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ILC-Americas
FY06 Work Package Technical Progress Report

Work scope period: 10/1/05 to 9/29/06
Work Package WBS Number: 3.10.4
Work Package Title: Final Focus Quadrupole Full Length Coil R&D

Work Package Leader: Michael D. Anerella
Laboratory: Brookhaven National Laboratory

Date: August 3, 2006

1. **Technical progress.**

Proof of Principle Sextupole / Octupole Construction & Test

This proof of principle magnetic element is a 4 layer single wire octupole coil with a 6 layer seven strand cable sextupole on top. Fabrication of this magnet coil set is complete; all coil layers have been wound and cured into final position. Warm magnetic measurements have been completed, which verify that the two magnetic centers are within 28 microns.

Shielding Coil Construction & Test:

A shielding coil is needed around the main final focus quadrupole coil to prevent disrupting the beam in the extraction line. A two layer shielding quadrupole coil was constructed on a separate support tube and installed around the previously fabricated 6 layer final focus quadrupole model coil assembly. This magnet pair was tested warm, and confirmed the shield ability at nulling the external quad field.

Long Coil Winding R&D:

Conceptual design of the direct wind machine modifications has been completed. These modifications are needed to minimize deflections of the 3 meter long small diameter coil support tube during the winding process. Similarly, conceptual design has begun on a machine to wrap the tensioned epoxy-impregnated fiberglass roving onto the completed 3 meter long small diameter coil assembly without causing damage to the coil from distortion.

Vibration Testing:

BNL RHIC CQS Magnet Laser Measurements:

Characteristics of a commercially available, actively stabilized vibration isolation table were studied. This table is installed in a beam line at the National Synchrotron Light Source (NSLS) at BNL. This table showed a reduction of nearly two orders of magnitude above about 10 Hz. A similar table was procured to improve the quality of the CQS laser measurements.

The experimental set up for the CQS laser measurements was improved significantly by decoupling the laser holder from the test stand. In the new set up, the laser holder was placed on a heavy steel table, separate from the test stand. This resulted in considerably less laser holder motion, as compared to the previous cold test in September 2005. The sensitivity of the laser vibrometer was further improved at frequencies above a few Hz by reducing the motion of the laser head. This was done by placing the entire laser source/interferometer, as well as the laser fiber heads, on an actively stabilized vibration isolation table described above. In this improved set up, the RMS head motion is below 1 nm/√Hz above 8 Hz.

The new set up was used to measure the horizontal motion of the CQS cold mass at cryogenic temperatures under various conditions of helium flow. The testing was done in the MAGCOOL experimental cold testing bay in the Superconducting Magnet Division (SMD) building complex. One of the laser targets did not function during this test due to contamination during pumping and cool down. Measurements were still possible with a second target located at the other end of the magnet. Two types of measurements were carried out with the helium flow off – one where the magnet was completely isolated (with the trapped gas not vented), and another where the magnet was also vented to the return line. A significant reduction (~2X in the integral above 1 Hz) in vibration was seen when the magnet was isolated, but the motion increased dramatically at 11 Hz when the magnet was vented. This increased motion reduced slowly with time, indicating that the increase may be associated with transients caused by venting.

Pick up coil work:

A 2500-turn pick coil was received from CERN. This coil has been mounted in a solid G-10 block and a fiberglass support tube. The assembly has a platform for mounting geophones to monitor the probe motion. Preliminary measurements of the vibration of the coil placed on (crude) support stands have been made. Some reduction in the coil motion was achieved by mounting one of the ends on a vibration isolation table. We need a second isolation table to further improve the stability of the coil.

2. Goals and plans for the remainder of FY06 and FY07.

Proof of Principle Sextupole / Octupole Construction & Test

The coil assembly has been installed onto a testing top hat and prepared for cold testing in a vertical dewar. Testing will be performed at 4.5 Kelvin and also in superfluid helium. All cold tests will be performed within a solenoidal background field.

Long Coil Winding R&D:

Detailed design work will be completed on both the direct wind machine modifications and the tensioned wrapping machine. Equipment will be built and used for full length prototype test coil winding and wrapping.

A critical issue for predicting the response of direct wind magnets to the localized and time dependent energy deposition is to determine the minimum quench energy for our coils under ILC conditions. To this end we plan to wind another short quadrupole prototype but this time with short quench heaters that are directly integrated into the coil structure. While we expect to gain related experience (i.e. developing measurement techniques and current lead infrastructure) while using quench heaters placed a top the ends of the just completed sextupole, the best determination of the direct wind IR magnet performance under simulated ILC conditions will come from future coil-integrated heater tests.

Vibration Testing:

Preliminary measurements will be made with the pick up coil placed in a room temperature quadrupole to study the effect of power supply ripple and probe alignment.

In FY07, the laser set up will be used to study vibration characteristics of a room temperature mock up of an ILC quadrupole. Since a real prototype will not be available for quite some time to come, this exercise will help develop the vibration measurement techniques to be employed for the actual ILC geometry. It will also help in identifying potential problem areas in the support structure for the ILC quadrupole cold mass. The laser setup will be enhanced by the addition of an actively stabilized support girder, which will be used to support the mock up, and later the prototype during the respective test of each. This support girder is being shipped from SLAC where it has been previously utilized.

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FY06 Work Package Technical Progress Report

Work scope period: 10/1/05 to 9/29/06
Work Package WBS Number: 3.10.5
Work Package Title: Conceptual Engineering Design
Work Package Leader: Michael D. Anerella
Laboratory: Brookhaven National Laboratory
Date: July 31, 2006

1. **Technical progress.**

14/20 mr Concept

The conceptual magnetic design work for the large, 14/20 mr, crossing angle has been completed. (This is in the category of MDI.) The optics have been developed for both the final focus elements and the beam extraction elements, which must be done in conjunction with one another due to the tight physical space limitations. This work has resulted in the present configuration of all beam delivery system magnetic elements being contained in a single common helium vessel and cryostat, for which preliminary mechanical modeling has been completed. Also, for this we have iterated with SiD to ensure that the cryostat design is compatible with the following: opening up the detector for access, determining the machine-experiment interface at the IP end of the cryostat, and permitting the integration of a room temperature kicker magnet between superconducting elements in the beam delivery system. These features are contained in the current mechanical model, as well as features to allow for the independent alignment of each element within the common vessel.

Anti-Solenoid Development:

The anti-solenoid concept was revisited to take into account a Machine Detector Interface (MDI) issue for the SiD detector concept. SiD plans to open their detector for access to inner components by sliding the solenoid yoke endcaps longitudinally away from the IP and the original anti-solenoid scheme interfered with this movement. Thus the anti-solenoid radius has been increased so that it can be incorporated into the yoke endcap but as this takes space from the SiD muon system we must keep the anti-solenoid cryostat as compact as possible. A conceptual design based on low temperature NbTi superconductor has been completed and a cost estimate for units of this design has been submitted for the CDR.

Tail-Folding Octupole

In the original BCD discussion of the tail-folding octupoles that are used to soften beam collimation requirements, it was presumed that rare-earth materials could be used to make these high-gradient superconducting magnets. Since then we developed a new, much simpler, superconducting octupole concept that does not require rare-earth pole inserts (avoids an R&D issue) but uses a modified Serpentine winding technique to insert conductor inside a full octupole cross section. So far a short demonstration winding was produced with an un-potted coil placed inside a solid yoke, and with some simple tooling needed to make 3 m long magnets, we expect this to be a very economical way to produce this octupole. A preliminary design was used to make a cost estimate for a stand alone tail-folding octupole magnet system using cryocooler technology similar to that already produce for a BNL AGS superconducting magnet (i.e. no extended cryogenic transfer line running back to the main linac is needed).

Reference Design Magnet:

As all concepts developed to date all appropriate irrespective of the choice of crossing angle between 20mr and 14mr, this work is therefore representative of the GDE reference design. A cost estimate has been developed for all magnetic elements (final focus elements and the beam extraction elements) for a fully integrated beam delivery system for the ILC.

Cryogenic Interface:

Primarily due to vibration issues, and to a lesser extent to provide a greater operating margin, sub-cooled helium is envisioned to be utilized for cooling the superconducting coils in the beam delivery system magnets. To that end, the mechanical modeling of the reference design magnet has been completed with due attention paid to the cryogenic interface. Specifically, an analysis has been completed and iterated to ensure that sufficient helium volume is present for the heat transfer between the supply helium and the coil volume helium. In this respect the common vessel for final focus and beam extraction elements has proven to be a significant advantage.

2. **Goals and plans for the remainder of FY06 and FY07.**

14/20 mr Concept

Magnetic designs will be iterated as needed based on feedback from accelerator studies and also based on results of prototype work.

Anti-Solenoid Development:

In addition to the low temperature superconductor (LTS), NbTi, design investigated so far we are considering using high temperature superconductor (HTS) conductor that would permit higher temperature (at say 35K) where the large coil force could be more reasonably managed. In future work we will develop the HTS concept more fully and work out mechanical designs for force management to get a cost benefit comparison between LTS and HTS. Also we will work with the other detector groups, LDC, GLC and 4'th, since their MDI issues and requirements differ from those of SiD.

Tail-Folding Octupole

When additional funding is available for this work we will start detailed engineering and design of a 3M long prototype using this new concept. This can then be vertically quench-tested to see if our ideas for supporting the conductor work as well as expected.

Reference Design Magnet:

Detailed engineering and design will continue for the integrated beam delivery system magnets. Work will be geared toward both providing a design for the accelerator magnets and for the planned construction of a prototype magnet.

Cryogenic Interface:

Work will continue on the conceptual design of the cryogenic interface. Future work will focus on the conceptual design and engineering of the service cryostat, which will contain the heat exchanger need to deliver sub-cooled helium to the magnets, as well as the necessary fill and vent lines for the helium volume within the common vessel. Also, the various power leads and instrumentation leads shall be incorporated into the service cryostat.