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## Abstract

The design for the Next Linear Collider (NLC) at SLAC is based on two 11.4 GHz linacs operating at an unloaded acceleration gradient of 50 MV/m increasing to 85 MV/m as the energy is increased from 1/2 TeV to 1 TeV in the center of mass[1]. During the past several years there has been tremendous progress on the development of 11.4 GHz (X-band) RF systems. These developments include klystrons which operate at the required power and pulse length, pulse compression systems that achieve a factor of four power multiplication and structures that are specially designed to reduce long-range wakefields. Together with these developments, we have constructed a 1/2 GeV test accelerator, the NLC Test Accelerator (NLCTA). The NLCTA will serve as a test bed as the design of the NLC is refined. In addition to testing the RF system, the NLCTA is designed to address many questions related to the dynamics of the beam during acceleration, in particular the study of multibunch beam loading compensation and transverse beam break-up. In this paper we present the status of the NLCTA and the results of initial commissioning.

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* Work supported by Department of Energy contract DE–AC03–76SF00515.

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## Introduction

The Next Linear Collider Test Accelerator (NLCTA) is a 42-meter-long beam line consisting consecutively, of an injector, a chicane, a linac, and a spectrometer[2].

The injector consists of a 150-keV gridded thermionic-cathode gun, two prebuncher cavities and two 0.9 m detuned accelerator structures. The injector is surrounded by solenoids to provide the necessary focusing. Downstream from the injector we have a magnetic chicane for longitudinal phase-space manipulation, energy measurement and collimation. After the collimation, the average current injected into the linac is comparable to the NLC specification, 1.0 nC/1.4 ns.

The NLCTA linac when complete will consist of six 1.8-meter-long X-band accelerator sections which are designed to suppress the long-range transverse wakefield. These sections will be powered by three 50-MW klystrons whose peak power is quadrupled by SLED-II RF pulse compressors. This yields an unloaded acceleration gradient of 50 MV/m over 10.8 m so that the maximum energy gain in the linac is 540 MeV. The NLCTA RF system parameters are listed in Table 1.

Downstream from the linac we have a magnetic spectrometer that can horizontally momentum analyze the bunch train after acceleration. A vertical kicker magnet in the spectrometer will provide a method for separating the bunches vertically so that the energy and energy spread can be measured along the bunch train. We can also measure the emittance in the spectrometer and in the chicane.

In the future we plan to increase the linac gradient to 85 MV/m by installing six 75 MW klystrons as shown in Table 2. We also plan to upgrade the injector in order to increase the bunch spacing and intensity, each by a factor of 16. This will permit more detailed beam-dynamics studies on a train of bunches similar to that required for the NLC.

Table 1. NLCTA RF System Parameters

| Parameter | Design | Upgrade |
|---|---|---|
| Linac Energy | 540 MeV | 920 MeV |
| Active Length | 10.8 m | 10.8m |
| Acc. Gradient | 50 MeV | 85 MeV |
| Inj. Energy | 90 MeV | 90 MeV |
| RF Freq. | 11.4 GHz | 11.4 GHz |
| No. of Klystrons | 4 | 7 |
| Klystron Power | 50 MW | 75 MW |
| Klystron Pulse | 1.5 μsec | 1.5 μsec |
| RF Compression | 4.0 | 4.0 |
| Structure Length | 1.8 m | 1.8 m |

## Klystron Status

The NLCTA (and NLC) specifications call for 50 MW klystrons operating with a 1.5 μsec pulse length (1.2 μsec for the NLC). Thus far, the klystron development effort at SLAC has produced four klystrons that meet or exceed the NLCTA specification[3]. Figure 2 shows the output power of the fourth in the series, XL-4. It is a very robust klystron with a very stable output power and can produce a 75 MW pulse 1.2 μsec long. Both XL-2 and XL-3 also produce more than the required 50 MW, and all of the three klystrons have the required bandwidth to work with the SLED-II compression system. The XL-4 klystron has been installed on the NLCTA injector modulator and is being used to power the initial commissioning of the injector.

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Several more klystrons of the XL-4 type will be produced for the NLCTA. However, the development effort for NLC klystrons has been turned towards the development of a periodic permanent magnet (PPM) focused klystron[4]. This eliminates the focusing solenoid from the klystron, reducing the capital and operating cost significantly. The initial tests of the first PPM klystron have just been completed yielding up to 60 MW with about 60% efficiency. This klystron power exceeds the 50 MW required for the 1/2 TeV NLC.

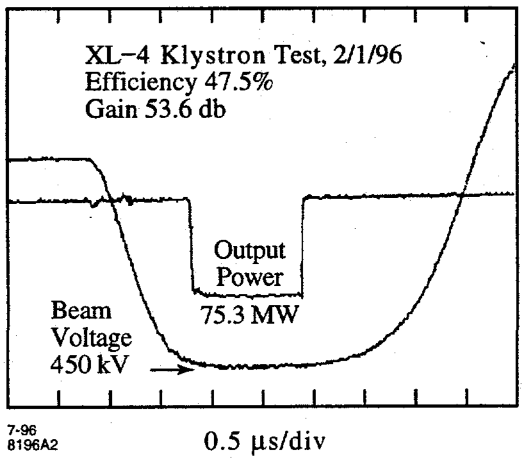


Figure 1. High-Power test of XL-4.

## RF Pulse Compression Status

In SLED-II RF pulse compression the klystron power flows through a 3-dB hybrid where it is split to resonantly charge two delay lines. After several round trip times, the klystron phase is flipped by 180 degrees, after which the power from the klystron adds to the power emitted from the delay lines to create a large compressed pulse of RF power. Figure 2 shows high-power tests of the SLED-II prototype for the NLCTA powered by the XL-2 klystron. The prototype exceeded the required output power of 200 MW, but with a shorter pulse of 150 nsec [5].

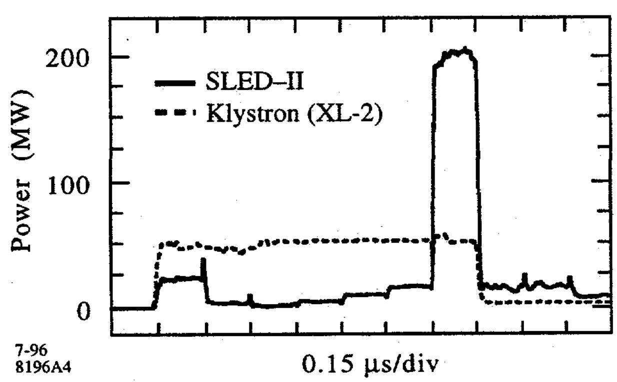


Figure 2. High-power test of the SLED-II prototype.

Three SLED-II systems have been installed in the NLCTA, one for the injector and two for the linac. Initial low-power tests of the injector SLED-II system have shown excellent performance with an overall efficiency that exceeded our expectations[6]. High-power processing of the injector SLED-II system is presently in progress. Thus far the system has been conditioned up to 135 MW output power with a 250 ns pulse.

## RF Structure Status

The NLC design requires accelerator structures that operate reliably with an unloaded gradient of 50 MV/m for the 1/2 TeV collider and 85 MV/m for the 1 TeV upgrade. The NLCTA will serve as a model of this upgrade path in that we will begin at the lower acceleration gradient and eventually increase the gradient to the required 85 MV/m (see Table 1).

In addition to the gradient requirement, the NLC structures must be designed to substantially reduce the long-range transverse wakefields that can cause beam breakup. To achieve this reduction we have pursued two basic types of accelerator structures, a detuned structure and a damped-detuned structure. There are a total of eight structures in the NLCTA. The first two are one-half-length detuned structures. The second pair are full-length detuned structures. The third pair are damped-detuned structures; and finally, the last pair will initially be KEK detuned structures and later will be damped-detuned structures.

### Detuned Structures

In a constant gradient traveling wave structure the irises are tapered to vary the group velocity in order to keep the gradient constant in spite of the loses in the structure. This tapering produces a variation of the frequency of the first dipole mode along the structure length that can be as much as 10%. The detuned structure takes advantage of this, but the profile of the iris taper is changed in order to create a smooth Gaussian-like distribution of higher-order modes. This leads to a Gaussian-like initial decay of the wake field behind the bunch[7]. We have successfully tested this concept using probe and witness beams in the Accelerator Structure Test Set-up (ASSET) facility in the SLC[8].

This technique has been used to manufacture four structures in the NLCTA. The first three are complete and the remaining structure will be brazed this fall.

### High-Power Tests of Structures

During the past several years we have performed many high-power tests of different types of structures[9]. These tests indicate that surface fields up to 500 MV/m can be obtained in copper structures at 11.4 GHz. In power-limited tests, average acceleration gradients in short structures have reached 120 MV/m[10]. The first 1.8 m detuned structure has been high-power tested up to 67 MV/m[11]. These tests indicate that the conditioning up to the desired 50 MV/m will be straightforward.

### Damped-Detuned Structures

In order to further reduce the wakefield and the tolerances, it is necessary to provide some moderate damping for the higher-order dipole modes. To accomplish this we have developed a damped-detuned structure that uses four symmetrically placed manifolds to provide the damping [12]. The structure cells are coupled to four waveguides that are formed when the cells are diffusion bonded together. The dipole mode is coupled out to the waveguide where is propagates to the end of the structure to a load. This techniques should damp the first dipole modes with Qs of about 1000. The signals from the manifold can be used as a beam position to align the structure to the beam.

The first two damped-detuned structures are being constucted in collaboration with KEK[13,14]. In addition, we have just completed an experiment to measure the wakefield of the damped-detuned structure[15]. The measured long-range wakefield is reduced by more that two orders of magnitude relative to the short-range wake and agrees well with the theoretical predictions[14,15]. Finally, the modes that are damped have now been shown to yield a sensitive position measurement along the length of the structure[16].

## Beam Line Commissioning

The entire NLCTA accelerator from the gun to the final dump has been constructed and installed except for the downstream 1.8 m accelerator structures. Spool pieces replace these structures in the beam line, and the entire system from the gun to the dump is evacuated. The current, position and profile of the beam are monitored from the gun all the way to the dump with monitors that are used to optimize and characterize the beam.

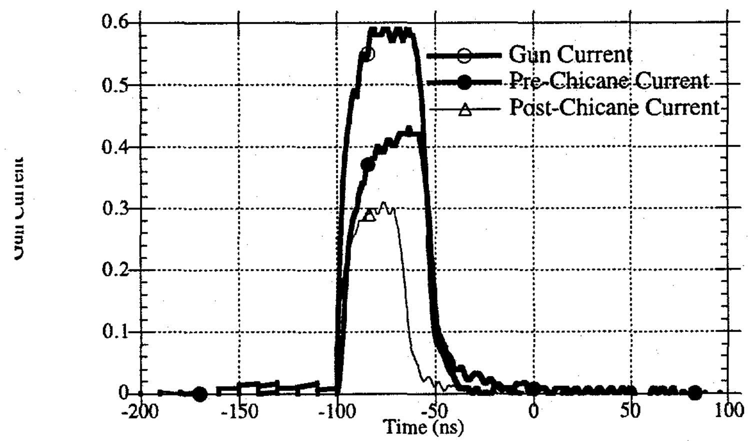


Figure 3. Torroid Current through the chicane

The first 150 keV electron beam from the gun was achieved in May. The gun and related electronics were characterized and beams varying in intensity from 0.2 to 2 A and in pulse length from 40 to 150 ns were transported to a Faraday cup one meter downstream. The calibration of the gap current monitor at the gun was verified against the Faraday cup.

In June and July 1996 the remainder of the injector system was installed completing the beam line between the gun and the chicane. In August, beam from the gun was accelerated and transported all the way to the final dump of the NLCTA.

For the initial turn on a 150 kV, 0.5 A, 40 ns wide beam from the gun was bunched into X-band buckets and accelerated up to 60 MeV in the injector. We obtained 65% beam transmission at the entrance to the chicane (0.32 A), and 55% of the gun current reached the toriod at the end of the chicane (0.27 A). The beam energy and energy spread were monitored on a profile monitor in the middle of the chicane. While all the phases of the bunching components and the accelerator sections are not completely optimized yet, an energy spread of 0.6% for the core of the beam was achieved. Figure 3 shows the signal from the various current monitors up to the end of the chicane. Commissioning of the linac will commence this fall as the remaining accelerator structures and klystrons are installed.

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