EVALUATION OF DOSE RATE OF PULSED SYNCHROTRON RADIATIONS EMITTED FROM LEP COLLIDING MACHINE AT CERN

T. YAMAMOTO AND M. HÖFERT*

The Institute of Scientific and Industrial Research, Osaka University, Mihogaoka, Ibaraki, Osaka 567
**CERN, CH-1211, Geneva, Switzerland*

1. Introduction

The LEP Project which is now going on at CERN is planning to realize the experiments of collisions between high-energy electrons and positrons of several tens of GeV. It goes without saying that such experiments are very important from a view-point of high-energy physics. In addition, even from a stand-point of radiation dosimetry, the hard X-rays up to several MeV which are the synchrotron radiations [1] emitted by the electrons and positrons rotating round the circumference of the LEP storage ring, the diameter of which is about 10 km, would attract attention of the dosimetrists because of their high power and high kerma rate. It is the purpose of this note to evaluate such quantities accurately and to calculate the energy deposition due to the scattered synchrotron radiations to the 4 pick-up electrodes which are utilized to detect the position of the electrons and positrons with 2 Monte Carlo Codes, EGS [2] and ACCEPT [3,4].

Both asymmetric energy deposition and temporal difference of dose rate are found through the Monte Carlo calculations, which might cause serious effects on the information from the pick-up electrodes.

2. Large Electron Positron Storage Ring (LEP)

In the LEP vacuum chamber of 27 km-circumference 4 electron bunches and 4 positron ones are accumulated and rotate in opposite directions with energies of 50 - 125 GeV, and the collision experiments are performed in the 8 underground experimental halls. Several parameters of LEP are shown in Table 1, by which evaluation of various quantities are performed.

3. Pulsed Synchrotron Radiations

As the synchrotron radiations are generated by the bunched electrons and positrons, they necessarily appear as repeated pulses if one observes them at a certain fixed point, and it is easily anticipated that the peak power becomes very high even if the emitted energy due to one bunch is not so high. In Table 2 are listed several quantities, that is, peak power due to one bunch (P_b), radiated energy due to one bunch passing through unit length (E_b) and average power due to one beam from 1 m length arc of the beam orbit. Figure 1 shows the relation among those quantities. The pulse duration is defined as the time during which a bunch passes through 1 m length of arc.

4. Asymmetry of Energy Deposition to Pick-up Electrodes

In the LEP vacuum tube 4 small disk electrodes will be inserted to pick up the electronic signals from the bunched beam in order to detect the beam position and to make feed-back control. Actually, the cross section of the vacuum chamber is rather ellipse, but in the calculation by EGS the cross section is assumed as shown in Fig. 2 for convenience in running EGS. The incident angle of the synchrotron radiation is set to be 45 degrees from the horizontal line.

It is clarified by EGS that the energy deposition to the pick-up electrodes becomes asymmetric. In order to make the energy deposition as symmetric as possible such a few attempt are tried that some traps are inserted between the incident point of the synchrotron radiations and the electrodes and also that a part of Pb shields are removed from Al chamber.

5. Temporal Variation of Dose Rate to Pick-up Electrodes

Temporal variations of the dose rate to the pick-up electrodes are calculated with another Monte Carlo Code "ACCEPT" where three-dimensional geometry can be utilized. Hence, in this case the geometry is so taken as 4 disk electrodes are embedded inside a cylindrical vacuum tube. The calculated results are shown in Fig. 3. The dose rate to the electrodes near to the incident point of the synchrotron radiations becomes very high as soon as the electron or positron bunch passes just in front of the electrodes, while the dose rate to the further electrodes is generally lower and the peak also delays. Such temporal difference might cause large effects on the pulsed electronic signals.

6. Conclusion

In the LEP Project the electronic signal of the pick-up electrode is required to be measured within the accuracy of 0.1 %. Calculation of the emitted electrons from the surface of the electrode with ACCEPT Code leads to the pulsed noise whose peak voltage is about 100 mV assuming the capacitance of the electrode is 10 pF. This disturbance will probably be acceptable judging from the present LEP design, but if the swarm electrons around the electrodes shield the electric field due to the bunched electrons, the disturbance due to the radiations might not be neglected.

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References

[1] T.Yamamoto and M.Höfert: CERN Report HS-RP/IR/81-58.
[2] R.L.Ford and W.R.Nelson: SLAC Report 210 (1978).
[3] ORNL-RSIC-CCC-374.
[4] T.Yamamoto and M.Höfert: CERN Report HS-RP/TM/82-27.

Beam energy	E	51.5 GeV	85 GeV	125 GeV
Current per beam	I	5.52 mA	9.25 mA	6.40 mA
Number of electrons per beam	N_e	3.07×10^{12}	5.14×10^{12}	3.56×10^{12}
Number of bunches per beam	n	4		
Circumference	C	26658.879 m		
Average radius	ρ	4.243 km		
Bending radius	ρ_0	3.104 km (Bending magnet) 264.9 m (Wiggler)		

Table 1.

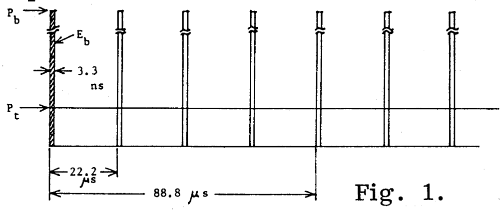

Fig. 1.

Beam Energy	E	51.5 GeV		85 GeV	125 GeV
		Bending magnet	Wiggler		
Peak power due to one bunch	P_b	0.384 MW	52.6 W	4.81 MW	15.4 MW
Radiated energy due to one bunch	E_b	1.28 mJ/m	175 mJ/m	16.1 mJ/m	51.3 mJ/m
Average power due to one beam	P_t	57.6 W/m	7.88 kW/m	725 W/m	2.31 kW/m

Table 2.

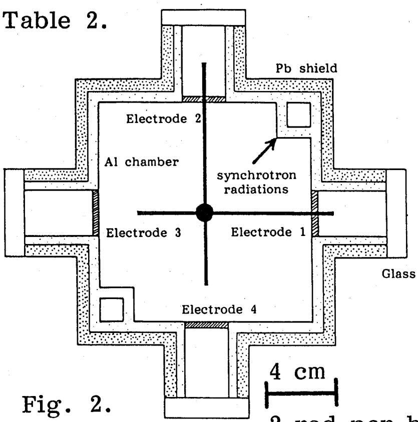

Fig. 2.

2 rad per bunch

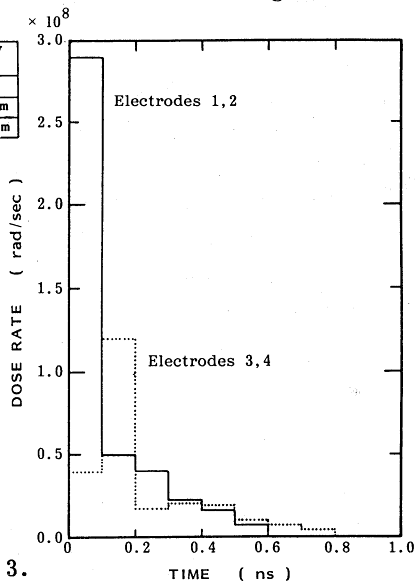

Fig. 3.