Design Of The e^+/e^- Frascati Linear Accelerator For DAΦNE

K. Whitham, H. Anamkath, S. Lyons, J. Manca,
R. Miller, T. Zante, P. Treas, D. Nett
Titan Beta, 6780 Sierra Ct., Dublin, CA 94568

R. Miller
Stanford Linear Accelerator Center (SLAC)
2575 Sand Hill Road Stanford, CA 94025

R. Boni, H. Hsieh, S. Kulinski, F. Sannibale,
B. Spataro, M. Vescovi, G. Vignola
Istituto Nazionale Di Frascati Nucleare
Frascati, Rome

I. INTRODUCTION

The electron-positron accelerator for the DAΦNE[1] project is under construction at Titan Beta in Dublin, CA. This S-Band RF linac system utilizes four 45 MW sledded[2] klystrons and 16-3 m accelerating structures to achieve the required performance. It delivers a 4 ampere electron beam to the positron converter and accelerates the resulting positrons to 550 MeV. The converter design uses a 4.3T pulsed tapered flux compressor along with a pseudo-adiabatic tapered field to a 5 KG solenoid over the first two positron accelerating sections. Quadrupole focusing is used after 100 MeV. The system performance is given in Table 1. This paper briefly describes the design and development of the various subassemblies in this system.

Table 1. DAΦNE Linac Parameters

General	
RF Frequency	2856 MHz
Klystron Power	45 MW
No. of Klystrons	4
No. of SLED Cavities	4
No. of Sections	16
Repetition Rate	50 Hz
Beam Pulse Width	10 nsec
High Current Electron Linac	
No. of Accelerating Sections	6
Input Current	up to 10.0 A
Input Energy (nominal)	120 kV
Output Current	>4.0 A
Output Energy	250 MeV
Output Emittance (geometric)	$\leq 1\pi$ mm·mrad
Energy Spread	± 5%
Focused Beam Spot	~1 mm radius
Positron Linac Mode	
No. of Accelerating Sections	10
Output Energy	$\geq$550 MeV
Input Energy (mean)	8 MeV
Resolved Output Current	36 mA
Emittance (geometric)	$\leq 5\pi$ mm·mrad
Energy Spread	± 1%
High Energy Electron Linac Mode	
Full Beam Energy	550 MeV
Peak Current	150 mA
Energy Spread	±0.5%
Emittance (geometric)	$\leq 1\pi$ mm·mrad

II. GENERAL SYSTEM DESCRIPTION

A. The Linac System

The linac system consists of:

1. A high current linac designed to produce 250 MeV with 4 amperes of beam current with a 1 mm focus spot on the positron target. This section includes the electron gun and injector which is useable in both the electron and positron modes. This linac utilizes a series of discreet solenoid coils over the first section and quadrupole focussing over the remaining 4 sections. A final focus triplet brings the beam to the 1 mm spot on the positron target.

2. An electron to positron converter based on the SLAC design.

3. A low current accelerator designed to produce 550 MeV for accelerating either the positron beam or a low current (150ma) electron beam. This section includes a 5 kG solenoid over the first two sections followed by an electron-positron separator prior to the remaining ten sections.

4. The system is computer controlled using a bussed architecture and a MacIntosh Quadra 700 computer running Labview.

B. Injector

The conceptual design of the first few meters of the DAΦNE linac is patterned after the original SLAC injector, which ran for 20 years delivering beams from a few nanoamps to 2 amps. The DAΦNE Linac injector consists of the following components:

1. A 120 kV thermionic triode (with a mesh grid) gun with a 3 sq cm dispenser cathode capable of currents up to 15 amps.

2. A single resonant cavity prebuncher, which bunches about $^3/_4$ of the electrons into a 90° bunch in the 21 cm prebuncher drift.

3. A 5 cell, 13 cm long, travelling wave buncher with phase velocity equal to 0.75c, which bunches the beam by about a factor of 3 to about 30° and accelerates the electrons up to about 0.5 MeV.

4. A 3-meter long constant gradient, velocity of light accelerator section, which completes bunching the beam to about 5° FWHM and accelerates the beam to about 45 MeV. According to the program PARMELA, used to design the injector, 80% of the beam from the gun should captured and accelerated, and 87% of the captured beam is within a 15° bunch.

5. The magnetic focussing system consisting of one iron core magnetic thin lens which matches into a solenoid consisting of 14 large aperture coils placed at the Helmholtz spacing around the prebuncher, buncher, first 3 meter long accelerator section. The solenoid has a nominal maximum axial magnetic field in the accelerator section of 1.25 kG. The beam from this section is focussed by a quadrupole doublet placed after this first accelerator section. This doublet matches the beam into a FODO array consisting of two large quadrupoles between sections.

This system is designed to be capable of running well for a wide range of currents from 7 amps (for producing positrons) down to the nominal 150 mA required for injecting electrons into the DAΦNE storage ring and indeed down to 1 mA or less.

C. E-Gun Pulser

The E-gun pulser was required to generate a low jitter, fast risetime pulse to the E-gun cathode (grounded grid configuration). A fast avalanche transistor based pulser has been developed to meet these requirements. Amplitude control of the pulser is via a PIN diode attenuator stack that was developed for this purpose. Previously the E-gun output has been shown to have rise and fall times of less than 800 picoseconds.

Control and trigger of the E-gun pulser is via fiber-optical links providing pulse width, amplitude, and fault detection through serial communication. Up to four 8-bit analog and six digital signals are transmitted over a single pair of fiber optical cables. The E-gun pulse width is fixed at 10 nanoseconds, but is locally settable between 1 and 10 nanoseconds in 1 ns increments using an on-board digital pulse width generator.

The E-gun floating deck is connected to a 150 kV DC power supply which provides the acceleration potential for the injector.

D. Positron Source

The positrons are produced by focussing a high current (4 to 7 amps) 250 MeV electron beam which has been accelerated through the first 5 three-meter sections of the linac onto a tungsten converter, creating an electromagnetic cascade of electrons, positrons and photons. The electrons are focussed onto the converter by close-spaced quadrupole triplet mounted about 1 meter upstream of the converter. The positron source was designed (as was the electron injector) using the simulation program PARMELA obtained from L.M. Young at LANL. We are using a SLAC SLC style source with a pulsed "Flux Concentrator" which produces a field tapering from 43 kG at the input to 0 kG in about 15 cm. Superimposed on this pulsed field is a DC magnetic field which tapers from 12 kG down to a uniform field of 5 kG which continues through the first 6 meters of acceleration.

The RF is phased to initially decelerate the positrons. The positrons which debunch because of the spread in pathlengths and velocities are rebunched in order to achieve a much better spectrum. With this design, over 2% yield was achieved into a ±1% spectrum with 250 MeV incident electrons.

After acceleration through 2 three-meter sections immersed in a solenoid, the positrons pass through a chicane consisting of 4 rectangular dipoles which deflect the positrons 2 cm off axis and then back on axis. The secondary electrons from the positron converter (the converter produces roughly twice as many electrons as positrons) are deflected in the opposite direction, and thus can be stopped on a collimator. Such a chicane is achromatic to all orders. The chicane makes the positron and current monitors between this point and the end of the linac effective for tuning the positron beam, since beyond the chicane the beam has only positrons. Beyond the chicane the beam is focused by a FODO array of large aperture quadrupoles mounted around the accelerator sections: six around the first 3 meter accelerator section; four around each of the next 3 sections; and 2 around the remaining 4 sections.

E. Modulators

Titan Beta is building four identical line modulators capable of delivering 100 MW peak power video pulse with 4.5 μsec flat top at 50 pps. There is a 8 stage PFN in each modulator, resonantly charged with requirement of ±0.1% pulse to pulse amplitude stability.

The system will also have a modulator to drive the positron flux concentrator. The design of this unit is based on existing SLAC unit and is expected to run at 50 Hz driving 12 k amp peak current through a 1 μh load.

F. Control System

The control system is distributed into various subsystem chassis located throughout the linac system. Each chassis has built-in fault detection circuitry to detect any fault condition and display all of the faults and indicate the first fault occurrence. In addition, all faults are summed in the master system controller for subsystem fault identification.

A bussed architecture is used to reduce the number of control cable wires. The fault detection system uses a multiplexed buss connected to the master system interface instead of individual wires for each fault. The first subsystem to detect a fault acquires the buss via logic located in the master control interface. This allows the use of 16 lines instead of >140 lines to monitor all possible fault conditions.

The entire system is operated through a CAMAC based computer control system. An Apple MacIntosh Quadra 700 Computer is used to run the National Instruments Labview 2 software. The computer is integrated with the control system and provides all system operating and monitor functions via software control with the exception of the safety interlocks which are hardwired. The computer can be located at the CAMAC rack location or can be remotely located up to 100m away using a fiber-optic IEEE-488 buss extender. A small control chassis is co-located with the computer to provide hardwire basic operating control functions.

G. Mechanical Systems

1. Vacuum System

Ultra high vacuum is maintained by the use of ion pumps distributed throughout the system. There are two pumps at the injector, a pump between each accelerating section and one at the beam output of the system. Additionally there is an ion pump at each SLED cavity as well as at each klystron window. Beamline valves are used to divide the system into four separate volumes.

2. Temperature Control

Temperature stability for the system is accomplished using two separate water systems. One system (accessory) removes waste heat from the klystron/pulse transformer tank assembly, beam line magnetics, and accelerating section RF output loads.

The second system regulates the temperature of the prebuncher, buncher 15 accelerating sections, 4 SLED cavities and the RF transmission waveguide system. Regulation is accomplished by mixing hot and cold water, followed by SCR controlled high power heaters. Heaters are located at the inlet to each accelerating section. Temperature stability is ± 1°C.

H. Acknowledgements

Schonberg Radiation Corp is supplying the accelerating structures and SLED cavities which are based on the SLAC design. Hermosa Electronics provided the electron gun. SLAC has provided support through the participation of several scientists, H. Hoag, H. DeRuyter, A. Kulikov, and through access to drawings and design information. In addition, a Technical Review Committee was established consisting of scientists from laboratories around the country including to review our designs and critique our approaches. Their input has been invaluable.

I. Conclusion

The DAΦNE accelerator is under construction at Titan Beta. It is proceeding on schedule and is expected to be delivered early in 1994.

References

(1) G. Vignola, INFN-LNF; "DAΦNE, The Frascati Φ-Factory", PAC '93 Conference Ib4, May 17-20, 1993.

(2) Z.D. Farkas, H.A. Hogg, G.A. Loew and P.B. Wilson, "SLED: A Method of Doubling SLAC's Energy", IXth Int'l Conf on High Energy Accelerators, SLAC, May 2-7, 1974.