TEST LINAC FACILITY AT PHOTON FACTORY, KEK

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Abstract

A test linac facility is progressing at National Laboratory for High Energy Physics (KEK), Photon Factory, Injector Division. The facility is used both for testing of components of the 2.5-GeV linac, which is the injector of PHOTON FACTORY and of TRISTAN, and for research on accelerator science and technology. The linac is to be the most suitable configuration for every experiment. Therefore, the linac doesn't have a fixed layout. A universal bed with a length of 13.5 meters is being prepared. The maximum beam output, restricted due to radiation safety, is 60 MeV and 10 μA. The design and manufacturing of both a conventional electron gun and a microwave electron gun are being carried out. The present status regarding the construction of the linac is presented.

Introduction

A new project to construct a test linac facility has started and is progressing. An increase in the total operation time of the 2.5-GeV linac makes it difficult to test its components, furthermore, the operation time for machine studies has not been sufficient under such busy machine operation. The basic motivations to develop this project has been to solve these problems. In addition to the testing of components of the linac, the following activities concerning accelerator science and technology are expected.

1. High-brightness beam acceleration experiments.
2. Improvement of the energy spectrum.
3. Experiments on a free-electron laser.
4. Testing high-gradient acceleration.
5. Development of a newly designed beam monitoring system.
6. Improvement of the production technique for a positron beam.
7. Experiments concerning large peak-current acceleration.
8. Testing microwave electron guns.
9. Others.

Site of linac

The site of this test linac is situated beside the electron-gun room of the 2.5-GeV Linac. One part of that room is partitioned by blocks with a thickness of 1 meter. The size of the room is 18 meters long by 4.5 meters wide and a universal bed for linac components with a length of 13.5 meters is installed in the room. The layout of this linac will be changed for every experiment, as mentioned above. A typical layout of the linac is shown in fig. 1.

Power source

The pulse modulator for the electron gun produces 17.0kV, 1300 amperes pulses with a width of 4.0 μs. A step-up transformer installed in the shield room connected by a low-impedance

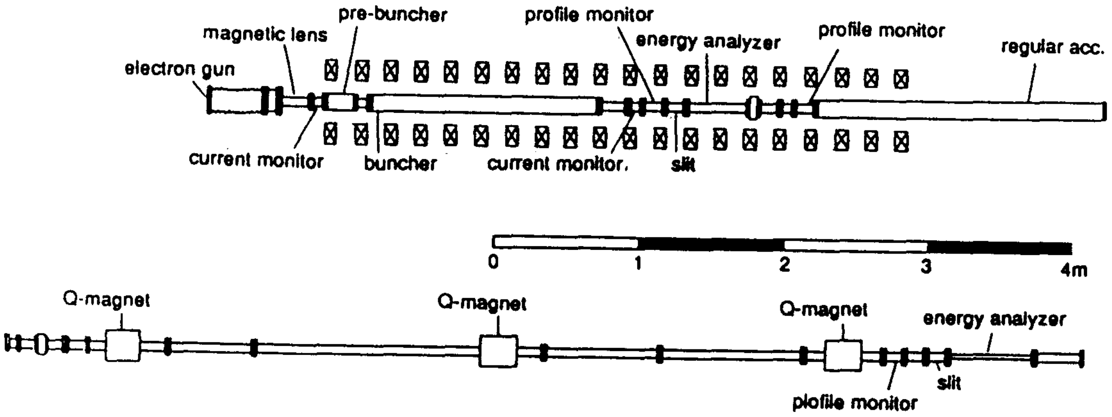

Fig.1 Typical layout of the test linac. The linac is assembled on a universal bed with a length of 13.5 meters.

cable with the pulse modulator can apply a 200 kV pulse to the electron gun under testing.

The pulse modulator for the klystron installed in the klystron gallery produces 84MW pulses with a width of 3.5 μs. The klystron, type PV-3030, generates microwaves of 30 MW. The microwave power is divided into two, and used for the buncher section and the regular section, respectively. The power for the pre-bunching cavity is picked up from the power for the buncher.

High-brightness beam acceleration

Preparation of experiments concerning the high-brightness beam acceleration has started. The production of a low-emittance beam is one of the main themes in this facility. Some users want to use synchrotron radiation generated by a micro-pole undulator installed in the linac complex to obtain a high time resolution. As is well known, the pulse width of the linac output is typically several picoseconds. A beam emittance similar to that of a storage ring is desirable for these purposes. Furthermore, some of the themes mentioned above can not be carried out without a low-emittance beam. For example, the beam quality is a crucial parameter for experiments on a free-electron laser oscillation. Research concerning the acceleration of a high-brightness beam is described below.

Conventional electron gun

The design of an electron gun with high quality represents the beginning of research on high-brightness beam acceleration. The brightness of a cathode is given by [1)]

$$Bn=3.7\times10^{9}J \quad (\text{amps./m}^2\text{rad}^2) \text{ at } 1300\text{K}, \qquad (1)$$

where J is the current density of the cathode in units of amps./cm^2.
The brightness is proportional to the current density of the cathode. We have tried to design an electron gun which has a emittance of ca. 1πm m mrad, 1/100 of that of the gun used in present 2.5-GeV linac. A high electric field is applied to the cathode surface, and the cathode area is reduced in order to obtain low emittance. An electron gun with a cathode diameter of 1 mm has been designed. The gun is operated at 180 kV. Calculations have been carried out using a computer code developed by Herrmannsfeldt.[2)] The distance between the anode and the cathode is 31 mm and is fairly long compared with the diameter of the cathode (1 mm). The entire area in the gun is divided into 4 blocks along the z-axis. One mesh size is 0.1mm by 0.1 mm and 6400 points are calculated in each block. The first block contains the cathode, and the output of this area is input of the second block. Calculations are repeated successively and, finally, the output of the gun is obtained at the fourth block. The emittance at each block in the gun was compared and degradation of the emittance at the anode hole was large. An anode hole with a mesh grid will be effective to avoid any lens effect. Calculations with and without the mesh grid were carried out and the emittance without the mesh grid was two-times larger than that with it. The results described below are for the case with the anode mesh. A current of ca. 600 mA is obtainable. The brightness and emittance from calculations are 5.3×10^{10} amps./m^{2}rad^2 and 1.1πmm mrad, respectively. Then, the current density of the cathode is 80 amps./cm^2. The brightness of the cathode calculated from equation (1) is 3.1×10^{11} amps./m^2 rad^2. The cathode assembly for this gun is shown in fig. 2. and its calculated ray-trace is shown in fig. 3 respectively.

The diode described above is to be used at the beginning of experiments; a triode will also be

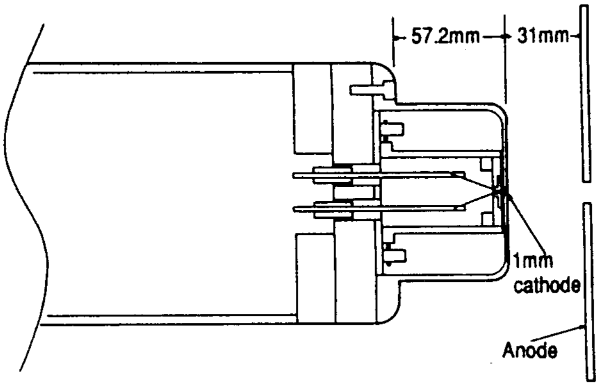

Fig.2 Cathode and anode assembly of the gun. The diameter the cathode is 1 mm.

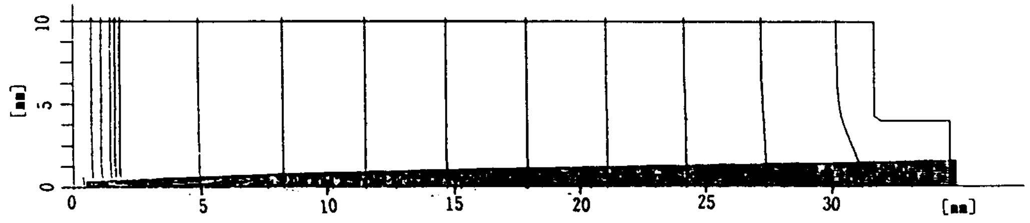

Fig.3 Ray-trace of the gun. The beam slightly diverges in the gun.

used in the linac for some experiments. The effect of the grid on emittance growth is also calculated. The emittance is increased by several times, depending on voltage of the grid.

Microwave electron gun

A microwave electron gun (RF-gun) is suitable for the production of a high-brightness beam. The design of a RF-gun with three electrodes (anode, cathode, grid) and testing it under low power have been carried out. When a photo-cathode is used, the pulse width can be controlled by the time duration of the laser pulse. In the present system, the pulse width is controlled by the energy selection. The single-cell RF-gun and the energy-analyzing system are shown in fig. 4. A multi-cell RF-gun is being investigated as a next step. A high-power test of it and beam acceleration will be carried out in the test linac facility.

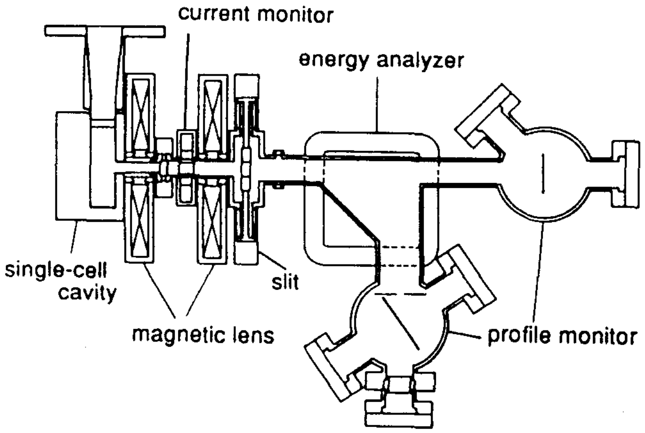

Fig.4 The layout of the RF-gun. The single-cell RF-gun, energy-analyzing magnet and the beam-monitoring system are shown.

Design of injector

The emittance growth in the buncher is serious problem for high-brightness beam acceleration. The cause of emittance growth is mainly lens action of microwaves excited in the cavity. T. Smith[3]et al. proposed mixing the fundamental and third harmonics in order to obtain a flat-top of acceleration field which would provide no phase-dependent effects. A small beam size is also effective to avoid emittance growth, since the radial force increases with a transverse displacement of the beam. A calculation of the emittance growth using PARMELA has been carried out. The emittance growth in a single-cell pre-buncher is described as one example. The phase space of the output of the electron gun described above is used as input data and is shown in Fig. 5(a). A magnetic lens converges the electron beam to a focus point at the center of the pre-buncher. The phase space at the output of the pre-buncher both with and without the magnetic lens are shown in figs.5(b) and 5(c), respectively. When the beam size is small at the pre-buncher, the effects of the radial force, depending on the microwave phase, are small. A focusing system used to minimize any emittance growth is being investigated.

Conclusion

The test linac facility is progressing. Construction of the shield room, installation of modulators and tests of the safety interlock system were completed. The design of the electron gun containing a very small cathode with a diameter of 1 mm was completed. Low- power tests of the RF gun were carried out and high-power tests will be performed after completion of the construction of waveguides for high-power microwaves.

References

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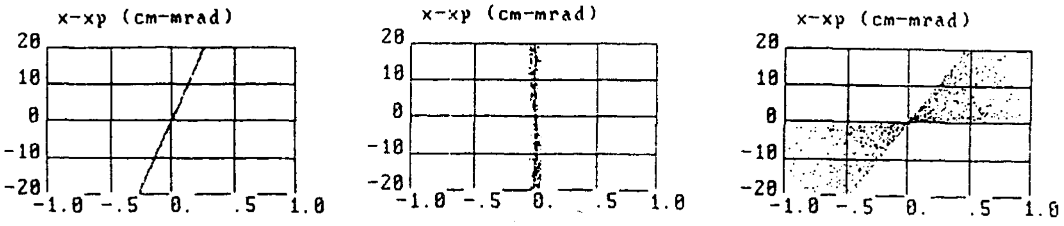

(a) (b) (c)

Fig.5 Phase space at the output of the gun, (a). Phase space at the output of the pre-buncher with focusing, (b) and without focusing, (c).