OPTICS AND MAGNETS DESIGN OF S-BAND HIGH-GRADIENT LINAC FOR THE ATF

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ABSTRACT

Linear colliders need an optics with large acceptance in the low energy region of injectors to get high luminosity, especially for a positron linac. We are developing the ATF (Accelerator Test Facility) project in advance of JLC (Japan Linear Collider) and obtained a solution for the optics with 1×10^{-3} $\pi\cdot$m$\cdot$rad acceptance in the S-band high-gradient linac.

To realize this optics, 6 quadrupole magnets have to be rolled around one accelerating tube with 138mm diameter.

This paper describes a feasible optics and a design of magnets.

INTRODUCTION

In the JLC various kinds of electron guns are planned;a polarized electron gun, an RF gun and a thermionic gun. As for the positron source, a target station will be used. To transport a beam with a large emittance, the optics with a large acceptance is indispensable.

The beam emitted from the electron gun is pre-bunched, bunched and accelerated to about 30MeV while focused in the transverse direction by solenoids. At the exit of the solenoids the beam is expected to be 4mm(2σ) in diameter and to be a Brillouin flow, where σ is the standard deviation. After that, the analyzer magnet is put in front of 16 S-band high-gradient accelerating tubes. The beam is accelerated to 1.54GeV and is transported to the damping ring.

The accelerating tube has a train of irises whose inner diameters are 26mm at the entrance and 18mm at the exit. The beam must go through these irises without any deflection.

The length of the straight line for the linac also restricts the optics, because the site space for the ATF has already been fixed.

In the last report[1] the quadrupole magnets rolled around the accelerating tube were also used for the high energy region. Afterwards these magnets proved economically inefficient. So this type of magnets should be minimized in number.

OPTICS DESIGN

Restricted conditions

The following items should be taken into consideration.

- The injector accepts 3σ beam under the assumption of a round Gaussian beam.
- The initial energy is 30MeV.
- The normalized emittance ε_n is 1×10^{-3} $\pi\cdot$m$\cdot$rad(rms).
- The drift space for the analyzer magnet is 1m including the space for flanges, slits and monitors.
- The total length of the linac must be less than about 72m.
- The types of magnets should be minimized in number to reduce the cost.
- The parameters for the accelerating tube is shown in Table 1.

Table 1
Characteristics of the accelerating tube

Number	16
Length(flange to flange)	3138.28mm
Outer diameter	138mm
Accelerating gradient	35.7MV/m
Iris diameter	26mm(entrance) ~18mm(exit)
Frequency	2856MHz

Method

KEK is developing a useful program, SAD[2], (Strategic Accelerator Design) for the optics design. Therefore we are designing the optics by using this program.

The critical point is inside the first accelerating tube (L1), especially near the entrance of L1. If we define the iris radius distribution by R(z) and the allowable maximum betatron function by $\beta_{max}(z)$, then the following inequality must be satisfied.

$$R(z) \geqq 3\cdot\sqrt{\frac{\varepsilon_n}{\gamma(z)}\cdot\beta_{max}(z)} \qquad (1)$$

,where z is the longitudinal position and γ the Lorentz factor.

β_{max} derived from Eq.(1) is drawn in thick lines in Figs.3~5. So the designed betatron function β_x, and β_y must be less than $\beta_{max}(z)$.

After the optics for L1 is designed, the one between the pre-accelerating tube (L0) and L1 is made by matching the initial parameter. The cyclic solution for the third accelerating tube (L3) ~ L16 is found by matching the parameters just behind the optics for L1. So the matching section is installed between L1 and L2.

Result

The optics is shown in Figs.2 ~ 5. After L3, Fig.5 is repeated until L16. The total length is 73.6m and the number of quadrupole magnets is 60.

To make β_x and β_y less than $\beta_{max}(z)$ in L1, 6 quadrupole magnets are needed around L1. Those magnets -B-type- are 250mm in length and 140mm in bore diameter. If the acceptance is desired to be 2×10^{-3} π ·m·rad, then 10 quadrupole magnets are needed around L1.

The magnets between L0 and L1 -A-type- are 150mm in length and 65mm in bore diameter, which are conventional.

A triplet is adopted for the cyclic solution between L3 and L16, because the round beam is accelerated uniformly. The strength of the triplet is determined by connecting it with the matching section. The outer magnets of the triplet -C-type- are 150mm in length and 33mm in bore diameter. The inner magnet -D-type- is 300mm long.

The matching section has 3 singlets -A'-type- whose length is 150mm, and bore diameter 42mm.

Magnet Design

Restricted conditions

The following items should be taken into consideration.

- The magnets are designed under the condition that initial energy is 50MeV, because the pre-accelerating tube can accelerate the beam up to that energy.
- The magnets are so close to each other that the thickness of the conductors wound around the sides of the pole pieces must be less than half the distance between the magnets.
- Considering the severest condition for each type of magnet, the necessary field gradients are 3.9, 8.2, 5.2, 31.5, 29.3T/m for A, A',B, C, D,respectively.

Method

POISSON has been used for the 2-dimensional magnetic field calculation and TOSCA for the 3-dimensional one.

Result

Cross sections for each quadrupole magnet are shown in Figs.6 ~ 8 and parameters in Table 2. Type B, C and D cannot be compact because of the large bore diameter for B and the limited coil thickness for C and D. The interference of adjacent magnetic fields is shown in Fig.9. The more important point is that the fringing field should not invade into the input coupler. The threshold of permissible field strength is not yet clear.

Table 2
Characteristics of quadrupole magnets

Type	A	A'	B	C	D
Field gradient [T/m]	5.9	12	7.65	38	38
Pole length [m]	0.15	0.15	0.25	0.15	0.30
Bore diameter [mm]	65	42	140	33	33
Ampere turn [A·turn]	2480	2106	14280	4120	4120
Current [A]	19.1	16.2	120.0	50.1	50.1
Number of turn [/pole]	130	130	119	81	81
Coil [mm]	Solid 3×5	Solid 3×5	Hollow conductor 6□ - 4□	Hollow conductor 6□ - 4□	Hollow conductor 6□ - 4□

CONCLUSION

We have designed the optics for the ATF linac whose normalized acceptance is 1×10^{-5} π ·m·rad, that is, 17 π ·mm·mrad. We have also designed quadrupole magnets to realize this large acceptance optics.

60 quadrupole magnets are needed including 6 ones rolled around the accelerating tube. The fringing field problem arises because the magnets are so close to each other and close to the wave guide. In order to investigate this problem, a prototype of magnets will be soon manufactured and the fringing field will be measured.

REFERENCES

(1)M.Nakai et al. , Proc. of the 16th Linear Accelerator Meeting in Japan (Sept. 1991)
(2)K.Oide et al. , Private communication

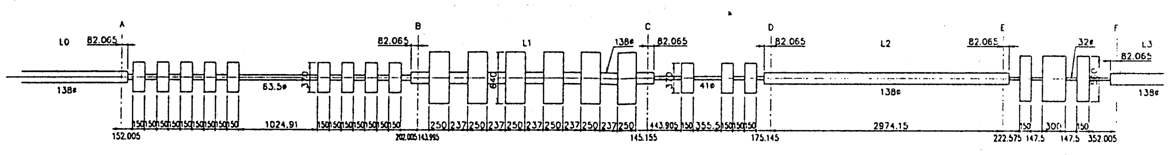

Fig.1 Layout of quadrupole magnets

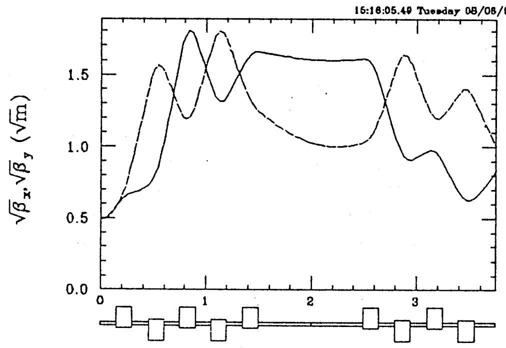

Fig.2 Optics between A and B

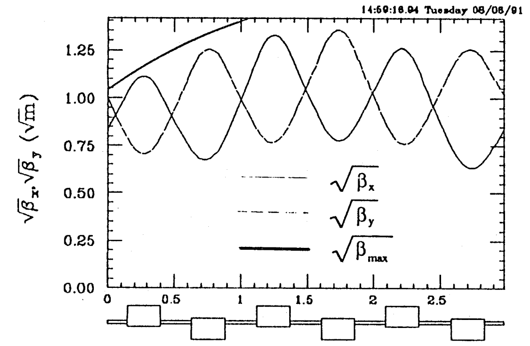

Fig.3 Optics between B and C

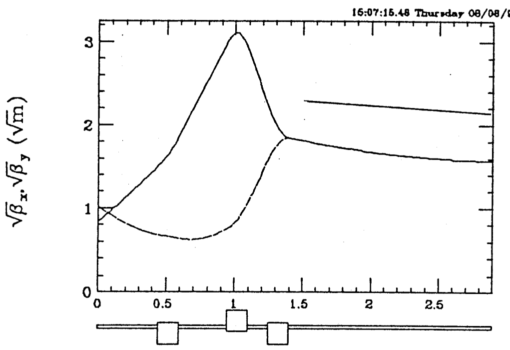

Fig.4 Optics between C and the center of L2

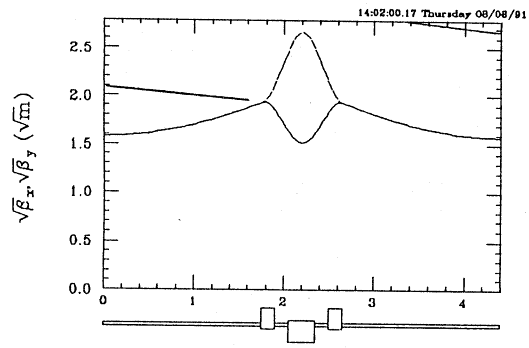

Fig.5 Optics between the centers of L2 and L3

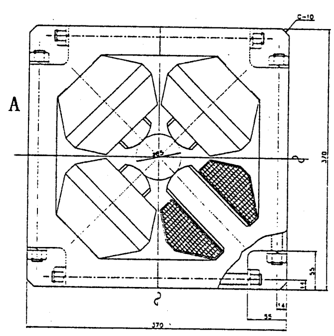

Fig.6 A type

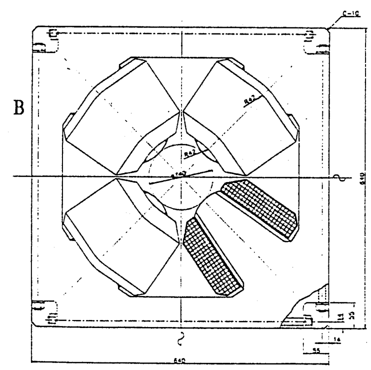

Fig.7 B type

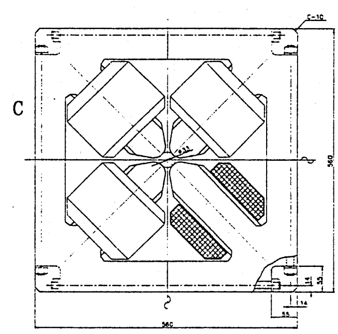

Fig.8 C,D type

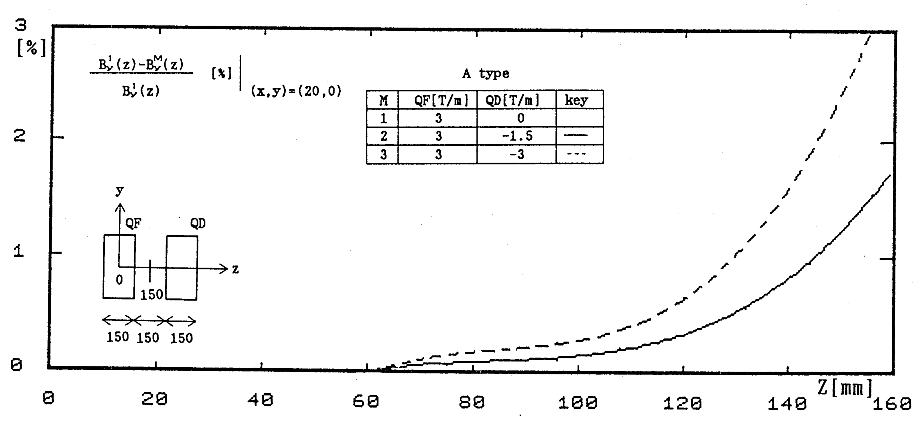

Fig 9 Interference of adjacent magnets