Energy, Energy Loss and Energy Fluctuation of Electron Beam of the SPring-8 Storage Ring

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1. Introduction

Energy and energy related parameters are one of the most basic parameters of a storage ring and precise values of these parameters should be determined. Fortunately the storage ring can be regarded as a huge spectrometer and we can easily determine the electron energy from the measured guide field strength. Therefore, we calculated electron energy, energy loss and energy fluctuation of the SPring-8 storage ring on the basis of measured field distribution of dipole magnets.

2. Electron Energy, Energy Loss and Energy Fluctuation

2.1 Energy

Electron energy is expressed by [1]

$$E = \frac{ec\int B(s)ds}{2\pi} \quad , \qquad (1)$$

where e is the electron charge, c is the velocity of light and B(s) is dipole magnetic fields. If field distributions are known, energy can be calculated according to Eq.(1). The SPring-8 storage ring has 88 dipole magnets and field distributions were measured by Hall probe for two of them [2].

Integration of the magnetic fields has been done for the dipole magnets and obtained as

$$B\ell_1 = \int B(s)ds \qquad (2)$$
$$=1.9052 \quad [Tm]$$

$$B\ell_2 = \int B(s)ds \qquad (3)$$
$$=1.9056 \quad [Tm] \quad .$$

Since the power supply and the current are different from that of the operation time, correction is needed. The corrected values are

$$B\ell_1 = 1.8991 \quad [Tm] \qquad (4)$$
$$B\ell_2 = 1.8994 \quad [Tm] \quad .$$

Relative values of integrated field strength Bl for all bending magnets are also measured by a long flipped coil [3]. Using these relative values, the average $B\ell$ over 88 dipole magnets is

$$B\ell = 1.8993 \quad [Tm] \quad . \qquad (5)$$

Measurement error was estimated to be $\sim 3\times 10^{-4}$. Using these values, the electron energy is obtained as

$$E = 7.975 \pm 0.003\, GeV \quad . \qquad (6)$$

2.2 Energy Loss

Electron loses its energy by emitting the synchrotron radiation. The radiation loss in one revolution is [1]

$$U_0 = \frac{CrE^2e^2c^2}{2\pi}\int B(s)^2 ds \qquad (7)$$

$$Cr = \frac{4\pi}{3}\frac{r_e}{(mc^2)^3} \quad , \qquad (8)$$

where r_e is the classical electron radius and m is the rest mass of an electron. As in the case of previous section, $B^2(s)$ is integrated for two dipole magnets:

$$B^2\ell_1 = \int B^2(s)ds \qquad (9)$$
$$=1.266 \quad [T^2m]$$

$$B^2\ell_2 = \int B^2(s)ds \qquad (10)$$
$$=1.266 \quad [T^2m] \quad .$$

Correcting to the present operating condition and averaging over 88 magnets, we obtained B^2l :

$$B^2\ell = \int B^2(s)ds$$
$$=1.258 \quad [T^2m] \quad . \qquad (11)$$

Inserting these values into Eq. (7), we obtained U_0:

$$U_0 = 8.91 \quad MeV \quad . \qquad (12)$$

Design value is 9.23 MeV. This difference is due to lower electron energy of the storage ring than the designed value and the actual field distribution which has a tail rather than a hard edge.

2.3 Energy Fluctuation

Standard deviation of the energy fluctuation is [1]

$$\sigma_\varepsilon = \sqrt{\frac{3\, Cu\, \hbar\, mc^3 r_0^4\, e\, c\int B^3(s)ds}{4J_\varepsilon E\int B^2(s)ds}} \qquad (13)$$

$$Cu = \frac{55}{24\sqrt{3}}$$

$r_0 = {}^{E}/_{mc^2}$
$J_\varepsilon = 2 + D$,

where η is the dispersion function and D≈0 for a rectangular magnet, which is the case of SPring-8 storage ring. Field distributions are integrated and obtained after correction and averaging over 88 dipole magnets as in the case of energy determination:

$$B^3\ell = \int B^3(s)ds \qquad (14)$$
$$=0.8438 \quad [T^3m] \quad .$$

Inserting the values of B^3l and B^2l into Eq. (13), energy fluctuation is obtained as

$$\sigma_\varepsilon = 8.65 \quad MeV \quad .$$

Designed value is 8.75 MeV. This value is slightly lower than the designed value due to actual field distribution.

3. Conclusion

Energy, energy loss and energy fluctuation of the electron beam of the SPring-8 storage ring are calculated on the basis of measured field distribution of dipole magnets. Calculated energy, energy loss and energy fluctuation are 7.975 GeV, 8.91 MeV and 8.65 MeV, respectively. Energy loss and energy fluctuation are smaller than designed value due to lower energy and actual field distribution, which has a tail rather than a hard edge.

References

[1] M. Sands, SLAC PUB SLAC-121(1970).
[2] J. Ohnishi, RIKEN SR Engineering Note, MAG-001-92.
[3] J. Ohnishi *et al.*, IEEE Trans. Magn., **32**(4) (1996) 3069.