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NLCTA Injector Experimental Results*

A. D. Yeremian, C. Adophsen, R. H. Miller, C. D. Nantista, J. W. Wang

Stanford Linear Accelerator Center
Stanford University, Stanford, CA 94309

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NLCTA INJECTOR EXPERIMENTAL RESULTS*

A. D. Yeremian, C. Adolphsen, R. H. Miller, C. D. Nantista, J. W. Wang
Stanford Linear Accelerator Center
Stanford, California 94309

Abstract

The purpose of the Next Linear Collider Test Accelerator (NLCTA) at SLAC is to integrate the new technologies of X-band accelerator structures and RF systems for the Next Linear Collider (NLC), demonstrate multibunch beam-loading energy compensation and suppression of higher-order deflecting modes, measure the transverse components of the accelerating field, and measure the dark current generated by RF field emission in the accelerator [1]. For beam loading R&D, an average current of about 1 A in a 120 ns long bunch train is required. The initial commissioning of the NLCTA injector, as well as the rest of the accelerator have been progressing very well. The initial beam parameters are very close to the requirement and we expect that injector will meet the specified requirements by the end of this summer.

1 INTRODUCTION

Much of the NLC related R&D for X-band accelerator systems can be accomplished with a simple bunch train, with bunches one X-band period apart. Thus a simple injector with only X-band components was chosen for the first phase of NLCTA. The possibility of upgrading the injector to produce the actual NLC bunch train format was taken into consideration during the design of the simple injector. For example enough space was left in the tunnel for additional beamline; magnet power supplies that would need to run at higher current for the upgrade were installed for the first phase. The fundamental frequency of the NLCTA as well as the NLC accelerator is 11.424 GHz.

The NLCTA injector consists of a thermionic gun, two X-band standing wave prebunchers, and two X-band traveling wave accelerators, and diagnostics as shown in figure 1. The phase velocities of the first three cavities of the first accelerator are tapered from 0.6c to 0.9c to accommodate the less than c speed of the electrons entering the accelerator. After the first few cavities the electrons reach the speed of light. Following the injector is a chicane which is currently set up to be isochronous. The profile monitor in the high dispersion region of the chicane is used to measure the beam energy spread from the injector. Current, beam position, profile, bunch length, energy, energy spread, and emittance monitors throughout the injector allow for tuning and measurement of the necessary electron beam parameters.

The injector was constructed based on simulation results using PARMELA and SUPERFISH [2]. The Injector has been producing 0.5 A, 120 ns long, 55 MeV electron bunch trains routinely during the initial commissioning of NLCTA. Very recently we have turned the current up to 1 A, but this report primarily addresses the injector commissioning at 0.5 A current.

2 BEAMLINE SETUP

The electrons are produced from a DC HV thermionic gun with a grided 2 cm^2 cathode, operated at 10 Hz. Flat top electron pulses of up to 2 A, 20 to 130 ns variable length, with a 5 ns rise and fall time electron pulses are generated from the gun by pulsing the grid. For a typical operations we have been generating 0.5 A, 120 ns pulses at the gun. This pulse is bunched and chopped into bunches in every X-band period by the first prebuncher. The bunching is further enhanced by the second prebuncher and the first 0.9 m buncher/accelerator section. The second 0.9 m section is used to further accelerate the beam.

One RF station, consisting of a single, 11.424 GHz, klystron and a SLED II [3] system powers both prebunchers and the two 0.9 m accelerator sections. Independent phase and amplitude control is available for each of the RF components in the injector [4]. According to simulation predictions a gap voltage of 8 and 30 KV is required in the first and second X-band prebunchers respectively for optimum bunching. The gradient in the two 0.9 m traveling wave sections should be about 50 MeV/m including the beam loading compensation. Beam loading compensation is accomplished by introducing a ramp in the leading 50 ns of the RF pulse until the beam loading reaches a steady state [5]. The plan is to condition the injector system to operate with 90 MW, 225 ns, RF power available to each of the 0.9 m accelerating sections. Currently for steady operating conditions we run with 155 MW, 225 ns RF power out of the SLED system. After accounting for losses in the rectangular wave guide and coupling of RF into the prebuncher systems, we currently have 65 MW available for the injector accelerating sections for routine operation. We have been able to achieve the 90 MW requirement during processing

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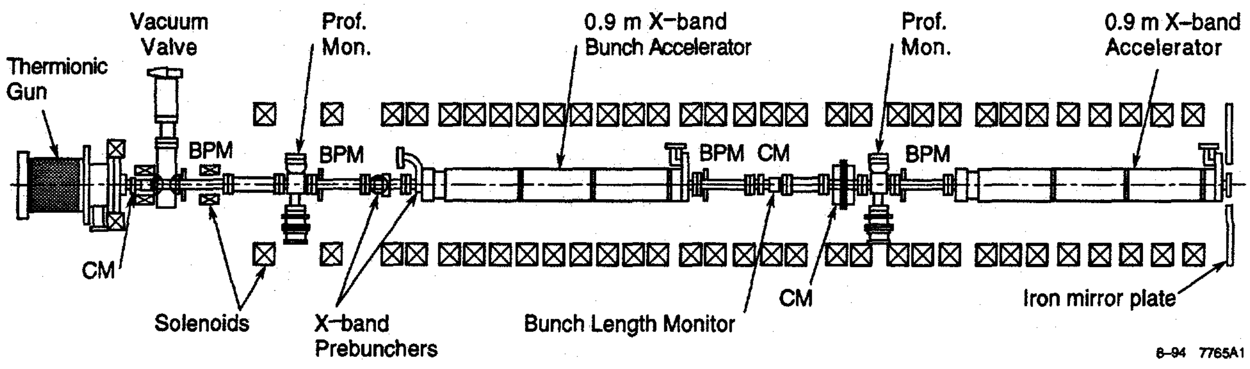

Figure 1. The NLCTA injector layout.

and expect to be able to run routinely at 90 MW soon.

The magic-T type phase-shifter/attenuator for the prebunchers [4] currently do not operate in an orthogonal fashion, because the prebunchers are overcoupled and are not matched to their respective magic-T. This makes it very difficult to tune the bunching parameters of the beam. Each prebuncher will be isolated from the Magic-T so that the phase and amplitude can be changed in an orthogonal fashion. We expect this to be very helpful in the proper setup of the injector bunching parameters.

The transverse beam profile is managed with axial magnetic field from solenoids covering the injector from the gun to the end of the second accelerator section. A bucking coil is used to zero the field at the cathode. The experimental settings for the solenoids are as required by simulations and the beam is to be optimized at these settings.

The current from the gun is measured and set using a gap current monitor [6], while the current out of the injector and after the chicane is measured with toroids [7]. The energy and energy spread of the beam are measured with the profile monitor in the high dispersion region of the chicane and the emittance of the beam is measured using quad scans and a screen upstream and downstream of the chicane [8]. Bunch to bunch energy and energy spread variations are measured at the end of the machine close to the final dump using a pulsed bend magnet with a ramped current to sweep the bunch train vertically for the duration of the pulse, while a DC bend magnet bends the bunches in the horizontal plane allowing the measurement of the energy spread, from the head to the tail of the train [5]. A bunch length monitor [4,9] after the first accelerator section is used to set the power and phase of the two prebunchers with respect to the first accelerator section for optimum bunching. The bunch length is not measured directly but is inferred from the minimum energy spread achievable as seen on the dispersion screen in the chicane and at the end of the linac.

3 EXPERIMENTAL RESULTS

Table 1. shows the achieved beam parameters, thus far, compared to the NLCTA requirements and expectations from simulation. While we have recently accelerated 1 A current from the gun, the data presented here is for 0.5 A, the current used for most of the initial running of NLCTA. Figure 2 shows the signal from the gap current monitor at the gun and the two toroids at the end of the injector and at the end of the chicane respectively. The slope on the top of the current pulses is a monitoring effect [7]. The actual current pulse shape is a flat top. The transmission from the gun to the entrance of the chicane is about 85% and the gun to the end of the chicane transmission is 75%.

Figure 3 shows the energy spread for the entire 120 ns long macro pulse at the dispersion screen in the chicane.

Table 1. Initial NLCTA injector performance compared to requirements and simulated expectations.

	Needed	Simulated	Experiment so far
Gun Current (A)	1	1	0.5
Gun pulse length (ns)	120	-	120
Transmission gun to end of injector. (%)	-	84	85
Power in accelerator sections (MW)	90	90	65
Energy at chicane with 65 MW in ea. acc. sec. (MeV)		70	55
Energy spread at the chicane FWHM (%)	< 0.5	0.3	0.6 to 1
Emittance out of injector rms (10^{-5} m- rad)	<5	1	5 to 8

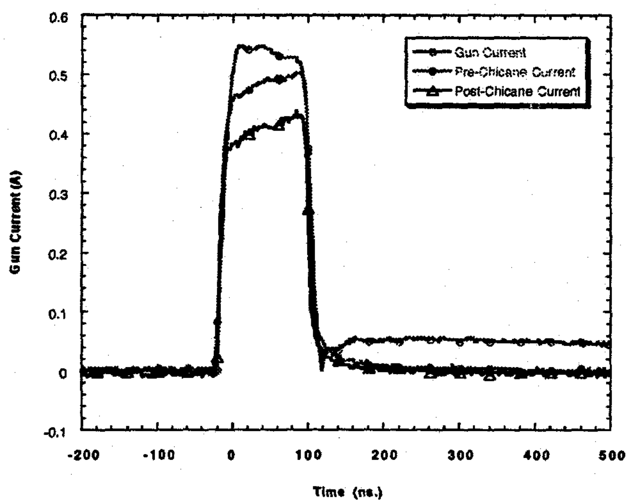

Figure 2. Electron beam current transmission from the gun to the exit of the chicane. The slope at the top of the current pulse is actually a monitoring effect.

The FWHM energy spread is 0.6 to 1%, twice as high as the requirement. Improved bunching energy spread is expected after the full commissioning of the injector.

With 65 MW available for each of the injector accelerating sections the expected electron beam energy at the end of the injector is 70 MeV for 0.5 A beam, however, we measure 55 MeV. At the end of the first accelerator section the beam is ahead of the crest by about 40 degrees, thus resulting in lower energy and larger energy spread than we expected. To minimize the energy spread at the end of the injector we phase the beam behind the RF wave crest in the second accelerator. This results in further reduction of energy out of the injector than expected from simulation. It is presently not clear why the beam is 30 degrees more ahead of the RF wave crest than expected from simulations. This problem can be studied more carefully this summer once the injector is operating at the design RF power level.

The measured normalized rms emittance before and after the chicane is 5 to 8 x 10^{-5} m-rad. This emittance is good enough for beam loading compensation R&D at the NLCTA however we expect it will improve by about a factor of two after the full commissioning of the injector.

4 SUMMARY

The initial commissioning results from the NLCTA injector show that NLCTA will meet the NLC R&D requirements it was designed for. The electron beam is very close to meeting the initial design goals, and with further RF processing and commissioning scheduled for this summer we expect to achieve these goals.

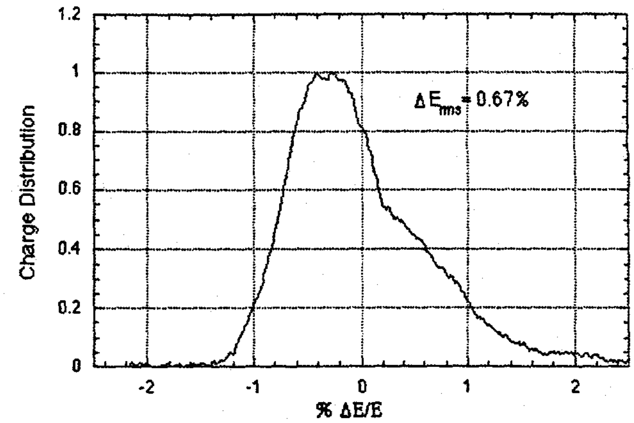

Figure 3. Energy spread as measured on the high-dispersion screen in the chicane for a 120 ns, 0.5 A beam from the gun.

5 ACKNOWLEDGEMENTS

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