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MEASUREMENTS OF BUNCH CURRENT AND BEAM TIMING FOR TRISTAN

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Abstract

The currents in the circulating bunches of the TRISTAN ring are measured remotely through the CAMAC interfaces which are supported by the minicomputers. Signals which are induced to a current transformer by the circulating bunches are converted to digital data by charge-sensitive ADC. The selection of one bunch from the circulating bunches is done by digital delay CAMAC modules with 508MHz RF clock, which generate the sampling gate pulse for ADC, from a revolution frequency. The currents in the bunches, that spaced at more than 80nsec intervals, are selectively obtained with accuracies less than ±0.1mA.

Measurements of beam timing (the timing of the circulating bunch measured with respect to the timing of the revolution frequency) are done using the bunch signal from a button electrode by a simple CAMAC system. Since the measurement accuracy of the beam timing is less than ±150psec, the relative bucket address of the circulating bunch is obtained correctly.

Introduction

An electron-positron colliding beam facility , TRISTAN , consists of three accelerators : a 2.5GeV linac , an 8GeV accumulation ring(AR) and a 30GeV main ring(MR). AR is operated in the single bunch mode, in which only one of the 508MHz RF buckets is filled with beam, for the main ring injection. MR has four beam interaction points for high energy physics. It stores electrons and positrons in 2 x two 508MHz RF buckets.

The MR orbit has 5120 RF buckets and the AR orbit 640 RF buckets at intervals of about 2 nsec, respectively. The AR/MR revolution frequency gives one of the 640/5120 RF buckets on the AR/MR. We call it the bucket address "#0". A symmetrical bucket of "#0" is the bucket address "#320/#2560". 550MHz digital delay CAMAC modules(TD-2)[1] are used to select an arbitrary bucket address of the 640/5120 RF buckets.

The current measurements of stored e^+/e^- single bunches are an indicator of the overall condition of a storage ring because they are affected by technical faults or instabilities. Therefore, the bunch current information is most helpfull to support the operator.

It is essentially important to inject bunched beams into MR to satisfy the colliding condition in physics run. Furthermore, it is also important in the accelerator operation to supply trigger timing signals for the beam transfer system[2,3], bunch currents monitor system , tune measurements and RF/magnetic beam damper sytem. Therefore, the beam timing must be measured within a precision of ±1/2 bucket.

In this paper, we describe the data taking processes for the measurements of the bunch current and the beam timing. The accuracy of their measurements is discussed and the summary is given.

Data Taking Process

Bunch Current

We selected a current transformer(CT) signal for the measurements of the bunch current, since the CT signal is independent on the transversal position of the bunch and is very sensitive to the bunch current. Their photographes of the CT signal for AR and MR obtained at the central control room(CCR) are shown in Fig.1. The rise time is less than ~3nsec and the fall time less than ~30nsec. The CT signal has a long undershoot and is repeated at the period of the revolution time (~1.2μsec for AR, ~10μsec for MR).

Data taking for the bunch current is done through 2249A ADC CAMAC module manufactured by LeCroy. This ADC is charge-sensitive and direct-coupled. Its digitizing time is 60μsec. The negative signal area in the first

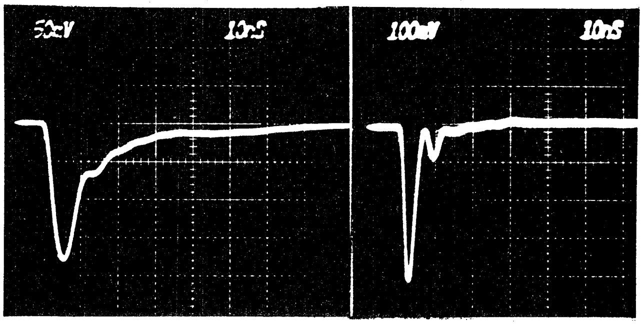

Fig.1. Typical examples of the CT signals at the ADC input terminals. (a) The CT signal of ~10mA e^- bunch in AR. (b) The CT signal of ~1mA e^- bunch in MR. Horizontal scale: 10nsec/div.

gate pulse after data clear is digitized. Therefore, the block diagram of the measurement system includes 2 WAY-180° Power Splitter in order to invert the CT signal, as shown in Fig.2.

The timing of the gate pulse for ADC is changed to measure the bunch current in an arbitrary bucket. The start pulse of TD-2 generated from the revolution frequency is delayed until the timing of the selected bucket by TD-2. The gate pulse of ADC is selected from two output pulses of TD-2 modules (AR/MR) by the EGC CAMAC module. The output pulse is changed to the gate pulse with ~30nsec pulse width by the discriminator. CSY CAMAC module is designed such that the ADC gate pulse dosen't coincidence with data clear pulse. The computer dosen't give the clear command to ADC but writes a flag to CSY. CSY goes out ~300nsec delayed pulse from input one to the external fast clear terminal of ADC and the flag is cleared by the output pulse, after the flag is written to CSY. Delaying the CT signal with ~30nsec by a cable delay, the correction data in the same gate pulse are measured in order to cancel the influence of the overshoot of the CT signal. Fig.3 shows the typical examples of the relation between the gate pulse and the CT signal.

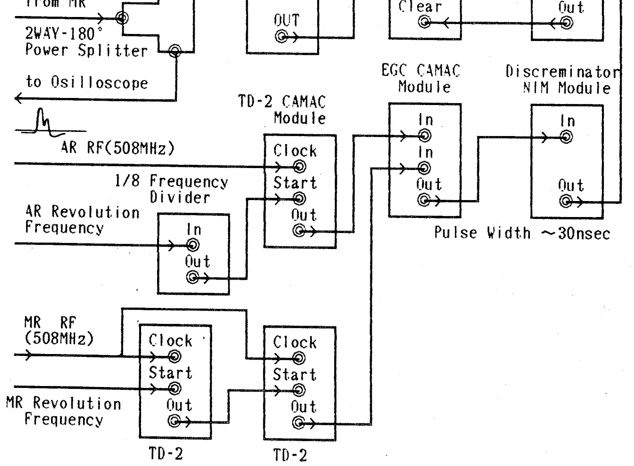

Fig.2. Block Diagram of the Measurement System for the Bunch Current.

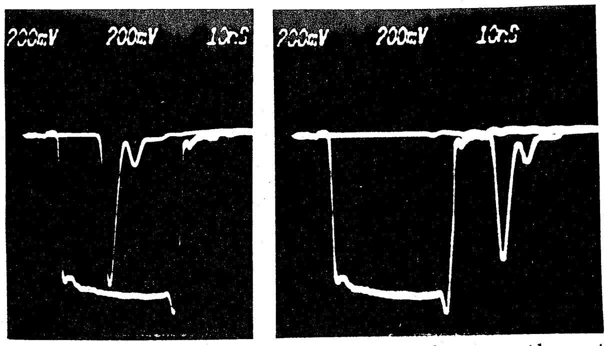

Fig.3. Typical example of the relation between the gate pulse and the CT signal. (a) The gate pulse and the CT signal are matched by the TD-2 modules. (b) The gate pulse and the CT signal delayed with ~30nsec by the cable delay.

Data taking routine is summarized as following:

I. The gate timing is matched to the bunch after the selection of the gate pulse.
II. The before data of ADC is cleared.
III. After checking of the finish of the data conversion, two data are obtained.
IV. After substraction of the correction data from main data and multiplying the normalization factor, the bunch current is obtained.

The bunch current is selectively obtained through NODAL functions[4] which contain the routine from I to IV, if the bucket address of the bunch is given within the accuracy of a few buckets.

Beam Timing

We briefly describe the measurements of the beam timing. Fig.4 shows the block diagram of this system. The start pulse timing of the TDC is changed by TD-2, according to the data table which the information of the bunch address given from the beam transfer system[3] is written.

The TDC used in this system is the LeCroy model 2228A. The bunch signal of the positron is the short bi-polar pulse with a reverse-phase of the electron one as shown in Fig.5. The first negative peak of the bunch signal is converted to ~30nsec NIM pulse by a constant fraction (CF) discriminator. Utilizing the time difference between the inverting signal and the non-

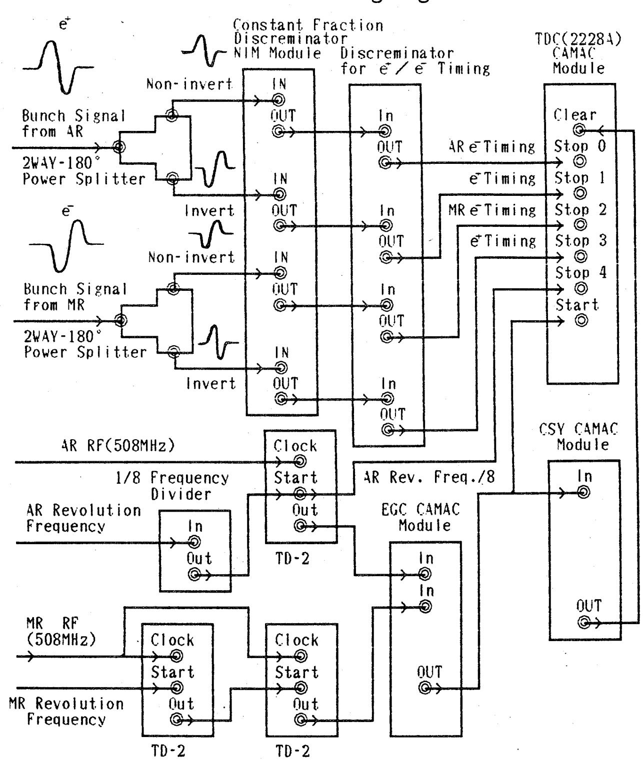

Fig.4. Block Diagram of the Measurement System for the Beam Timing.

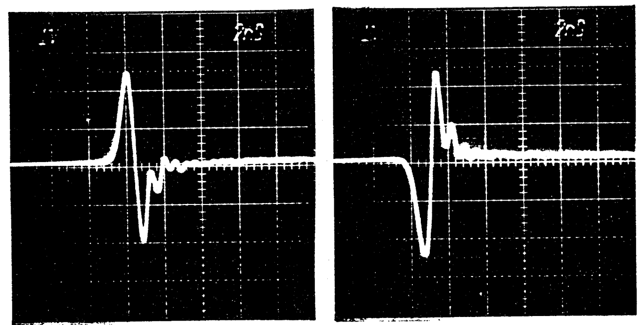

Fig.5. Oscilloscope photographs showing the bunch signals at CCR. (a) The positron bunch in MR. (b) The electron bunch in MR. Vertical scale: 1V/div., Horizontal scale: 2nsec/div.

inverting signal, the beam timings for the positron and the electron are separated. The start pulse of TDC is selected from two revolution timings (AR/MR) by the EGC module. The clear pulse of TDC is made with same method as the bunch current measurement by the CSY module.

Because the bunch signal more than the threshold level of the CF discriminator is necessary to generate the bunch timing pulse, the level of the bunch signal is checked by the measurement of the bunch current.

Data taking routine is summarized as following:

I. The start pulse is selected after the offset data are loaded to TD-2 modules according to the data table.
II. The before data of TDC is cleared.
III. After checking of the finish of the data conversion, the time difference is obtained.
IV. After multiplying the calibration factor and the addition of the offset data, the bunch adress is obtained.

The beam timing is measured through NODAL functions[4] which contain the routine from I to IV, if the bucket address of the bunch is given within the accuracy of a few buckets.

The total precision of these measurements

Bunch Current

We discuss the relation of the gate pulse and the CT signal digitized by ADC, according to Fig.6. In order to correct the influence of the overshoot, the pedestal of ADC is adjusted to about 40. As shown in Fig.6, if digital values of each area are indicated by S_0,S_1,S_2 and S_3, and if the pedestal by P, the digital value of ADC obtained by the gate pulse 1 is $(P+S_0-S_2)$ and one by the gate pulse 2 is $(P-S_3)$. Therefore, the value obtained by NODAL functions is $(P+S_0-S_2)-(P-S_3)=(S_0+S_3-S_2)=(S_0+S_1)$. (S_0+S_1) is proportional to the area of the CT signal in the gate pulse 1.

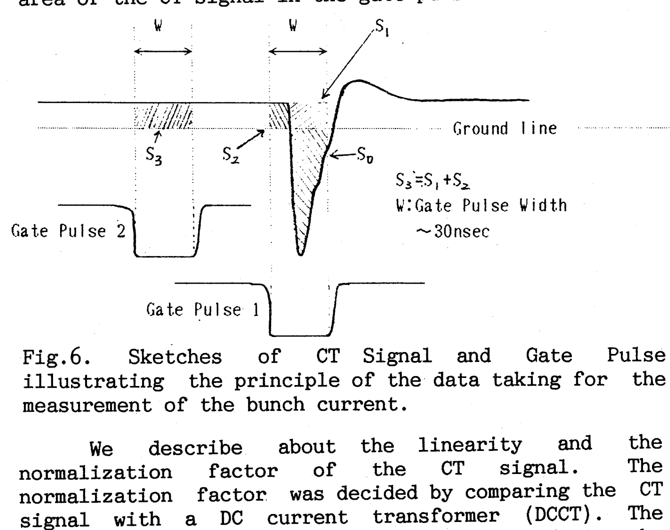

Fig.6. Sketches of CT Signal and Gate Pulse illustrating the principle of the data taking for the measurement of the bunch current.

We describe about the linearity and the normalization factor of the CT signal. The normalization factor was decided by comparing the CT signal with a DC current transformer (DCCT). The linearity of the CT signal was investigated in the single bunch mode. The results are shown in Fig.7. We obtained almost perfect linearity in the range from 0mA

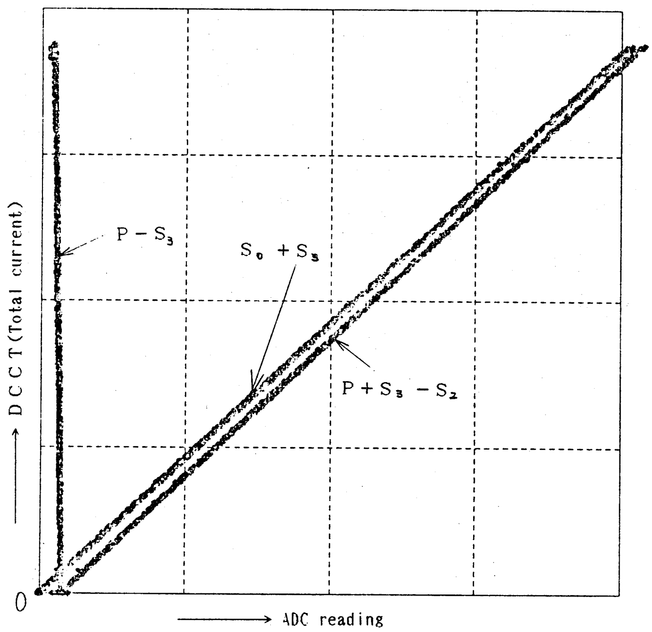

Fig.7. Linearity of the measurement system for the bunch current of AR.

to 30mA in the case of the AR CT signal and from 0mA to 3mA in the case of the MR CT signal.

We investigated how the relation between the bunch current and the bucket address depends on the width of the gate pulse. The width of the gate pulse is carefully adjusted to ~30nsec in order to obtain the precision of ±0.1mA. Ratios of the total current measured by DCCT to the summation of the bunch current were obtained in the vicinity of the correct bucket address(±10 buckets). The results are shown in Fig.8. One can see that the total current measured by DCCT is equal to the summation of the bunch current within the accuracy of 1% from the correct bucket address to ±2 buckets. Therefore, we can confirm the bucket address of the bunch with a precision of ±2 buckets.

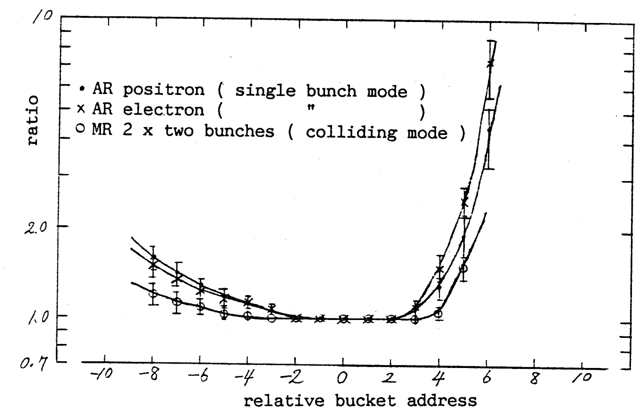

Fig.8. The ratios of the total current measured by DCCT to the summation of the bunch current obtained in the vicinity of the correct bucket address(±10 buckets).

The minimum measurable limit of the bunch current is discussed by the investigation of the noise involved in the CT signal at CCR. Its noise is less than 3.0mV except for the beam injection and extraction. Due to the high sensitivity of the CT signal, it is possible to measure upto ~10μA. From the CT signal shape and the influence of the overshoot, the bunch currents, that spaced at more than 40 buckets intervals in the multi-bunch operation, are selectively measured with accuracies less than ±0.1mA by this system. In this case, the pick-up electrode of the CT signal must be set at the middle point of the nearest colliding points. Since the noise level of the CT signal is about ten times among the beam injection or extraction more than others, the measurment accuracy is ~±0.5mA for AR and ~±0.1mA for MR in the beam transfer.

Beam Timing

The time difference between the AR revolution/8 and the MR revolution is measured in order to adjust the beam transfer timing.[2] The precision of this measurement is less than ±150psec.[3] The measurement accuracy of the beam timing is also less than ±150psec since the fall time of the bunch signal is ~1nsec. Therefore, the relative bucket address which the beam is injected is obtained correctly.

Conclusion

The measurement of the bunch current has successfully continued to provide the helpfull information for the accelerator operation, during the last about one year. An typical example of the bunch current measurements in the MR electron-positron

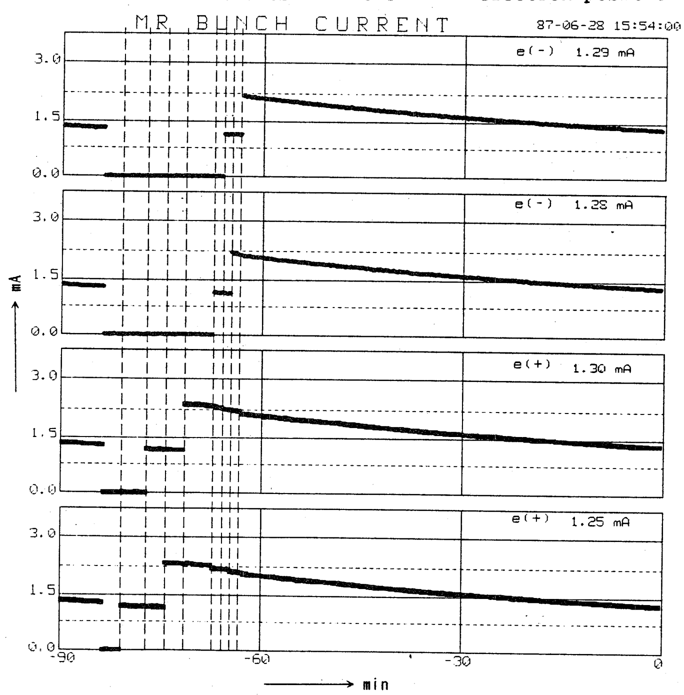

Fig.9. An example of the bunch current measurements in the MR electron-positron colliding mode.

colliding mode is shown in Fig.9. One can easily see the beam loss at the injection timing from the bunch current display with the mark showing the injection timing. The currents in the bunches, that spaced at more than 80nsec intervals, are selectively obtained with accuracies less than 0.1mA.

The bunch address is confirmed within a few buckets by the measurement of the bunch current but it is essentially important to monitor the beam timing within a precision of ±1/2 bucket for the colliding operation. The beam timing is measured using the bunch signal from a button electrode by a simple CAMAC system. Since the measurement accuracy of the beam timing is less than ±150psec, the relative bucket address of the circulating bunch is obtained correctly.

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