BEAM MEASUREMENTS OF THE ANL-APS LINAC INJECTOR TEST STAND*

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Abstract

The Argonne Advanced Photon Source (APS) injection S-band linac consists of a thermionic gun, a single gap pre-buncher, a constant impedance buncher with $v_p = 0.75$ c and a 3-meter long constant gradient traveling waveguide. Results of the electron beam measurements at 56 MeV and comparison with calculations and beam simulations are presented.

Introduction

The APS electron linac consists of a injection system and 4 constant gradient accelerating sections to produce and deliver a 30-nsec, 50-nC macro-bunch of 250-MeV at 60 Hz to a positron production target.

The linac test stand was assembled in order to study beam parameters and to evaluate the performance of individual components. The test stand was operational in April, 1992. The beamline layout is shown in Figure 1. Table 1 shows the test stand main beam parameters.

Table 1
Test stand beam parameters

Parameter	Symbol	Nominal
RF frequency	f	2856 MHz
Beam energy	E	56 MeV
Beam current	I	1.7 Ampere
Pulse length	σ_t	30 nsec
Pulse rep. rate		3 Hz
Accelerating field	dE/dZ	18 MV/m
e^-/pulse	N_{e^-}	3×10^{11}

Beamline Layout

The injector consists of a −110 kV Hermosa thermionic electron gun, a single gap reentrant cavity prebuncher, a constant impedance 5-cell traveling waveguide buncher, and a S-band constant gradient disk-loaded structure with a length of 3.0 m. The main features of the buncher and the accelerating structure are shown in Table 2.

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Table 2
Buncher and accel. structure parameters

Parameter	Buncher	Accel. Structure
Frequency	2856 MHz	2856 MHz
Operating mode	$2\pi/3$	$2\pi/3$
r/Q	36 $M\Omega/m$	57 $M\Omega/m$
Group velocity v_g/c	0.0119	0.0204 - 0.0065
Attenuation (neper/m)	0.228	0.57
Max. phase excursion	2°	2°
VSWR	≤ 1.1	≤ 1.2
Peak power	5.0 MW	30 MW

RF System

A. High-level

The RF power source at 2856 MHz is provided by a 35 MW klystron amplifier (THOMSON TH 2128), fed by a high power modulator. The modulator consists of a pulse-forming network (PFN) which is resonantly charged from a high-voltage supply and discharged by triggering a thyratron through a triaxial cable into a step-up transformer feeding the klystron. Approximately 30 MW of RF power is fed into the accelerating structure to give an electric field gradient of about 20 MV/m.

B. Low-level

The 2856 MHz low-level output of a highly stable master oscillator is amplified by bipolar transistor amplifiers, of which the last 6 stages are pulsed and produce an output of 400 W, which provides the RF input signal to the klystron. The RF phase and power amplitude attenuation to the prebuncher and the buncher are controlled by four independent electromechanical phase shifters.

Beam Instrumentation

Several diagnostic tools have been used for beam measurements. Briefly, a toroidal current monitor right after the gun measures the gun's current and pulse width. A grid pattern fluorescent screen has been used to observe the beam profile at the end of the accelerating section. Beam position and intensity are measured by a strip-line beam position monitor (BPM). A wall current monitor (FCT) has been provided by the APS Diagnostic Group to measure the beam current at the end of the injector linac. A Faraday cup at the end of the beamline provides a final measurement of the beam current and is used as a beam stop.

A dipole magnet of length 120 cm has been used as an energy spectrometer. The electron beam is bent 10° and passes through an energy-defining slit of ±1.2% resolution. A Faraday cup, located immediately after the slit, measures the beam current and is used as a beam stop. The beam energy is measured by varying the magnetic field and maximizing the beam current through the energy-defining slit into the Faraday cup.

Results and Summary

A 30-nsec, 1.6-A beam was accelerated to an energy of 56 MeV with ±6.25% energy spread. Figure 2 shows the measured beam signals on a digitized scope. Left trace is the toroid signal which shows the gun current and right trace is the Faraday cup signal showing the beam current at the end of the beamline. The measured beam parameters are summarized in Table 3. Beam simulations give an energy spread of ±1.2% for 0.3 A of beam current (no beam loading). The beam loading calculation gives an energy spread of ±4% (for 48 nC). Figure 3 shows the beam energy spectrum of the accelerated beam. The energy spread at FWHH is 12.5%.

Table 3
A summary of beam measurement results

Parameter	Measured Value
I_{toroid}	1.6 Ampere
I_{WCM}	1.1 Ampere
I_{BPM}	1.1 Ampere
I_{F-cup}	1.12 Ampere
Trans. efficiency	70%
Beam spot size	6 mm
Beam pulse length	30 nsec
Total charge/pulse	48 nC
Beam energy	56 MeV ±6%
Energy spread $\delta E/E$	±6.25%

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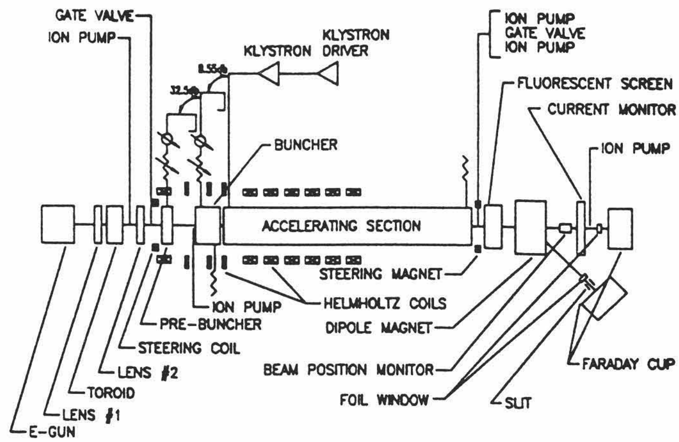
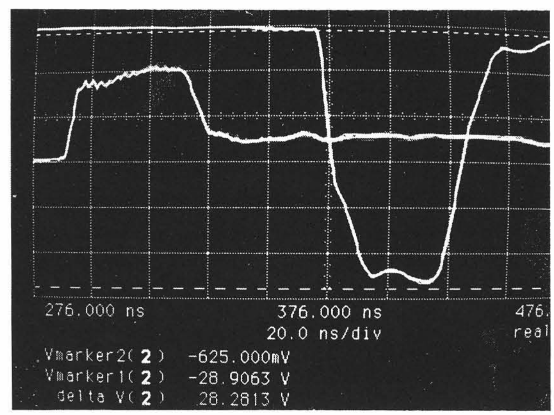


Figure 1
APS electron linac test stand layout



Horiz.: 20 nsec/div, Vert.: 1 volt/div .
Figure 2
Toroid and Faraday cup beam signals

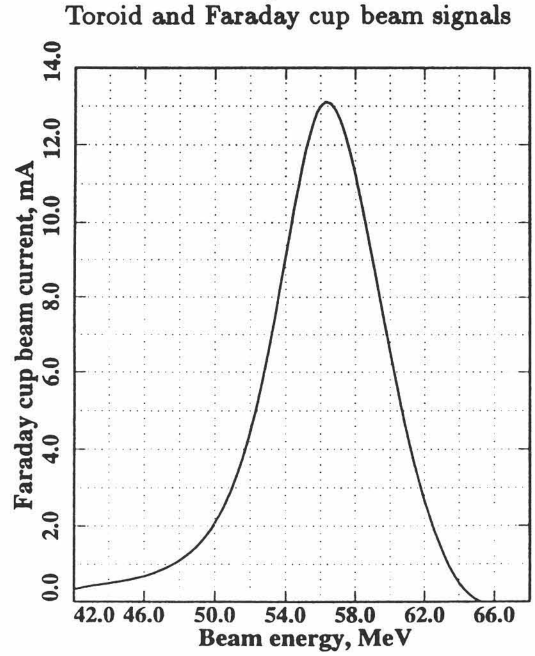


Figure 3
Beam energy spectrum