Acceleration Characteristics of Positron Generator Linac

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Abstract

Positron generator linac was planned for the purpose of supplying a positron beam to TRISTAN-RING. This plan was proposed in FY 1977. This proposal was authorized and enforced with a year for 3 years from FY 1982. A construction of this linac facility began in April 1982 and completed in March 1985. The first operation began on April 1985. After three month, the positron generator linac succeed in a first acceleration of a positron beam.

In March of this year, the positron beam and the electron beam was alternatively transported to a accumulator ring of TRISTAN, there succeeded in a first collision of those beams. This report describes an operation, an outline and an acceleration characteristic.

Operation

The trial operation began in April 1985. At this run, an positron generator linac executed an examination of an electron acceleration, and succeeded in an energy acceleration of 270MeV.

The 2nd trial operation was performed in July after 3 month from the first run. At this run, the linac succeeded in a first positron acceleration, and accelerated the positron beam of 1.2mA to the energy of 250MeV.

The 3rd trial operation was executed in October of the last year. At this run, the linac succeeded to accelerate the intensive positron beam of about 8mA, the positron beam was transported to PF injector and was accelerated to the energy of 2.5GeV, and then the beam current of about 2mA was transmitted at the end of the injector. The 4th trial operation was accomplished in December of the last year. In this run, the positron beam current achived 10mA at the end of the positron generator linac. This beam, was accelerated and was transported from PF injector to PF storage ring and was storaged in the ring. This trial examination succeeded to storage the positron beam current of 5 mA. The 5th trial operation was executed at the end of in the December, the positron beam and the electron beam were transported interchangeably to an accumulation ring of TRISTAN and succeeded in simultaneous storage of the 2 beams. At present, the trial that reinforces a beam current of short pulse (2ns) by using a subharmonic buncher is executing. Fig.1 shows a relation between this linac facility and the other facilities.

An outline of the linac for the positron generator

A linac facility for a positron generator was constructed on the west side of PF injector. The accelerator is housed in a slender two-story building. The length of the building is about 90 m. The first story of this building is an underground tunnel and a floor of the second story is the concrete of a thickness of 1.5 m. The thick floor is the defense wall of radiation.

This new linac facility consists of accelerators of an electron linac and a positron linac.

An electron gun room was partitioned by a thick concrete wall from a beam line room in the underground tunnel. A gun and a power supply for it were in the electric gun room. Cavities, accelerator guides, focusing magnets, solid circuits, vacuum ducts etc. were settled in the beam line room. The positron (generator linac) beam line was parallel with the beam line of the PF injector and the interval of the 2 beam line was set to 15 m. The end of the positron linac beam line was joined to a beam line between the 5th acceleration unit and the 4th acceleration unit of the PF injector.

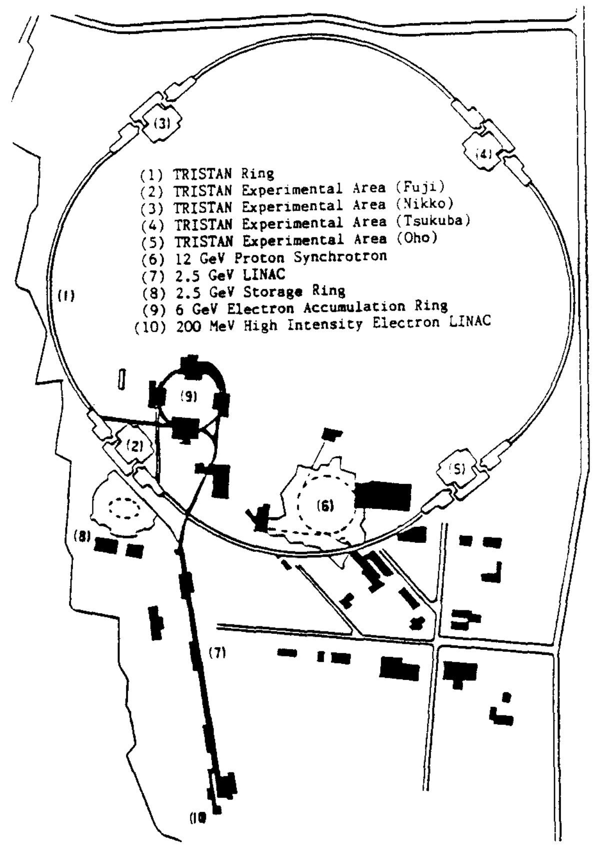

Fig. 1. Overall layout of the KEK accelerators.

A sub-control room was partitioned from the klystron gallery in the second story of this building. The subharmonic buncher power supply, the power supply for a subbooster, 6 sets of high frequency power supply with a klystron, power supplies for beam transport, ion-pumps and power supplies for those, a pulsed power supply for a positron focusing coil etc. were installed there.

A Klystron and an accelerator guide were connected with a waveguide through a pipe that buried it in the floor of the gallery. An electron gun, a subharmonic buncher cavity and a prebuncher cavity, a buncher accelerator guide, a 2m regular accelerator guide, 5 4m regular accelerator guides, a magnetic lens, 30 solenoid coils, 5 triplet quadrupole magnets and one doublet quadrupole magnet, 3 wall current monitors, 5 profile monitor etc. were installed in the beam line of the electron linac. A target of tantalum, 4 4m regular accelerator guides, 4 4m regular accelerator guides, a pulsed focusing magnet, 9 triplet quadrupole magnets, a pair of 30 degree bending magnets, 10 singlet quadrupole magnets, 5 wall current monitors, 15 profile monitors etc. were set up in the beam line of the positron linac.

Main parameters of the positron generator linac are described in table 1.

Table 1 Design parameters of the positron generator linac

	electron linac	positron linac
energy(MeV)	230	250
beamcurrent	10A	10mA
pulse width of beam (ns)	2-10	2-10
frequencyofacceleration(MHz)	2856	2856
repetition(pps)	50	50
numberofaccelerationunit	3	3
number of accelerator guides (2m & 4m)	1 & 5	4 & 4
acceleration mode	2 N/3	2N/3
number of klystron	3	3
output power of klystron (MW)	25	25
number of prebuncher cavity	7	
number of buncher cavity	44	
frequency of subharmonic buncher(MHz)	119	
voltage of gun (KV)	150	
current of gun cathode (A)	10	
thickness of target(Ta)(mm)	8	
maximum flux density of focusing coil	1.4T	

An outline of the arrangement of this linac facility is shown in Fig 2. Photo 1 shows the underground tunnel of the positron generator linac. Photo 2 is a panoramic view of klystron gallery.

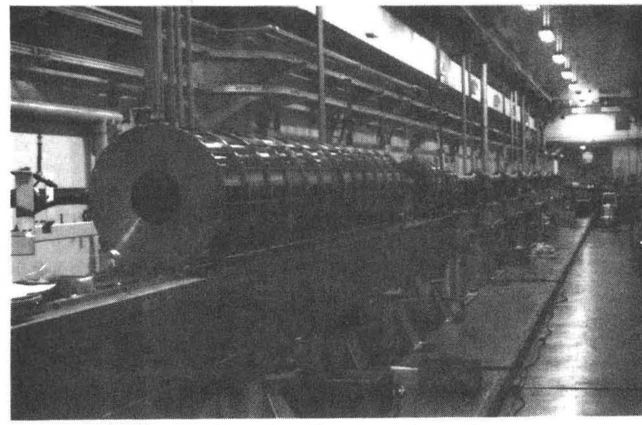

Photo. 1. Accelerator tunnel.

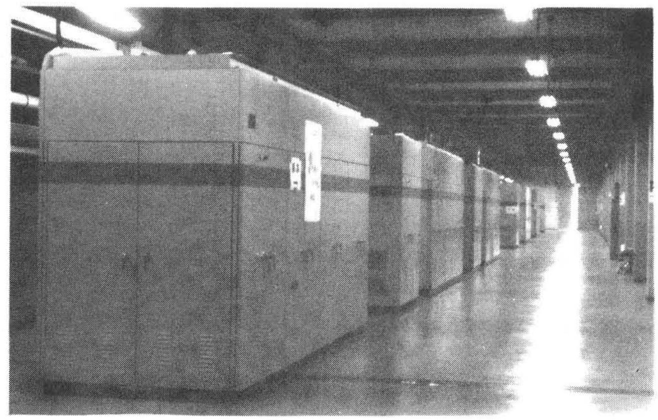

Photo. 2. Klystron gallery.

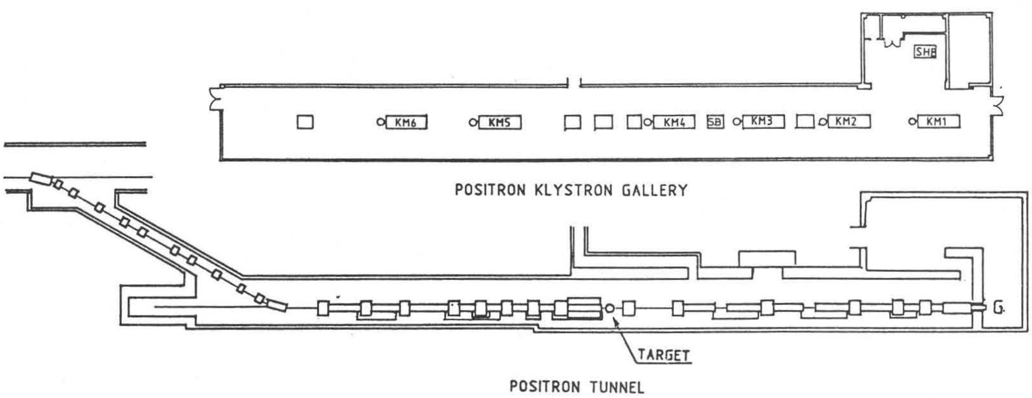

Fig. 2. The positron generator housing.

The Performance of the positron generator

The performance of the accelerator is as following.

First of all, the pulse voltage of about 100KV is supplied to an electron gun (triode with an oxide cathode). A pulse voltage of about 5ns is supplied to a control grid of an electron gun and an electron beam of about 10A is emitted from the cathode. The most of this electron beam pass a control grid and reach to the anode.

The electron beam that pass through an anode hole is focussed with a magnetic lens and the current value is about 6.3A. The velocity of an electron beam is modulated with a sub-harmonic buncher cavity (119MHz) and condensed to a pulse width of about 2ns. The electron beam is furthermore bunched with microwave electric fields of the pre-buncher and the buncher. The traveling electron beam is converged by a axial magnetic flux of solenoids at this section. The electron beam is accelerated to an energy of about 230MeV with traveling waves of the regular accelerator guides. Then the electron beam hits to a metal target. A current of the electron beam in front of the target is about 3.5A. A positron beam emitted from the target has a wide range of energy distribution and is discharged in a large solid angle. Large number of positrons are distributed in a range of several Mev. The positron beam is focussed with a strong parallel magnetic flux. The maximum flux density of about 1.2T can be obtained when a pulse current of 5,000A (100 micro-sec) is supplied to the solenoid coil.

The positron beam is accelerated to the energy of about 65MeV with a 4 m regular accelerator guide that was located in the central axis of a focusing coil. The magnetic flux density of the coil is about 0.2T. The positron beam is accelerated 250MeV with other 2 m and 4 m regular accelerator guides. The positron beams on this section are with 7 triplet quadrupole magnets and one doublet quadrupole magnet. The positron beam is transported from the positron generator linac to PF injector, while the beam is bent and focussed by a 30 degree bending magnet and by 10 singlet quadrupole magnets. After that, the beam is bent again 30 degree with another bending magnet for coinciding to the beam line of PF injector. The positron beam is accelerated up to 2.5GeV through the injector linac. The positron beam is transported to an accumulator ring of TRISTAN and is accumulated and accelerated to the energy of 8GeV. The beam will be taken out from the ring and transported and stored in a main ring of TRISTAN and stored.

Acceleration characteristics

In a test operation, the beam pulse width was expanded to about 5ns to facilitate the adjustment of a beam track. Beam currents of the electrons and the positrons were measured by using a wall current monitor. The beam current shapes of the electron and positron were shown in Fig. 3.The former is observed current shape of electrons at just before the metal target. The latter is the current shape of the positron at the end of a positron linac. Conversion efficiency from the electron to the positron were evaluated as about 0.3 %.

Energies of the electron and the positron were measured by using a 30 degree bending magnet installed at the end of a straight beam line in the positron generator linac.

An energy spectrum of the electron beam is shown in Fig. 4. In this measurement,the positron linac was standby. Therefore, the energy of electron beam at the end of the electron linac is considered to be slightly larger than this measured value. Fig. 5 shows the relation between a beam current shape and energy spectrum of electron beams. The front of the pulse beam shape is in a high energy level than the back. This effect is estimated for wake fields that were induced in accelerator guides of the electron linac.

An energy spectrum of a positron beam is shown in Fig. 6. From the positron generator linac to PF injector beam transport efficiency of a positron beam was estimated 0.67. The positron beam currents along the beam line of PF injector are shown in Fig. 7.

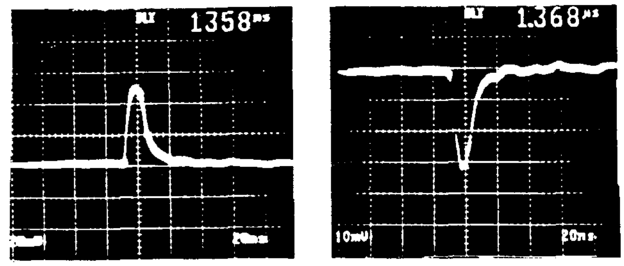

Fig. 3. Signals from wall current monitor. Electron beam (left) and the positron beam (right).

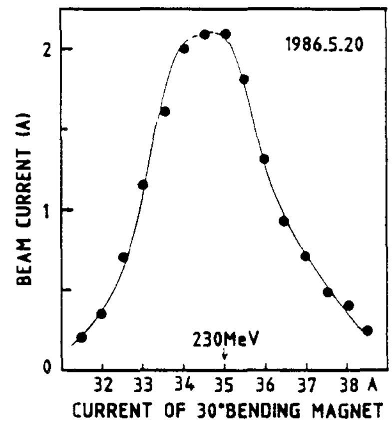

Fig. 4. Energy spectrum of the electron beam.

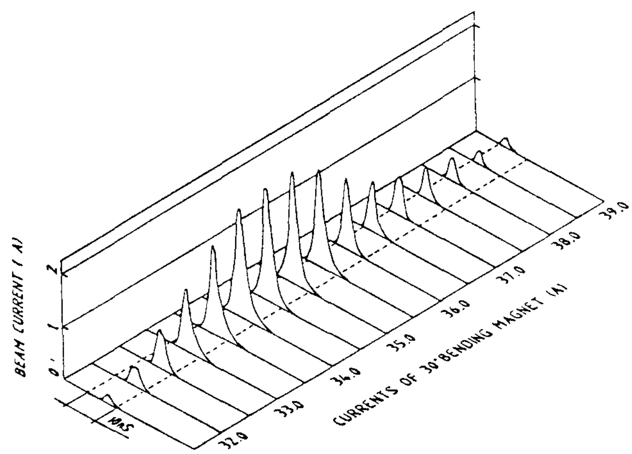

Fig. 5. Beam pulse structure.

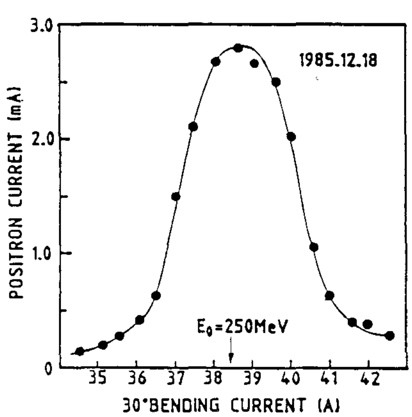

Fig. 6. Energy spectrum of the positron beam.

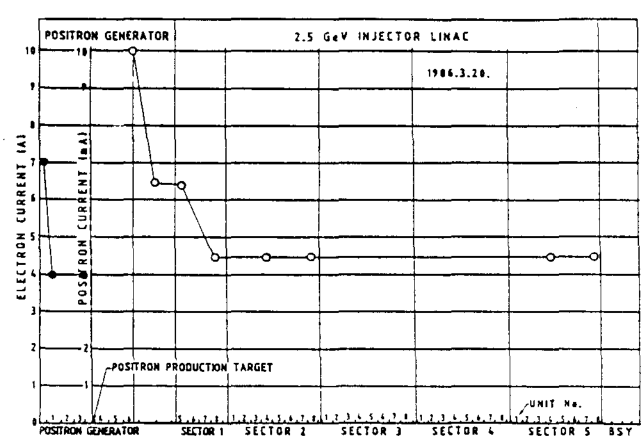

Fig. 7. Electron and positron current distribution.