ILC R&D Board Task Force on High Gradients (S0/S1)

Draft Workplan 2007 for S0 –

Improving the Performance Yield in Production-like Experiments

H. Hayano, T. Higo, L. Lilje, J. Mammosser, H. Padamsee, M. Ross, K. Saito

Version: 28-Sep-06

1 Introduction

In the following a more detailed work plan will be laid out to achieve the task force goals on the multi-cell cavities[1]. This document focuses on the planning for 2007. In another document the more general planning will be described. As described there are two basic ways of performing test cycles: the 'tight-loop' and the 'production-like' efforts. The tight-loop experiments have the main goal to give confidence in processes and procedures during the surface preparation. The procedures will be monitored closely and key parameters controlled. The production-like efforts introduce the added complexity of dealing with factory manufactured cavities. Thus the full cavity production cycle yield can be determined.

1.1 Production-like experiments

As said in the document on the tight-loop experiments will allow separating the cavity preparation yield from the overall cavity production yield. But it is the cavity production yield which matters from the ILC project point-of-view. Therefore a production-like measurement with many cavities being fabricated and prepared is needed.
It is likely to iterate this production-like operation as new cavity vendors need to be qualified for the demanding fabrication process. In addition to this, a certain quantity of cavities is needed for the fabrication of full accelerator modules which eventually are being used in the various test facilities to reach the emerging goals for S1 and S2.

Our ultimate goal is to establish 95% yield for 35 MV/m in a production-like batch of cavities by mid-2009 including at most one repeat preparation and testing cycle. This translates to an 80% yield goal for the first test. We adopt a phased approach towards this goal. The approach is based on a model for yield improvement in 2007 and 2008. The maximum number of cavities planned must be compatible with the maximum preparation and testing capability planned globally.

[1]For the goals see :
http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache=cache&media=rdb%3Ardb_external%3As0s1definitions_final.pdf

1.1.1 Phase 1: (till end of 07)

In the fall of 2006 we plan to order a large batch of cavities and, during 2007, apply the best treatments available from the on-going tight-loop and R&D activities outlined above. These production cavities will be treated separately to those cavities ear-marked for the tight-loop activities. Cavities limited by field emission will be re-treated and re-tested until they pass 35 MV/m. Some cavities will be rejected due to low field quench from manufacturing or material defects. Rejected cavities will be targeted for thermometry analysis in order to identify the nature of the material or manufacturing errors. Information from this activity will be fed to the material supplier or the cavity manufacturer in an effort to improve the yield for the next batch of cavities. Successful cavities will immediately pass to cryomodule population for subsequent S1 and S2 activities[2].

- A US supply of 24-28 cavities is foreseen by beginning 2007:
    - 8 TESLA design cavities have already been ordered from industry.
    - 12 – 16 short TESLA cavities will be ordered in 06 from industry.
    - Jlab will make 4 cavities (2 short TESLA and 2 TESLA).
- DESY/XFEL
    - ~15 out of 30 cavities of the current production are still to be tested
    - 30 cavities are on order by DESY for the XFEL and will be delivered around April 2007
- KEK
    - KEK requests 10 cavities to be built in 2007 (order April and delivery in October). The shape for these cavities is currently under discussion.

Therefore it should be possible to obtain a batch of 36 or more cavities globally for this phase. Assuming a fabrication yield of 0.7, and an overall processing yield of 0.4 it should be possible to obtain 24 good cavities after 90 treatment and testing runs. These 24 successful cavities would be sufficient to populate three cryomodules with cavities > 35 MV/m for S1 in 08 (as required for S1) and one RF unit in 09 (if required by S2).

1.1.2 Phase 2: (till end of 08)

In the fall of 2007 we plan to order a second, larger batch of 160 cavities. This order will involve new vendors under development. However, at least 128 cavities (80%) should be ordered from vendors who have already qualified to deliver cavities capable of reaching 35 MV/m. We assume a fabrication yield of 0.9 for these vendors, to yield 115 good cavities. For the 32 cavities from new vendors we assume a cavity success rate of 0.5, which will yield 16 good cavities. As before the failed cavities will be sent to a lab to test with thermometry and determine the cause of failure.

During 2008, these cavities will be treated by improved processes learnt from phase 1, tight-loop program and the R&D program. Therefore we assume an overall processing yield of 0.8 requiring 200 total processing and testing cycles.

[2] For the description of the cavity names, please refer to the addendum.

For the yield study, a processing yield of 0.8 means that we can expect a 95% yield after 2 cycles of processing. This is consistent with the goal for the ultimate yield. The statistical error for a batch of 100 cavities is significantly less than the fraction of failed processes.

With 130 good cavities it should be possible to populate 16 modules in 09 and 5 RF units in 2010 (if required by S2)

1.1.3 Resources needed

1.1.3.1 General timeline

The total number of processes and tests for the two phases (including vendor development) will be about 290. In addition a 100 processing and testing cycles are needed for the tight loop operation, yielding a grand total of 390 process and test cycles. Below we estimate the existing and planned global facilities to show that a significant expansion is necessary.

An analysis of the various steps in the preparation and testing cycle shows that it takes 21 working days (or about one calendar month) for a cavity to go through the complete set of operations (see table below). Here we assume that just one set-up is available for each of the operations, such as EP, tuning, 800 C, baking stand, test-stand, etc. and that these facilities are utilized for only one shift per 24 hours. The rate is limited by the occupation of the test stand which is about 4 days. If the work is done in an assembly line mode, it is therefore possible to treat and test 5 cavities per month. A completely equipped facility can therefore reach a capacity of 60 cycles per year. Accounting for 20% downtime and maintenance time could bring this rate down to about 50 per year.

Degrease & EP 100-120 um	3 days
HPR	1 day
Drying	1 day
H-removal, 600 – 800 C	3 days
Tune field flat	1 day
EP 20-30 um and degrease	1 day
HPR	1 day
Dry	1 day
First stage assembly & HPR	1 day
Dry	1 day
Final assembly to test stand, evacuation	2 days
120 C bake on bake stand	2 days
Attach to test stand, evacuate	1 day
Cold test, warm up	3 days
Total:	**21 days (4 weeks)**

Table 1: Prep and Test Cycle: Modeled After DESY Procedure Described by Matheisen, 1st ILC Workshop @KEK 2004. The details in the processes vary between the various laboratories.

1.1.3.2 Testing

If KEK, DESY and Jlab can provide this test rate, for 07 and 08, it will give the total number of cycles available to be 300. But there are other projects competing for the same resources at these labs. At DESY the main project will be XFEL, at JLAB it is the upgrade and at KEK it is the drive to demonstrate ACD goals (ICHIRO cavities). In addition, there is the need to carry out single cell tests for developing improved techniques. Clearly we will need to increase this capacity by a substantial number to fulfill all needs.
Therefore it will be very important to push forward as rapidly as possible on plans to install additional capabilities at other labs. Argonne has plans to bring on a new EP and Fermilab has plans to bring on line a new vertical test capability. These should be operational in tandem by mid 2007, yielding 1.5 years x 50 cycles/year = 75 additional cycles. Cornell is working on bringing a vertical EP facility on line. If this gives comparable results to the horizontal EP facility, it will add 12 cycles x 2 years = 24.

It will also be important to add more test stands and/or more shifts at existing or soon to be finished facilities. Adding a second test stand at Jlab and KEK by mid 2007 will increase the rate by 100 cycles/year x 1.5 years = 150. The grand total of all these efforts approaches the required 550 cycles in two years. Of these 390 cycles will be required for the S0/S1 efforts.

The need to diagnose defective cavities can take place at other facilities. LANL has core SRF capabilities and a proposal to HPR and test cavities that get EP elsewhere, for example at Argonne or at Jlab. LANL could be a location for analysis of failed cavities with thermometry. MSU has also core SRF capabilities, and could be developed as another site for testing with thermometry diagnostics.

1.1.3.3 Next generation infrastructure

2007 will be a year of intense activities on cavity preparation and testing, standardization of recipes, and improvements of procedures. As our knowledge and experience mature through these intense activities, it would be appropriate to begin planning for the next generation of preparation and testing infra-structure that would incorporate improvements as well as begin a scaling up in preparation for the pre-production phase of ILC.

In this context, it is instructive to examine the “preparation activities” for CERN LHC construction. The LHC requires 1200 cryomodules (15 m long) as compared to the ILC’s 2000 modules (12 m long). There were three stages of preparation before launching a sizable “pre-construction” series of 90 modules.

- Stage 1: After design and modeling work at CERN, 3 prototype coils were built in industry and modules assembled and tested at CERN.
- Stage 2: Vendors assembled 9 modules (3 per vendor) at CERN using facilities installed at CERN.
- Stage 3: Vendors then manufactured a total of about 20 modules (7 per vendor). About 6 of these were fully tested (2 per vendor).

In all, a total of 32 modules were prepared by the CERN/industrial collaboration before launching the pre-series. After these preparatory activities, the "pre-construction" series consisting of 90 modules by 3 vendors was successfully finished over a 2 year period.

One concept for scaling up the next generation infrastructure could therefore be modeled on the CERN preparation activities of 32 modules, which would require preparation and testing for 256 cavities.

The ongoing effort of the XFEL module production will serve as an important basis in the ILC production effort. Industry has already been invited to participate in the assembly of XFEL accelerating modules for training. This will result in a study including suggestions to improve the processes towards being the basis for the assembly in industry. Afterwards industry will start to build the first prototype modules. The natural development will be the production of 100 XFEL accelerating modules by 2013. The sooner the ILC couples into this process, the more the benefit will be for both XFEL and ILC.

1.2 Addendum

1.2.1 Explanation of Cavity Names

- TESLA (= TTF 4th production cavities):
  - NbTi flanges using aluminum gaskets
  - HOM : 'Mirrored' geometry, build from tube material, larger antenna port for simpler adjustment
  - Magnetic shielding external to He tank
- TESLA (short)
  - Identical to above but beam tube length 'short' on both sides (symmetrical ends)
- TESLA-like (KEK version)
  - Design to increase stiffness at He tank end plates
    - Different coupler port distance
  - Flange system using indium seals
  - HOM: 1 TESLA + 1 with special geometry to fit frequency tuner, CNCed from full material
  - Magnetic shielding in He tank
- ICHIRO (Original KEK ICHIRO design)
  - Similar to LL shape
  - HOM design not completed
  - Larger cut-off tubes
  - Stainless flanges using indium seals
- Improved ICHIRO
  - ICHIRO center cells
    - Very similar to low-loss shape
  - End-groups: new end cells with new geometry and HOM coupler a la SLAC, J. Sekutowicz and KEK

	Nine-cell program						Single-cell studies			Other developments				
	Production-like effort			Tight-loop effort			Confirm recipe	Basic R&D		Diagnostics development		Alternatives		
Region	KEK	Europe/XFEL	Americas	KEK	Europe	Americas	KEK	All				Large-grain/single-crystal	LL/RE	Material
Jul-06		15 (of 30) TESLA (ZANON)				Assembly tight-loop : 4 TESLA (ACCEL)	7 existing Ichiro center Confirm KEK recipe	Investigations on contaminants	In-situ Bakeout (CEA, Jlab)	Multi-cell T-map (or twin T-map for suspicious cells)	Monitoring in EP systems: Polarization curve, HF content	3 TESLA (DESY, ACCEL)		
Oct-06				2 ICHIRO without HOM		Full EP tight loop		Rinsing methods: H2O2, Alokohol, Oxipolishing		Acid QC: Chemical analysis and polarization curves			KEK: 2 Ichiro without HOM (see left)	
Jan-07			12 TESLA (short)	2 Europe + 2 American to KEK		6 TESLA (2 Jlab + 4 AES)	6 Ichiro center Confirm KEK recipe. Alternative: Compare EP with and without Barrel Polishing	Q- disease: Effect of Acid film at beginning and end of process, cathode shield and geometry				2 ILC (large-grain)		Titanisation?
Apr-07		30 TESLA		2 Improved ICHIRO with proper end-cells+HOM									KEK: 2 Ichiro with HOM (see left)	
Jul-07						Improved final rinse tight loop								
Oct-07	10 TESLA short as requested by S0 Task Force												KEK: 4 Ichiro with HOM (see right - STF Phase 1.5)	
Jan-08			24-36 TESLA short											
Apr-08														
Jul-08														
Oct-08	24 ILC for STF II													
Jan-09			48 ILC											
Apr-09														
Jul-09														
Oct-09														
Jan-10														

Table: Overview on planned ILC cavity R&D activities today. This list serves as a basis for further proposals from the task force. As outlined in the text it is proposed to increase the number of cavities from 2008 significantly.