MEASUREMENT OF LOCAL LONGITUDINAL LOSS FACTOR USING BPM IN TRISTAN MR

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Abstract

The TRISTAN operated as a light source at 8 GeV and 10 GeV during the later part of 1995. We use BPM to record the beam orbits as functions of their currents and RF voltage in TRISTAN main ring (MR), and in this way measured the beam energy saw contributed mainly by both synchrotron radiation and parasitic losses. The energy loss due tothe synchrotron radiation is about 4 MeV per turn in TRISTAN MR at 8 GeV, which is of the same order of magnitude compared to the estimated parasitic effect in the ring other than the RF section. The synchrotron radiation effect on the beam energy is eliminated by subtracting two sets of BPM readings for different beam current or RF voltage and then determine the local property of the longitudinal impedance in the ring. In this paper, the principle and the procedure of the measurement are described, and also the results are discussed in comparison with the calculation.

1 INTRODUCTION

After the completion of the high energy physics program, TRISTAN Main Ring (MR) operated as a light source at 8 GeV and 10 GeV from middle of September to end of December 1995. The lattice was modified so that a 5.4 m long undulator was able to be installed and a low-emittance beam could be achieved [1]. Table 1 lists the major parameters for the light source of TRISTAN MR.

Table 1 Main Parameters for the Light Source of TRISTAN MR

Beam energy	GeV	8 - (10)	
Beam current	mA	16	
Bunch number		1, 8, 16, 32	
Phase per cell μ_x/μ_y		90° / 90°	
Tune ν_x/ν_y		47.611/40.769	
α_p		0.000739	
RF voltage	MV	(80) - 103	
Damping wiggler field	T	0	1.4
Radiated energy per turn	MeV	1.54	3.93
$\tau_{x,y}/\tau_E$	ms	105/52	41/20
σ_E	10^{-3}	0.496	1.25
σ_{z0}	mm	1.91	4.83
Natural Emittance ε_x	nm	4.62	4.73

The emittance wigglers were applied to enhance the radiation-damping rate in order to reduce the emittance and stabilize the coherent beam instability. In the meantime, 64 out of 104 normal RF cavities and all superconducting cavities were removed from the ring to reduce the higher-order modes impedance. The detailed performance of the TRISTAN MR light source will be reported elsewhere in this conference [2]. It is one of our major interests, from the machine point of view, to study the impedance behavior in the new configuration of TRISTAN MR.

2 ENERGY SAW IN TRISTAN MR

Figure 1 exhibits the layout of the TRISTAN. The remaining 40 RF cavities in MR are placed in the straight sections of the Oho region.

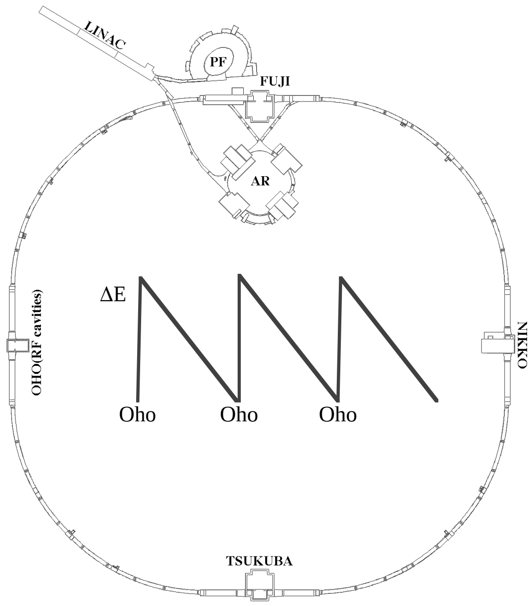

Fig. 1 Layout and Energy Saw of TRISTAN MR

Electrons lose their energy in the ring due to synchrotron radiation, interaction with metal environment and other mechanisms, while gain energy from the RF cavities so that the tip of the energy saw is right at the exit of the cavities and the base at its entrance, see Fig. 1. The energy saw can be measured with beam position monitors (BPM) in the regions with non-zero dispersion. However, in order to measure the parasitic energy loss due to electron-environment interaction in the ring, the

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contribution of the synchrotron radiation should be taken out.

3 LONGITUDINAL LOSS FACTOR

The energy loss in accelerator rings due to impedance is proportional to the longitudinal loss factor as an integral over the real or resistive part of longitudinal impedance times the bunch spectrum. Four types of components, namely 40 RF cavity, 160 RF bellows, 32 gate valve bellows and 560 shielded bellows, were considered as the major contributors to the impedance in TRISTAN MR. The loss factors contributed by these components were computed using the computer code ABCI [3]. Figure 2 shows the computed longitudinal loss factors for different bunch length. It can be seen from Fig.2 that the major parts of the longitudinal loss factor k_L come from RF cavities and the longer the bunch the smaller the k_L.

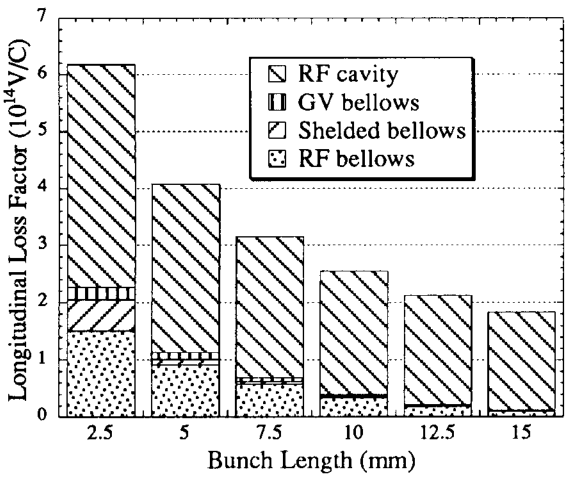

Fig. 2 Longitudinal Loss Factor Computed with ABCI

Longitudinal loss factor can be measured globally by detecting the synchro-phase as a function of beam current:

$$k_L = f_0 V_{RF} \cos\phi_s \frac{d\phi_s}{dI_b} \qquad (1)$$

where f_0 is revolution frequency, ϕ_s the synchrotron phase, V_{RF} the RF voltage and I_b the beam current.

Figure 3 gives the results, which show that the measured k_L = 6.3x10^{14} V/C for V_{RF}=103 MV when bunch length is roughly 5 mm for bunch current between 0 to 2 mA. This means the measured k_L is about 2.2×10^{14} V/C or 50% larger than the calculated. It is assumed that some of the impedance sources have not yet been taken into computation. In this case, the local impedance measurement may help to locate the hidden sources.

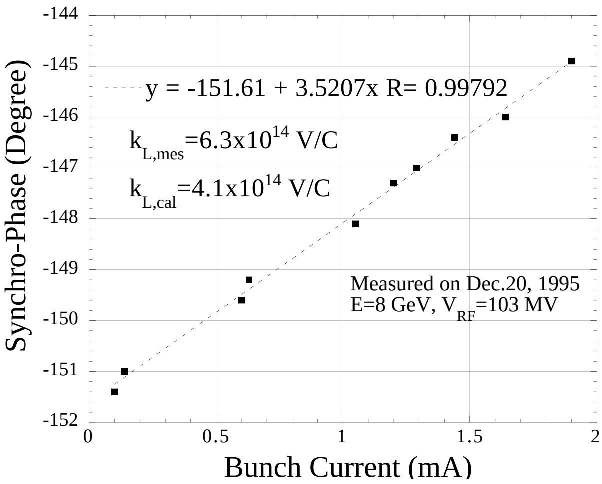

Fig. 3 Global Longitudinal Loss Factor

4 LOCAL LONGITUDINAL LOSS FACTOR MEASUREMENT

The parasitic energy loss in the RF regions is compensated simultaneously by the cavities themselves. By using BPM's, one may measure the local property of the longitudinal loss factor in other parts of the ring.

$$k_L = \frac{Ef_0}{e\eta_x} \frac{\Delta x_{c.o.}}{\Delta I_b} \qquad (2)$$

where η_x is the dispersion at the local component and $\Delta x_{c.o.}$ is the orbit change for the differential bunch currents ΔI_b.

It is found from Fig. 2 that k_L contributed by gate valve bellows and shielded bellows is about 3×10^{13} V/C for σ_z=5 mm, which may cause an energy loss dE/dI_b= ek_L/f_0 = 0.3 MeV/mA or an orbit displacement of 0.02 mm/mA at the maximum dispersion of 0.5 m in the MR light source configuration. This shows that it is possible to detect the local longitudinal loss factor in TRISTAN MR where the BPM resolution is around 20~50 μm [4].

4.1 Orbit scaled with bunch currents

The distribution of the energy loss around the ring can be obtained by comparing the orbit difference for two bunch currents. The measurement was done for different bunch currents from 0.1 mA to 2.0 mA at RF voltages of 103 MV, 50 MV and 20 MV. The bunch length measurement in TRISTAN MR shows no significant lengthening or shortening in this bunch current range. Figure 4 displays the distribution of longitudinal loss factor measured with BPM’s. The step between exit and entrance of the RF cavities in Oho region shows the total loss factor in the ring other than the cavities.

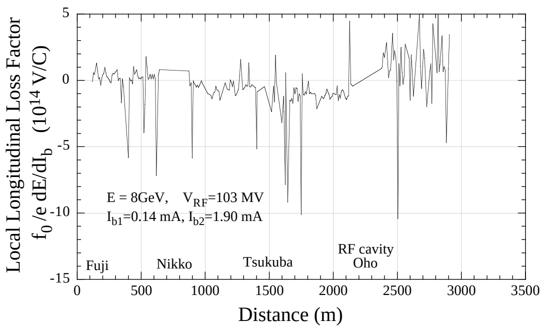

Fig. 4 Measured Longitudinal Loss Factor

4.2 *Orbit scaled with RF Voltage*

It can be found from Fig. 2 that the longitudinal loss factor reduces significantly with increasing bunch length. This provides a way to investigate the differential loss factor around the ring for the different RF voltage. The orbit was measured for a bunch current of 0.4 mA with RF voltages of 10, 15, 30, 50, 70, 90 and 110 MV. Each of the orbit sets is compared with the orbit at 10 MV when the bunch length is the longest of about 15 mm. The differential loss factor is expressed as

$$\Delta k_L = \frac{E f_0}{e \eta_x} \frac{\Delta x_{c.o.}}{I_b} \qquad (3)$$

Figure 5 shows the differential loss factor for V_{rf1}=10 MV and V_{rf2}=110 MV.

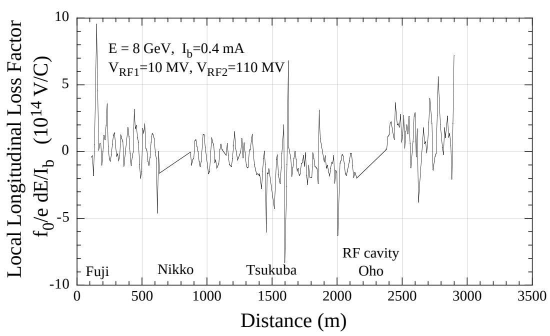

Fig. 5 Measured Differential Longitudinal Loss Factor

4.3 *Discussion*

The energy saw due to the parasitic loss can be seen in Fig. 4 and Fig. 5, which show that the method of measuring the longitudinal loss factor by using BPM's is feasible. However, for such a small orbit change, the error of BPM reading of a few tens micro meter adds the evident ripple on the measured curve of loss factor.

The measured longitudinal loss factor in the ring for different bunch lengths is plotted in Fig. 6 together with the calculated loss factor of gate valve bellows and shielded bellows, which indicates that the measured k_L is obviously larger than the calculated values. Their difference at σ_z=5 mm is about the value of $k_{L,mes}$-$k_{L,cal}$= 2.2x10^{14} V/C. Similar results can be found in the differential loss factor measurement, shown in Fig. 7. The measurement suggests that there are other non-negligible impedance sources, such as resistive-wall, masks, BPMs, pumping slots and etc., in the TRISTAN MR while the measured loss factor distribution may help to locate the hidden sources.

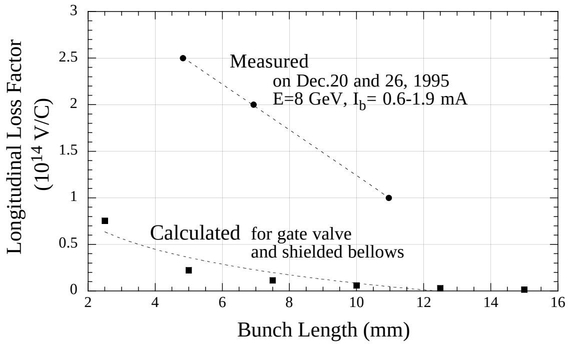

Fig. 6 Measured and Computed k_L vs. I_b

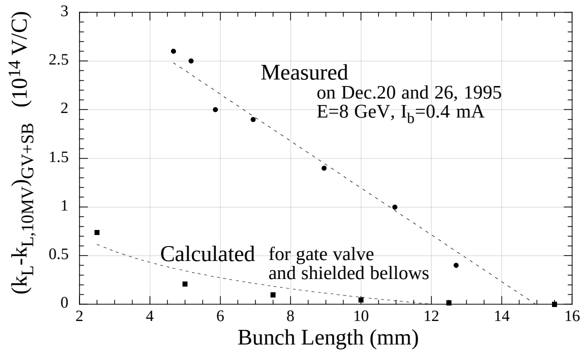

Fig. 7 Measured and Computed Δk_L vs. I_b

5 SUMMARY

The method of longitudinal loss factor measurement by using BPM's is demonstrated in TRISTAN MR light source. Due to the small energy loss in the ring and the low dispersion function in the light source configuration, the accuracy of BPM is of prime importance for this measurement. In the KEKB case, the accuracy of BPM is improved by a factor of 5, while the expected longitudinal loss factor is one order lower than of TRISTAN MR. However, with the factor of 2 larger dispersion, the local loss factor could also be detected by using this method.

REFERENCES

[1] S. Kamada et al., Rev. Sci. Instrum., Feb. 1995.
[2] H. Fukuma et al., These proceedings.
[3] Y.H.Chen, CERN SL/94-02, 1994.
[4] H.Ishii et al., Proc. 6-th Symp. Acc. Sci. and Tech., 1987.