection hardware and recognized the kicker pulse tail issue which should be improved for the 5 trains of muti-bunch beam operation.

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