Several-bunch Beam-operation of SPring-8

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Abstract

Multi-bunch, single-bunch and several-bunch beam-operations were tested during commissioning of SPring-8. In the beam-operations, aimed rf buckets of the storage ring could be repeatedly filled with a beam from the booster synchrotron. The multi-bunch beam with a bunch train of 1 μs or 40 ns was injected from the linac to the synchrotron, the single-bunch beam was formed by an rf knockout system (RFKO) in the synchrotron and the beam was injected into the storage ring.

1. Introduction

Multi-bunch, single-bunch and several-bunch beam-operations of electron or positron beam were designed in the storage ring. Multi-bunch beam-operation means uniform filling of all rf buckets in the storage ring. This beam- operation of electron was mainly carried out at the beginning of the commissioning and it has occupied the most part of user's time. Several-bunch beam-operation means filling of equally-spaced several rf buckets. Filling in 21 rf buckets has been adopted for users of beam-lines. Single-bunch beam-operation means that only one rf bucket is filled with electrons. This beam-operation has not been provided for users because of short lifetime and small stored current.

2. Multi-bunch beam-operation

At first the beam commissioning of the synchrotron was practiced in the multi-bunch mode operation of an electron beam with the bunch train of 40 ns and 1 ms from the linac [2]. The beam commissioning of the storage ring was also started in the multi-bunch beam-operation with the bunch train of 1 ms and 40 ns. The maximum stored beam current per pulse in the storage ring was about 0.5 mA for 1 ms and about 0.2 mA for 40 ns. To store a beam current of 20 mA of which value was limited by the radiation security, many beam pulses of 1 ms or 40 ns were injected in the storage ring repeatedly. When the beam current was decreased to less than 15 mA, the beam was injected again. The beam from the synchrotron were almost put into the aimed buckets of the storage ring, and it was exactly confirmed by a single- bunch mode operation.

3. Several-bunch beam-operation

In the storage ring the multi-bunch, the single-bunch and the several-bunch beam-operations are required. However it takes a few days to replace a circuit of a gun grid-pulser for the multi-bunch beam-operation by that for the single-bunch beam-operation. An experiment which converts a multi- bunch beam from the linac into a single-bunch beam with RFKO installed in the synchrotron, was tested.

The beam is kicked out in the vertical direction by RFKO at an injection energy of 1 GeV. Because a vertical aperture is smaller than the horizontal one, a damping time of 0.87 s at 1 GeV is estimated to be longer than that of 2 ms at 8 GeV and the required RFKO power at 1 GeV is smaller than that at 8 GeV. A phase difference of rf currents on the four electrodes for RFKO must be 180 degree alternately as shown in Fig. 1.

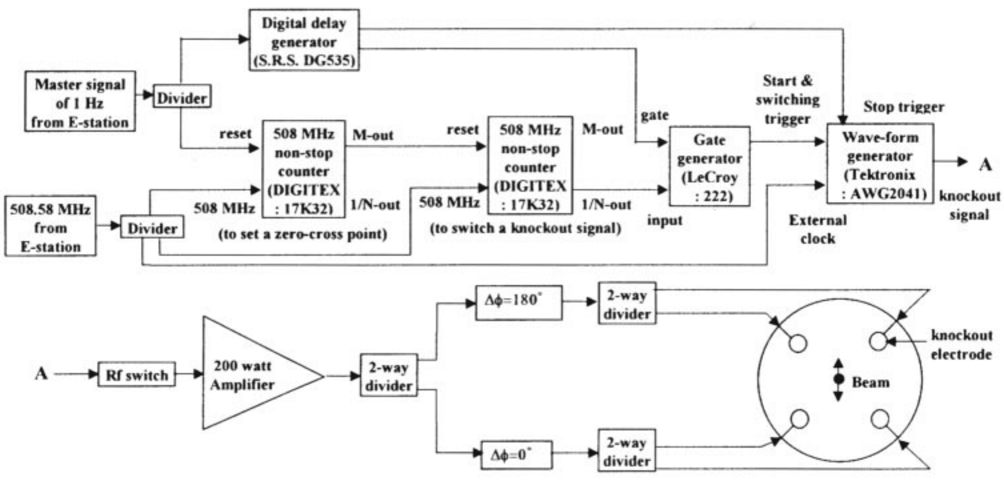

Fig.1. Block diagram of RFKO for the formation of the single-bunch mode

The maximum rf power is 50 watt per electrode. The beam is kicked out at a resonance point of a vertical betatron oscillation, and the beam is lost within about 30 ms after the beam injection. The condition of the resonance is expressed in equation (1).

$$f_{knockout} = [n \pm \{\nu_y - \mathrm{Int}(\nu_y)\}] \times f_{revolution} \quad (1)$$

n : 0 or positive integer

where $f_{revolution}$ is a revolution frequency of the synchrotron and its value is 756.8 kHz, νy is a vertical tune and Int(νy) means an integer of ny. The vertical tune value were selected to 8.7833. Fig. 1 shows a block diagram of RFKO for a formation of the single-bunch beam-operation. The bunch train of 1 µs or 40 ns for the multi-bunch beam-operation is injected into the synchrotron, most of the beams are kicked out at the vertical betatron resonance with RFKO and only one bunched beam remains. A signal of RFKO is made by composition of a sine wave resonating with vertical betatron oscillation and three rectangle pulse of $f_{rf}/12$, $f_{rf}/21$ and $f_{rf}/32$. Eq. (2) is the RFKO signal for the single-bunch beam-operation.

$$V_{knockout} = V_0 \sin(2\pi f_{rf}/376)t \times \mathrm{rectangle}(2\pi f_{rf}/m)t \quad (2)$$

m : 12, 21, 32

f_{rf} is a radio frequency of 508.58 MHz. f_{rf} /376 means the knockout frequency of 1.3526 MHz. It corresponds to n=1 and plus sign in Eq. (1). The least common multiple of 12, 21 and 32 is equal to a harmonic number of 672. There are only two points of a revolution cycle at which the beam is not kicked out commonly by three kinds of the RFKO signal. If the beam is not injected at one point but at the other point, only one bunched beam remains. The three kinds of RFKO signals are switched at intervals of 40 ms one after another in a flat bottom of 150 ms [3][4]. Fig. 2 shows a signal for RFKO. Fig. 3 shows a waveform of four equally-spaced bunches in the storage ring changing the aimed bucket four times. An interval of bunchs is 609 buckets. Fig. 4 shows a beam profile of 21-bunch beam-operation. The profile was measured in BL09 with a photon counting method. There is no satellite bunch because there is no intensity at a distance of more than 2 ns from a main peak. The intensity of the main peak is about 8×10^{-6}. The impurity is less than 10^{-6}.

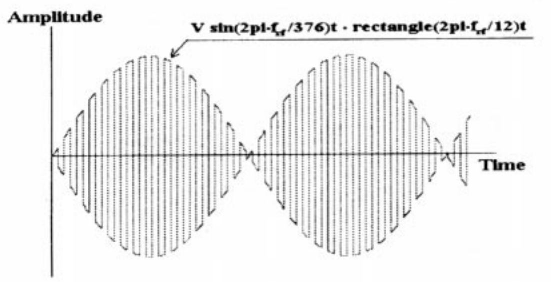

Fig.2. Signal for RFKO.

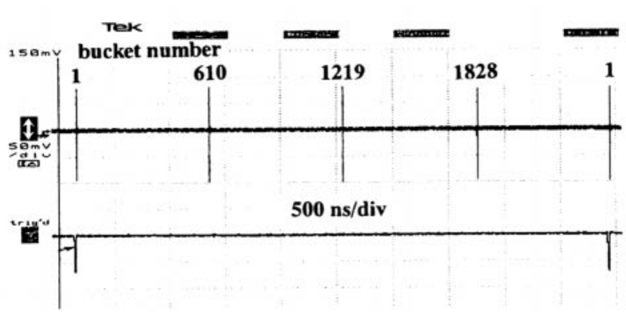

Fig.3. Wave-form of four equally-spaced bunches in the storage ring changing the aimed bucket four times.

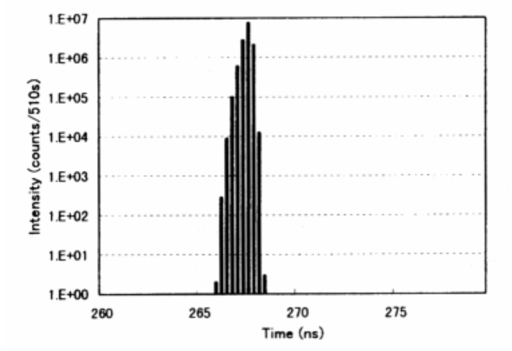

Fig.4. Beam profile of 21-bunch beam-operation.

4. Conclusion

A performance is confirmed with the multi-bunch, the single-bunch and the several-bunch beam-operations. The commissioning of SPring-8 was succeeded smoothly. The beam is supplied steadily to the storage ring.

The single-bunch-beam was successfully made from a bunch train of 1 µs or 40 ns with RFKO in the synchrotron.

We could realize the single-bunch and several-bunch beam- operation with an impurity of less than 10^{-6}. The impurity is defined as a ratio of a number of electrons in a neiboring bunch to that in an aimed bunch. The impurity in the storage ring was measured with the photon counting method. The 21-bunch beam-operation in the storage ring was really provided for users. When the stored beam current decreased to be less than 12 mA, we could pile the beam current into the same 21 bunches up to 19 mA. An increase in impurity was not observed in the restoration. The deterioration in purity was not observed at all.

References

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