NLC News -

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Program Director's Corner:
See the October issue!

Collaboration News:
Development at Fermilab of Permanent Magnet Quads for NLC
William Fowler, Vladimir Kashikhin and Jim Volk

When Fermilab joined the NLC Collaboration in the fall of 1999, a major R&D question was whether permanent magnet quadrupoles might be used in place of some of the several thousand proposed electromagnets, in particular those in the main linac. It was uncertain whether permanent magnet quadrupoles could be designed with the adjustable range of gradients required for beam-based alignment and whether there might be true cost savings. At that time, Fermilab had built over 100 permanent magnets for the 8 GeV beam transfer line and the Recycler Ring using ferrite and was convinced that a significant cost savings was possible for NLC. However, a new design was needed to allow a 20% variation in gradient while maintaining the magnetic center of the quad to within one micron of nominal position.

The effort officially began when Nan Phinney of SLAC wrote "NLC Magnet Configurations - Possibilities for strings or permanent magnets " (September, 1999), and Andy Ringwall produced a "Technology Definition Sheet" and a "Table of Specifications for Permanent Magnet Candidates." At Fermilab, Jim Volk developed permanent magnet designs using the "hybrid" principal that Bill Foster had used for the Fermilab Recycler. In these, permanent-magnet bricks produce the field and the field shape is determined mainly by precision-contoured iron pole pieces. The intrinsic temperature coefficient of the ferrite material (-0.18%/degree C) is canceled by interspersing a "compensator alloy" between the ferrite bricks. These designs use rotating permanent magnet rods to change the integrated gradient by either aiding or opposing the other magnets driving the field in the gap. The initial designs all used ferrite magnet material, and in January 2000 an internal review was held at Fermilab.

Over this last year, SLAC and Fermilab, with help from LBNL (Steve Marks, Kem Robinson and Ross Schlueter), produced design variations that were presented at coordinating meetings and video- conferences. The biggest uncertainty has been the stability of the quadrupole center throughout the rotation of the adjustment magnets. Samarium cobalt (Sm-Co) was substituted for the ferrite to address this. For the required fields and small apertures of the NLC magnets it was discovered that Sm-Co was several times more efficient than ferrite. Even though Sm-Co is about ten times more expensive than ferrite, the amount of material required is so small that the estimated magnetic material cost per linac quadrupole is approximately equal to that for the ferrite magnets. Jim Volk then developed two designs similar to the ferrite designs using Sm-Co magnets, and Vladimir Kashikhin produced an alternative design using iron shunts to modify the field in the gap. After investigation of various shunt configurations, Vladimir Tsvetkov's design was accepted in which, to provide better centering stability, the shunt moves into position longitudinally. A fourth design was developed using quadrupole sections that rotate in opposite directions in order to change the integrated field strength. All four designs will be tested as prototype magnets constructed at Fermilab to determine which design best meets the NLC specifications at the lowest cost. In these prototypes, SLAC has responsibility for the design and construction of the hardware to rotate the adjustment magnets and to move the shunt or quad sections, including the instrumentation and control equipment.

At Fermilab, Hank Glass and Joe Dimarco have constructed a stretched wire system to measure the prototype magnets. It will need improvements to obtain the one-micron accuracy. Zack Wolf's Magnetic Measurements Group at SLAC have set up a rotating coil measurement facility, but have also determined that a new setup will be required in order to achieve the one-micron measurement accuracy and are making modifications. The first permanent magnet quadrupole is on the test stand at Fermilab. It is anticipated that all four Fermilab models will be competed by the beginning of FY01. It may be necessary to make test-stand improvements and perhaps rework some of the models to achieve the centering stability. The goal is select the best permanent magnet design by the end of this calendar year.

As a separate effort at SLAC, Carl Rago and Cherrill Spencer have designed and constructed an electromagnetic quadrupole that would provide a basis of comparison to the new permanent magnets. Currently, the electromagnet is undergoing tests on the improved test stand at SLAC. See NLC News, November 2000, for more about the electromagnet development program.

Development Work at LBNL
John N. Corlett

Work on the NLC damping rings systems has focused recently on three technical areas; RF cavity engineering design, vacuum systems design for the arc and wiggler sections, and the rings layout. While much of this work is relatively mature, ongoing R&D activities include building robust high-power RF vacuum windows, and measuring very low outgassing rates of aluminum machined by a variety of processes. Low outgassing from the aluminum vacuum chambers may remove the need for distributed pumping, very important in the 50 m of wiggler in the main damping rings. A robust RF window, based on the proven PEP-II design, is needed to accommodate ~ 250 kW of power transmitted to each accelerating cavity.

Progress has also been made at LBNL in developing tools to understand the nonlinear effects of the wiggler on the beam dynamics. Advanced Light Source (ALS) physicists have characterized the "base" lattice, and we will soon augment our effort to address the detailed effects of the wiggler on the dynamic aperture. Layouts of the damping ring complex and individual components continue to be developed to incorporate these refinements in lattice, vacuum, and RF systems.

Expertise at Berkeley in design and fabrication of permanent magnet systems is being used to aid the permanent magnet program for NLC, particularly in the development of generic formulations for parameterization, evaluation, and optimization of hybrid magnets. In the near future LBNL will contribute more extensively to this important research program.

RF Breakdown Workshop
Marc Ross

A 3-day Workshop was held in late August at SLAC to review the latest results of very high gradient accelerator structure testing. Workshop planning began in late May, during the NLC collaboration and Machine Advisory Committee meeting held at Fermilab. Immediately after an organizing group with members from CERN, SLAC, Fermilab and KEK was formed to assemble an agenda.

The impetus for the workshop came from the disappointing performance of copper accelerating structures in NLCTA and CTF (CLIC Test Facility) tests. A critical enabling factor in the tests was the first-time availability of enough high frequency RF power and a properly functioning delivery system that allowed us to power structures well beyond the nominal NLC accelerating gradient.

The workshop sessions focused on: 1) the latest results from the labs, 2) structure fabrication and materials handling, 3) theoretical explanations of breakdown phenomena, 4) the interaction of structure electrical design and breakdown, and 5) a general discussion of how to proceed. New

Spring 2000 test results were presented, yielding quite lively and open discussion.

Greg Loew, who has worked on this topic for longer than most of the other participants, opened the meeting by posing three key questions: 1) What causes breakdown in a copper structure? 2) Is there any fundamental frequency dependence? 3) When does breakdown cause damage? Experimental results from NLCTA and CERN suggest a fundamental difference between single and multi-cell performance. Single cells, much easier to fabricate and test than multi-cell structures, have achieved limiting surface fields well above those needed for NLC in a variety of conditions. Lisa Laurent, Daryl Sprehn and Arnie Vlieks, all of SLAC, presented results from a broad spectrum of tests all based on an 11.4 GHz apparatus that allows quick exchange and inspection of copper coupons or 'noses.' Walter Wuensch, of CERN, also showed preliminary results from a 30GHz CLIC single cell and multi-cell test apparatus. While the experiments differed in detail, especially in the definition of breakdown, they both show a characteristic 1/v(t) dependence of the peak achievable voltage on pulse length, *t*. Explaining the pulse length dependence, because of the interaction with the collider design, became the focus of our first discussion section.

Hasan Padamsee, a superconductive RF expert from LNS Cornell, summarized parallel studies done with superconductive cavities. While there are many fundamental differences between copper and niobium cavities, the workshop organizers felt that materials handling technology developed for niobium might help push the performance of copper structures. The original cause of each breakdown in niobium cavities (always a contaminant particle) could be identified using appropriate surface analysis techniques, especially surface Auger analysis. Very high pressure, 80 bar, pure water rinsing was most effective in reducing the density of surface contaminants.

Chris Adolphsen and Rod Loewen, who have spearheaded the test work at SLAC, reported on the structure damage seen after a few thousand hours of 60 Hz operation at ~ 65 MeV/m accelerating gradient. All cells near the structure input were detuned through repeated vacuum arcs – so much so that Chris estimates that 5 mm^3 of copper were removed from the irises of the cells. His explanation related the potential of the arc to do damage to the group velocity in the traveling wave structure. Zenghai Li presented the designs of the structures the KEK/SLAC group is preparing in order to test this idea.

Juwen Wang and Toshi Higo, of the group that fabricates the 11.4 GHz structures at KEK/SLAC, reviewed the materials machining, handling and bonding steps they use. We discussed how contaminants were introduced in the process and how they might be removed.

Padamsee presented a well-developed simulation of what he termed a 'unipolar arc' that develops quickly once field emission from a zone containing a contaminant particle exceeds a threshold. The interaction of the field emission current and gas surrounding the contaminant play an important role in the explanation.

The meeting closed with two very active discussion sections, one aimed at Greg's second and third questions (see above) and another aimed at experimental technique and high power processing strategy. In the first, following the suggestion of Jean-Pierre Delahaye of CERN, we agreed to consolidate gradient and pulse length data. In the second session, we focused on experiments that would provide insight into the time scale of the breakdown events. A key tool would be a monitor able to provide a breakdown precursor signal.

There will be a successor meeting in about 6 months to review new results.

Beam Delivery Status Report

Tom Markiewicz

The Beam Delivery group is investigating the consequences of two proposed changes to the NLC baseline configuration. The first change is the switch from the final focus (FF) system described in the 1996 ZDR to that recently proposed by Pantaleo Raimondi and Andrei Seryi. The second change would modify radically the ZDR-era NLC site layout. The standard picture called for two interaction points (IP) separated transversely by ~44 m and longitudinally by ~280 m; only one IP at a time would receive the total available NLC luminosity. In this design, the electron and positron linacs and collimation sections were co-linear; a so-called IP switch and two ± 10 mrad "Big Bends" directed the beams to the IPs. As the FF length shrank dramatically it became more difficult to achieve a reasonable IP transverse separation. Moreover, as the new FF length is very insensitive to increases in energy, the 10-mrad bend became the element that would limit the ultimate energy that could be transported to the IP without serious emittance degradation. In the proposed configuration, the linacs are oriented to provide the 20 mrad crossing angle (required so that parasitic collisions within the bunch train are avoided), and the IP switch and Big Bend to the primary IP are removed. Lower initial cost and energy reach to the 3-5 TeV range are achieved. A separate transport line, picked off the linac at some to-be-determined maximum energy, would serve the second IP. If the injector systems and the front end of the linacs can be designed to operate at 180 Hz, the low energy IP would operate at 60 Hz simultaneously with a 120 Hz high energy IP physics program.

The Beam Delivery group is investigating the consequences of the reduced protection from detector backgrounds that result from removing the Big Bend and shortening the distance from the collimation system. Synchrotron radiation calculations for the new FF lattice and apertures are in progress. As the new FF is also relatively insensitive to changes in the position of the final lens relative to the IP (L*), we hope roughly to double the separation from 2.0 to 4.3 m. This requires changes in the concept of how the lens will be supported and very different mask configurations. The goal is to report the work status at the October 4-6 MAC meeting and to present preliminary results at the international linear collider physics workshop at Fermilab October 24-28.

Most of the parts and drawings for the construction of a prototype rotary ("consumable") collimator are ready; time in the SLAC shops is needed. Additional raw materials, parts and drawings have been acquired or produced for a first-generation system that would freeze a molten metal into a rotating drum in a smooth and uniform manner such that it could be used as an alternative collimator technology. The groundwork for making systematic outgassing measurements of potential beam pipe materials was advanced. Incremental work was done on inertial vibration sensors, test beam and fixed target beamline design, and the collimator wakefield experiment apparatus.

Recent Linear Collider Publications

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

I. Recent Journal Articles

Paul Bellomo, Carl E. Rago, Cherrill M. Spencer, Zane J. Wilson, "A Novel Approach to Increasing the Reliability of Accelerator Magnets," *IEEE Trans. Appl. Superconductivity*, **10**(1): 284-287, Mar. 2000. Presented at MT16.

II. Linear Collider Collaboration Notes

LCC-0046, "Comparison of Discrete Klystron-Produced RF to Two-Beam Produced RF for Large Accelerator Systems," Rainer Pitthan, 09/00.

Calendar of Upcoming Events

I. Conferences

5th International Linear Collider Workshop (LCWS 2000), 12-28 Oct 2000, Batavia, Illinois,http://d0server1.fnal.gov/users/hefisk/LCWS2000/Linear_Collider_Workshop_2000.htm

The 22nd Advanced ICFA Beam Dynamics Workshop, Nov. 6-9, 2000, SLAC, Menlo Park, CA http://www-project.slac.stanford.edu/lc/wkshp/GM2000/default.htm

Nuclear Science Symposium, Lyon, France, October 15 – 20, http://NSS2000.in2p3.fr/

2001 Particle Accelerator Conference, Chicago, IL, June 17-22, 2001.

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

II. Meetings

September 21,22, Internal NLC Review, SLAC, Menlo Park, CA.

October 3 - 6, Collaboration /MAC Meeting, SLAC, Menlo Park, CA.

November 14 – 17, ISG 6, KEK, Tsukuba, Japan.