How to make beam-filling patterns in the storage ring

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1. Introduction

In the SPring-8 storage ring, there are 2436 buckets which are filled with beams according to two beam-filling patterns. One is multi-bunch mode and the other is single-bunch mode. The multi-bunch mode is to fill many buckets in the storage ring with beams in one beam injection. On the other hand, the single-bunch mode is to fill a bucket with a beam in one beam injection. We can make beam-filling patterns in the storage ring with either of the two. To realize any beam-filling patterns that users make request, beam control system for the SPring-8 had been discussed in our group. Both frequencies of the SPring-8 linac RF (2.856 GHz) and the synchrotron RF (508.58 MHz) can not be connected with any integers and so no mutual relation made a beam handling difficult. Our solution was to develop very precise timing system. The timing system consists of three tools, such as a precise clock transmission of 508.58 MHz, a 508.58 MHz non-stop synchronous counter and pulse transmission line suppressed time jitter. They have been developed since 1992 and at last completed. Now precise timing system was installed in the SPring-8. Here we briefly explain how to realize beam-filling patterns in the storage ring by using the precise timing system.

2. Relation between the storage and the synchrotron rings

Both rings of synchrotron and storage are synchronized with 508.58 MHz frequency generated by a synthesizer. The fundamental frequency is transmitted with an optical fiber cable. The phase of the frequency is kept the accuracy of ±0.1° by phase lock loop (PLL). The bucket numbers are 2436 for the storage ring and 672 for the synchrotron ring, respectively. In case of single-bunch mode, both numbers are connected with the relation of

$$672 \times N1 + 84 \times N2 = 2436 \times N3, \quad (2\text{-}1)$$

where N1, N2, N3 are integers and 84 stands for the number of total synchrotron bucket number divided by eight. Thus we fill eight buckets of synchrotron with beams from the linac. The beams in eight buckets of the synchrotron ring are rejected to only one bucket in the storage ring [1]. All bucket numbers in the storage ring are always addressed by a 508.58 MHz non-stop synchronous counter [2]. If we would like to inject a beam into an aimed bucket in the storage ring, we only input the bucket number in a 508.58 MHz non-stop synchronous counter from a computer. This is a simple scenario about a single-bunch mode. On the other hand, concerning a multi-bunch mode, beam train with the time width of about 1 μsec is injected from the linac to the synchrotron. Then about 500 buckets in the storage ring are filled with beams. Therefore, five times beam injections from the linac make full-filled mode in all buckets of the storage ring. We, of course, can fill all buckets with beams using single-bunch mode, too. In this case, beam injections of 2436 times must be carried out. The beam filling time is about 1 sec.

3. Beam injection from the linac to the synchrotron

As above mentioned, no relation between RF frequencies of the linac and the synchrotron ring made us develop new three tools. Using them, beam injection timing signal is transmitted from the storage ring to the linac. The distance between them is about 1000 meters long. Time jitter measurement about a pulse transmission line was carried out using beam of the linac for 500 meters long optical fiber cable and was obtained about 8 psec as a standard error [3]. Pulse transmission tool with small time jitter made it possible that a beam from the linac is exactly injected into the aimed bucket in the synchrotron ring. In case of the single-bunch mode, 8 beams from the linac are injected into 8 buckets in the synchrotron as shown in

Fig.1. These beams are also injected into an aimed bucket in the storage ring. When we want to fill with a beam an aimed bucket in the storage ring, we only input the bucket number in a 508.58 MHz non-stop synchronous counter located in the storage ring. Likewise, if we want to fill bucket numbers from 1 to 10 with beams, we change the input number at the rate of 1 Hz. As a result, the bucket numbers 1 to 10 are filled with beams. Thus our system could realize any beam filling patterns. The beam handling system in the SPring-8 is schematically shown in Fig.2.

References

[1] H. Suzuki et al., SPring-8 Ann. Rep., 109 (1995)

[2] Y. Kawashima et al., SPring-8 Ann. Rep., 145 (1994)

[3] H. Suzuki et al., 9th Symp. on Accel. and tech., 252 (1993)

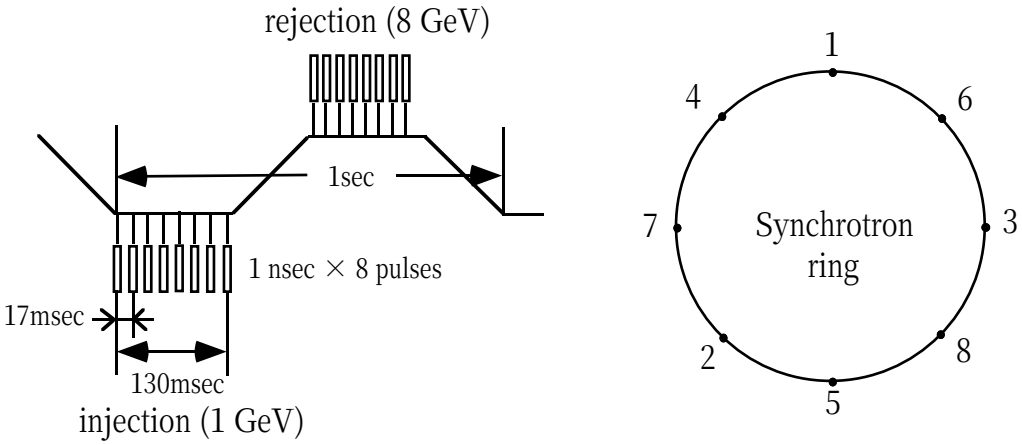

Fig. 1 In single-bunch mode, 8 beams with energy of 1 GeV are injected into the 8 buckets in the synchrotron ring where beams are accelerated to 8 GeV, then rejected to the storage ring. The numbers from 1 to 8 in the synchrotron ring refer to injection turns from the linac.

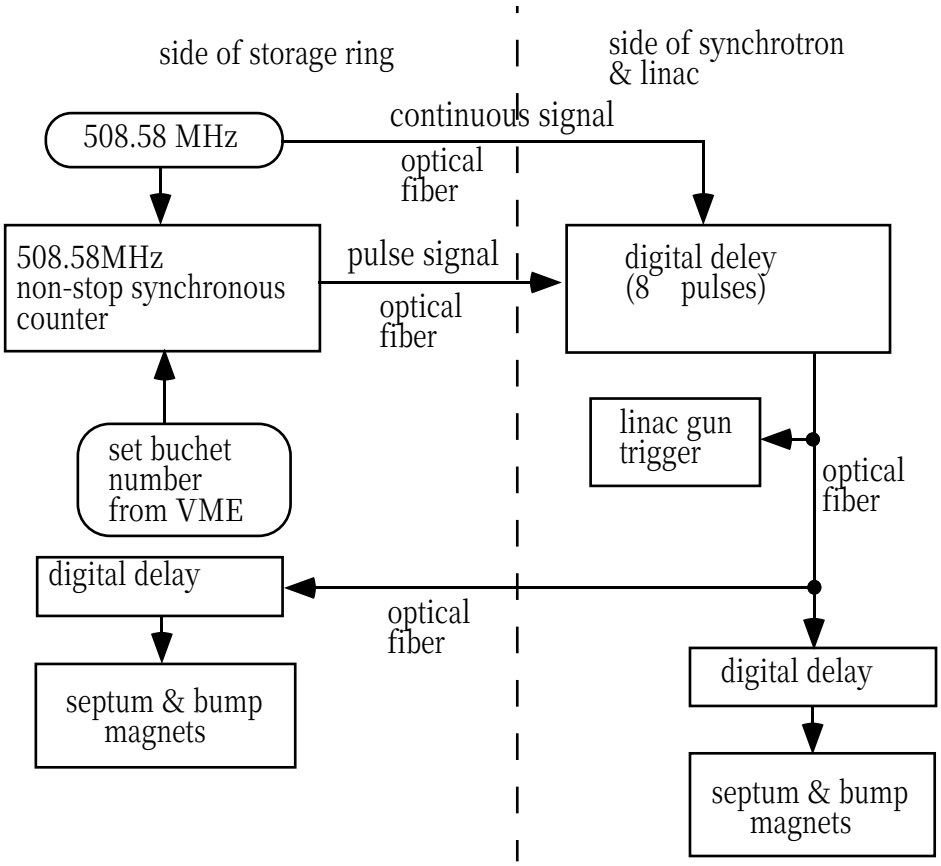

Fig.2 Block diagram of beam handling system in the SPring-8.