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Program Director's Corner:
David L. Burke

Due to the Program Director's heavy travel schedule, there will be no Director's Report this month.

NLC Cost Reductions through Leading-Edge Technology Advances
John C. Cornuelle

The NLC will cost roughly the equivalent of a Nimitz-class aircraft carrier for the U.S. Navy. While the U.S. Navy already has eight of these ships with a ninth in construction, the budget for particle accelerators is expected to be much leaner. Much of the NLC R&D is aimed at trying to reduce costs to the lowest levels consistent with the desired performance and reliability.

The NLC R&D program was formally reviewed by the Department of Energy in May of 1999, a so-called "Lehman Review" familiar to those in the high-energy physics community. In its response to the review, the Department of Energy instructed the NLC "to continue to pursue a vigorous program of R&D aimed at improving the energy reach and reducing the cost of the NLC." In the February 2001 issue of NLC News, Tom Markiewicz reviewed the changes made in the NLC Interaction Region to ensure its compatibility with 5 TeV center of mass beams, thus extending the energy reach as requested.

Much of the balance of the NLC R&D activity, and certainly the lion's share of the funds, has been devoted to cost reduction. Most of this has come from a systematic plan of evaluating leading-edge technologies to determine their applicability to the NLC. Sometimes this becomes a trade-off of the benefits, limitations, and costs of several technologies, all vying to be incorporated into the current NLC design. The reason leading-edge technologies have a prime role here is that the best-available "conventional" technology was in most cases already selected for the baseline configuration of the NLC, and the leading-edge technology has to show that it has sufficient merit to displace a technology whose strengths and weaknesses are well-known.

Previous issues of the NLC News have already featured some of these cost-saving new technologies. The displacement of the pulse-forming-network-style modulator to operate the X-Band klystrons by a solid-state-switch (IGBT) version reduced the modulator cost by over 50%, since the newer technology drives eight klystrons while the older drove two. Such solid-state-switch supplies are well-known up to several thousand volts, but not at 500,000 volts. The doubling of the pulse-width (before the pulse compression system) on the X-Band klystron cut the number of klystrons in half, since half as many are now on for twice the time. Almost anything done in this area is leading edge, since these permanent-magnet-focused X-Band klystrons produced at SLAC are unique in the world. By adopting a dramatically different Final Focus design with the chromaticity locally corrected at the final doublet, the length of the final focus region was abbreviated dramatically to 30% of its former length. Since there is no rf in this region, costs are purely proportional to length, and so costs have been reduced an equivalent amount. Adjustable permanent magnets have been adopted in the Main Linac and some of Injector Systems in the expectation that the savings in power supplies, cabling, and increased reliability will offset some cost increase in the magnets themselves. This will be the first use of permanent magnets outside the detector area of major linear colliders.

Other advanced technologies have not had as much exposure. The pulse compression and distribution system for the X-Band power in the Main Linac (DLDS) was extended to use two modes instead of one, reducing the amount of waveguide from 300 km to 170 km, a 43% reduction. This was made possible by sophisticated techniques that allow two different microwave transmission modes to be created, propagated, and reconverted at will at the same time in the same physical devices with almost no unwanted microwave side-effects. This has never been done before at the peak power levels and almost-perfect transmission requirements of the NLC. An even more exotic design is being evaluated that would reduce the amount of waveguide even further by using four modes simultaneously, along with a revolutionary waveguide switch that would either pass or reflect efficiently enormous amounts of peak rf power. The concept of Tunnel Electronics Enclosures will enable the use of non-radiation-hardened electronic components sequestered in narrow aspect ratio holes in the concrete walls, and minimize the number of costly cables that need to extend up to the electronic rack areas. A unique feedback design for the timing system for the low-level rf enables extremely tight control of the rf phase to be maintained over tens of kilometers of fiber-optic cable without the need for costly and difficult temperature control over a separate vault for the fiber. Liquid metal is being evaluated for use as an alternate positron target material and in the collimators in the Beam Delivery area, in both cases replacing systems that are more costly to construct and to maintain. Even though the NLC bunch train is short (under 400 nanoseconds), a state-of-the-art inter-bunch feedback approach is being explored that will keep the beams in collision after only a nominal number of bunches have collided. If successful, this will be a much less costly solution than other stabilization approaches.

R&D continues at all NLC collaborating laboratories with the goals of further reducing costs while maintaining machine robustness and physics mission. The principal US partners in the collaboration are SLAC, Fermilab, LLBL and LLNL. International partners include KEK, Oxford and Brunel Universities, the University of British Columbia, and BNIP, among others. There are a number of US university collaborators. In addition, industrial collaborations are developing to support this R&D effort.

Solid State Modulator Update
Ray Larsen

The first full-scale prototype modulator, known by the unflattering name of 4-Dog (due to its intended test load of four "doggy" klystrons that serve as diode loads), has had its initial partial power tests into a water load. The modulator consists of two 38-cell tall stacks of Metglas cores (*Fig.1*) with an IGBT driver card (*Fig.2*) plugged into front and back of each core for a total of 152 drivers. When fully populated the stack will produce 6,000 A peak at 3 µs at a voltage of 170 kV (2.25 kV/core). When the 1:3 step-up transformer is installed later, the output of 500 kV, 2000 A peak will drive eight 75 MW peak rf output klystrons. The power delivered by the modulator will be one gigawatt peak.

Fig. 1: Dual Stack with First Driver Cards

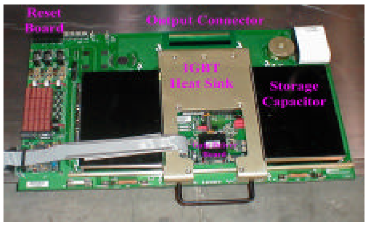

Fig 2: IGBT Driver Card

The SLAC-LLNL-BN team has now installed the first half of the IGBTs (76 Drivers) with the second half due for delivery in early April. The first 76 have been tested and mounted in the modulator. Initial tests were run into the water load (*Fig. 3*) at a maximum voltage and current of 75 kV, 1100 A for 3µs (*Fig.4*). In this test, 38 of the boards were run with shorts applied to other driver slots in the cores in order to test the IGBT Drivers closer

Fig.3: 1-Turn Output to Water Load Connection

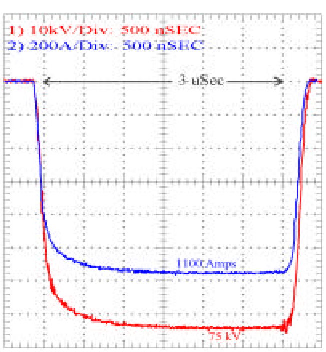

Fig: 4: Waveform into Water Load

to their full power rating. The voltage limit of 75 kV was held because the single-turn transformer is in air and not in oil as it will be eventually. In Fig. 4., the apparent slow settling time is because there is no load capacitance present, which, with the transformer inductance will cause an overshoot. The strategy for controlling the overshoot and maintaining a flat pulse top is to trigger some IGBTs to turn on later than others. According to simulations, this should result in a smooth, fast-rising pulse with a +/-1% flattop.

One problem experienced in the test has been the failure of a protection diode when a group of boards was delayed in time. This effect has been studied and is, for the moment, controlled. The diode manufacturer is analyzing the failure mode. Several problems of this nature have been encountered in the course of development and so far solutions have been found. Power IGBTs and diodes have not been characterized for fast pulse operation, so occasional surprises are to be expected

Another important milestone is the completion of design of the prototype 1:3 transformer (Fig. 5), now being placed into fabrication at contract vendors. This assembly not only has to withstand 500 kV at its output, it also has to carry wires, hidden in slots in the concentric tubes that make up the turns, to feed the klystron cathode heaters and bring back signals from cathode beam current monitors.

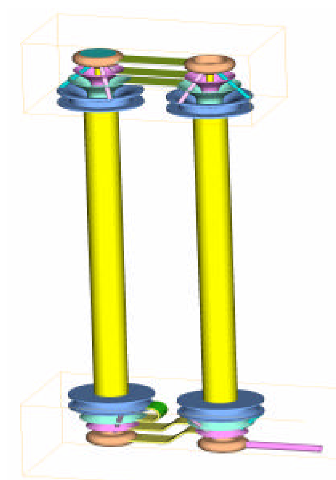

Fig. 5: 500 kV 1:3 Transformer

The full stack is now being reassembled after mechanical retrofitting to improve contact of protection diodes. Testing will continue using the water load until the 1:3transformer is delivered in May. During this time, the 4-Dogs (5045 klystrons) will be installed with all supports and the oil tanks will be filled. In June, testing is scheduled for up to about 400 kV, 1800 A, the maximum levels the four klystrons can withstand.

Winter Collaboration Meeting

We had hoped to include an article reviewing the winter meeting of the NLC US Collaboration. This article will appear in the April issue.

Recent Linear Collider Publications

If you would like an NLC-related paper listed, please send information to amlarsen@slac.stanford.edu

I. Linear Collider Collaboration Notes

http://www-project.slac.stanford.edu/lc/ilc/TechNotes/LCCNotes/lcc_notes_index.htm

LCC-056 "Design of an NLC Intra-Pulse feedback system," Stephen R. Smith, 03/01.

LCC-0057, "Study of Alternative Optics for NLC Prelinac Collimation Section," Yuri Nosochkov, Pantaleo Raimondi, Tor Raubenheimer, 03/01.

Calendar of Upcoming Events

Collaboration Meetings

? May 16 – 18, 2001, NLC MAC Meeting, LBNL.

Conferences of Interest

? HEACC01, March 26 - 30,2001 Tsukuba, Japan, http://conference.kek.jp/heacc2001/

? 2001 Particle Accelerator Conference, Chicago, IL, June 17-22, 2001, http://pac2001.aps.anl.gov/.

? 2001 Asian Particle Accelerator Conference, Beijing, China, Sep. 17 – 21, 2001, http://apac01.ihep.ac.cn.

? 2001 Nuclear Science Symposium, San Diego, CA, Nov. 4 – 6, 2001. Abstract deadline, April 20, 2001, http://www.nss-mic.org/.

? ICALEPCS 2001, San Jose, CA, Nov. 27 – 30, 2001, Abstract deadline April 20, 2001, http://icalepcs2001.slac.stanford.edu.

? 8th European Particle Accelerator Conference, June 3-7, 2002, Paris, France.