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

Draft Workplan 2007 for S0–

Improving the Performance Yield in Tight-Loop Experiments

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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.

An additional R&D program, such as on single-cell cavities and sample studies must be focused on the procedures applicable to multi-cell cavities and must provide feedback for the improvement of the preparation processes. Especially the R&D program should include suggestions from the proposal from the TTC[2]. Sample tests and accompanying surface studies are also needed to follow important process steps.

1.1 Available experimental setups

1.1.1 Today

The main process to yield high gradient cavities is electropolishing (EP) together with high-pressure ultra-pure water rinse (HPR) and 120-130°C 'In-situ' bakeout (bake). The exact parameters to be used in the process should be determined during the TTC meeting at KEK in September 2006.
The overall process of cavity preparation includes a large number of process steps with many parameters to be monitored and be adjusted. In order to get sufficient statistics on

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

[2] For the TTC Proposal see:
http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache=cache&media=rdb%3Ardb_external%3Attc_proposal17jan2006.pdf

the processes it is mandatory to perform a reasonable number of preparation and test cycles. The overall resources available indicate that efforts have to be made to increase the overall capacity of cavity preparations and tests. At the same time a more effective use of existing resources needs to be implemented.
Currently, three setups for multi-cell electropolishing are available today: KEK/Nomura, JLab and DESY. The largest available preparation and test capacity will probably be at KEK with about 40 preparations and tests per year. The preparation and test capacity at DESY is needed to a large degree for the ongoing effort to build prototype modules for the XFEL.

1.1.2 Near future

An increase in the preparation capacity especially on the EP and KPR are needed. Existing facilities should be maintained to an as large degree as possible.

In the near future the KEK setup at Nomura will be phased out of operation as the newly built setup at STF will become available. It needs to be assured that during this transition the current large preparation capacity at Nomura/KEK remains intact As the number of multi-cell cavities at KEK is relatively small, but the overall preparation capacity is large it is proposed to send cavities to KEK for treatment (see below).

In addition to the JLab facility a new EP facility will be brought online at ANL/FNAL. The timely installation of this facility is of great importance to increase the overall turnaround on surface preparations. At Cornell a vertical EP facility has been assembled for 9-cells and is presently under test. If this method gives results comparable to horizontal EP it will add to the overall EP capability in the US and increase the number of cavities which can be processed.

In Europe it is expected that industry will be building nine-cell EP facilities for the first (pre-furnace) EP step. This would considerably increase the capacity for the final EP at the existing setup at DESY.

1.2 Available Cavities

1.2.1 Terminology

- 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
- 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

1.2.2 General

The overall number of cavities available for the first phase of the tight-loop experiments (see below) seems sufficient. In order to be able to go to a production-like experiment a larger number of cavities is needed. This is being addressed in the long-range workplan currently being finalized.

1.2.3 Japan

Currently, only 2 ICHIRO cavities are available. The current beam tubes with HOM damping will be replaced by beam tubes without HOM dampers. In 2006 there will be 2 improved ICHIRO cavities will be built. These cavities feature the newly developed end-cell geometry for asymmetric HOM damping (by SLAC , J. Sekutowicz and KEK).
The other existing cavities will be used for STF Phase 1. Another 8 cavities (4 TESLA-like and 4 improved ICHIRO with new HOM damping) are planned to refurbish the STF cavities in STF Phase 1.5.
The large preparation and testing capacity at KEK could be used more efficiently by adding TESLA cavities to the Japanese R&D program.

1.2.4 Europe

In Europe the production-like operation is underway for the XFEL. About 15 more cavities will be tested from the existing 4th production cycle until the end of 2006. Another production cycle of 30 is being ordered soon.
It seems that a few cavities can be put in use for the ILC. It is worthwhile noting that the effort to make the process more reproducible is important for both the XFEL and the ILC. It is acknowledged that the gradient goals for these projects are different (In low-power test: 28 MV/m for XFEL and 35 MV/m for the ILC).

1.2.5 US

In the US 4 TESLA (ACCEL) cavities are currently being processed. Another 6 TESLA cavities are being fabricated, 4 at AES and 2 at Jefferson Lab. In addition, 14 short TESLA cavities are being ordered (6 from AES, and the remaining 8 from a vendor to be determined shortly). Another 24 cavities are being planned for FY07.

1.3 Nine-cell R&D program - Tight-loop experiments

The very first step is evidently to use the existing cavities to qualify procedures and setups in the labs. It is assumed that necessary diagnostics e.g. HF monitoring and witness samples for process monitoring will be added to all the setups (see section 1.5 'Other developments' below). At this stage all available multi-cell cavities are useful to demonstrate that handling of cavities does not deteriorate field flatness and that the parameters are reproducible in a lab. The goal should be to gain experience in the setups by the end of the year 2006. A database format for the process variables should be developed. A common set of measurements for the cavity tests has already been agreed upon[3].

After the initial treatment with a large removal of about 100 um and the 800°C furnace treatment, the basic treatment tight-loop will consist of the three basic processes: Short EP (30um after furnace, then 10-20um), High Pressure Rinse and In-situ bakeout.

Although the basic process is very similar, there is a large variation in the detailed steps. A more detailed analysis is under way and a more detailed proposal will be discussed during the upcoming TTC meeting at KEK. To illustrate the variations some examples are given:

- EP
- Low pressure water rinse to pH or resistivity
    - KEK uses hot water.
- HPR
    - 0.2um filter (KEK)
    - 0.04 um filter (JLab, DESY)
- Assembly with all but bottom flange
- HPR
    - KEK 6 hours
    - DESY 10 hours
    - JLab 16 hours
- Drying
- Evacuation
- Bake
    - Temperature
    - Time
- Assembly to test stand
- Pumping during cryo cycle

The overall process cycle at KEK is currently very different as the facilities for EP and HPR are at Nomura, whereas the final assembly is at KEK. Currently, the second HPR step is not being done at KEK. With the installation of the STF facilities this will change.

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[3] For the descriptions of the measurements see: http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache=cache&media=rdb%3Ardb_external%3As0s1definitions_cavity_tests.pdf

During the phase I testing cycle, each region should identify the best 3 cavities and do at least 3 preparation loops on them. These cavities should then be sent to the other regions for repeated testing and for calibration of the results from lab to lab. Again, three cycles per cavity should be planned. This experiment will allow comparing the different setups without being strongly influenced by cavity production problems. It will give a measure of the gradient yield of the cavity preparation process. For this type of measurements a sufficient set of cavities must be available. As the initial yield in the process might be low at least 20 cavities are needed world-wide. This task should be finished by mid of 2007.

A previously agreed upon data base of testing and preparation parameters will be prepared and closely analyzed to monitor the tight loop operations.

As it is expected that improvements to the cavity preparation steps will be suggested from the parallel single-cell and other R&D programs (see section 1.4 below), in a second phase the same cavities should go through the improved processes and should yield a higher average gradient with a smaller spread in performance thus increasing the yield of the cavity processing.

1.3.1.1 Proposed steps in Japan

At KEK there will be Ichiro-like nine-cells available where the end groups will be changed to simple beam tubes. These cavities are ideal for the setup of the infrastructure. As the flange design is different from the original TESLA and the short TESLA design the exchange of those cavities needs development of transition pieces.

To make best use of the KEK facilities in 2007 sending 6 TESLA (or short TESLA) cavities from Europe and the US to KEK for tight-loop processing is proposed. A delivery is expected in March 2007. If cavities have been tested, they should perform at a minimun of 25MV/m and not be quench limited. First results on the tight-loop might be expected autumn 2007. A comparison between the performance of TESLA and ICHIRO cavities tested at KEK (for example using peak electric and magnetic fields) will facilitate the future inclusion of ICHIRO cavity data into the overall statistics of preparation yield.

In addition, the fabrication of another 10 cavities at KEK is proposed for the production-like processing. These cavities could be partially used for the tight-loop effort or as exchange for the shipped cavities mentioned before.

1.3.1.2 Proposed steps in the US

The existing cavities should be used to establish procedures at JLab, send 3 cavities to KEK and make the selection of the three best cavities for the tight-loop processing. The first tight-loop experiments will start at JLab in beginning 2007. The infrastructure for testing e.g. variable coupling needs to be made compatible with the current planning of cavity preparations. The cavities destined for KEK will be short TESLA cavities. Delivery of these is expected to begin in May 2007.
Further cavities would be needed to setup the EP facility at ANL/FNAL. Being a new facility, the EP facility at ANL would be checked out with single cells first.

1.3.1.3 Proposed steps in Europe

Three lower performing or untested cavities should be sent to KEK as mentioned above. It is proposed to continue the production-like mode in the ongoing cavity production cycles. The three best cavities should be used for the tight-loop effort. The tight loop effort will also be important to the XFEL program.

1.3.2 Production-like experiments

As said above 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.

A more detailed proposal is under development and should be available by mid of September 2006.

1.4 Single cell R&D

The single-cell R&D should aim at improving the nine-cell preparation process. The time the results must be available is October 07 to allow a timely feedback into the nine-cell preparation cycle. If important results become available much earlier the baseline process will be re-visited. Since single cell results tend to have better statistics than 9-cell results, any " improved treatment" should be repeated several times and results compared with a baseline single cell treatment which is also established through several tests on the same cavity.

The single-cell program needs to includee the recommnedations of the proposal by the TTC group as mentioned earlier. Sample and surface studies will continue in co-ordination with single and 9-cell cavity activity.

1.4.1 Rinsing studies

A special focus need to be the rinsing studies after the EP process. There are several methods of rinsing being pursued. The list gives a prioritised view of the task force:

1. Oxipolishing
    a. HF rinsing
2. US degrease
3. Megasonic with water only
4. Ethanol
5. H_2O_2

It is proposed that at the TTC a discussion is initiated on who would be willing to take over which task.

1.4.1.1 Proposed steps in Japan

At KEK the 'fresh acid' recipe needs to be confirmed. The results on single-cells should be compared to sample studies using standard surface analysis tools. This should finish by end of the year.

1.4.1.2 Proposed steps in the US

A dedicated program with single-cells on the other options of rinsing described in the TTC report namely oxipolishing and alcohol rinsing should be pursued. This program should make use of the one-cell setups available at JLab and Cornell. The results on single-cells should be compared to sample studies using standard surface analysis tools.

1.4.2 Overall preparation recipe comparison

An alternative preparation cycle proposed by KEK includes centrifugal barrel polishing. This method smoothens the welds, and has the potential to reduce the amount of EP necessary. The benefits should continue to be explored.

1.4.2.1 Proposed steps in Japan

It is proposed to compare a sufficiently large batch of cavities with centrifugal barrel polishing with a batch of cavities with the standard process as described in the BCD. This could be done as a follow-up of the study mentioned under 'Rinsing studies' (1.4.1.1).

1.5 Other developments

For an improved monitoring of the various preparation processes several diagnostics need to be developed or implemented. Most of these activities should be implemented by mid/end 2007.

1.5.1 Acid monitoring

The quality control of the electrolyte needs further improvement. This is true for both offline measurements between EP cycles and online during the EP process. A standard set of data should include the HF content and the polarization curve amongst others. Methods for offline acid quality control should be developed in each region and compared to each other. This should be supplemented with niobium sample studies.

1.5.2 High Pressure Rinsing parameters

A method needs to be established to make water rinsing cycles in the different labs comparable.

1.5.3 Cavity measurement

See also:
http://www.linearcollider.org/wiki/lib/exe/fetch.php?cache=cache&media=rdb%3Ardb_external%3As0s1definitions_cavity_tests.pdf
For cavity testing it is important to have the diagnostics at hand. This includes especially the development of a temperature mapping system in each laboratory performing multi-cell tests.
It is a necessity to apply temperature mapping diagnostics to cavities which consistently show poor performance to track down the source of the problems, whether material defects or welds, for example.

	Nine-cell program						Single-cell studies			Other developments								"Management"		
	Production-like effort			Tight-loop effort			Confirm recipe	Basic R&D		Diagnostics development		Alternatives			Modules for Test Facilities			Milestones	Decisions	Comment
Region	KEK	Europe/XFEL	Americas	KEK	Europe	Americas	KEK	All				Large-grain/single-crystal	LL/RE	Material	KEK	Europe	Amerikas			
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)							Need to understand EP capacity for the Americas for tight-loop	
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)			Test of M6, Build M7 (25MV/m class)		Define "standard" nine-cell test	Need to discuss european cavities for the tight loop at KEK or DESY	Can standard flange systems be defined?
Jan-07				3 Europe + 3 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?		Test of M7		Use ACC6 results to initiate cavity shape down-select at KEK		
Apr-07		30 TESLA	14 TESLA short(6 AES + 8 ?)	2 Improved ICHIRO with proper end-cells+HOM									KEK: 2 Ichiro with HOM (see left)		STF Phase 1: 4 Tesla-type + 2 IS			Industry involved in surface preparation (prototyping)	KEK: Decide shapes of next 10 cavities for October	
Jul-07						Improved final rinse tight loop													9 cavity down-select: distribute 3 cavities to each region	difficult to achieve, low number of cavities and new manufacturers might not perform initially
Oct-07	10 additional as requested by S1 Task Force												KEK: 4 Ichiro with HOM (see right - STF Phase 1.5)		STF Phase 1.5: 4 TESLA-type + 4 IS (includes replacement of TESLA-type + added IS)		US Module 1st	Single-cell program:Rinse parameters; Multi:Demonstration of reproducibility between regions	Define Final Surface Preparation	
Jan-08			24-36 TESLA short																	
Apr-08																			Final shape decision for ultimate goal	
Jul-08																	US Module 2nd			
Oct-08	24 ILC for STF II														32 for STF II			Demonstration of reproducibility between regions with improved parameters		
Jan-09			48 ILC														US Module 3rd			
Apr-09																				
Jul-09																				
Oct-09																		Demonstrate S0 Ultimate		
Jan-10																				

Overview on workplan: Production-like effort still under investigation.