1.54GEV ATF LINAC FOR DAMPING RING

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Abstract

Accelerator Test Facility (ATF) is under construction in the TRISTAN Assembly Hall consists of 1.54GeV S-band Linac, beam transport line, damping ring, bunch compressor, final focus system and positron target test-stand for linear collider R&D. The S-band Linac is an injector of the damping ring supplies a multi-bunch beam train which is 20 bunches with 2×10^{10} electrons/bunch and 2.8 ns bunch spacing. The newly developed techniques which are high gradient accelerating unit, precise alignment system, beam energy compensation system, compact modulators, multi-bunch beam monitors are described.

Introduction

ATF is a test-stand of key components to realize a linear collider such as multi-bunch beam generation, high gradient acceleration, low emittance beam, short bunch length beam and so on. The construction was started in the TRISTAN Assembly Hall which is 120m x 50m width since 1991. The reinforcement of the floor was done at first to support heavy concrete shield blocks of tunnels. The movement of 80MeV preinjector from Nikko Hall was completed on August '93. The 80 MeV electron beams are now utilized to test structures and monitors. The ATF Linac summarized in Table 1 is consist of 80MeV preinjector, 8 regular accelerating units, two unit of energy compensating structures. At this stage, whole tunnel construction, Linac tunnel air conditioning, Linac water cooling system and installation of Linac main components were completed.

1.54GeV ATF LINAC

80 MeV Preinjector of LINAC [1]

The role of preinjector is to generate 20 multi-bunch of 2×10^{10} electrons/bunch with 2.8 ns bunch spacing and to inject it to 1.54GeV Linac. Since the preinjector was originally designed to generate a high current single bunch, the buncher cavities are now re-designed to have low R/Q values in order to reduce beam induced voltage which affects to bunching of successive bunches.

The extraction of multi-bunch from ordinary thermionic gun is done by applying RF wave of 357MHz to the grid[2]. The extracted bunch has 1ns(FWHM) and 3A peak current with 200kV energy. The bunch is shrunk to 20ps(FW) by the two 357MHz SHB cavities and the four single cell 2856MHz buncher cavities. After bunching, the bunches are accelerated up to 80MeV by a 3m structure, then go into beam diagnostic section.

High gradient accelerating unit [3]

The limitation on the length of Linac comes from the length of tunnel. An 1.54GeV beam energy is required within 80m of total Linac length including preinjector, Quadrupole magnets and beam monitors. The high gradient of 33MeV/m is necessary for the beam acceleration. The limit of accelerating gradient in the accelerating structure is determined by the break down of the electrical field and the intensity of the field emission current. Since the break down comes from the field emission current, to reduce the current is to get high gradient. From the conclusion of the high gradient experiment which we have done for several years, the effort for high gradient structure has done as listed below;

1. keep cleanness during fabrication and tuning in order to avoid dust and contamination on the surface of the structure.
2. the input and output coupler are carefully designed to avoid field enhancement like tuning dimple.
3. use HIP(Hot Isostatic Press) OFHC for the disks to reduce voids between crystal grains.

As a result, a maximum gradient of 52 MV/m was achieved with 200MW peak rf power input.

Beam Energy for D.R.	1.54 GeV
Total Length	70 m
Injector	10m
Linac	60m (active length 48m)
Accelerator Structure	2π/3mode constant gradient
Total length	3m
Total number	16
Accelerating Field	
Maximum Field	43 [52] MV/m
with Beam Loading	33 [40] MV/m
RF Frequency	2.856 GHz
Feed Peak Power	200 MW/structure
Klystron	
Klystron Peak Power	80 [85] MW
Klystron Pulse Length	4.5 μs
Number of Klystrons	8
Pulse Compression	Two-iris SLED
Power Gain	5.0 (average)
S-band Preinjector	
Beam Energy	80 [105] MeV
Number of Bunches	20
Bunch Population	2×10^{10} electrons
Bunch Separation	2.8 ns

Table 1 1.54 GeV ATF Linac Parameters
([ ]: actual value during 1994 summer run)

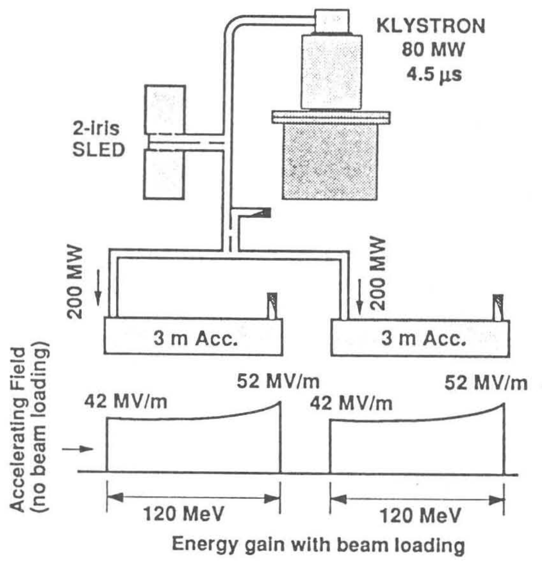

Figure 1. Regular accelerator unit of ATF Linac.

Using these high gradient structures, the regular accelerating unit is composed by 80MW klystron, two-iris SLED and two 3m structures. This system can generate 400MW peak power rf from the SLED (200MW peak power rf into 3m structure) and 240MeV energy gain with beam loading (see Fig. 1).

Wire Alignment System [4]

The stages of Linac have an active mover mechanism and wire position sensors. In order to monitor the stage position and to align the whole stages, two stretched wires are used with the length of about 80m(Fig. 2). The wires are stretched in both side from the preinjector stage to the end of the Linac. The one ends are fixed to the preinjector stage which does not have active mover mechanism, and the other ends are stretched by the tension weight of 33.5kg. The sag of wires are calculated in each sensor position as far as no kink on wires and assumption of uniform wires and no creep. The center position of wire

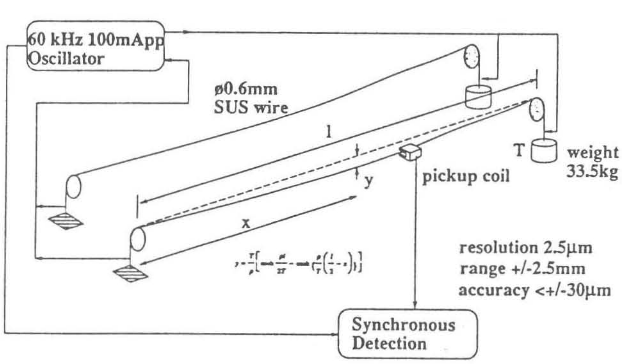

Figure 2. Block diagram of the wire alignment system.

sensors mounted on support stage are calibrated in its calculated position in the calibration stand. Each sensor mount is fixed to the reference surface of the stage which is machined with less than 10µm in accuracy. In this way, when the stages are aligned so as to get the wire position into the center of the sensors, the reference surface of the stages are aligned to the wires in straight. The resolution of position sensor is 2.5µm and the accuracy of center finding is ±30µm. The wire position is detected by a synchronous detection of the signal from the differential coils using 60kHz current on the wire.

Energy Compensation System

In multi-bunch acceleration, a beam energy decreases from front to end gradually by beam loading of structures. Since the maximum energy acceptance of Damping Ring is ±1% and since a variation of bunch spacing is not acceptable, the new energy compensation scheme for multi-bunch was developed. Using the accelerating structure which is operated in slightly higher frequency, the front bunches can get deceleration and the rear bunches can get acceleration. To cancel out an energy spread within bunch, the other structure which is operated in lower frequency of same amount with opposite slope. With this system the energy spread among bunches can be reduced from about 5% to 0.2% peak to peak (Fig. 3). In order to simplify the timing system, the frequency deviation was chosen to 4.327 MHz which is just twice of Damping Ring revolution frequency[5]. The system consist of two klystrons and 3m structures which are operated in 2856+4.32MHz and 2856-4.32MHz each. The maximum output of klystron is 50MW, 1µs square wave which can compensate 80MeV maximum in one unit.

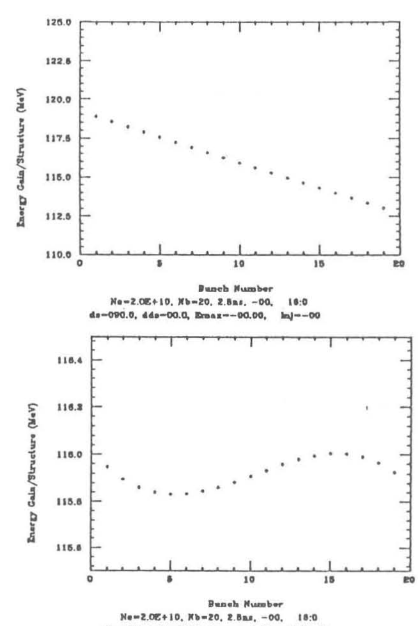

Figure 3. Energy gain without compensator (up)
with compensator (down)

200MW compact modulators [6]

A 200MW modulator development has been continued since 1987. The main effort of this development is focused on the total size, stability and efficiencies which will directly affect on the scale of the linear collider machine. The use of the compact self-healing type capacitors makes the PFN more compact. The packing of each device into the modulator box was re-checked to make high density packing. By discarding the electric standard for spacing of high voltage device, 1.5m x 2.5m width and 2.2m height modulator was realized. To make a hold-on time of thyratron shorter, the charging into the PFN is initiated by the command from the controller. To avoid reverse voltage on the thyratron, a tail clipping circuit are added. By these method, the lifetime of the thyratron will be longer. The energy loss of the de-Qing circuit is collected by a simple circuit which makes 5% saving of wall plug power.

Multi-bunch Beam Monitors

In addition to ordinary monitors such as toroid current monitor, screen profile monitor, stripline beam position monitor and bunch length by streak-camera, we are developing bunch by bunch position, size and current monitors which measures each bunch in the 20 bunch train. The preliminary result of gated beam size measurement done by a fast gated camera on OTR light and gated gamma detection in the wire scanner is reported in elsewhere [1,7]. The fast current measurement using wall-current monitor and gated position measurement using fast sample-hold circuit are now under developing. The beam monitors are placed as shown in Figure 4.

Schedule toward commissioning

Since the 80MeV preinjector is cut off from the Linac till March '95, the multi-bunch generation development on the preinjector and rf processing of the regular unit in the Linac can be done independently. At March '95, the connection of the preinjector, the Linac and the beam transport line which include a beam diagnostic section and dump will begin. The completion of construction will be July '95 including the energy compensation system, beam monitors and control software. We will have the beam commissioning of ATF Linac on summer '95.

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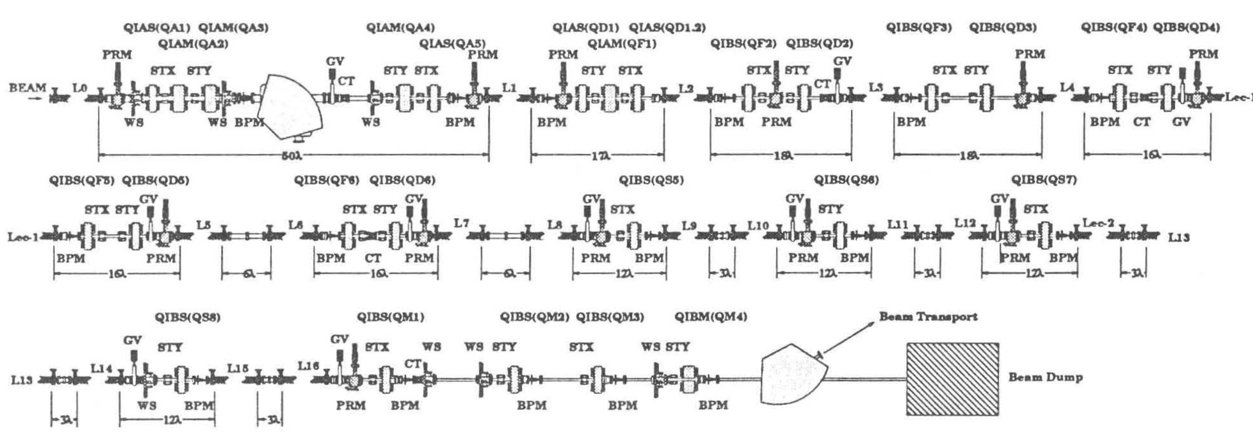

Figure 4. ATF Linac component diagram.