Beam Monitors and Transverse Feedback System of TRISTAN Main Ring

T. Ieiri, H. Ishii, J. Kishiro, Y. Mizumachi, K. Mori, K. Nakajima, A. Ogata, T. Shintake and M. Tejima

National Laboratory for High Energy Physics (KEK)
Oho, Tsukuba, Ibaraki 305, Japan

Introduction

The construction of 30 GeV TRISTAN Main Ring (MR) started in 1983 soon after the commissioning of 8 GeV Accumulation Ring (AR). We have prepared 392 position monitors, 6 synchrotron radiation monitors, 9 screen monitors, 2 DCCT's, 3 scrapers, 12 bunch monitors, transverse feedback systems for two beams and DC separators. Since the required monitoring devices of AR and MR are almost the same, the experiences in AR were very useful in the design of MR monitors. [1] However, machine parameters of two rings are very different and we had to review the performance of each item. From the monitor point of view the most important is the difference of revolution frequency; 794.6 kHz for AR and 99.33 kHz for MR. This means that average beam current of MR is 1/8 as small as AR current with the same bunch number and intensity. Therefore, the sensitivity of each monitor must be better in MR. The second difference is that MR should be used as a collider from the beginning. Therefore we must prepare for multi-beam and multi-bunch operation. The layout of whole instrumentations are indicated in Figure 1.

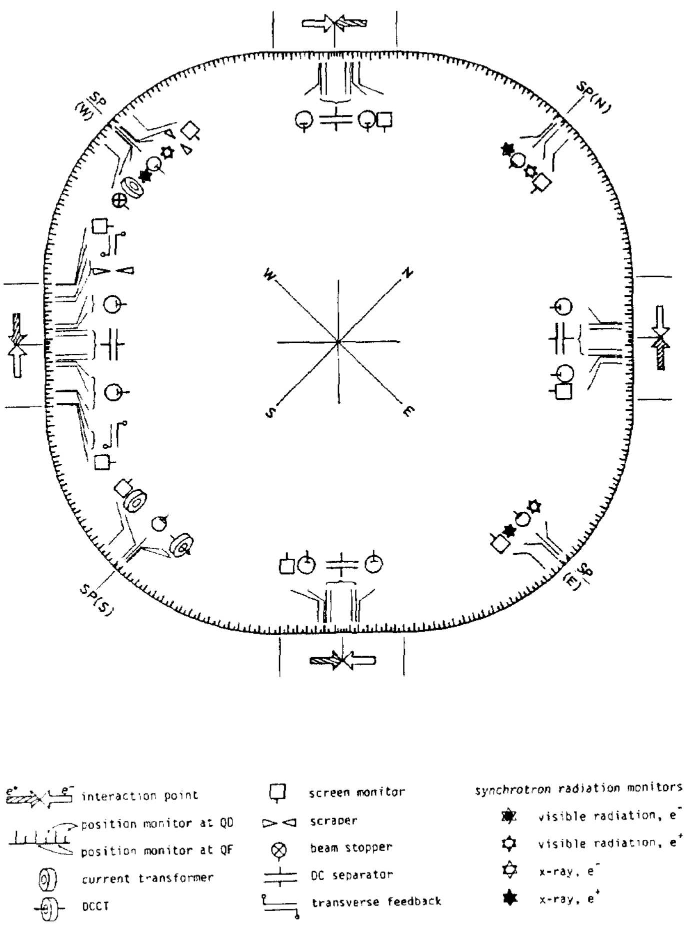

Fig. 1 Distribution of beam equipments in MR

Position Monitors

System Configuration

We have prepared a position monitor at each Q magnet. Among 392 monitors 288 are on race-track chambers and 104 are on circular ones. There are twelve local control buildings around the MR ring. Therefore, we divided 392 monitors in 12 groups, each group sending signal to the assigned local control building. Each group is divided into three or four subgroups, each subgroup using a common signal cable up to the local control. We detect signals of each group with a single electronics selecting a monitor and its electrode one by one by the action of coaxial relays.

Detector Circuit

We adopted superheterodyne circuit (same as in AR) which picks up a particular harmonics component of revolution frequency from bunch signals. Detection frequency is the same as for AR (~380 MHz) but for MR it is 479th x 8 = 3832th harmonics. Block diagram of the circuit is shown in Fig. 2. Input RF filter and the following two mixer circuits are almost the same as in AR circuit but we introduced a third heterodyne stage to increase the sensitivity. In the final synchronous detector circuit we have a phase lock loop preparing against possible RF frequency change. One big advantage of harmonics detection scheme is that we can measure the beam position near the interaction points even when we have colliding bunches. This feature is very useful in making fine orbit adjustment during the physics experiments.

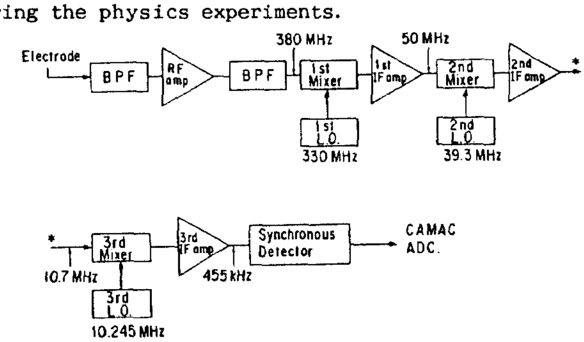

Fig. 2 Block diagram of position monitor electronics

Calibration of Monitors

Calibration of all the monitor was made before the final welding work. We set a signal source antenna at the position (X,Y) and measure the four electrode outputs A,B,C,D and then get the normalization of the signals as H=(A+D-B-C)/(A+B+C+D) and V=(A+B-C-D)/(A+B+C+D) [2]. The calibration were made at 231 points in the central chamber area of 20 mm x 12 mm with 1 mm steps. We fitted forth order polynominals of two variables to the 273 calibration data to convert (X,Y) into (H,V) or vice verca for each of 392 monitors. Using the same data, we have obtained three electrode calibration in which we obtain the relation between (X,Y) and the three electrode normalization (H',V'). For example, if we take three elctrodes BCD, H'=(2D-B-C)/(2D+B+C) and V'=(2B-C-D)/(2B+C+D).

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Monitor Error Check

In actual closed orbit measurements, we sometimes obtain false position data in a few monitors mainly due to poor contact in coaxial switches. To reject a false data we have developed the following software check. We measure the four electrode outputs, obtain the beam position using the four electrode calibration and then copare it with the positions derived from three electrode calibrations. If all electrode signals are correct, we will get the same result from the five combinations of (ABCD), (ABC), (ABD), (ACD) and (BCD). Indeed, we found that five results agree well with deviations less than 0.01 mm. Therefore, we can abandon the data when there are large deviations among the five results although we cannot identify which electrode signal is wrong. We now use this procedure in the closed orbit measurement.

Cable Check

A monitor error occurs when the cable connection is wrong between a monitor electrode and the detector circuit. However, it is not an easy task to check the cable connection all the time because the position monitors are distributed along the ring tunnel of 3017 m long. Therefore, we have developed a system with which we can find wrong cable connections or uncertain coaxial relays as shown in Fig. 3. We select a monitor electrode one after another with a relay driver and then send current to the monitor from a constant current source. The voltage at the cable input depends on the condition of the signal line. The voltage is very much different from the normal value if the cable is open somewhere or the electrode is shorted to the chamber wall. The whole check takes about 10 minutes.

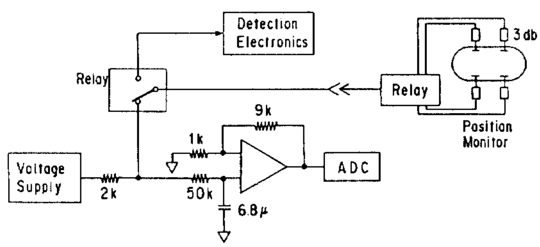

Fig. 3 Cable check circuit

Synchrotron Radiation Monitors

The place for synchrotron radiation monitors in the MR lattice is extremely restricted because of the tight arrangement of magnets and RF cavities. We can use only the symmetry point (SP) regions. We have installed main optical monitors in the west and x-ray monitors in the east. The layout of the optical system is shown in Fig. 4.

Optical Devices

A head Be mirror plate in the vacuum chamber reflects the visible component of synchrotron radiation out into the air. The thickness of the mirror is 10 mm but within this thickness a hole of 5 mm diameter is bored through at the beam level to reduce the effective thickness. The mirror plate is mounted on a water cooled aluminunm block. The second and the third remote controllable mirrors guide the light upwards into the surface local control building. We can make the adjustment of optical devices without interrupting the beam operation [3]. The synchrotron light is focussed by a telescope and this light is split by half mirrors and supplied to a TV camera, a CCD array, an optical fiber array and a streak camera.

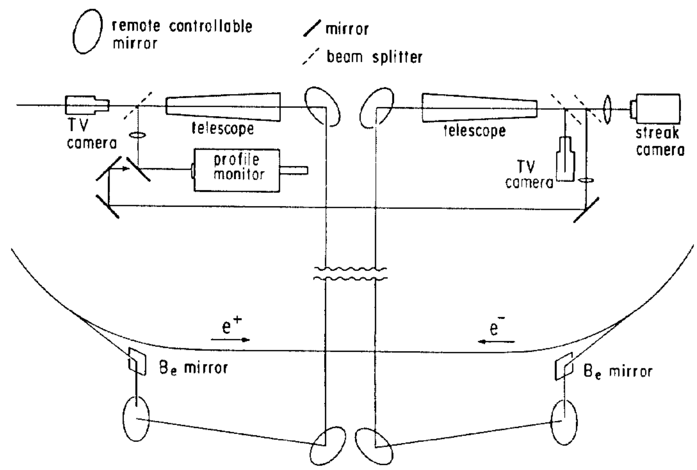

Fig. 4 Layout of optical monitor

The length between the source point and the devices are about 25 m. TV display is monitored all the time as a general diagnosis tool.

Streak Camera

We can measure the time structre and one dimensional space distribution of the light pulse with a streak camera [4]. It has time resolution of 2 psec and very powerful in the observation of bunch lengthening. Recently a dual time base streak camera has been developped which can display multiple periods of a light pulse on a single display (Hamamatsu C1587). Fig. 5 shows an example of the display of two diagonal MR bunches for several revolutions.

Fig. 5 Display of dual time base streak camera

Profile Monitor

Beam profile is monitored by an array of optical fibers which send a light pulse successively to a photomultiplier(PM) [5]. We store the output of PM in a transient digitizer for later investigation. Fig. 7 shows the mountain view display of horizonal profile when the bunch shows a large synchrotron oscillation. In this figure transverse profile movement is observed owing to the dispersion at the source point.

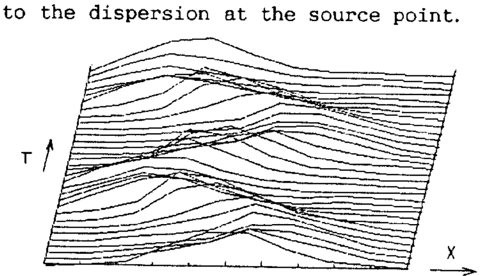

Fig. 6 Digitizer display of beam profile

Current Monitors

Total stored beam current is monitored by a DCCT of the same type as AR. We have installed two identical sets in the ring, one for general machine control and the other particularly for RF power level control. From the experience in AR we took some distance between DCCT cores and lattice magnets to avoid the influence of magnetic field, which disturbs the DCCT during enegy ramping. Two current transformers have been installed at two symmetry points where electron and positron bunches come with equal interval. The dimension of the ferrite core is 18 cmOD x 14 cmID x 3 cm. The output signal is sent to the control room with about 300 m corrugated coaxial cables.

Transverse Feedback System

Feedback System

Transverse system consists of stripline pickups, bunch oscillation detectors(BOD), phase shifters, power amplifiers and deflectors. Fig. 7 shows the block diagram of the system for one beam. Two stripline pickups of 30 cm long are installed in a dispersion free straight section. One is for a horizontal motion and the other for a vertical motion. The pickups form 50 ohm line with a circular vacuum chamber with one end connected to the electron BOD and the other end to the positron BOD. They have directivity with respect to the beam motion if it is terminated with a matched load. Actual directivity is 18 dB in the frequency region below 300 MHz. The bunch oscillation detector detects the amplitude modulation of the bunch signals and hence a coherent oscillation.

We prepared two travelling wave type deflectors in the ring. One is for electron beams and the other for positron beams. The deflector consists of four pararell rods of 260 cm long. The rod also forms 50 ohm line with the chamber wall. The available kick strength is 1.28 gauss*meter. We adopted travelling wave RF structure rather than a standing wave structure because the separation of electron and positron bunch at the deflector is rather short (600 ns) for a resonant structure to make an individual feedback for each of four bunches.

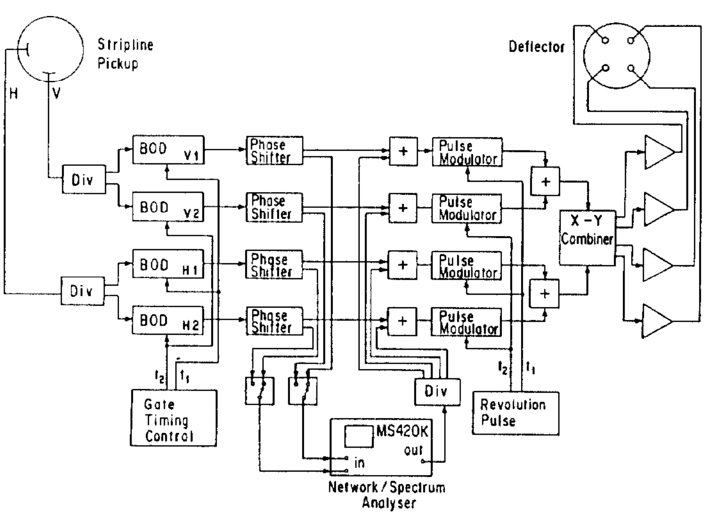

Fig. 7 Transverse feedback system

Since MR is equipped with a large number of RF cavities, a strong excitation of coherent transverse dipole instabilities was anticipated at the design stage of MR. The growth rate by the full set cavities was estimated by RF group for TM 111 mode in the APS cavities as 1200/sec with 2x2 beams at 8 GeV with intensty 5mA/bunch [6]. In the actual beam operation, obtained damping rate is 3500/sec at 6.5 GeV (with feedback gain 60 dB).

Tune Measurement

Betatron frequencies are measured with a two-channel network/spectrum analyser (Anritsu MS420K) and with the transverse system. The beam is kicked by the tracking generator output of MS420K and the response of the beam is detected by the BOD and then analysed and displayed on the scope. Fig. 8 shows the analyser display for the vertical oscillation. With this system we can observe a tune shift during the beam collision and estimate the luminosity.

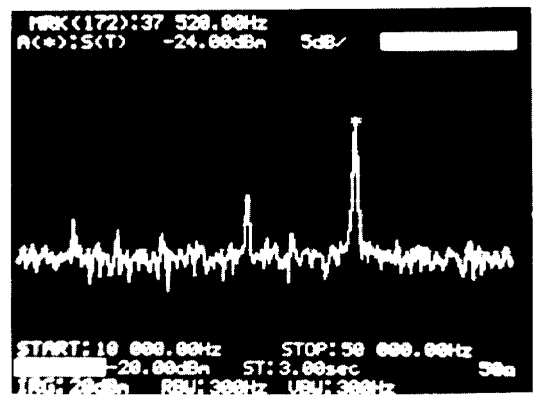

Fig. 8 Tune measurement display

Acknowledgements

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