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Abstract

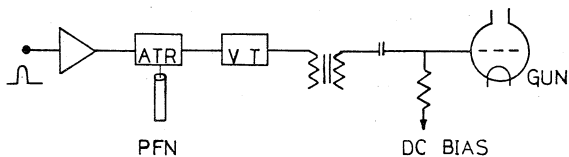
UVSOR is a 600 MeV electron storage ring dedicated to ultraviolet synchrotron orbital radiation research in molecular science and related fields. The injector is a 600 MeV electron synchrotron with a 15 MeV linac. The radio frequency of the storage ring and the synchrotron is 90 MHz. (Harmonic numbers of them are 16 and 8 respectively.) Therefore, the period of the pulsed light is about 11 nsec, when all buckets of the storage ring are filled. Some experiments require the longer pulse period. Single bunch can be injected into the storage ring for that purpose. In this case the pulse period is elongated to 180 nsec which is the revolution period of the storage ring.

Introduction

Two methods to store a single bunch in the storage ring were tried. First, "nano-second grid pulser" method was tested. 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 storage ring. As the radio frequency systems of the two rings are synchronized, it is easy to transfer the bunch from the bucket of the synchrotron to the bucket of the storage ring. As the ratio of the harmonic numbers of the two rings is 2, two buckets of the storage ring are synchronized to a bucket of the synchrotron. Therefore the transfer timing must be synchronized to either of the two buckets. These two methods can be used together to improve the purity which is the ratio of beam current in the single bunch to total current.

Nano-second Grid Pulser

As the bucket width of the synchrotron is about 10 nsec, a short beam must be injected into the bucket or the adjacent buckets are also filled. We decided the pulse length of 5 nsec (FWHM) taking jitters of the grid pulse into consideration. The grid circuit of the electron gun was slightly changed, i.e. the termination resistor was attached because it had no matching network for the old micro-second pulser. The nano-second grid pulser was installed on the top of the pulse transformer tank of the electron gun. The channels of the nano-second pulser and the micro-second pulser are switched by coaxial switches. The blockdiagram of the nano-second pulser is shown in Fig.1. A pulse forming circuit consists of avalanche transistors and a coaxial cable which forms a pulse forming network. The formed pulse is amplified by a three stage vacuum tube amplifier and fed to the grid of the gun.



ATR : AVALANCHE TRANSISTOR PULSER
 VT : VACUUM TUBE AMPLIFIER

Fig. 1 Blockdiagram of Nano-second Pulser

A pulse shape monitored at the pulse divider of the output circuit of the pulser is shown in Fig. 2. Pulse width is slightly longer than the designed value. Though the pulse length of the beam of the linac ought to have been measured, it was difficult to measure because of the poor frequency response of the current transformer in the linac. For that reason we observed adjacent buckets to the aimed bucket of the synchrotron and the storage ring. The result is discussed in the following section.

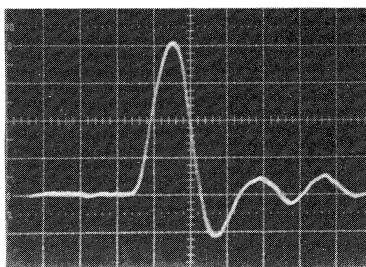


Fig. 2 Output Pulse of Pulser (5 ns/div)

RF Knockout Method

An RF Knockout system in the synchrotron which was installed to measure numbers of betatron oscillations (tunes) is diverted to the single bunch forming system. The knockout signal must be modified, as all bunches are destroyed without the modification. A blockdiagram of a circuit which generates the knockout signal is shown in Fig. 3. Two sinusoidal waves whose frequencies are f_{rev} (revolution frequency in the synchrotron) and qf_{rev} (q is the fractional part of tune) are generated, a signal proportional to the product of them is formed by means of a double balanced mixer (DBM), the signal is amplified and supplied to the deflector of the knockout system. Two bunches which correspond to π and 2π phases of the revolution frequency survive as the knockout signal vanishes at these phases, and all bunches except them are killed. One of two survivors must be selected and injected into the storage ring. As a rise time of the fast kicker magnet of the extraction system is about 60 nsec and an interval between two bunches is 44 nsec, only one of two survivors can be extracted.

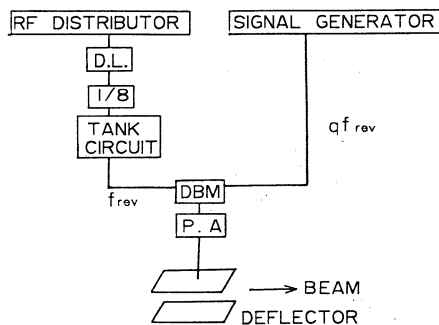


Fig. 3 Blockdiagram of Knockout System

Timing Circuits

The short electron beam must be injected into a specially fixed bucket of the synchrotron, extracted from the bucket and injected into one of two buckets of the storage ring which are synchronized to the bucket of the synchrotron as described before.

Trigger pulses of the injection into the synchrotron and the extraction from it (or the injection into the storage ring) are controlled by a main timing system which consists of a master pulse generator and digital delay circuits. The master pulse generator triggers power supplies for synchrotron magnets. When magnetic field of the magnets reaches previously fixed values, the injection and the extraction systems are triggered. Though we have a magnetic field monitor system (B-clock system), we use digital delay circuits which generate trigger pulses equivalent to ones generated by the B-clock system, as the stability of the magnetic field is sufficient after about one hour warm-up.

These trigger pulses are not synchronized to the RF buckets. The synchronization is done by a single bunch control module of which blockdiagram is shown in Fig. 4 . Main circuits of the module are octal and binary counters and fast D-type flip-flop circuits. The counters count the radio-frequency from a master oscillator for the acceleration system. The octal counter marks a certain bucket in eight buckets of the synchrotron and the binary counter marks one of two buckets of the storage ring which are synchronized to the fixed bucket of the synchrotron. The trigger pulses from the main timing system are synchronized to the marked bucket by means of the D-type flip-flop circuit. A variable delay line between the master oscillator and the single bunch control module is used to compensate a signal delay in cables and transit time of the beam in a beam transport system.

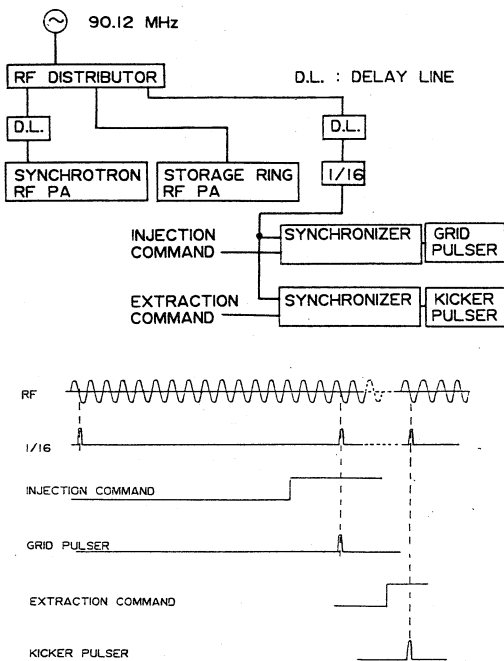


Fig. 4 Timing System

Experimental Results

The single bunch was stored successfully using the nano-second grid pulser in March. The beam current in the single bunch was too weak to measure. The beam current was not improved because of a bad condition of a tuner of the storage ring RF cavity. The RF phase between the synchrotron and storage ring jumped suddenly, and some buckets adjacent to the fixed bucket were also filled. The second try of the single bunch storage using the nano-second pulser is not done yet, and it must be done as soon as possible.

The RF knockout method was also tried in August. The vertical deflector was used, because the required voltage for the vertical knockout is smaller than the

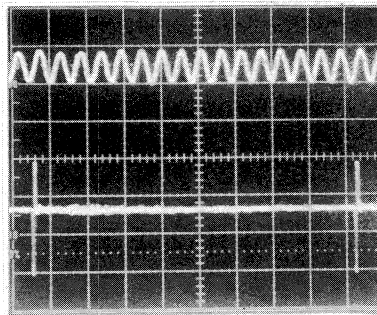


Fig. 5 Single Bunch
in Storage Ring
(20 ns/div)

horizontal one. When energy of electrons was about 90 MeV, the knockout voltage was supplied, as the change of tune was small at this energy level. The single bunch formed by the knockout method is shown in Fig.5. Upper. and lower traces of Fig. 5 show the cavity voltage and the signal from a button monitor. Only one bucket in sixteen buckets is occupied, and background current is too small to measure.

Discussions

The single bunch was stored successfully. Single bunch purity required by users is better than 99% (This figure depends on experiments.) i.e. background current must be less than 1%. In the case of the nano-second pulser, the purity is determined by field emissions from the electron gun and the accelerating structure of the linac. The background current due to the field emissions is estimated at about 1%. As an observation of the short beam from the linac is difficult as mentioned before, this figure is not confirmed yet.

In the case of the RF knockout method, factors which determine the background current are the tune spread of low energy electron beam in the synchrotron, phase jitters of the knockout voltage, unstable tune due to flickering of the power supply for the synchrotron magnets and so on. We have no way except oscillograms of the single bunch to measure the low background current precisely for the present. The background current measured by the oscillograms is less than few percents. If the better purity is required, the nano-second pulse and the RF knockout method can be used together.

Acknowledgement

We would like to thank K. Yoshida of INS and K. Takami of KURRI for their suggestions in several discussions, and also our many colleagues in the UVSOR group who contributed to this work.