

RF-KO System for Single Bunch Mode Operation of a Storage Ring

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Abstract

A new RF-KO system for the single bunch mode operation of a storage ring has been developed. The knockout signal is modulated by the sum signal of the RF acceleration frequency of the storage ring and a bunch selection signal. We do not need any special device or a timing unit with this method. We obtain a high purity of bunch structure in a short knock out time. The single bunch impurity of 0.2% has been achieved.

1. INTRODUCTION

The single bunch mode operation of a storage ring is required for some experiments which use a long time interval. For example, a high purity and a high current of a bunch is essential for the Time of Flight experiments. Because a full bunch mode operation causes a coupled bunch instability which leads to the bunch lengthen, and degrades the peak current. In the case of the Free Electron Laser (FEL) experiments, the bunches in a storage ring are killed to get a high peak current. The other requirement is offered from the FEL experiments. Because the storage ring FEL has a small gain, we have to protect the mirror from the radiation damage caused by the useless bunches.

There are several method to get the single bunch mode operations. The short bunch injection system or the RF knockout (RF-KO) system realize the single bunch mode operations[1]. We have also tried to use the RF-KO method to get the 3-bunches mode operation for the FEL in the storage ring TERAS at Electrotechnical laboratory (ETL)[2]. The single bunch mode operation has also been tried in the TERAS and the FEL ring NIJI-IV. The principle of the RF-KO method is explained as follows. The bunched beam circulating a storage ring has a betatron oscillation in the transverse direction. We can shake the beam using the extra force synchronized to the revolution frequency of the beam and the betatron tune. If the beam shake is large to exceed the physical aperture of the storage ring, then the beam is lost. If we avoid the beam shaking only one bunch, we can get

the single bunch mode operation of the storage ring. Since the harmonic number of the TERAS is 18, our original RF-KO system employ the 1/6 frequency of the RF acceleration frequency. By using the 1/6 signal, we get the 6-bunch operation. The next step, we kill the half number of the residual bunches by use of the 1/12 frequency of the RF acceleration frequency. At last, we get the single bunch mode operation by the 171MHz divider to kill the useless bunches one by one. Figure 1 shows the wave form of the previous RF-KO system. However, there are several shortcomings in this system. 1) We spent a long time to get the single bunch. Consequently, obtainable bunch current was relatively low with the previous system. 2) Because the low frequency sinusoidal signals were employed in this system, the purity of the single bunch was relatively low. So a new RF-KO system is developed to overcome the shortcomings described above.

In this paper, we describe the design and the experimental result of the new RF-KO system installed in the TERAS.

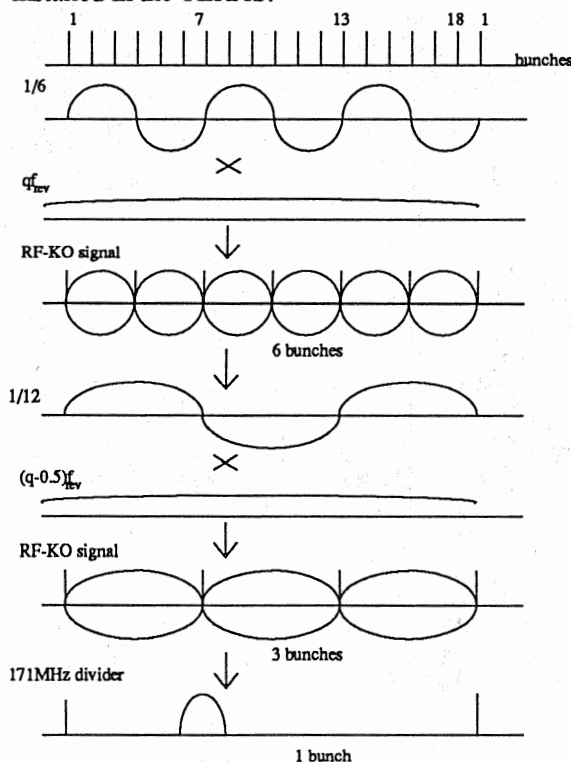


Fig.1 Wave forms of the previous RF-KO system.

II.RF-KO System

In order to get the single bunch mode operation in the storage ring, we employ the 1/2 frequency of the RF acceleration frequency for the RF modulation signal. Because an ordinal type of the double balanced mixer (DBM) is used as an RF switch, the number of knockout node is just same as the bunch number. If we use the 1/2 RF frequency signal as the modulation signal, the all bunches are homogeneously shaken and lost. So we add the bunch selection signal, the 171MHz divider output, to the 1/2 RF frequency signal. If the pulse amplitude and the shape of the

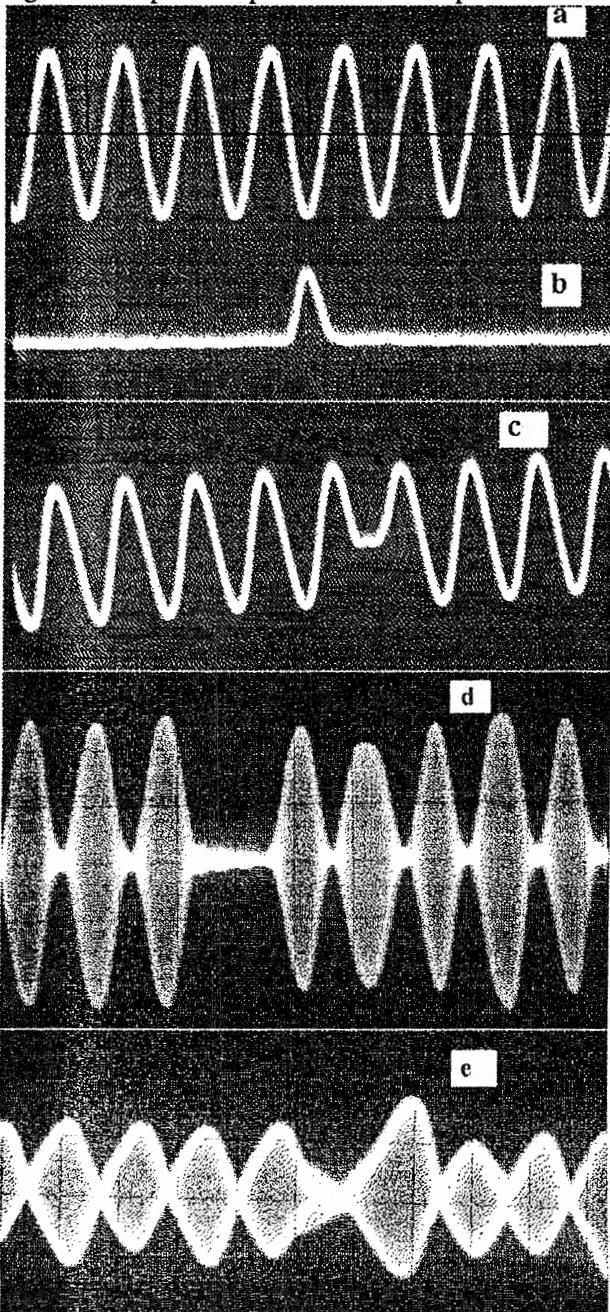


Fig.2 Wave forms of the new RF-KO system.a;1/2 frequency signal, b;bunch selection signal, c; a+b signal, d;RF-KO signal modulated by signal c, and e;a signal passing through the whole system.

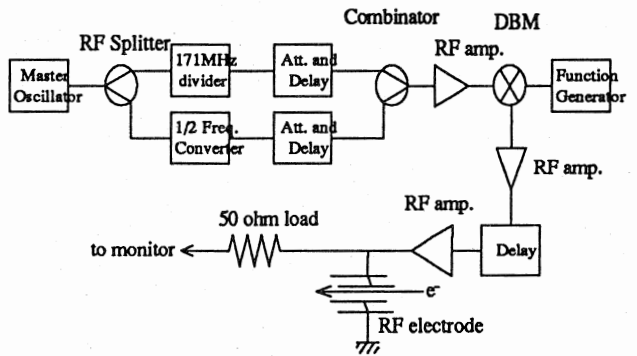


Fig.3 Block diagram of the new RF-KO system.

bunch selection signal are adjusted to the half sinusoidal wave form of the 1/2 RF frequency signal, we obtain a modulation signal for the single bunch mode operation. Then we mixed the qf_{rev} knockout signal to the modulation signal by use of the DBM in an ordinary way. In this expression, q is the fractional part of the vertical betatron frequency, and f_{rev} is the revolution frequency of the storage ring.

Figure 2 shows the wave forms of the new RF-KO system. In this figure, we show the wave forms of a; 1/2 frequency signal, b;bunch selection signal, c; sum of the signal a and the signal b, d;RF-KO (qf_{rev}) signal modulated by signal c, e;a signal passing through the whole system. Figure 3 shows the block diagram of the RF-KO system. Since we employ the 1/2RF acceleration frequency as the RF-KO signal, a high speed wideband RF amplifier is required for the system. Moreover, the impedance matching is very important to preserve the wave form of the RF-KO signal. In spite of the careful treatment of the high speed RF signals, the knockout signal passing through the system becomes dull, that is seen in fig.2.e.

Table 1 Parameters of TERAS.

Electron Linac: TELL (Operation)	
Energy	300 MeV
Peak Current	100 mA
Repetition	2 Hz
Storage Ring: TERAS	
Operation Energy	150-750 MeV
Injection Energy	300 MeV
Current	300 mA (750 MeV full bunch mode)
Circumference	31.4 m
Bending Radius	2 m
Betatron Tune	2.25(H), 1.25(V)
RF	171.695 MHz
Harmonic Number	18

III. Single Bunch Experiment

The RF-KO system was installed in the storage ring TERAS at ETL. The storage ring parameters are listed in Table.1. As is shown in Table 1, the RF frequency is 171.695 MHz and the harmonic number is 18. About 308 MeV electrons were supplied from the electron linac TELL. The repetition was 2 Hz and TERAS was filled with 300 mA electron in a few minutes. At the first step for the single bunch mode operation, we kicked the only one bunch by use of the RF-KO signal modulated by the bunch selection signal only (fig.2.b). In this way, we confirmed the timing of the KO bunch. There is dull in the modulated RF-KO signal, we had to adjust the timing between the RF-KO signal and the bunches carefully. After the timing was set, the knockout was done during the injection into the TERAS.

Figure 4 shows the wave form of the single bunch observed with the pickup electrode. We did not process the signal from the pickup electrode, so the bunch shape was not seen clearly. However, the unnecessary bunch was too small to distinguish the differential signal of the main bunch and the unnecessary ones. The single bunch mode operation was succeeded with the new RF-KO system. In order to observe the purity of the single bunch mode operation, we measured the time structure of the beam circulating the storage ring by use of the multichannel plate(MCP). Figure 5 shows the time structure of the single bunch mode operation. We can see the residual bunch at 77 ns, that is the synchronous time just before RF bucket of the main bunch (at 83 ns). However, the time structure of the single bunch mode operation is quit pure. Consequently, the single bunch impurity is about 0.2%.

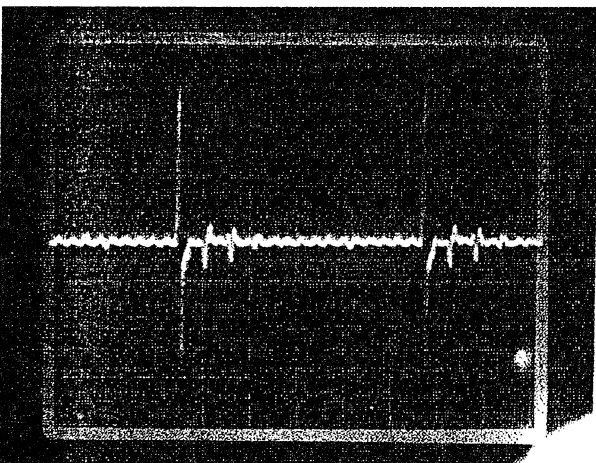


Fig.4 The signal from the pickup electrode.

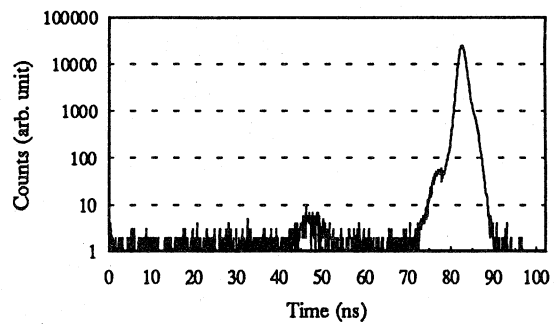


Fig.5 Time structure of the single bunch mode operation measured with a MCP.

V. Conclusion

We have developed a new RF-KO system for the single bunch mode operation of a storage ring. The knockout signal is modulated by the sum signal of the 1/2 RF acceleration frequency of the storage ring and a bunch selection signal. The system was installed in the storage ring TERAS at ETL. We obtain a high purity of bunch structure in a short knock out time. The single bunch impurity of 0.2% has been achieved with this system. If we use the several bunch selection signals, we can obtain any bunch pattern of the storage mode with the new RF-KO system.

Acknowledgements

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