Reminder: We meet tomorrow at 1:30 - 3:30 in the Fujii room.

Agenda: Subcommittee reports on schedule, manpower, and dollars. We will start to put together the individual R&D items for the Structure Design, Manufacturing and QC, Operations/Processing, and Theory. This includes schedules for use of the test facilities at the NLCTA, Windowtron, and elsewhere as required.

-Dave
Hi Nobu,

Very good. We are having a number of continuing discussions here at SLAC on the planning of the high-gradient R&D, just as you on the MAC instructed us to do!!

We will have a summary meeting tomorrow, and will indeed have some comments for what our opinions are on the TxxxV GyF sequence. We will send these to you along with notes from our discussions. It would be good to plan to hold a video meeting on Thursday/Friday. Will that be ok with your side?

More later,
Dave

-----Original Message-----
From: Nobu Toge [mailto:toge@lcdev.kek.jp]
Sent: Monday, October 23, 2000 5:57 AM
To: Wang, Juwen; Adolphsen, Chris; Cornuelle, John C.
Cc: Burke, David L.; toshiyasu.higo@kek.jp; toge@lcdev.kek.jp
Subject: High-power Test Structures by KEK/IHI

Hi, Chris, John and Juwen -

Nobu Toge from KEK here. The IHI folks are finally getting up to speed in precision fabrication of the so-called F-type (flat-type) disks and we at KEK are right now trying to re-evaluate the whole schedule for the fabrication and bonding assembly of the test structures; i.e. the ones to be fabricated *and* diffusion bonded in Japan, then tested at SLAC.

At this stage we would like to ask your opinion on the following two points -

1. What are the relative priorities of the short-, mid-sized- and long structures for testing, and what is your preferred "delivery" dates from KEK? As you started running DS2S and DDS3 in late September, we presume you'd be accumulating well over 1000 hrs by the end of this year, and might be interested in switching to another pair of test structures in Feb or March (... or may be much sooner ??)

You already have bonded the first short N-type structure (vg = 5 %). The next batch (100 N-type disks; vg = 5%) will be shipped from KEK to SLAC soon. We presume that they'd be your natural next candidate structures to process. In that case would there be good points or little points in our (KEK/IHI) working very hard to deliver you a couple more 5 % structures with F-type disks early next year? You might be more interested in having 6 % type ones or something else... In that case, "now" is the right time to speak up. Missing such things will result in our having wrong structures at a wrong timing.

2. What is the overall strategies and time frame for scanning this Vg vs L space after all? We have been kind of avoiding this question for a while, since setting up the production line or the high power station to work with has been our first priority. However, now, we'd better revisit
this question, since our engineering and industry cohorts had better hear exactly how hard they have to work, and understand why. Do you have any records of your internal (SLAC) discussions or memo or whatever you can share with us (KEK)?

Discussions on the item 2 can take some time, perhaps worth another set of TV confs several times. However, as for the item 1, I'd appreciate if we could converge fast, e.g. within a few days or within this week.

Thank you for your attention on this matter.

- Nobu Toge (toge@1cdev.kek.jp)
From: Ross, Marc
Sent: Wednesday, October 18, 2000 4:45 PM
To: Sprehn, Daryl W.; Jobe, R. Keith; Frisch, Josef C.; McCormick, Douglas; Smith, Tonee J.; Burke, David L.; Adolphsen, Chris; Miller, Roger H.; Wang, Juwen; Tantawi, Sami G.; Garwin, Edward; Pearson, Chris; Cornuelle, John C.; Baumgartner, William; Raubenheimer, Tor O.
Subject: Meeting to review tasks for High Gradient RD - Operations (NLCTA/Test stand 1) 15:30 Thursday Klystron 1st floor

This message is addressed to the High Gradient R&D Coordinating Committee and the NLCTA/Special Projects group.

We have been asked to produce a plan that supports the structure RD -
with a prioritized project list and schedule. I would like to spend our (first) meeting
tomorrow, reviewing and discussing the plan. I have attached a draft list of projects and
goals.

Marc Ross
Operations
(Ross/Sprehn) Tuesday, October 17, 2000

Plans and responsibilities

1) Process DDS3 and DS2S; new structures as delivered
2) Develop infrastructure to support the activity; with a goal of 95% operation (see list)
3) Develop and exploit instrumentation to explore high gradient breakdown (see list)
4) Handling and installation
5) Understand the connection between test stand 1 and NLCTA results
6) Compile system failure analysis and lessons in general from NLCTA operation; understand and define successful operation

1) **Processing**: DS2S will be removed Dec 4. DDS3 processing is proceeding very slowly; perhaps not at all. We plan to use DDS3 as a test structure for instrumentation and released gas studies. It has the best pumping speed and thus the best position for an RGA. DDS3 should be in-situ baked as soon as possible, but no later than early Dec. The RGA should be installed at that time.

2) **Infrastructural efforts** are focused on supporting 3) and 4).

3) **Instrumentation** will be used to answer the following:
   - What are the pre-cursors to breakdown?
   - Which breakdown events cause damage?
   - Why are the downstream sections less damaged?
   - Can pulse length be exchanged with RF peak power for processing purposes?
   - What determines the sharp gradient threshold?

Precursors should appear as optical signals and should become visible with the imagers listed. By detecting differences in breakdown events (as a function of gradient/pulse length) and measuring with regular beam tests, we should be able to determine the rate of damage. Using acoustic sensors to more accurately determine the location of the power deposition in the structure, we will be able to determine the extent to which multiple arcs affect damage.

4) **Handling and Installation**. With the introduction of truly 'cleaned' structures into NLCTA, we will have to make substantial changes in procedure / technology. The most difficult part will be the collection and training of technician teams. An evaluation of the surrounding vacuum systems is also required if we want to open the adjacent beamline valves.

5) **Understand the connection between test stand 1 (windowtron) and NLCTA**. Breakdown is defined as undesirable delivery of energy into dark current, reflected energy or radiation. In each case, the level of power emerging from the RF coupler at the end of the structure is reduced. We will connect the threshold for a 'breakdown' in a structure with one in the windowtron using this definition. Light, vacuum and reflected energy, each by itself, have been shown to be less useful. We need to develop a plan to study the connection between 1 and multi-cell structure performance. Success in structure operation results in a breakdown rate of less than ~1 to 0.1/hour at nominal operating gradient. Also, damage should occur at a low rate since the replacement cost of the structure is equivalent to 1 years operating cost. It seems clear from the experience at NLCTA that each NLC structure must be instrumented for monitoring breakdown events.

6) **System failure analysis compilation**, infrastructure and operation.
### NLCTA improvement projects (FY01 Operations)

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<td><strong>Total</strong></td>
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### NLCTA structure breakdown diagnostic projects

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<td>2</td>
<td>Beam current monitors (*)</td>
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<td>3</td>
<td>Acoustic sensors</td>
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<tr>
<td>4</td>
<td>Optical structure imager</td>
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<tr>
<td>5</td>
<td>Vacuum RGA</td>
<td>25</td>
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<tr>
<td>6</td>
<td>Waveform digitizer channels for RF (amp/phase), beam I, radiation (optical/x-ray) (VME/VXI/Scope)</td>
<td>25</td>
<td></td>
<td>1</td>
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<tr>
<td>7</td>
<td>Monitoring of HOM manifold signals</td>
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<td>2</td>
<td></td>
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<tr>
<td>8</td>
<td>Beam energy monitoring</td>
<td>15</td>
<td>2</td>
<td></td>
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<td>9</td>
<td>X-ray calorimetry</td>
<td>10</td>
<td>2</td>
<td></td>
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<tr>
<td>10</td>
<td>Full length structure boroscope</td>
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<td>2</td>
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<td><strong>Total</strong></td>
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### Capital Equipment requirements - NLCTA

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<td>1</td>
<td>Spectrum Analyzer</td>
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<tr>
<td>2</td>
<td>Digital oscilloscope (2)</td>
<td>70</td>
<td>1</td>
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<tr>
<td>3</td>
<td>Signal source with FM/AM/PSK (2)</td>
<td>60</td>
<td>2</td>
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<td></td>
<td><strong>Total</strong></td>
<td></td>
<td>165</td>
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High Gradient R&D Coordinating Committee
October 17, 2000

Agenda

1. Reports from Subcommittees - (Attached)

2. Homework Assignments and Work Orders

Scheduled Subcommittee Meetings
Structure Design - Monday, 23rd at 3:30 in Klystron Conf
Manufacturing - Monday, 23rd at 10:00 in Fujii
Theory - TBA
Operations - TBA
Structure Design Subgroup #1 10/17/00 J.W.

1. Ongoing Program
   Structure testing: DS2S and DDS3 at NLCTA
   Structure fabrication: T20VG5N, T105VG5N by end of November
   Next high priorities: T53VG3R, T53VG5R
   Investigation of surface cleanliness using travelers:
   Expectation for structure being fabricated
   DDS1 bead pulling studies
   Damage analysis for DS2 and others: Missing copper studies

2. SW Structure Option
   Basic aspects: Mode stability for π mode structure
   Pi-period structures
   Structure types and their RF parameters
   Reflected power handling and RF system
   HOM compression
   Pulse heating for side-coupling or pi-period structures
   High gradient and breakdown mechanism
   Review of past work
   Possible steps: Test structure design for a 15-cavity π mode structure
   Fabrication of test structures
   High power testing

3. Windowtron Experiment Related Issues
   Understand the connection of single- and multi-cell structures,
   What do the single-cell results tell us about long structures?
   Choices of RF parameter for new test cavity

4. Low Group Velocity Structures
   Continued simulation studies: including manifold damping
   mediate damping analysis
   interleaving analysis

5. Reduction of Surface Fields
   Optimization of cavity profile
   New design for input/output couplers
Program for Testing Full-Scale Structures

- Related Activities: Next few weeks
  - Bead Pull DDS1
  - Cut Apart DS2: Measure and Examine Surfaces
  - Process to 40 MV/m and run > 300 hours
  - Process to 50 MV/m and run > 300 hours
  - Run at 65 MV/m for 500 hours (Rep rate to 120 Hz ?)
  - Process to 70 MV/m
- T20VG5 and T105VG5: Dec, 2000 – April, 2001
  - Gradient goal and processing method based on DDS3 and DS2S results.
  - Tests if breakdown in the downstream section of T105VG5 makes upstream section worse.
  - Split power 60/40 to pair to yield same gradient.
  - Tests if lower group velocity yields less damage in the same length structure.
- NLC-like Structures: April, 2001 – July, 2001 (Snowmass)
  - High phase advance (150 deg) structure: 91 cm, group velocity = 4.4-1.3 %c.
  - Standing wave structure.
Station 0 Structure ‘Quick-Test’ Facility

Use to gauge effect of different manufacturing and cleaning techniques on processing time: cannot run beam through structure but it would be vacuum isolated.

Top View

- Possible Tests Starting March, 2001
  - T20VG5R: High Temperature Bake and Vacuum Seal
  - T20VG5F: High Pressure Rinse and/or Megasonic Cleaning
Suggestions for Windowtron Cavity

- Want cavity with similar RF circuit properties as NLC structures to make tests more relevant.
- Develop version that has a Q of 20 (equivalent to 5% group velocity) and requires 90 MW input power to produce 150 MV/m surface fields on the noses.
  - May want modify nose shape to yield a similar H/E as the structure irises.
- In the mean time use Resonant Ring version, which has Q of about 90 compared to a Q of about 700 for the Test Stand 1 cavity.
<table>
<thead>
<tr>
<th>Principle Variables</th>
<th>Relevant Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gas (CO, CO₂, H₂O, H₂)</td>
<td>Vacuum fire ≤ 1000 °C</td>
</tr>
<tr>
<td>• Surface</td>
<td></td>
</tr>
<tr>
<td>• Grain boundaries</td>
<td></td>
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<tr>
<td>• Bulk</td>
<td></td>
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<tr>
<td>2. Chemistry (Principally C and P)</td>
<td>Wet H₂ Firing</td>
</tr>
<tr>
<td>• Surface</td>
<td>Ar/O₂ Glow Discharge</td>
</tr>
<tr>
<td>• Bulk</td>
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</tr>
<tr>
<td>3. Particulates and Inclusions (Incl. Porosity)</td>
<td>Chemical Cleaning</td>
</tr>
<tr>
<td>• Surface</td>
<td>Etching</td>
</tr>
<tr>
<td>• Grain boundaries</td>
<td>High Pressure Water Rinsing</td>
</tr>
<tr>
<td>• Bulk</td>
<td>Ultrasonics/Megasonics</td>
</tr>
</tbody>
</table>

**Process Steps – Structures versus Windowtron Noses (Tentative)**

<table>
<thead>
<tr>
<th>Structures</th>
<th>Windowtron Noses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Selection – Specs and QC</td>
<td>Material Selection – Specs and QC</td>
</tr>
<tr>
<td>Rough Machining</td>
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</tr>
<tr>
<td>Chemical Cleaning</td>
<td>Chemical Cleaning</td>
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<tr>
<td>Anneal at 500 °C</td>
<td>Braze</td>
</tr>
<tr>
<td>Finish Machining</td>
<td>Chemical Cleaning</td>
</tr>
<tr>
<td>Chemical Cleaning</td>
<td>Final Machining</td>
</tr>
<tr>
<td>Handling and QC</td>
<td>Special Chemical Clean (Low Particles)</td>
</tr>
<tr>
<td>Chemical Cleaning</td>
<td>800 °C Vacuum Fire</td>
</tr>
<tr>
<td>Stacking and Bonding (Vacuum Furnace)</td>
<td>Handling in Air</td>
</tr>
<tr>
<td>Ship to SLAC</td>
<td>Vacuum Bakeout at 500 °C</td>
</tr>
<tr>
<td>Handling and QC</td>
<td>Hermetically Sealed into Windowtron</td>
</tr>
<tr>
<td>Brazing in H₂ (2 Times +)</td>
<td>In-Situ Bakeout</td>
</tr>
<tr>
<td>RF and Mechanical QC</td>
<td></td>
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<tr>
<td>ASSET Testing</td>
<td></td>
</tr>
<tr>
<td>Vacuum Bakeout (4 Days at ~ 500 °C)</td>
<td></td>
</tr>
<tr>
<td>Handling and Installation into NLCTA</td>
<td></td>
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</table>
Prioritized Experiments to Run:

1. Gas
   a. In-Situ Bakeout in NLCTA at ~ 220 °C
   b. Vacuum firing at ≤ 1000 °C
   c. Comments:
      • Perform on Short T20VG5N Structure
      • Ideally/Eventually with Windows on All Ports (to maintain vacuum)
      • Reviews Relevant Windowtron Experience
        o Repeat if not definitive
        o Extrapolate results to structure where applicable

2. Surface Chemistry/Inclusions
   a. Wet H₂ Fire Windowtron Nose
   b. Wet H₂ Fire T20VG5N
   c. Comments
      • Follow with dry H₂ firing if oxidation concerns

3. Understand Asymmetry in Arcing in Windowtron Noses
   a. Double H₂ Fire Both Noses (Solid nose now has only one H₂ brazing)
   b. Measure/Equalize Nose Temperatures

4. Cleanliness
   a. Determine the Impact of SRF Cavity Processes
      • Re-surfacing and/or Removing Particles
   b. Windowtron Noses
      • High Pressure Water Rinsing
        o Location: Cornell, JLab, DESY, SLAC
        o Define Protocol – pressure, flow, water filtration
      • Ultrasonics/Megasonics at SLAC
   c. Auger Scans for Non-Copper at Breakdown Sites
      • Niobium Samples from Cornell
      • Windowtron Noses
      • Issue of Particle Visibility versus Scanning Voltage
Operations
(Ross/Sprehn) Tuesday, October 17, 2000

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<td></td>
<td>Total</td>
<td>219</td>
<td>305</td>
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NLCTA structure breakdown diagnostic projects

<table>
<thead>
<tr>
<th>#</th>
<th>Title</th>
<th>FTE KS</th>
<th>MS K</th>
<th>priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Optical telescope (*)</td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Beam current monitors (*)</td>
<td></td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Acoustic sensors</td>
<td></td>
<td>25</td>
<td>1</td>
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<tr>
<td>4</td>
<td>Optical structure imager</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Vacuum RGA</td>
<td></td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Waveform digitizer channels for RF (amp/phase), beam I, radiation (optical/x-ray) (VME/VXI/scope)</td>
<td>25</td>
<td>1</td>
<td></td>
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<tr>
<td>7</td>
<td>Monitoring of HOM manifold signals</td>
<td>5</td>
<td>2</td>
<td></td>
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<tr>
<td>8</td>
<td>Beam energy monitoring</td>
<td>15</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>X-ray calorimetry</td>
<td>10</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Full length structure boroscope</td>
<td>5</td>
<td>2</td>
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<tr>
<td></td>
<td>Total</td>
<td>85</td>
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Capital Equipment requirements - NLCTA

<table>
<thead>
<tr>
<th>#</th>
<th>Title</th>
<th>FTE KS</th>
<th>MS K</th>
<th>priority</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Spectrum Analyzer</td>
<td>35</td>
<td>1</td>
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<tr>
<td>2</td>
<td>Digital oscilloscope (2)</td>
<td>70</td>
<td>1</td>
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<tr>
<td>3</td>
<td>Signal source with FM/AM/PSK (2)</td>
<td>60</td>
<td>2</td>
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<td></td>
<td>Total</td>
<td>165</td>
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High Gradient R&D Coordinating Committee
October 11, 2000

Agenda

1. Goals, Charge, and Guidelines
2. R&D Activities
3. Homework Assignments and Work Orders
High Gradient R&D Coordinating Committee

Goal: Reliable operation of NLC X-Band accelerator structures at NLC design gradients ($E_a \approx 75$ MV/m).

Charge to This Committee: Coordinate use of resources and facilities to achieve this goal.

Guidelines and Tasks:

1. Focus is on NLC X-Band accelerator structures to the exclusion (if need be) of other issues.
2. Attack problems on each major front - design, manufacture/QC, and operations. Are there others?
3. Fully utilize experience here and elsewhere:
   - SLAC Linac/ATF Linac
   - X-Band structures and tests to date
   - R&D in superconducting systems
   - Semiconductor industry
   - Space technologies
   - Others?
4. Identify resources needed or jobs to be done that will speed up or focus the R&D process.
   - Scientific/technical support
   - Programming support
   - Facilities
5. Develop a roadmap and schedule of activities.
6. Track results, costs, and schedules.
Activities

1. Breakdown Theory (Tantawi/Wilson)
2. Structure Design (Adolphsen/Miller/Raubenheimer/Wang)
   a. Minimization of surface gradients and susceptibility to damage - couplers and cells - length, group velocity, phase advance, and R/Q. Standing wave structures? Other parameters? Understand connection to single-cell tests.
   b. Manufacturability - can we (do we want to) design a structure that can be inspected and cleaned after it is assembled?
3. Manufacturing and QC (Cornuelle/Garwin/Pearson)
   a. Material properties.
   b. Manufacturing processes - machining, joining, assembly.
   c. Cleaning techniques - piece parts and/or finished assembly.
      i. SLAC Standard. Other-Lab Standards?
      ii. HP H2O
   iii. Megasonic
   iv. Bake-out/Vacuum firing
   d. QC
      i. Visual inspection techniques.
      ii. SEM, Auger, laser scattering.
4. Operations (Ross/Sprehn)
   a. Handling and installation.
   b. Processing control and protocol.
   c. Operational security - system design and failure analysis.

(Convener/Secretary)

This is a large parameter space. We must pick a path through it that optimizes success. Fishing expeditions to experimentally eliminate a wide range of possibilities is not going to get us there! Start with processes that have recognized success and acceptance (good practices) - focus on correlation with HV properties.
Homework Assignments:

1. Identify critical variables, processes, and techniques in each area of activity.
2. Create a prioritized task list of questions to be answered, modeling/calculations, and/or experiments to be done.
3. Create a prioritized list of resources and time needed to complete each item on the task list.
4. Identify need (not "opportunity") for collaboration by other institutions or industries.

Working Plan and Orders:

1. Coordinating Committee is to identify appropriate broader discussions necessary to include everyone in the work. The regular weekly Structures (Wang), Power Handling (Tantawi), and High Gradient (Adolphsen) meetings may be adequate.

2. Conveners/secretaries are to schedule necessary sessions with Coordinating Committee subgroups. Include DLB in your session, and notify entire Coordinating Committee.

3. Conveners/secretaries are to report to full Coordinating Committee each week.
Hi Cindi
Rd - Mangle

(1) Ed - Get a single line pencil
→ Can we see "Arpa"
petites with low volts?

Arpa → Dry & "cheval remont" not "petit remont"

Arpa → Badly - Oxygen / Carbon

(2) Asymmetry in pits on nose in Windham
→ More on [hollowed at side (4 to 1)]
[adjacent little 1 & 2 & tiny]

Note: Nose "over" = 1/100 of 20"-cell stack

"Like more"
[3 holes in fishs

100 breakers on nose
[3 holes @ 100/min]

Area Store & Gravy

10 YY

Surface coat?
E/H
The SEM may be able to look at the iris one cell into the first short RF gradient test structure, T20VG5N. It will require some fixturing to hold it at the proper angle.

There was some disagreement about whether the SEM observations of the test sample (traveler) that went along with T20VG5N were made of the correct side. This will be determined later.

Ed discussed the proper RGA to install in NLCTA with Ed Wright and Marc Ross, and they reached an agreement. The MKS unit is presently on backout.

Ed has not looked at the Windowtron noses in the past with Auger. To do this will require a service call on the XPS machine to obtain a more precise beam for imaging. The best time to do this is in January, 2001.

Agreement was reached on how to section the remaining higher group velocity portion of DS2 to look at iris damage. A non-contact technique will be used to measure the iris dimensions. Orientation marks will be made on the parts so that any orientation-specific information can be retained. Ed will then look at the iris inner surface with the SEM.

For the Megasonics and High Pressure Water cleaning tests, Ed prefers the 1" diameter test pieces that have been utilized in the past. They have a hole for handling, a 1 cm$^2$ raised area, and can be numbered for control. Ed proposes that they be cleaned, weighed to one microgram accuracy on their balance, AFM checked, Megasonics or High Pressure Water cleaned, weighed again to determine if any material has been removed, and then AFM rechecked. Chris Pearson will turn the parts on a lathe to obtain an 8 muinch or so surface.

Keith mentioned that the ultra-high purity water may etch the copper surface if it ismoving above some unspecified velocity, possibly impacting both the Megasonics and High Pressure water tests. We will need to setup a test with both low and high velocity water.

Dave has asked/will ask both DESY and Cornell for High Pressure Water Rinsing assistance, as opposed to (re)developing it at SLAC. Carl Rago will look for the Greg Mulhollan high pressure water setup used for gun cleaning that was last resident in Building 6 and report back to Keith. We also need to see if there is any data from this effort on the corrosion of copper by ultrapure water.

Dave proposed that we prepare an overall plan including the decision points of where we want to go with the work of this subgroup. Dave also would like a similar plan for the production of a "particle-free" structure. There was considerable discussion of how to simplify this by making it more of a "Chevy" test instead of a "Cadillac" test.

Keith asked if we could feed filtered hydrogen into a structure during brazing and keep it under a positive pressure with respect to the ambient in the furnace. Chris Pearson thought that this was feasible.

Chris Pearson outlined the test he is making with respect to measuring the hydrogen gas content after brazing and different amounts of vacuum firing/baking. Ed commented that the results will be different with a vacuum on both sides of the part in question versus air on one side and vacuum on the other.

Minutes by John Cornuelle
Dave:

I sent this to Daryl earlier today:

At our RF breakdown sub-group meeting, Ed Garwin asked about obtaining niobium samples from Cornell that are representative of the point Padamsee made about Auger analysis - that only with Auger could they see non-niobium in the starburst areas (EDX did not see anything). Ed wants to duplicate the Cornell work to see if the same thing applies here. Since Auger is very slow compared to EDX, he would prefer to use EDX if it can be shown to work.

Have you or Lisa had any contact with Padamsee on this?

Daryl responded that he thinks that he is on hold until you make the initial contact with Padamsee. Is this OK?

Thanks,

John C.