LATTICE DESIGN OF 2-LOOP COMPACT ENERGY RECOVERY LINAC

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Abstract

Compact Energy Recovery Linac (Compact ERL) is planned to construct in the KEK site as a test facility of 5GeV-ERL project. For achieving the high energy with a limited refrigeration power, the electron beam is accelerated twice by the same super-conducting cavity in a 2-loop design. At the branch of the two loops, a chicane is installed for flexibility of the ratio of the lower energy in the inner loop to higher energy in the outer loop. The angle of merger of the injection is 16 degree. The linear optics of the linear accelerator section is optimized for the two accelerator and two decelerator beams using the "dummy loop", which is used for determination of the twiss parameters of the entrance/exit of the two loops. Both inner and outer loop are designed to be an achromat and isochronous.

1. Introduction

5GeV energy recovery linac project has been promoted as the next generation light source, which is planned to be sited in KEK. For saving the building cost, site area and the refrigerating power, 2-loop scheme is a strong candidate for KEK project as well as others projects, such as Cornell Laboratory [1]. On the other side, the higher order mode (HOM), which accumulated in the superconducting cavity at lower current and the complicated beam dynamics are critical issues.

Compact ERL, which is a test facility of 5GeV-ERL, is using 2-loop scheme for achieving the higher electron energy with a limited refrigerating power. For optimization of the optical functions, the main linac section is should be careful because two accelerating and two decelerating beams pass though the same magnets. In this paper, we proposed the method of optimisation of optical functions and the simulation results for the Compact ERL.

2. Lattice layout of 2-loop Compact ERL

2.1 Main parameters and magnet layout

Figure 1 shows the schematic drawing of the layout of the Compact ERL. 500kV electron beam from DC photo cathode electron gun [2] is accelerated up to 5MeV at the injection section and lead to the main linac section at the merger section, which is composed of three bending magnets [3]. The electron beam accelerated up to 65 MeV passes though the inner loop and then is accelerated again up to 125 MeV. 125 MeV electron beam passing though the outer loop is decelerated twice at the main linac section down to 5 MeV. 5 MeV electron beam is lead to the dump with the extraction section. Total electron path length and the site area of the circulating section are 291.9 m and 47 m × 9.3 m, respectively. The lengths of the two main superconducting cavities are 8m and 10m, which contain four 9 cell-cavities in one cryostat and in two cryostats, respectively [4]. 60MeV acceleration per a turn will be upgrade to 120MeV in the future, in which the maximum electron energy is 245 MeV.

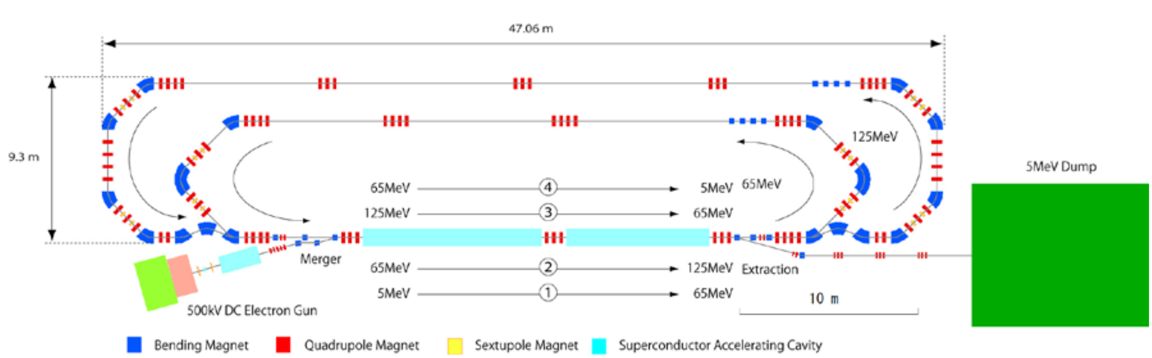

Fig. 1 : Schematic of 2-loop of compact ERL

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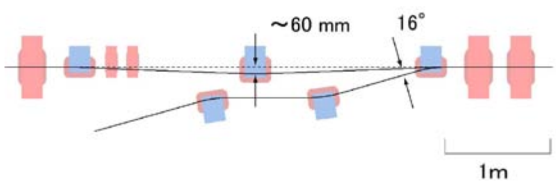

Fig.2 : Layout of merger section

2.2 Merger section

The schematic drawing of the merger section is shown in Fig.2. 5 MeV injection electron beam are merged at the chicane with three bending magnets at the angle of 16 degree. A chicane is installed for the circulating beam because to compensate the change in the orbit kicked by the merging bending magnet. The minimum electron energy of the circulating beam is 35 MeV and then the displacement of the orbit at the center of the chicane is about 60 mm.

2.3 Energy branch chicane

The energy ratio between the inner and outer loop depends on the injection and acceleration by the main linac, e.g., 65:125 and 125:245. The change in the ratio is 4%. For leading the full energy electron bean to the center orbit of the outer loop for both energy ratios, we installed the branch chicane at the entrance of the inner/outer loop. The schematic drawing of the branch chicane is shown in Fig.3, where the change in the orbit is enhanced. The change in the energy ratio, 4%, induces the orbital shift 10 mm at the center of the branch chicane.

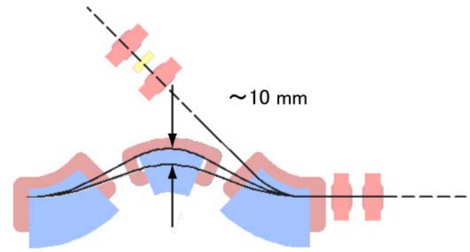

Fig.3 : Schematic drawing of energy branch chicane and the change in orbit.

3. Optical function of main linac

In the main linac, two cryostats of the superconducting cavity are between the three triplets, and then the two accelerator and two decelerator beams pass though the same triplets. The optical function should be designed not to be large at the last triplet just before the extraction section because the electron energy is low and the transverse emittance becomes larger at the loop sections. The focus strength of the triplets is optimized for the lowest energy beam. For the higher energy, the optical function is controlled by the twiss parameter at the boundary to the loop section because the focus strength is too small. The optical function is optimized using the SAD (Strategy Accelerator Design) and the two dummy loops, which consists of four quadrupole magnets, are inserted for calculation of the twiss parameters at the boundaries. The twiss parameters at the exit of the injector section is (βx, αx, βy, αy) = (13 m, -2, 0.7 m, 0).

Two results of the optical functions are shown in Fig.4. Figure 4 (a) is minimized the optical function at the main superconducting cavities. The optical function at the

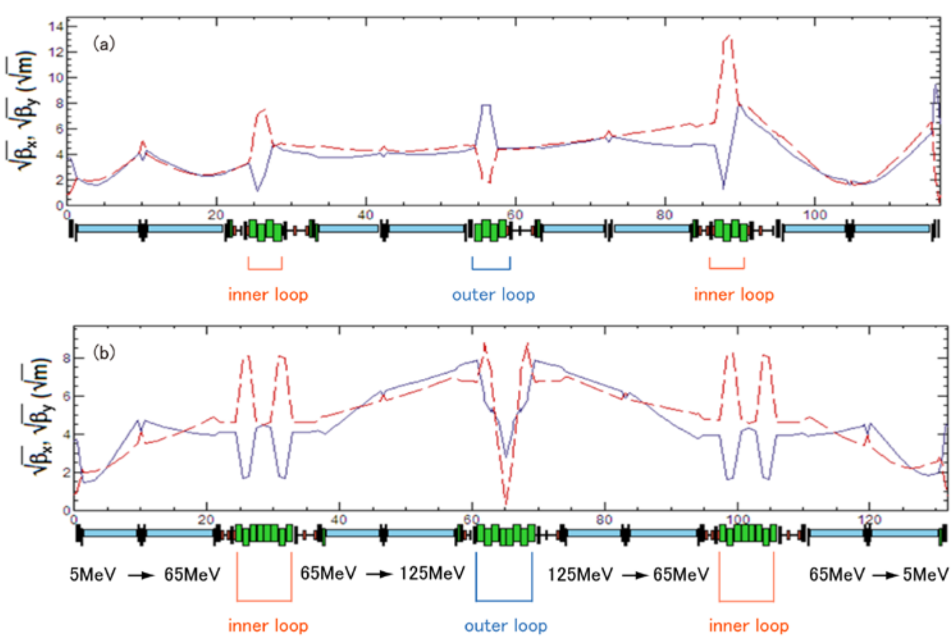

Fig.4 : Optical function of the main linac

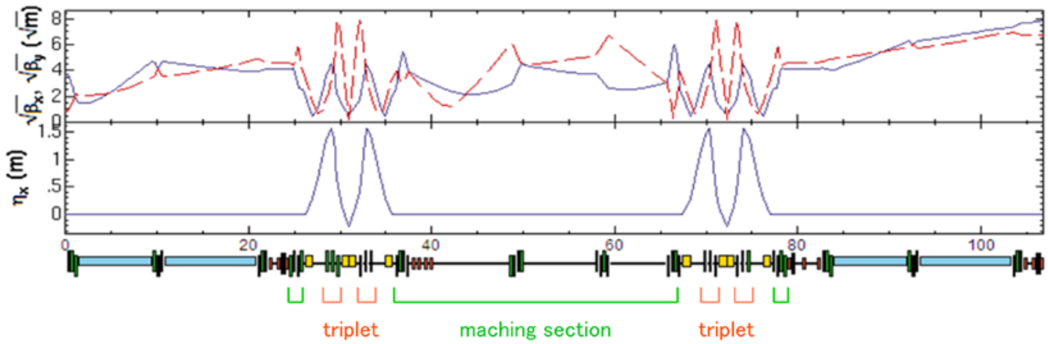

Fig.5 : Optical function of the inner loop

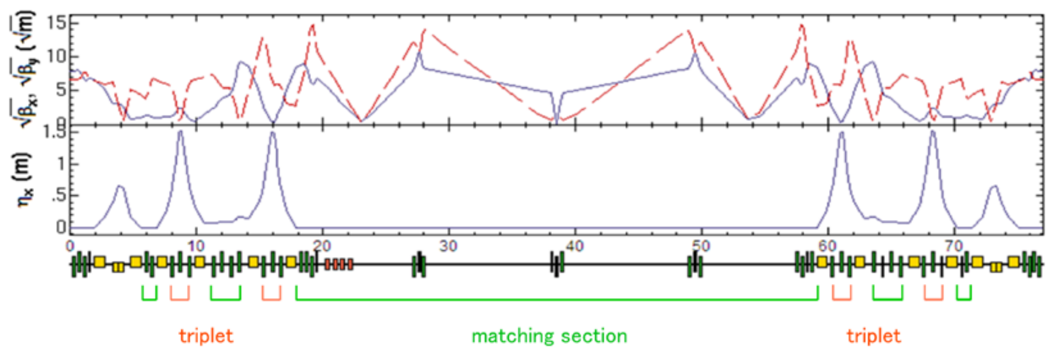

Fig.6 : Optical function of the outer loop

decelerator linac is larger than accelerator linac and the betatron function at the last triplet is over 90 m. In such a optics, the transverse beam size can be over the chamber size at the deceleration linac and extraction section. On the other side, in the symmetric optical function shown in Fig.4 (b), the betatron function is suppressed down to 20 m at the last triplet.

4. Optical function of inner and outer loops

The arc section of both inner and outer loops are designed to be an achromat and isochronous optics (R_{56} =0) for minimization of the transverse beam size and maintaining the longitudinal bunch length. The two arc sections are TBA like lattice consisting of four bending magnets with the bending angle of 45 degree in order to change R_{56} for bunch compression. The outer loop follows the branch chicane for electron beam with several energy ratios. The triplets between the bending magnets are used for the achromat and isochronous optics and the matching sections consist of several doublet and are used for matching the twiss parameter between the main linac section and arc section. For simplicity, the edges of the bending magnets are rectangle at the branch chicane and sector at the arc sections.

Examples of the optical functions of the inner and outer loop are shown in Fig.5 and Fig.6, respectively. The twiss parameters at the boundary are the same with the Fig.4 (b). The optical function has a flexibility over all and we can find several optical function.

5. Summary

We report the strategy of the liner optical function and the first optical function of the 2-loop Compact ERL. At first the optical function of the main linac is optimized by using the dummy loops. At the loops, the triplets are calculated for an achromat and isochronous optics, and finally the matching sections are used for matching between them. In ERL optics, it should be caureful to pay attention that all electron beams with different energy pass though the same magnets with a reasonable optical function. In this paper, we showed the example of the symmetric optical function with low betatron function at the last triplet.

References

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