PRELIMINARY CRYOGENIC COLD TEST RESULTS OF THE FIRST 9-CELL LSF SHAPE CAVITY

Jefferson Lab

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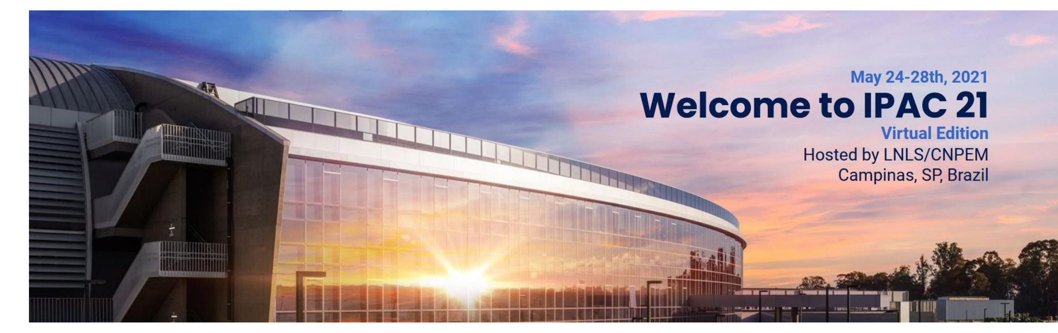


Abstract

The first 9-cell LSF shape cavity LSF9-1 was successfully constructed in-house with an improved process at JLab. The cavity was shipped to KEK for mechanical adjustment, treatment and surface processing. Cold testing was carried out at JLab VTA facility instrumented with a suite of Kyoto instruments. The favourable measured values of the bath pressure detuning sensitivity and Lorentz force detuning coefficient validate our in-cell stiffener design. Pass-band measurements indicate 4 out of 9 cells are capable of reaching a gradient > 45 MV/m, up to 51 MV/m in 2 cells. Cornell OST detectors identified the current quench source. Multipacting-like barriers observed in end cells are investigated both analytically and numerically. The cavity has now received a light EP of 40 micron surface removal at the joint ANL/FNAL facility and further cold testing at JLab is underway. Two new 9-cell LSF shape cavities are being constructed including one made of large-grain niobium material.

Background and Introduction

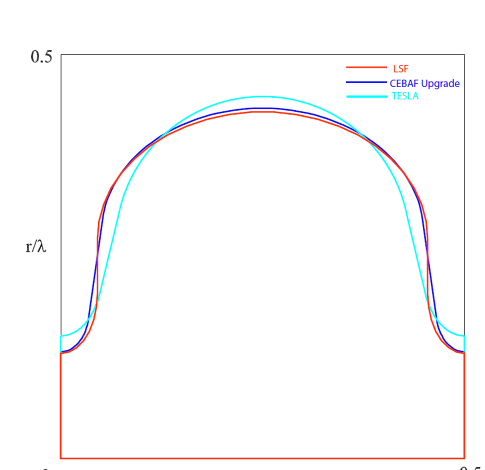
The idea of cavity shaping for higher ultimate acceleration gradients has been proposed for some time, KEK's Low Loss/Ichiro and Cornell's Re-entrant being examples, both seeking a lower B_{pk}/E_{acc} at the expense of a higher E_{pk}/E_{acc}. Experimental verification in single-cell cavities of those shapes was very successful including record E_{acc} of 59 MV/m. That success established a path forward for achieving higher E_{acc} well beyond 35 MV/m and it was well captured in the ILC Technical Design Report (TDR). Pushing multi-cell cavities of those shapes to higher E_{acc} was however prevented by FE - a bottle neck although not a fundamental limit.

The Low-Surface-Field (LSF) shape, conceived at SLAC, seeks not only a lower B_{pk}/E_{acc} but also a lower E_{pk}/E_{acc}, therefore it has the advantage of raising ultimate Eacc at reduced FE.

Test results of LSF shape single-cell and 5-cell proto-type cavities have been previously reported. In this contribution, we present the fabrication, processing and preliminary testing results of the first 9-cell LSF shape cavity LSF9-1.

Comparison of attributes of various cavity shapes

		TESLA	Low-loss/ICHIRO	Re-entrant	Low-surface-field
frequency	MHz	1300	1300	1300	1300
Aperture	mm	70	60	60	60
Epk/Eacc	-	1.98	2.36	2.28	1.98
Bpk/Eacc	mT/(MV/m)	4.15	3.61	3.54	3.71
Cell-cell coupling	%	1.90	1.52	1.57	1.27
G*R/Q	Ω^2	30840	37970	41208	36995



Summary of RF test results and Issues

Parameter	Unit	Value
Frequency	MHz	1300
Iris radius	mm	30
Stiffener radius	mm	63
Equator radius	mm	99
E_{pk}/E_{acc}	-	1.98
B_{pk}/E_{acc}	mT/(MV/m)	3.71
G	Ω	279
R/Q	Ω	1158
Cell-cell coupling	%	1.27

Design Choice in Wall Stiffening

- Small cell-to-cell coupling a design driver
- Design goal
  > Lorentz force detuning coeff. equivalent to ICHIRO
  > Field flatness preservation within 5% from handling
  > Small shape distortion no forced dumbbell correction
- Lessons learned from ICHIRO and CEBAF upgrade LL
- Available community inputs in numerical optimization
- 3-arc-pieces, each ~ 34 mm long at $R_{stiff}/R_{eq} = 0.64$
- Partial penetration weld at piece-to-wall interface

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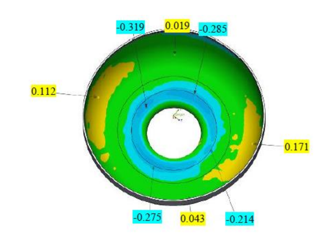
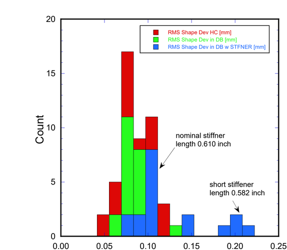
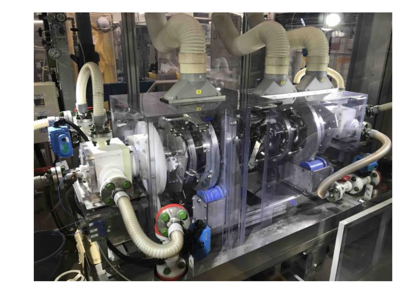
Cavity Fabrication and Processing





Half-cell shape accuracy measurement using a laser scanner (L). Shape deviation statistics and evolution (R).



LSF9-1 EP processing (L) and iris and end-group brush cleaning (R) at KEK STF

Systematic and progressive laser scanning of the half-cell shape established that our current fabrication technique is capable of achieving the RMS shape deviation of 0.08 mm at the individual half-cell stage and 0.1 mm at the DB stage with stiffeners welded.

This positive first data plus the low-cost fact of our much simpler DB stiffener welding process, relative to the standard one where post stiffener welding equator edge machining and aggressive cell deforming with complicated fixtures are required, give us confidence that a cost-effective method capable of delivering predictable DB cell shape accuracy, needed for mass production, is within reach.

First 9-cell LSF shape cavity LSF9-1 as completed electron beam weldment at JLAB

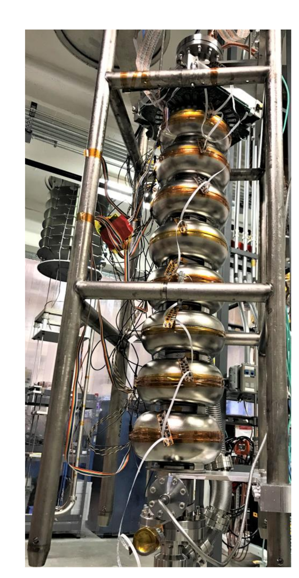
Treatment, Processing, and Optical Inspection at KEK (ILC TDR type)

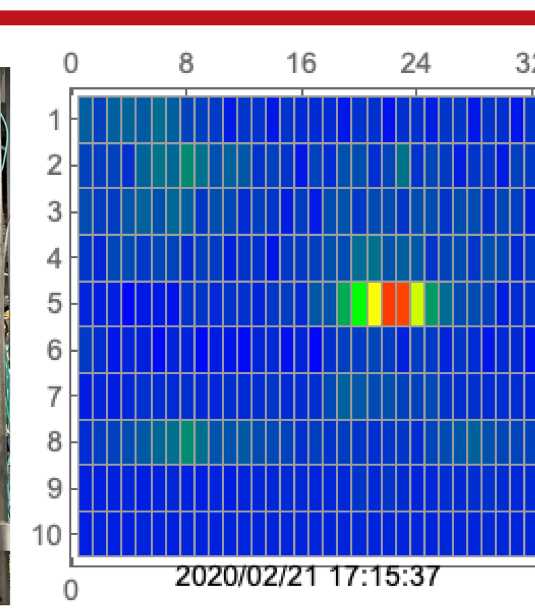
- Cavity straightness adjustment to within ±0.7 mm for all cells.
- Field flatness tuning to 93% using automatic machine.
- Pre-EP 5 µm with no acid circulation.
- Bulk EP 100 µm.
- Ultrasonic cleaning with detergent and HPR with ultra-pure water.
- Vacuum furnace annealing at 800 ºC for 2 hours.
- Optical inspection of the inner surface at iris and equator weld regions.
- Field flatness tuning to 93%.
- Optical inspection of the inner surface at iris and equator weld regions.
- Local grinding for removal major defects in cell equator region (3 each).
- Final EP at 50 µm removal.
- End group brushing and iris brushing followed by HPR.

Final Surface Processing/handling at JLAB

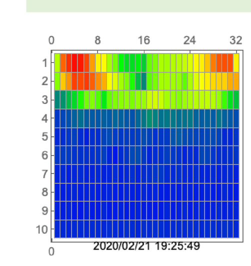
- HPR
- Clean room assembly, slow pump down
- In-situ bake at 120 ºC for 48 hours

Cryogenic RF Testing and Results



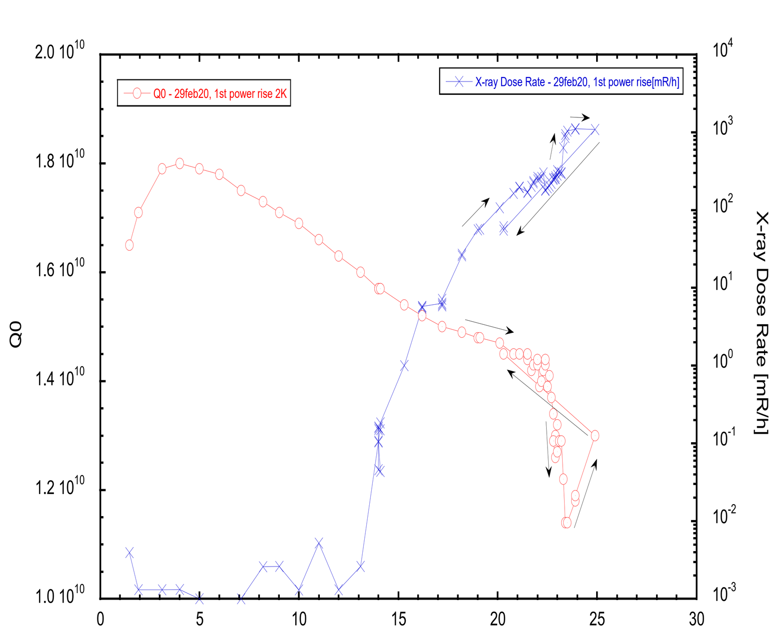


- During the initial power rise with the π mode excited, sX-mapping revealed transient local "X-ray hot spots" at strip sX6 & sX5 attached to irises in mid-cells that are attributable to activation and processing of local field emitters (movie left).
- When the cavity was excited in the 4/9-π mode, repeat-able hot spots appeared at sX1 & sX2 attached to the end cell irises right before the cavity ran into the quench limit at a field of 18.6 MV/m in the end cells (image below).

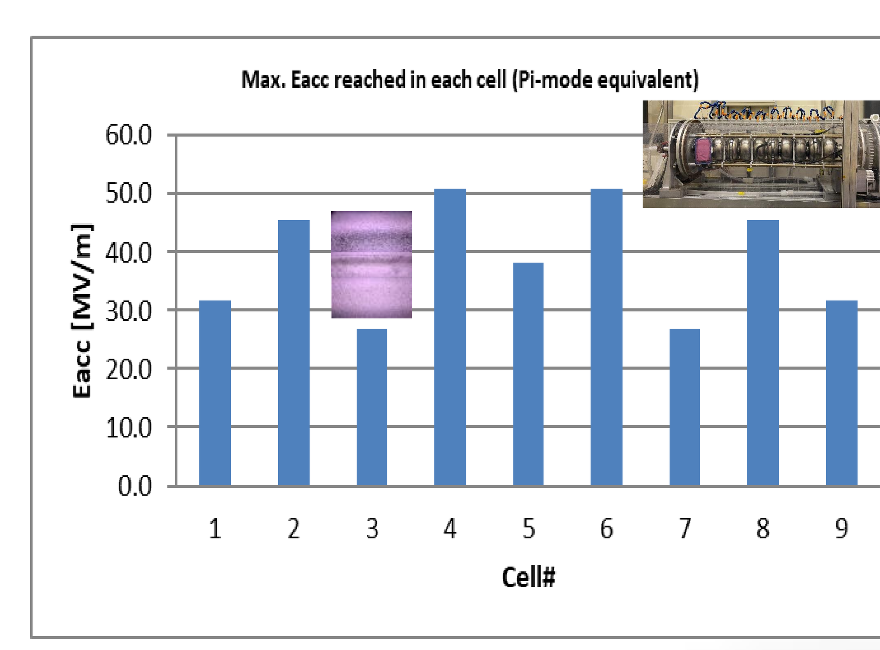


- End cell x-ray hot spots attributed to MP
- Systematic analytical calculations ruled out hard MP barrier.
- Unusual hot DI water soak of cavity over night suspected to cause an increase in SEY.

1622 sensors attached to LSF9-1 (a) and X-ray hot spots captured by Kyoto U sX-mapping system.



Best Pi-mode performance achieved so far by the cavity LSF9-1 at 2K.



Gradient capability of each cell of LSF9-1. Inset shows the RF surface image of quench location in Cell#3. Light EP 40 µm processing done (upper right) at joint ANL/FNAL facility aimed at curing the defect.

Summary

In summary, the first 9-cell LSF shape cavity has been successfully fabricated and tested in a joint in-ternational effort. The highest gradient attained is 25 MV/m so far. 4 of 9 cells demonstrated capability of reaching a gradient of > 45 MV/m including 2 capable of 51 MV/m. Test results confirmed our stiffener scheme with an average df/dp of -138 Hz/Torr and Lorentz for detuning of -2.7 Hz/(MV/m)2, on par with the values measured in the standard TESLA 9-cell cavities tested in the similar configuration at JLab.

Presently, continued testing of LSF9-1 is on-going. Two new 9-cell LSF shape cavities including one made of large-grain niobium material are being fabricated.

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