Beam Quality in Single Bunch Mode of UVSOR Ring

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The UVSOR storage ring is a synchrotron radiation light source for the molecular science and its related fields. The radio frequency of the ring is 90 MHz and its harmonic number is 16. The pulsed light is supplied with the period of 11 ns, when all buckets of the ring are filled. The storage ring can be operated in the single bunch mode when the longer pulse period is required. In this mode, the period of the pulsed light is 180 ns, which is the revolution period of the beam in the ring. The single bunch is made in the booster synchrotron and it is transferred to the only one bucket of the ring. The usual impurity (the beam population in non-aimed buckets/that in the aimed bucket) is 1×10^{-4} just after the injection at the beam energy of 600 MeV. Bunch lengthening and widening were also measured in this mode. The coupling impedance of 4 Ω of the ring was obtained with this measurement.

Introduction

Two methods to store a single bunch in the storage ring were tried.[1] At the first time, a nano-second grid pulser method was tried. The grid of the electron gun of the linac is excited by a short pulse which is synchronized to a certain bucket of the synchrotron, and only this bucket can be filled with electrons. Another method is an RF knockout method. All bunches except two bunches in the synchrotron are destroyed by a deflector which excites a betatron side band, and one of two survivors is transferred to the ring. The latter has the advantages of the operation and maintenance. In the early days, the knockout signal was modulated by the sinusoidal wave synchronized to the revolution of the beam to leave two bunches. With this method one bunch in two is dumped before injection into the ring and it is difficult to kill the other without influence on the bunch. The improvement of the RF knockout system was carried out to survive only one bunch as described in the next section.[2] To measure the electron populations of the bunches in the single bunch mode operation of the ring, a photon counting system is equiped. With these systemes, we can supply the synchrotron radiation in the single bunch mode beam with impurity of 10^{-4} just after the injection to the users. Main parameters of the UVSOR ring is shown in Table I.

TABLE I

Energy	E	600-750 MeV
Mean radius	R	8.47 m
Circunference	C(=2 R)	53.2 m
Bending radius		2.2 m
Revolution frequency	f_{rev}	5.63 MHz
Radio frequency	f_{rf}	90.1 MHz
Harmonic number	h	16
Momentum compaction factor	$_p$	0.026
Peak RF voltage	V_0	75 kV
Synchrotron frequency	f_s	16-14 KHz

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RF Knockout System

The beam circulating in the synchrotron is lost if the frequency of the transverse excitation satisfies the following condition:

$$f_{ko} = \begin{cases} qf_{rev} \\ (1-q)f_{rev}, \end{cases} \qquad (1)$$

where f_{ko} is the frequency of the excitation, q the decimal part of the tune value and f_{rev} the revolution frequency of the synchrotron. The knockout signal is modulated by a signal synchronized to the revolution frequency to leave one bunch. The principle of this system is illustrated in Fig. 1. The based

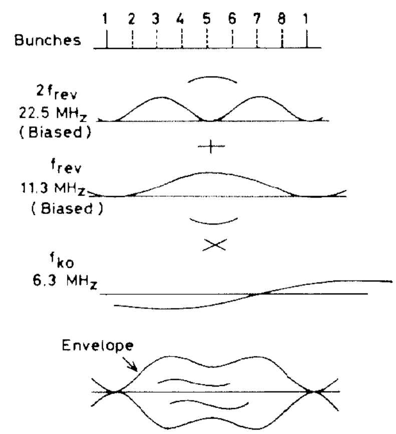

Fig. 1 Wave forms of RF knockout system.

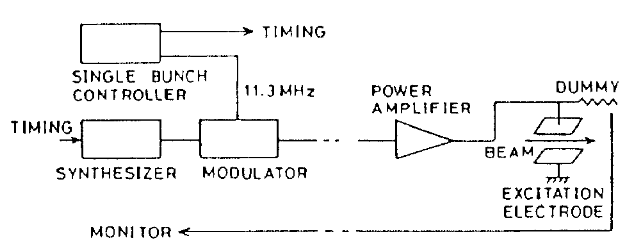

Fig. 2 Blockdiagram of RF knockout system.

fundamental component in the modulation signal knocks out all bunches except aimed one and the second harmonic kills the adjacent bunches perfectly. Figure 2 shows the blockdiagram of the RF knockout system. The burst signal from a synthesizer(Kikusui, Model FGE 3250) is modulated with a modulator. The spectral lines of the modulated signal

$$f = f_{rev} \pm f_{ko} + 2f_{rev} \pm f_{ko} \qquad (2)$$

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occur. The frequency coverage of the system must be at least 5-29 MHz. The modulated signal is transmitted from the control room to the synchrotron and amplified by a wideband power amplifier(ENI, model A300). The beam is vertically excited through a excitation electrode which consists of two parallel plates. An example of the knockout signal at the electrode is shown in Fig. 3. The lower trace in this figure shows the beam signal monitored with a beam intensity monitor which is a fast current transformer.

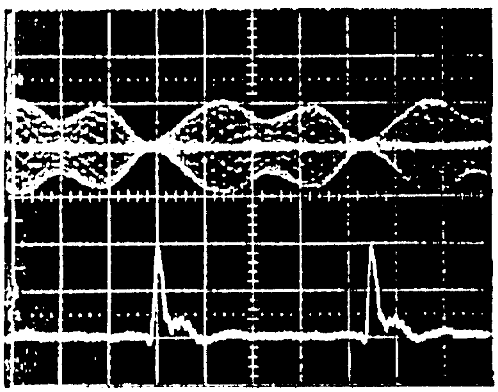

Fig. 3 Knockout signal at electrode (upper trace), Single bunch in Synchrotron (lower trace).

Photon Counting System

The electron populations in the bunches are measured with a photon counting system, the block diagram of which is shown in Fig. 4. Photons emitted in a bending magnet of the ring are reflected by a metal mirror and visible part of the photons are passed through a glass window to an atmosphere. The

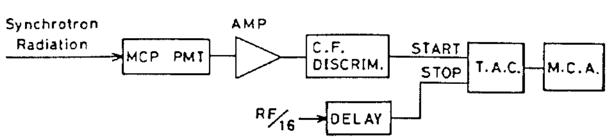

Fig. 4 Blockdiagram of photon counting system.

intensity of the photons is decreased with a slit placed at the outlet of the window in order to suppress a miss count in this system. The photons are detected by a channel plate-type photomultiplier(PM) (Hamamatsu Photonics, R156U) and the output signal of the PM starts a time-to-amplitude converter(TAC; TENNELEC, TC864). The TAC is stopped with the signal synchronized to the revolution frequency. The time interval between the two signals is corresponded to the position of the bunch train in the ring and is converted to the amplitude by the TAC. The output of the TAC is analyzed by a multichannel analyzer (NORLAND, IT-5400) as shown in Fig. 5. Each peak is proportional to the electron number of each bunch and the highest peak in this figure is 0th bucket and the lower peaks correspond to the following buckets(1st, 2nd ...).[3] In this figure the analyzer was started to accumulate the signals at the beginning of the user time, when the beam current was 10.7 mA and the duration of the measurement was 2000 seconds. The counts of the 0th, 1st and 2nd peaks are 657000, 70 and 30 counts, respectively.

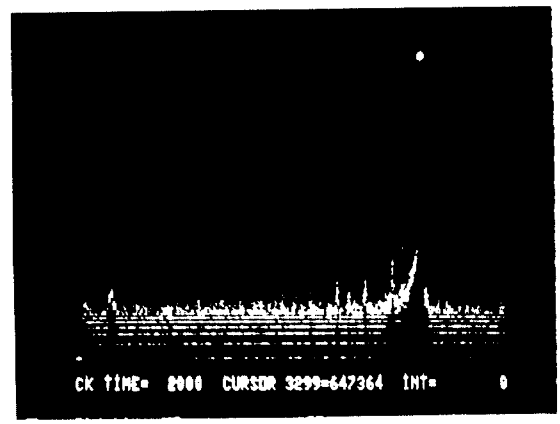

Fig. 5 An example of the electron population in the buckets. The peak intensities are proportional to the electron numbers of the buckets. The ordinate shows the intensity in arbitrary unit of logarithm.

Conclusion

With the RF knockout system which makes the single bunch mode of the UVSOR ring, we supplied the single bunch beam of 10 mA at the beginning of the user time with the impurity of 1×10^{-4} and recently we can supply the beam current of 25 mA to the users. The impurity in the single bunch mode of the UVSOR ring becomes worse by the order of 10^{-3} within several hours after the injection. This phenomena was explained by the recapture of electrons scattered by the Touschek effect. The greater part of the machine studies is performed in the single bunch mode. We measured the beam-current dependence of the bunch lengthening in the single-bunch mode and estimated the longitudinal coupling impedance of the UVSOR ring of about 4 Ω.[4] Since the ion trapping effect hardly occurs in the single bunch mode operation, this mode is suitable to observe effects of insertion devices on the tune. It is also suitable to clarify the behaviour of the beam, since the single bunch is free from the coupled bunch instabilities.

Acknowledgement

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