WG1 summary

TESLA Technology Collaboration Meeting
19 – 21st January 2021

WG1 conveners
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Hosted by DESY
Hamburg, Germany
https://indico.desy.de/event/27572
Summary

- 4 sessions, 3 topics and 20 talks

- Topics:
  - cryomodule testing (5)
  - heat load measurements (5)
  - linac operation (10)

- Talks „origin“: 4 from Asia, 5 from Europe, 11 from US/Canada

- Talks „gender“: only one female presenter… we need to get better!

- Participants among the different sections: Tue: 95~100, Wed: ~85
WG1 Charges

Several SRF linac projects or upgrades have recently come on-line. Several others are in the advance prototyping phase where whole cryomodules or prototype assemblies are being qualified in horizontal test centres. **WG1 is focused on the performance of operational cryomodules or cryomodules during qualification before installation on-line.** The discussions would include such topics as dark current and radiation damage, the calibration of cavity gradient, the performance after thermal-cycling and cryogenic aspects including the measurement of dynamic heat load. WG1 is asked to concentrate on the integration of components rather than on the performance of single subcomponents.
Cryomodule testing: SRF Gun

Axel Neumann (HZB), Experience with SRF gun module operation and lessons learned for SRF CW modules

1.4x½ cells + Choke cell

Troy Petersen (ANL), WiFEL srf e-gun refurbishment and testing

200 MHz QWR

Cold Q0 measurement: "Why so low?"
Cold test decay curve (left image) and RF power measurements confirmed lower Q₀, ~4e+7

"Dark current, where does it come from?"

Simulating Possible Causes

"The culprit is found"

- Simulation
- Measurement
- Coldbox test, no operation
- Retraction of Cu cathode
- RF test with retracted cathode
- RF test after He processing
- Dark current w/o cathode after He processing
- Dark current w/cathode, 2nd time
- Dark current w/Cu cathode
- Simulation
- Measurement
- Coldbox test, no operation
- Retraction of Cu cathode
- RF test with retracted cathode
- RF test after He processing
- Dark current w/o cathode after He processing
- Dark current w/cathode, 2nd time
- Dark current w/Cu cathode
- Cathode too far in: No Laser tool yet!
- Here cathode holder already damaged
- Last screen Vacuum incident
- Cathode lost
- Salineoid shorts

E₀ (MV/m)

30.42
19
7.3
12
10
0

CST PIC model
Cryomodule testing: low-beta cryomodules for ESS and PIP-II

* Han Li (Uppsala Univ.), RF Performance and experience of the 1st series spoke cryomodule for ESS

FREIA test stand @ Uppsala Univ.

* Joe Ozelis (Fermilab), PIP-II Half-Wave Resonator Cryomodule Test Results

HWR, SSR1 Cryomodules at PIP2IT

Then we have, for a 2K heat load of 1.18 W/cavity

\[ Q_{\text{pCM}} = 1.3 \pm 0.1 \times 10^{19} \]

Operation with Beam

* Alexander Sukhanov (Fermilab), Test Results from PIP-II SSR1 pCM

"The system is ready for spoke series CM test"
Cryomodule testing: heat load measurement
Measurements of single components and whole facilities

* Adnan Ghribi @ GANIL, SPIRAL-2 online and offline measurements
  * Measurement repeated each run (yearly)
  * Used to verify status of the linac, some degradation noticed, P vs Eacc studied
  * Used for automatic compensation, monitoring beam losses and anomalies

* Rajinikumar Ramalingam @ DESY, XFEL measurements
  * Comparison of single cryomodule and whole linac measurements, good agreement
  * Results compared over few years, stable behavior
  * Dynamic heat loads to evaluate average cavity Q0
Cryomodule testing: heat load measurement
Measurements of single components and whole facilities

* Elvin Harms @ FNAL and Michael Drury @ JLAB: heat load measurements of LCLSII cryomodules
  * Many tests, different techniques at different test stands, measurement verified among different labs
  * Spec Q0 values reached, oft repeated VT results in cryomodule test

* Sang-hoon Kim @ FRIB
  * Cavities met Q0 specs, solenoid degaussing was Measurement online and offline
  * Measurement after partial thermal cycle shows no degradation

Results – 1.3 GHz

- 32 g/s nominal fast cooldown
- 3-fold independent analyses
- low Q0 correlated to known cavity material with poor flux expulsion
- CMT51 average: 3.06E+10

Degaussing of Superconducting Solenoid

- Routine operation: degauss the solenoid prior to warm-up
- Tested warm-up without degaussing
  * Obtained 50% increase of the dynamic load in Cavity 4 and 6. Likely, 120% increase in Cavity 4, adjacent to the solenoid
  * Will establish an operation plan concerning the unscheduled warm-up

Special runs – F1.3-09

- Compare several fast cooldown rates
- Attempt 3p/3t technique

Ample margins in the dynamic loads and, therefore, total 2k heat loads.
Linac Operation: dark current and field emission (KEK/FNAL)

* Dark current from SC cavity may generate heating and quenching for SC-magnets in CM
* The particle tracking simulation revealed most of the electrons are captured and deposited much energy in the magnets
* The SC magnets should have higher tolerance as SC cavity has higher gradient in future
* They will start the new R&D to select the possible SC conductor
Linac Operation: commissioning experience for hadron SC linacs (low-beta)

* Naruhiko Sakamoto (RIKEN), Commissioning and Operation of RIKEN Heavy Ion SC Linac (SRILAC)

* Kazutaka Ozeki (RIKEN), Power coupler issues in CW operation from RIKEN

Degradation of Power coupler

For several FPCs, condensed water stood on Teflon support

- Purge water
- Examine inside of FPC (air side)
- Spot after water evaporation
- Green rust

Almost similar condition for all surviving FPCs

One possible scenario to vacuum leakage
- Dew condensation @ air side of vacuum window
- Galvanic corrosion of metallization of alumina (Molybdenum-Manganese metallization)
- Degradation of brazing of vacuum window

Vacuum leakage

Temporary treatment

- Machinable ceramics
- Vacuum lock: O-ring

Evacuation (inside of IC is also evacuated)

N2 gas
- Periphery of vacuum window
- Inside of IC

Comparison of Field Emission Levels

After an impact of SC06 coupler-window-break emission levels of SC07, SC08 became higher than those of the measurement #1.
Linac Operation: commissioning experience for hadron SC linacs (low-beta)

*John Popielarski (FRIB), FRIB Linac SRF Commissioning: Lessons Learned in Field Calibration, Mitigation of Field Emission, and Resonance Control*

**SRF Calibration Results from FRIB so Far**

- In-situ Qe2 calibration from cold cryomodule

**FE mitigation by pulsed RF conditioning**

- "After thermal cycle, No reduction in FE!"

*Feng Bai (IMP), Cryomodule development at IMP-lessons learned from operation of C-ADS and recent design for HIAF project*

- In the precooling process, the temperature of superconducting cavities in CM is not uniform and the temperature difference is relatively large.

- Temperature fluctuation of HTS current leads

- LN2 cooling system for HTS current leads
Linac Operation: experience in long-term operation (CBETA)

* They have picked off vibration sources to reduce the detuning frequency
* They have tested “Narrowband Active Noise Control” system while searching many parameters
* They achieved the energy recovery efficiency of >99%
Linac Operation: experience in long-term operation (ARIEL)

* The beam energy has been increased year and year, and beam power also

* They observed very low $Q_0$ in one cavity after installation, then reprocessed and performance recovered

* They have done the microphonic suppression by improving waveguide/cooling air/vacuum/LN supply systems

* They achieved the beam energy stability of 0.1% (rms)
Linac Operation: experience in long-term operation (SNS)

* The accelerator performance has been very stable

* Recently, they observed vacuum leaks from gate valves, but no sings there

* They also observed vacuum leaks from choke joint by brazing in power couplers, and replaced

* They have done in-situ repair and maintenance works for CMs in the tunnel
Linac Operation: experience in long-term operation @CEBAF

* They observed the substantial reduction in “electronic” quench rate after warming up CMs
* Viton seal damaged by radiation in the long term and repeated actuation caused by vacuum spikes at electronic quench events
* They changed the vacuum interlock to avoid closing GVs, to reduce less particle emissions
* The use of “shielded” ion pump for less particle emission is under plan

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**Valve Failure Due to Radiation and Repeated Actuation (1 March 2019)**

- When seal radiation hardened and had repeated operations due to vacuum spikes caused by electronic quench events.
- Initial symptoms were stuck in an indeterminate position.
- Initial remedial action taken was to lock the valve open and top-up to 20 K, which would no longer sustain gradient, and release the gradient in 225-6 and 225-7.
- Overall, the responsible accelerating voltage was initially reduced from 79 Mv to 59 Mv after securing the issue.
- It was further reduced to 47 Mv.
- A few months later, when it was restored from the machine and the extent of the damage was discovered, the remaining of the similar valves were locked in the open position.
- As part of removing the valve the upstream and downstream by-pass valves were pressurized up to 59 Mv when they were cooled back down the expansion of the high pressure and the low pressure side of the valve was 25 degrees, but to have calibration 1 and 2 for normal and other pressure gradients were reduced substantially resulting in a net change from 47 Mv to 30.8 Mv.

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**Shielded Ion Pump for Reduced Particle Emission.**

- A shielded ion pump was developed by Agilent and is currently available for purchase.
- Measurements using a Faraday cup to collect emitted particles indicate a reduction in particle emission by more than three orders of magnitude.
- The particle emission is one order of magnitude lower as compared to conventional shields, with improved pumping speeds as compared to conventional shields.
- The cost of the pump is comparable to that of a non-shielded pump.
- We plan on procuring and testing such a pump.
- I would be interested if others have tested this design for particle emission.

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**Faraday Cup Current (particles) For Non Shielded and Shielded Pumps**

Note: The vertical scale on the standard pump is in nA while the shielded pump vertical scale is in pA.
Linac Operation: experience in long-term operation @E-XFEL

- Dark current monitoring has been done by three types of devices: RadFet, RadCon, and MARWIN robot
- MARWIN works to make mapping of radiation profile for each CM string
- One big radiation burst was observed Oct/2018, killed one MARWIN (“Tears in heaven”)
- Total reduction: ~ 160 MV (in 2 years, confirmed degradation during operations)

By the way, this energy reduction is acceptable for ILC?
Concluding Remarks

* WG1 conveners thank all speakers, particularly for bringing their real issues to this open table. This will be certainly helpful for new SRF cryomodules and linacs from design, testing, commissioning, operation aspects.

* Thanks to all speakers, we believe the charges to WG1 are addressed.
  * (But many work is going on, we still need to endeavor to achieve good performance in cryomodules and linacs, preserve it in long-term operation)

* Speakers were invited from various areas, to meet the mission of TTC, "advance SRF technology R&D and related accelerator studies across the broad diversity of scientific applications":
  * Electron-gun, accelerating, ERL cavities
  * Low-beta coaxial cavities, medium- to high-beta elliptical cavities
  * hadron, electron linacs
  * Various design of cryomodules and subsystems

* We also thank all audiences
Thank you