A High Betatron Amplitude Insertion for the SSCMEB Lattice *

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Abstract

A high betatron amplitude insertion for the SSCMEB lattice is proposed. High-betatron amplitude function is useful in obtaining higher cooling rate for the proton beam. The high-beta insertion provides also higher slow extraction efficiency.

1 INTRODUCTION

Using electron cooling, the circulating beam in the SSCMEB may be reduced by a factor of 3 in about 60 seconds[1]. It was subsequently examined that the cooling rate can be increased when the transverse temperature of the proton beam is decreased, provided that the electron beam can also be adiabatically expanded. These encouraging results pointed to the need of higher beta-values with round beam configuration at the electron cooling region. In this paper, we shall examine the possibility of modifying the SSCMEB lattice functions in the long straight section.

The SSCMEB lattice was designed by R. Gerig[2]. The basic lattice structure is composed of regular FODO cells in the arc separated by straight sections for injection, rf stations, abort, slow extraction, etc. The length of a regular FODO cell is 36.0789 m. The total circumference is 3960 m with six long dispersion free straight sections. The length of the half of a long insertion is 83.4612 m.

Fig. 1 shows a half-insertion with zero dispersion. The dispersion matching is achieved through missing dipole scheme with maximum betatron function about 78 m. Thus the dynamical aperture is properly matched in the whole ring. The available free space is about 25 m with zero dispersion. In the following, we shall discuss method of modifying the lattice without perturbing the basic MEB structure.

2 INSERTION MODIFICATION

Several conditions in the SSCMEB lattice should be considered in the insertion modification. We list them in the following:

1. The distance from the center of the symmetry point in the insertion to the FODO cell is 83.4612 m. This condition is important to maintain the total circumference of the machine.
2. We like to obtain high-β value with round beam condition, i.e. $\beta_x^* = \beta_z^*$, and dispersion free for efficient electron-cooling. Thus the configuration of the insertion quadrupoles will be a triplet matched to a doublet.
3. Since the betatron amplitude function, β_z, is large in the straight section, it is preferably moving dipoles toward the FODO cell instead of the missing dipole dispersion correction.
4. Possible tuning of β_x and β_z values.

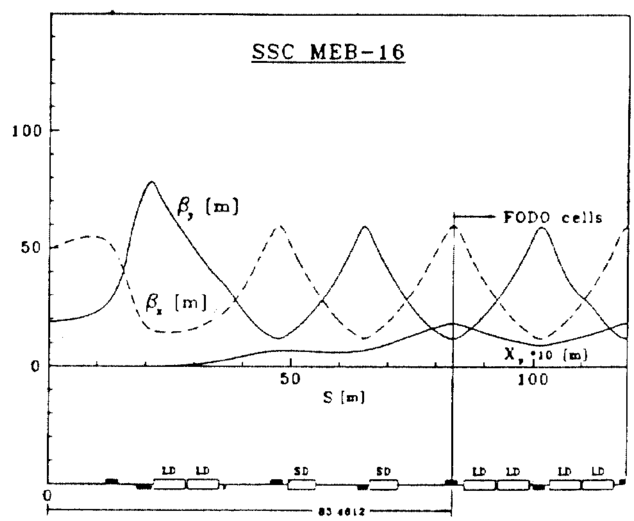

Fig.1: Half insertion of the SSCMEB standard insertion are shown

These conditions can be met easily by the configuration shown on Fig.2. Two dipoles are fitted into the half cell adjacent to the regular FODO cell in the arc. A triplet is located near to the symmetry point with dipole around it to achieve dispersion correction. The space available becomes about 45 m. The betatron amplitude function is shown to be 200 m with maximum $\beta_z \approx 380$ m. The full beam size is $6\sigma = 34$ mm for the beam with an RMS $\epsilon_N = 1\pi$ mm-mrad at $\gamma = 12$. Thus the vertical gap in the short dipole near to the maximum β_z should be about 68 mm or 2.75 inches. Similarly the quadrupoles at the maximum β_z should be a large aperture of about 4 inches diameter. The symmetric insertion requires 4 quadrupoles.

*I like to thank Rod Gerig for his information about the SSCMEB lattice design and for his SSCMEB-16 SYNCH program file.

These quadrupole strength are listed in table 1. The β^* value, shown in Fig.2, can also be tuned by adjusting the quadrupole strength.

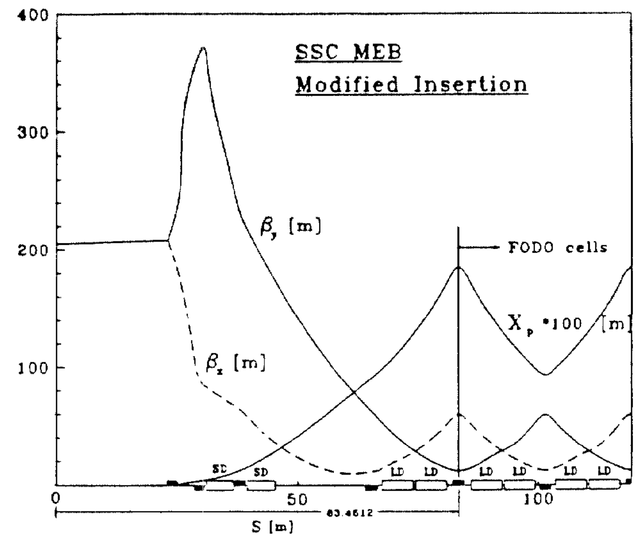

Fig.2: The modified half insertion of the SSCMEB with $\beta^* = 200$ m.

3 DISCUSSION AND CONCLUSION

The high β value insertion offers some interesting features: (1) The transverse velocity or the transverse temperature for the proton beam at high β insertion becomes smaller, which gives rise to smaller electron cooling time. (2) The free space in the high β insertion is more than 45 m. The phase advance between the straight sections in the modified insertion is also about 90^o. The corresponding kicker arm from the center of the insertion to the 18.87 meter straight section is about

$$L = \sqrt{\beta_1 \beta_2} \sin \Delta\Psi \approx 35.2 \text{ to } 46.5 \text{ m},$$

which is about the same as that of the original lattice. (The kicker arm from the center of the original insertion to the 9.46 meter straight section is about 34.5 to 52.1 meters.) Thus the kicker requirements are comparable. Since the slow extraction efficiency is proportional to $1/\sqrt{\beta}$, high β-insertion can offer high efficiency for the slow extraction.

In conclusion, we have made some preliminary modification to the SSCMEB lattice for the electron cooling. The present calculation is only a *demonstration* of possible modification with minimum impact on the SSCMEB lattice design.

Our result does point out that the modified configuration can be found to be useful for improving the electron cooling efficiency. Such high-beta configuration gives a very long straight sections without grossly perturbing the basic SSCMEB lattice structure. The high-beta insertion may prove to be useful for improving the slow extraction efficiency. The present configuration can also be varied to

Table 1: The focal length of quadrupoles in the modified insertion with $\beta^* = 200$ m.

Quadrupole	focal length
Q1	13.8113
Q2	-11.4808
Q3	49.7785
Q4	-143.6449

obtain optimal β^* values. Due to the symmetric insertion, the β_x^* is not necessary equal to β_z^*. Thus it may be possible to optimize the insertion for special applications. For the purpose electron cooling, a round beam configuration offers some advantages.

If six high β^* insertions are used in the SSCMEB lattice, a total of 12 quadrupoles will be saved. However, the modified insertion does require adjustment on the phase advance of the FODO cell in the arc to achieve favorable betatron tunes. Further works are needed if the modified insertion is incorporated into the SSCMEB lattice design.

4 REFERENCES

1. D.R. Anderson et al., Design of a 6 MeV electron cooling system for the SSCMEB, these proceedings.

2. R. Gerig, SSCMEB lattice design, private communications.