NLC News -

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Director's Corner

David L. Burke

Several events of importance to the NLC have occurred over the past weeks.

The Machine Advisory Committee (MAC) spent three days at SLAC reviewing our R&D and design progress, and plans for the upcoming 1-2 years. The MAC was impressed on all fronts. There was particular excitement over progress on the operating gradients in accelerator structures, and the start of the 8-Pack project that will put on the floor of the NLCTA the full 1-TeV power pack for the NLC. This was the fourth meeting with this committee, and they have dug deeply into the status of the NLC - the summary conclusion, given by Chair Satoshi Ozaki, is that we are in "good shape, but keep up the good work just the same."

Last week the DOE/NSF High Energy Physics Advisory Panel was presented with the recommendations from the "Bagger-Barish" Subpanel that "the highest priority of the U.S. program be a high-energy, high-luminosity, electron-positron linear collider," and that "the United States prepare to bid to host [it]" (http://doe-hep.hep.net/lrp_panel/index.html). Built on Snowmass, this conclusion is part of a world-wide consensus that the linear collider is the next major facility to be built in High Energy Physics. The recommendation will set a new level of focus on the U.S. scene, and enhance both collaboration and competition with our colleagues in Asia and Europe.

DOE Undersecretary Card, who has oversight of the Department's civilian science programs, visited the Bay Area laboratories just as the HEPAP Report went public. Card's visit was largely to "kick the tires," and he clearly enjoyed getting his hands on the hardware at the NLCTA. He left with a good appreciation of what we do and of the importance of the NLC to the HEP mission.

The seventh ISG meeting, held in mid-November at KEK, was an important opportunity to evaluate ongoing work, and to prepare for upcoming reviews with the rest of the international community. The first of these will be in February when SLAC hosts the 9th International Workshop LC02. An international technical review committee, formed by ICFA and chaired by Greg Loew, will be putting together a summary of the status of the designs, technologies, and plans of the NLC, TESLA, and CLIC collaborations.

There will be interesting ups and downs in this story over the coming months. For now we will take Ozaki's advice andfocus on delivering the best design and technology possible.

Photocathode Milestone Achieved

Takashi Maruyama and Jym Clendenin

The polarized electron beam for the NLC will most likely be generated with a solid-state source utilizing a p-doped GaAs-type photocathode operated with a negative electron affinity (NEA) surface. An NLC-sponsored R&D effort has been in progress at SLAC for the past several years with two principal goals: 1) to achieve significantly higher polarization than the ~80% that was norminal for the SLC; and 2) to overcome the surface charge limit (SCL). Recently, a new cathode structure was developed and tested at SLAC that completely overcomes the SCL, thus satisfying one of these goals.

The SCL, first observed in 1992 [1], results during photoemission when electrons are trapped at the cathode surface at a rate that is higher than the combination of emission to vacuum and recombination with holes. The temporarily trapped charge causes the build-up of a surface photovoltage, effectively blocking further emission during the pulse. The problem is made acute for an NEA surface by the absence of holes in the surface depletion layer. For recombination to take place, holes must tunnel through the depletion layer to the surface (or equivalently the trapped electrons tunnel to the bulk), a relatively improbable process. To illustrate the seriousness of the problem, a typical SLC freshly-activated 20-mm diameter strained photocathode (100-nm strained GaAs with a medium doping level of $5\text{x}10^{18}$ cm^{-3}) saturates (meaning no additional increase in charge when the laser energy illuminating the cathode is increased) at the level of $8\text{x}10^{11}$ e^- for a 300-ns pulse. The saturation level decreases as the cathode quantum efficiency (QE) decreases. In contrast, the NLC is presently designed to operate with a train of 190 microbunches, spaced 1.4 ns apart (total of 266 ns), and each microbunch is required to have as much as $1.4\text{x}10^{10}$ e^- per pulse in 0.5 ns (full width) *at the gun*, totaling $2.7\text{x}10^{12}$ e^- per train [2], which is 3 times the saturation level quoted above.

Soon after the SCL was discovered, it was reported that increasing the dopant density would reduce the effect [3]. A more recent study showed that the surface photovoltage build-up can be reduced significantly by increasing the doping concentration to at least $2\text{x}10^{19}\text{cm}^{-3}$ [4]. However, increasing the doping level leads to depolarization of the electron spin. This report describes the successful application of a gradient-doping technique [] in which a high dopant density is used only in the final few percent of the thickness of the epilayer (i.e., the layer in which valence band electrons are promoted into the conduction band by incident photons) at the surface to overcome the SCL without a deterioration in either the polarization or the QE.

The SLAC experiment utilized a modified version of the standard SLC cathode in which a 100-nm GaAs epilayer is grown by MOCVD on a GaAsP substrate to produce the strain necessary to split the otherwise degenerate heavy- and light-hole valence bands sufficiently for high polarization. For the new structure, the dopant density was $5\text{x}10^{17}$ cm^{-3} throughout the 100-nm epilayer except in the final 10-nm at the surface the density was $5\text{x}10^{19}$ cm^{-3}. To compensate for the energy barrier created at the surface by this gradient doping, a small amount of P was added to the low dopant-density volume.

The QE and polarization spectra were measured at low cathode bias voltage. The peak polarization of 80% and the corresponding QE of 0.2% were similar to that of typical SLC cathodes, but the polarization peak was 40-nm blue-shifted to 805 nm because the small amount of P in the epilayer increases the band-gap energy.

Since a laser system capable of producing the NLC multibunch structure was not available, the NLC beam condition was approximated by using a long-pulse flashlamp-pumped Ti:sapphire laser (Flash-Ti), tuned to 805 nm, overlaid by a short-pulse Nd:YAG-pumped Ti:sapphire system (YAG-Ti). The YAG-Ti would not lase at 804 nm, so it was tuned to 780 nm. The Flash-Ti could generate an electron pulse equivalent in pulse length and charge to one NLC pulse train without the multi-bunch structure. However, only the YAG-Ti could produce the NLC peak current of 9 A (i.e., $1.4\text{x}10^{10}$ e^- in 0.25 ns FWHM).

The new cathode was cleaned, activated twice, and inserted into the SLAC polarized gun using standard SLAC techniques. The cathode was operated in the normal manner at 0° C and with a bias of –120 kV. Over a 6-week period the QE decreased by about 10% a day. The cathode was re-cesiated every third day to restore the QE to its original maximum value. The dark current was typically 35 - 40 nA. This performance is similar to that with typical SLC cathodes.

A 300-ns long *flattop* pulse with a maximum energy of 80 mJ per pulse was sliced out of the 10-ms pulse of the Flash-Ti laser. This energy was sufficient to produce a maximum charge of about $8\text{x}10^{11}$ e^-. By abandoning the flattop shape, the maximum laser energy could be increased to 300 mJ/pulse. The YAG-pumped Ti:Sapphire laser (YAG-Ti) produced a 4-ns long pulse with a maximum optical energy of about 20 mJ/pulse.

Fig. 1 shows representative temporal profiles of the emission current pulses measured using varying energies of the *flattop* Flash-Ti with a laser spot size at the cathode of 20 mm. As the laser energy was increased, the temporal profile simply scaled without developing the leading edge spike typically observed in the surface charge-limited photoemission. The charge output was linear up to the maximum laser energy.

To further test for the SCL, the Flash-Ti pulse length was shortened to 270 ns, and both lasers were focused to a 14-mm spot diameter at the cathode. (For even smaller spot sizes, photoemission was limited by the space charge limit of the gun.). The charge output was first measured as a function of the Flash-Ti energy alone. Then the YAG-Ti was overlaid on the Flash-Ti. Keeping the YAG-Ti laser energy was fixed at 20 mJ/pulse, the charge output was measured as the Flash-Ti laser energy was increased. Figure 2 shows the charge output as a function of the Flash-Ti energy with and without the YAG-Ti. The charge output of the Flash-Ti by itself was linear up to the maximum charge that could be produced of $2 \times 10^{12} e^-$/pulse. The YAG-Ti by itself generated a charge of $2.3 \times 10^{11} e^-$/pulse, equivalent to 9.2 A peak current (assuming a Gaussian pulse). The charge output of the combined lasers was also observed to be linear, producing a total charge of $2.2 \times 10^{12} e^-$ in 270 ns when using the maximum available laser energy. Assuming the charge scales with the illuminated area of the cathode area for a constant laser energy density, one can expect to be able to produce with the future-NLC laser *at least* $4.5 \times 10^{12} e^-$/pulse-double the NLC requirement-with no pulse shape distortion from a 20-mm diameter cathode of this type.

This is the first demonstration that an NLC pulse structure with polarization approaching 80% is achievable. The prospects are quite good that the structural modifications made to the cathode here to eliminate the surface charge limit can be applied equally well to other cathode structures presently being studied to increase the polarization.

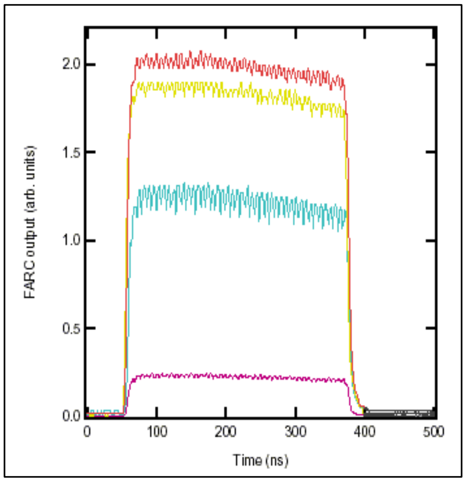

Fig. 1. Faraday cup signal (FARC) measured using varying Flash-Ti laser energies.

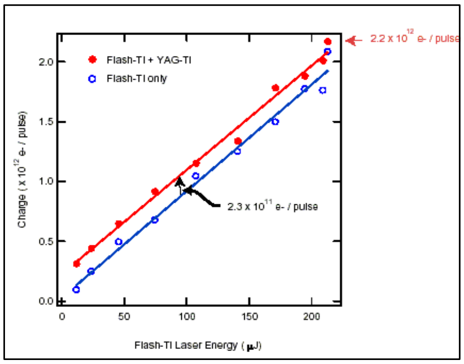

Fig. 2. Charge output as a function of the Flash-Ti laser energy.

Footnotes

[1] M. Woods et al., J. Appl. Phys. 73 (1993) 8531.
[2] www-project.slac.Stanford.edu/lc/local/Reviews/ Apr2001/Electron sources including e- Booster v2.pdf .
[3] H. Tang, in Proc. of the Workshop on Photocathodes for Polarized Electron Sources for Accelerators, SLAC-432 Rev. (Apr. 1994), p. 344.
[4] G.A. Mulhollan et al., Phys. Lett. A282 (2001) 309.
[5] K. Togawa et al., Nucl. Instrum. and Meth. A 414 (1998) 431; and T. Maruyama, "Strained GaAs with High Surface Doping," PPRC-TN-00-2 (Dec. 2000).

R&D Notes
Modulator Milestone

Ray Larsen

The 8-Pack IGBT modulator R&D program achieved a new milestone of running two 5045 klystons in diode mode. The HV connections from the output stack 1:3 transformer to a voltage divider and klystron cathodes are shown in Figure 1, along with monitoring current transformers. The waveform is shown in Figure 2. No voltage breakdowns occurred either on the previous 500 kV water load test, or on the current 400 kV tests. Tests will continue on breakdown protection, followed by full power testing with four klystrons. Figure 3 shows the newly delivered 500 kW 5 kV power supply that will supply the full power for the 4-Dog, followed by a 500 kV, 2000 A peak at 120 Hz test of the final 8-Pack. The project is a tripartite effort of SLAC, LLNL and Bechtel Nevada.

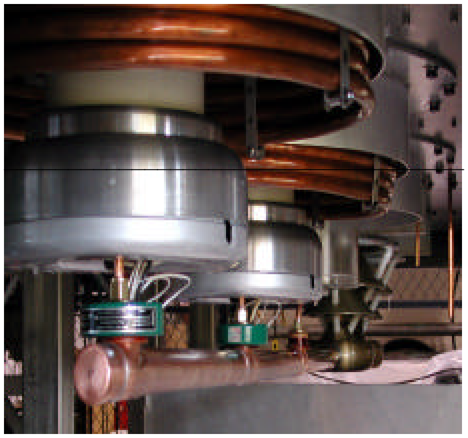

Figure 1

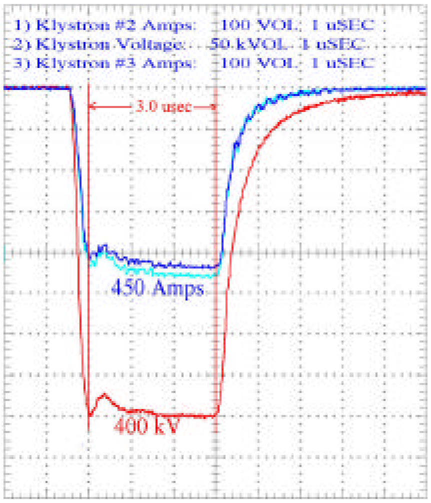

Figure 2

Figure 3

Recent Linear Collider Publications

If you would like to have 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-0073, "Microwave Quadrupoles for beam break-up Suppression in the NLC Main Linac," K.L.F. Bane and G. Stupakov, September 2001.

LCC-0075, "Plasma Discharge Cleaning of NLCTA Cells," R. E. Kirby, E.L. Garwin, F. Marcelja, C. Rago, M. Robertson, November 2001.

Calendar of Upcoming Events

Conferences of Interest

ICALEPCS 2001, San Jose, CA, Nov. 27 – 30, 2001, http://icalepcs2001.slac.stanford.edu.

Physics and Detectors for the Linear Collider, University of Chicago Gleacher Center, Chicago, IL, Jan. 7-9, 2002, http:// LCworkshop.uchicago.edu

LC02, 9th International Workshop on Linear Accelerators, CA , February 4 - 8, 2002, at SLAC. For information http://www-project.slac.stanford.edu/lc02/ or LC02@slac.stanford.edu.

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