DESIGN OF TEST LINAC FOR FREE ELECTRON LASER*

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Abstract

Pohang Accelerator Laboratory (PAL) is constructing the 2-GeV Pohang Light Source (PLS), a dedicated synchrotron radiation source. The injector of the storage ring is a 2-GeV linear accelerator. The construction of the linac will be completed by the end of 1993. We plan to construct a test linac using some spare components after the linac construction. The design of the test linac is based on two accelerating columns and a matching girder, a klystron, and a modulator after upgrading current 60-MeV preinjector. The energy of the test linac will be 50-MeV, and the peak current be 30 A. The radiation wavelength is expected to be from 3 to 30 microns. A thermionic RF-gun is considered as an electron beam source. The whole test linac can be installed by sharing present 2-GeV linac tunnel and the gallery.

I. INTRODUCTION

Pohang Accelerator Laboratory is constructing a 2-GeV linear accelerator as a full energy injector to the storage ring, a dedicated synchrotron radiation source. The 60-MeV preinjector was completed by February 1992 under the international collaboration with Institute of High Energy Physics, Beijing, China. At present, nearly half of the 2-GeV linac is completed, and by December this year, the whole linac will be installed and will be ready for its commissioning [1]. The 2-GeV linac will be controlled under VME-based control system during commissioning and normal operation that is expected from July 1994.

However, the preinjector control system which is based on INTEL Bitbus system is different from the rest of the 2-GeV linac. Thus, a modulator and a klystron of the preinjector along with its control system will be replaced by VME-based ones later this year.

There are also spare parts from the preinjector and the main linac. Two accelerating columns and an aluminum girder are left from the preinjector program. Some of waveguide components will be available if they are not completely used during the installation. The design of the test linac for a free electron laser (FEL) is based on these left-over components.

II. LINAC DESIGN

A. General Layout

Figure 1 shows a general layout of the test linac assigned at the corridor of the E-gun room in the tunnel. This space is approximately 30-m long and 4-m wide. The linac consists of a thermionic cathode RF gun as an electron source, an alpha magnet for bunch compression and energy selection, and two standard accelerating columns.

A 30-MW klystron will provide RF power to the gun cavity and two accelerating columns. Two undulators will be set up at the end of each column. A circulator and an integrated phase shifter/ attenuator will be used for RF gun system. The klystron and its modulator will be located at the corner between the klystron gallery and the test lab. One penetration hole to the tunnel has been prepared at this corner for the waveguide.

B. Design Parameters

For the SLAC type accelerating column, the peak value of the beam induced voltage is about 0.15 MV/m/$10^{10}e^-$ due to the longitudinal wakefield effect [2]. It gives a peak voltage of 45 kV/m for a bunch of 0.5 nC charges. Throughout the total 6-m long accelerating sections, the peak induced voltage will be about 270 kV. This is about 0.5 % of final beam energy which is 50 MeV. To compensate this effect, a phase shifter will be inserted to the waveguide line in the second accelerating column.

The phase change of the RF field from the klystron creates an energy spread. The tolerance of the phase change should be less than 2.5 degrees in order to minimize the energy spread. An adaptive RF feed-forward control of the klystron is currently studied [3]. Major parameters for the test linac is summarized in Table 1.

Table 1. Major parameters for test linac.

Beam Energy Range	20 ~ 50 MeV
RF Frequency	2,856 MHz
Electron Beam Source	Thermionic RF gun
Beam Energy after RF-gun	0.9 MeV
Klystron Output	30 MW
Pulse Length	8 μs (flat top)
Tolerance of Phase Change	< 2.5 deg.
Energy Spread	< 0.5 %
Micropulse Peak Current	30 A
Normalized Emittance	< 95 π mm-mrad for λ = 3 μm at 50 MeV
Repetition Rate	10 Hz

III. RF-GUN DESIGN

A. Type of RF-Gun

There are usually three different electron sources dedicated to FEL research. One is a conventional type thermionic gun with a subharmonic buncher and a buncher. Others are a photocathode RF-gun which uses short laser pulses, and a thermionic RF-gun. The conventional type is a reliable one, but it is limited

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in reducing the emittance. The photocathode type is very expensive and complicated, although it has many good features. We have, thus, chosen the thermionic RF-gun for the test linac. Although this has some disadvantages such as back bombardment, it is quite compact and relatively inexpensive. In order to reduce the back bombardment, several methods have been proposed such as an 1-1/2 cell with different field amplitude, a ring cathode, and a magnetic deflection [4].

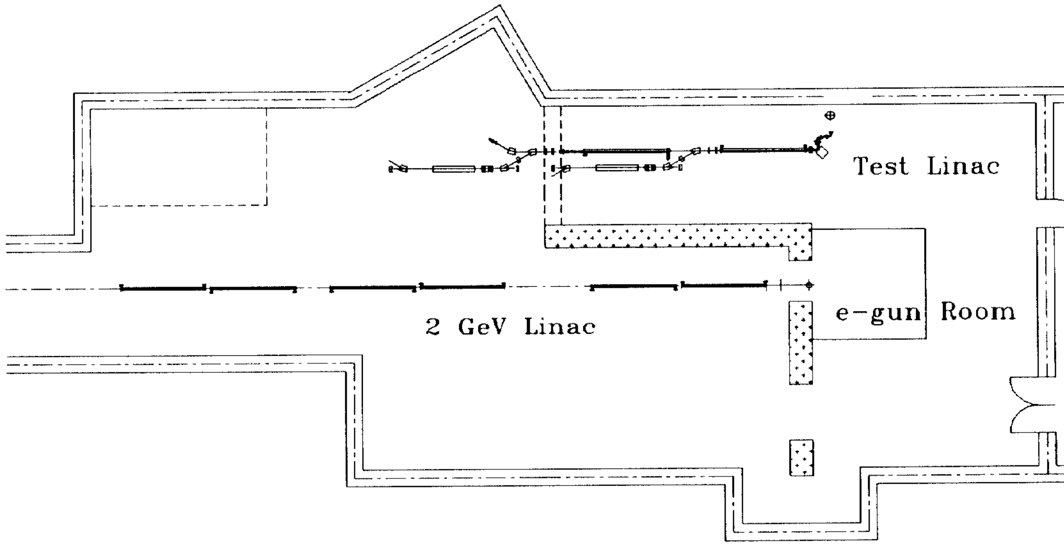

Fig. 1: Layout of test linac with present 2-GeV linac tunnel.

B. RF_GUN code

A code called RF_GUN is used to simulate the RF-gun cavity. This code integrates the longitudinal equation of motion under external electric field. The field profile is calculated by the SUPERFISH program in the absence of space charge, and the RF_GUN code uses it as an input data. The RF_GUN code includes a power balance equation in the cavity. With a given input power, the RF_GUN runs until the sum of beam loading power and power loss at the wall equals the input power.

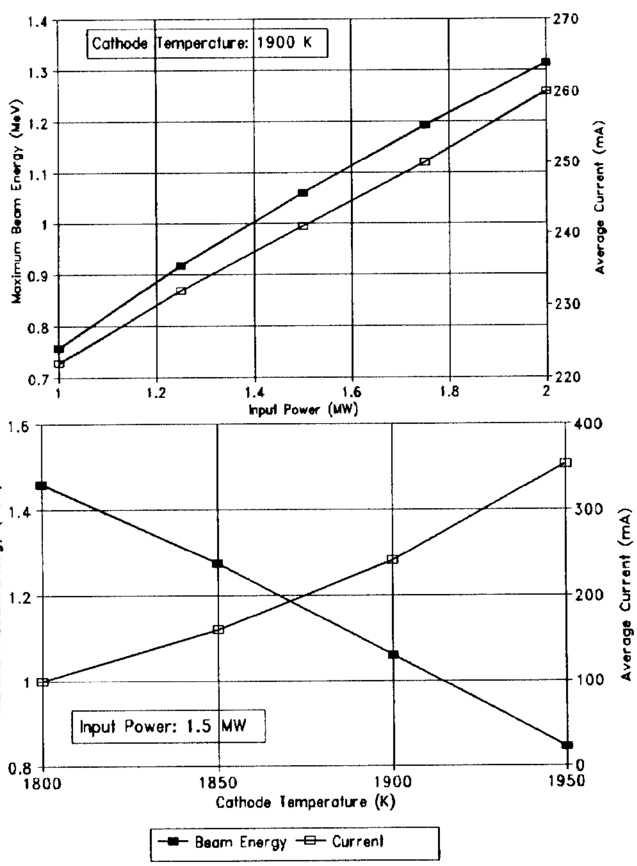

Fig. 2: Beam energy and current changes in terms of input power (top) and cathode temperature (bottom).

Figure 2 shows changes of maximum beam power and average current in terms of the input power and cathode temperature, respectively. The average current is a sum of electrons with their momenta within the range of ±40% with respect to the peak momentum of the bunch. The bunch length of useful electrons is about 20 ps. Normalized rms emittance calculated by PARMELA is 35 π mm-mrad.

C. RF-Gun Design

The RF-gun is a standing wave type one-cell cavity. Optimization of the cavity shape was done by using the SUPERFISH and the RF_GUN codes. The ratio of the peak axis field to the peak surface field is about 0.5, and the ratio of the field at the cathode to the field on the axis is about 0.64. The cold coupling coefficient β ($= 1 + P_{beam}/P_{cavity}$) calculated by the RF_GUN is about 2.5. It is chosen, however, as 3.5 in order to allow higher beam loading. The iris hole size of coupling structure is determined by MAFIA code.

Figure 3 shows a cross-sectional view of the RF-gun cavity. The cathode assembly can be demountable, and an RF choke joint around the cathode stem is adopted. Cathode material is LaB_6 and its diameter is 3 mm.

D. Gun-to-Linac Design

The Gun-to-Linac (GTL) transport line is shown in Figure 4. An alpha magnet is used to match the longitudinal acceptance of the linac. The good field region of the alpha magnet is about 13 cm. A momentum filter is introduced inside the alpha magnet vacuum chamber. A pair of electric plates (30mm x 30mm, 2 cm gap) is placed inside the alpha magnet vacuum chamber in order to deflect undesirable electrons which are generated during the RF-filling time (~ 0.83 μs) of the accelerating column. Required voltage is larger than 4 kV.

IV. FEL DESIGN

A. FEL Parameters

Parameters for undulators and optical radiation are summarized in Table 2 and 3, respectively. The wavelength of resonant radiation is given by

$$\lambda = \lambda_w (1+K^2) / 2\gamma^2 \qquad (1)$$

where λ_w is the undulator period, γ is the relativistic factor, and K is the undulator parameter.

Table 2: Undulator parameters

Period Length (λ_w)	3.0 cm
No. of Period	50
Gap	10 ~ 15 mm
Undulator Parameter (K)	0.5 ~ 1.5
Structure	Tapered
Type of Magnet	NdFeB

B. Electron Beam Transport

There are two electron beam exits in the test linac as shown in Figure 1. Main considerations in the design of beam transport lines were that the beam waist be located at the center of the undulator, and that the size of the beam waist be less than 0.8 mm for 3 μm radiation. The effective length and the bending angle of bending magnets in the achromatic section are 27 cm and 30°, respectively. A quadrupole triplet is used to match the electron beam waist to that of the optical beam at the center of the optical cavity.

Table 3: Design parameters for optical radiation

Spectral Range	3 ~ 30 μm
Cavity Length	4.5 m
Reyleigh Length	0.75 m
Mirror Curvature	2.5 m
Beam Waist (min.)	0.85 mm for λ = 3 μm
	2.68 mm for λ = 30 μm
Spot Size (radius) on Mirrors	2.53 mm at λ = 3 μm
	8 mm at λ = 30 μm
Macropulse Length	5 μs (flat top)
Micropulse Length	5 ps (FWHM)
Small Signal Gain for I = 30 A	73 % at λ = 10 μm
Operation Mode	- Oscillator
	- Amplifier
	- Harmonic Generator

The layout of optical resonator beamline is shown in Figure 5. There are three beam profile monitors (BPRM) in the beamline. The first one is located to find the center of the electron beam. Second and third BPRMs will be used to measure the energy spread.

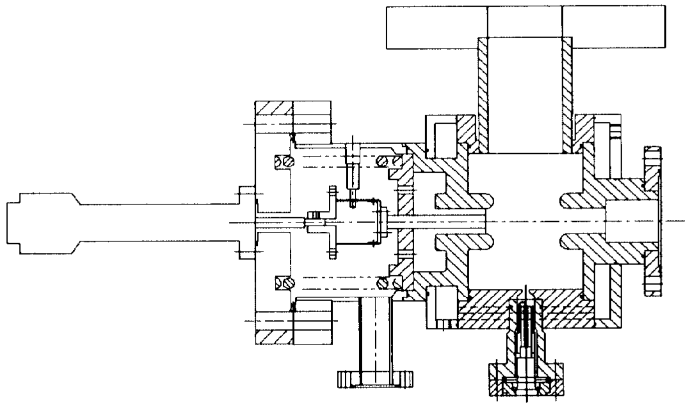

Fig 3: Cross-sectional view of RF-gun cavity.

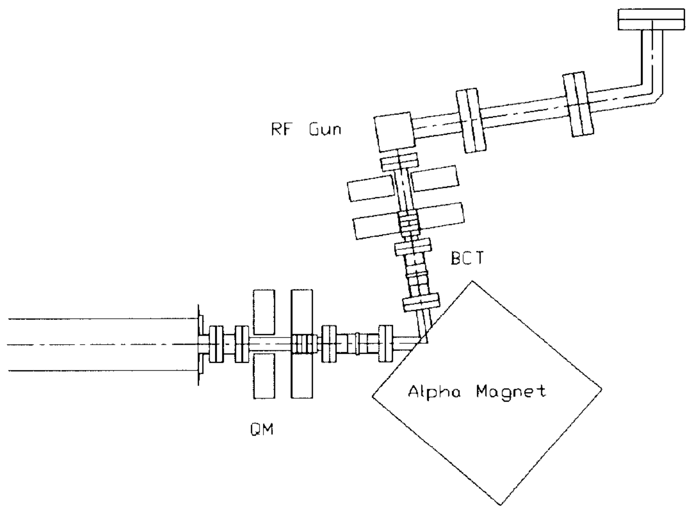

Fig. 4: Gun-to-Linac transport line.

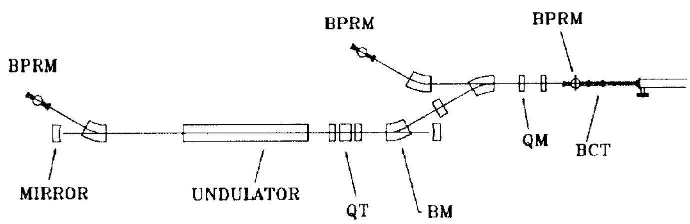

Fig. 5: Layout of optical resonator beamline.

V. REFERENCES

[1]. W. Namkung, et al., "Progress of PLS 2-GeV Linac," these proceedings.

[2]. P. B. Wilson, et al., "Application of Storage Ring RF systems and Linear Colliders," *AIP Conf. Proc. Series*, Vol. 87, p. 450 (1982).

[3]. J. Xie, "An Adaptive RF Feed Forward Control System for ATF," CAP-ATF-Tech. Note 12 (1991).

[4]. C. B. McKee, J. M. J. Madey, "Optimization of a Thermionic Microwave Electron Gun," *Nucl. Inst. and Methods*, **A304**, pp. 386-391 (1991).