DESIGN OF AN LEBT OF A CW MICROTRON

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Abstract

A low energy beam transport (LEBT) has been designed for a CW microtron. The LEBT mainly consists of two solenoid magnets, a bending magnet, a quadrupole magnet, and a chicane magnet. Fringe fields of the bending magnets are optimized by adjusting gaps of auxiliary pole pieces (clamps) of the bending magnets. Calculation and measurement results of magnetic fields show that a field integral (FINT) related to the fringe field is proportional to the gaps of the clamps. The studies also show two dimensional calculation results and three dimensional calculation result of the FINT are within accuracies of 10 % and 0.5 %, respectively.

1 INTRODUCTION

High power electron beams are necessary for industrial applications: electron beam and X-rays irradiation. Electrostatic accelerators and linear accelerators have been used for the applications. However, accelerators operated in a continuous wave (CW) mode are more suitable for these applications. We have proposed a CW microtron with a 500 MHz RF cavity for the applications [1]. In the CW microtron system, an LEBT should be compact and have large acceptance for a high power electron beam. Therefore, a bending radius of a bending magnet of the LEBT is small, which has much effect on transverse beam focusing. Careful consideration of a fringe field of the bending magnets is necessary. This paper describes a lattice design of the LEBT taken into account a fringe field effect and a design of the bending magnet.

2 LATTICE DESGIN

Figure 1 shows a schematic drawing of the LEBT of the CW microtron. The LEBT mainly consists of two solenoid magnets (SOL1, SOL2), a bending magnet (BM1), a quadrupole magnet (QM) and a chicane magnet (BM2, BM3, BM4). An electron beam is injected to the CW microtron with the chicane magnet.

Electron beam parameters at an exit of an electron gun are studied with beam simulation and shown in Table 1 [2]. Table 2 shows design parameters at an exit of the LEBT. The LEBT is designed using MAD [3] and TRANSPORT [4]. In the LEBT, the length of the chicane magnet is determined by the layout of the CW

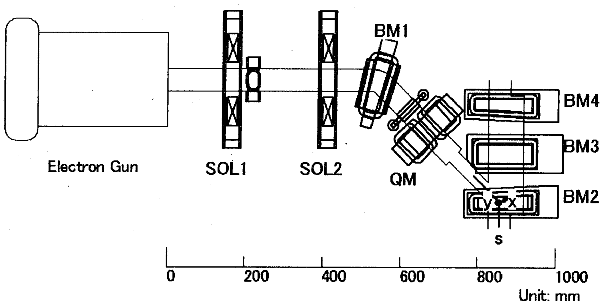


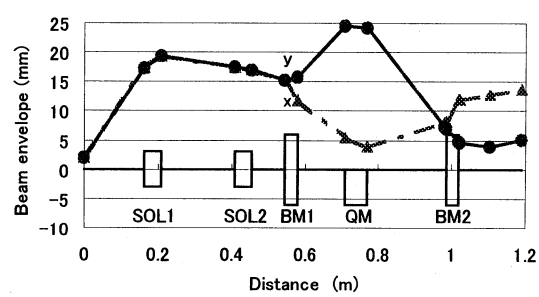
Figure 1: Schematic drawing of the LEBT of the CW microtron.

Table 1: Beam parameters at an exit of an electron gun.

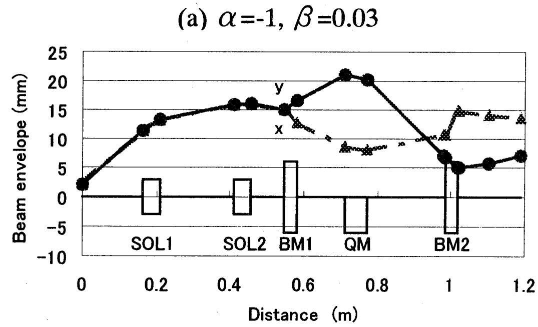
Beam energy		80 keV
Normalized emittance (1 σ)		20 π mm・mrad
TWISS parameters	α	-3 ~ 0
	β	0 ~ 1

Table 2: Design beam parameters at an exit of the LEBT.

TWISS Parameters	α	-1 ~ 1
	β	0 ~ 2



(a) α=-1, β=0.03



(b) α=0, β=0.03

Figure 2: Two typical examples of beam envelopes of the LEBT. Emittances are of 2 σ.

microtron. The bending radius of the BM2 is small, which has much effect on transverse beam focusing. Edge angles and fringe fields of the bending magnets should be adjusted accurately. The fringe field effect is introduced into MAD and TRANSPORT as a field integral (FINT). Calculation results show that the FINT of BM1, BM2, and BM3 are 0.39, 0.33, and 0.33, respectively. Figure 2 shows two typical examples of beam envelopes of the LEBT. Instruments of the LEBT were designed and made based on these results.

3 BENDING MAGNET

Studies of the fringe fields of the bending magnets were done with a magnetic field calculation and measurement. The FINT is calculated with POISSON and TOSCA. The FINT is given by

$$FINT = \int_{-\infty}^{\infty} \frac{B_y(s)(B_0 - B_y(s))}{g \cdot B_0^2} ds,$$

where $B_y(s)$ is the magnitude of the fringing field on the magnetic mid-plane, B_0 is the asymptotic value of $B_y(s)$ well inside the magnet entrance, and g is the full gap of the magnet [5]. The FINT of the bending magnets are smaller than that of a typical magnet (0.45) [4]. Figure 3 shows a schematic drawing of the BM2. The BM2 has auxiliary pole pieces (clamps). Figure 4 shows calculation and measurement results of the magnetic field distributions. The magnetic field calculations were done with POISSON. The calculation result of the BM3 is in agreement with the measurement results. The calculation result of the BM2 is different from the measurement results significantly. Figure 5 shows calculation and measurement results of the FINT as a function of the gaps of the clamps. These results show that the FINT is proportional to the gaps of the clamps. The calculation results of the FINT of the BM2 and the BM3 are accuracies of 10% and 3%, respectively. A magnetic field calculation of a three dimensional model of the BM2 was done with TOSCA. Figure 6 shows a magnetic field distribution of the BM2. The FINT calculated with

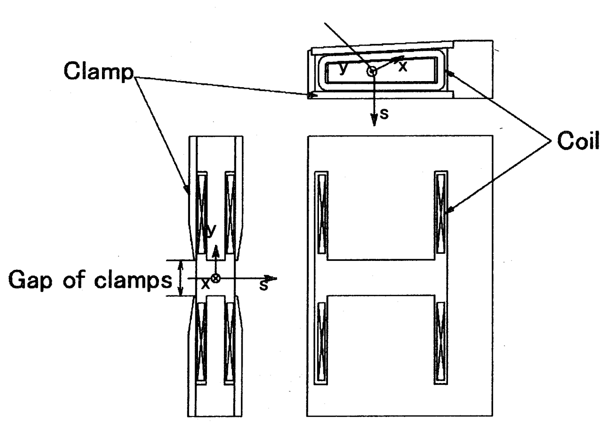
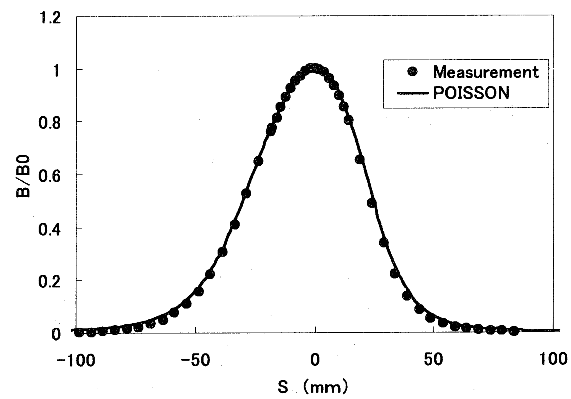
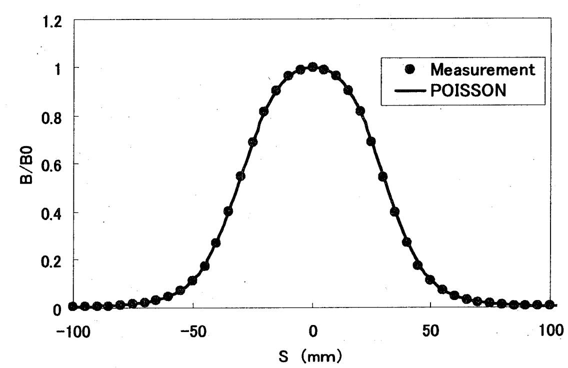


Figure 3: Schematic drawing of the BM2.

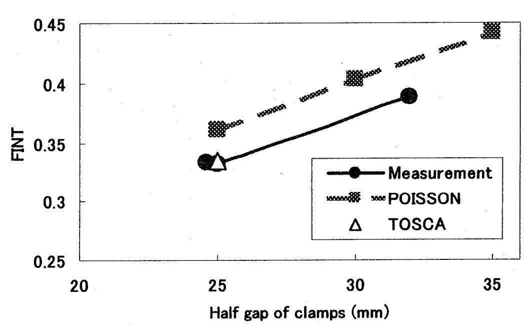


(a) BM2

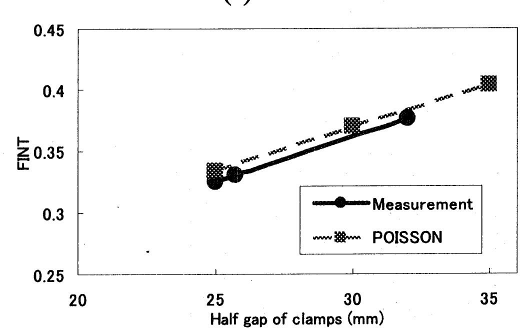


(b) BM3

Figure 4: Calculation and measurement results of the magnetic field distributions.



(a) BM2



(b) BM3

Figure 5: Calculation and measurement results of the FINT as a function of the gap of the clamps.

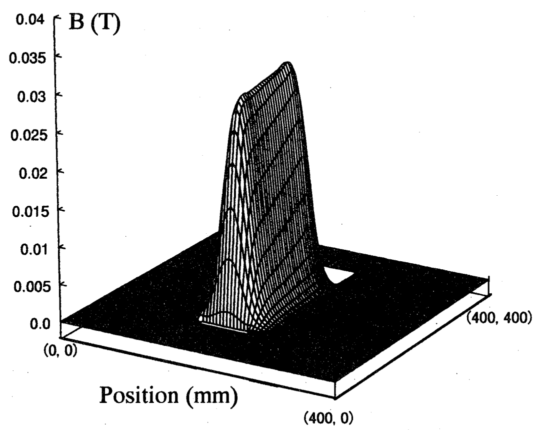


Figure 6: Magnetic field distribution of BM2

TOSCA is in agreement with the measured FINT, as shown in Figure 5. Difference between the accuracies of the calculations with POISSON is due to three dimensional effects of shapes of the bending magnets. Because the BM3 is an approximately rectangular bending magnet, the accuracy of the calculation results of the BM3 is better than that of the BM2. A bending magnet which is short along a beam orbit should be designed with a three dimensional magnetic field analysis program.

4 SUMMARY

The LEBT of the CW microtron is designed and is proved to be practicable. The instruments of the LEBT have been made and the beam test will be done.

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