Discussion

1.3 GHz & 650 MHz Cavity RD&D at RRCAT

Discussion Coordinated by :

Avinash Puntambekar, RRCAT :POC-Indian Institutions
Camilee Ginsburg (c/o Chuck Grimm) :Sub Project Manager FNAL

Draft -Discussions points / Further plans

- Analysis of the cavity test result TE1CAT001 & 002
- Various factors for limiting cavity performance
- What should be done to take these cavities from 21 MV/m to > 35 MV/m ?
- X-Ray inspection & data analysis
  - (X- Ray inspection of a good quality weld bead (for comparison)
- 2K testing of TE1CAT002 (2nd test)
- 1.3 GHz Aluminum / Copper cavities for thin film deposition R&D at FNAL
- IUAC EBW facility modifications needed for 650 MHz Five cell cavity
- Schedule
- Eddy current scanning of 650 MHz size sheet, Scanner capacity ?
- FNAL progress and plans on 650 MHz cavities – Jim Kerby
- Schedule of five cell cavity design including end group from FNAL?
- Niobium and Nb-Ti for 3 Single cell (650 MHz) cavity from FNAL by Early Jan 2011
- To bring back the cavities TE1CAT001 & 002 for various process qualification activities at RRCAT (with known test result as bench mark)
- Any design and other issues seeking information / clarification from FNAL on SC cavity design & fabrication issues ?
- Any other issue ?

TE1CAT001 summary

- Optical inspected
- Tumble polishing in ~120 micron
- 40 micron light EP
- Hydrogen degassing at ANL/APS 600C 16 h.
- RF test, 19.4 MV/m quench
- 100K 8 h hold
- RF test, 19.9 MV/m quench
- Optical inspection showed some weld bead remained. Quench location showed no features.

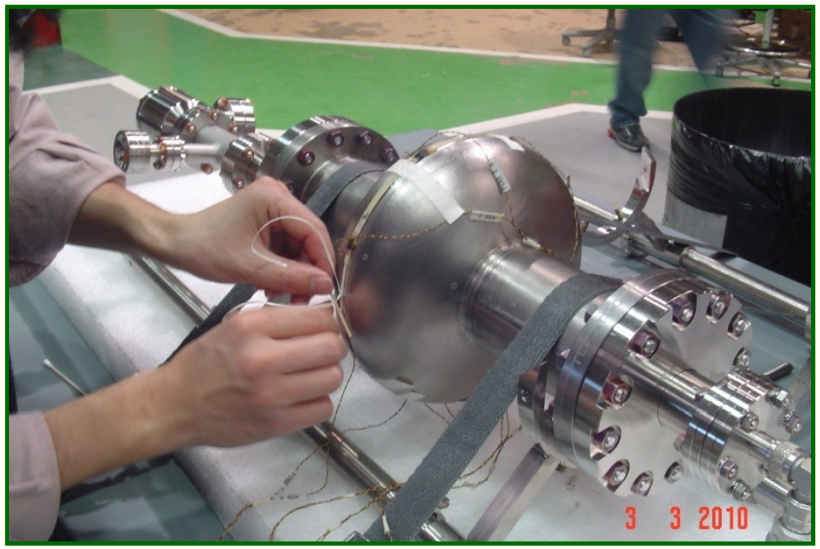
TE1CAT002 summary

2K testing of TE1CAT002 (2nd test)

- Optical inspected
- Bulk EP 120 micron.
- 120C baking 48h
- RF test, 21 MV/m quench
- Optical inspection showed many weld bead remained. Quench location showed no features.
- Tumble polishing in ~120 micron
- 30 micron light EP
- Hydrogen degassing (pending)

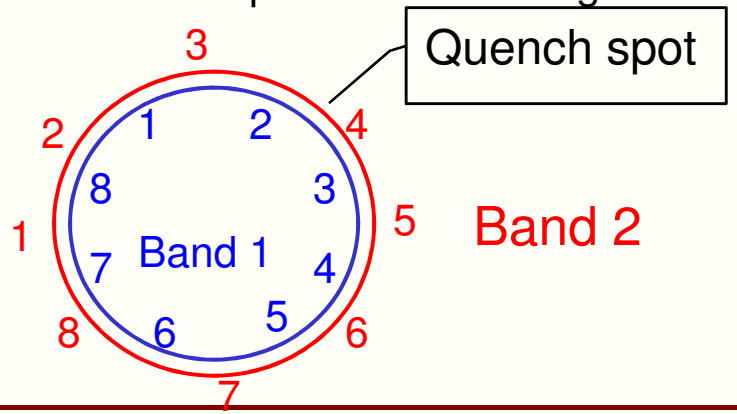
2 K Testing

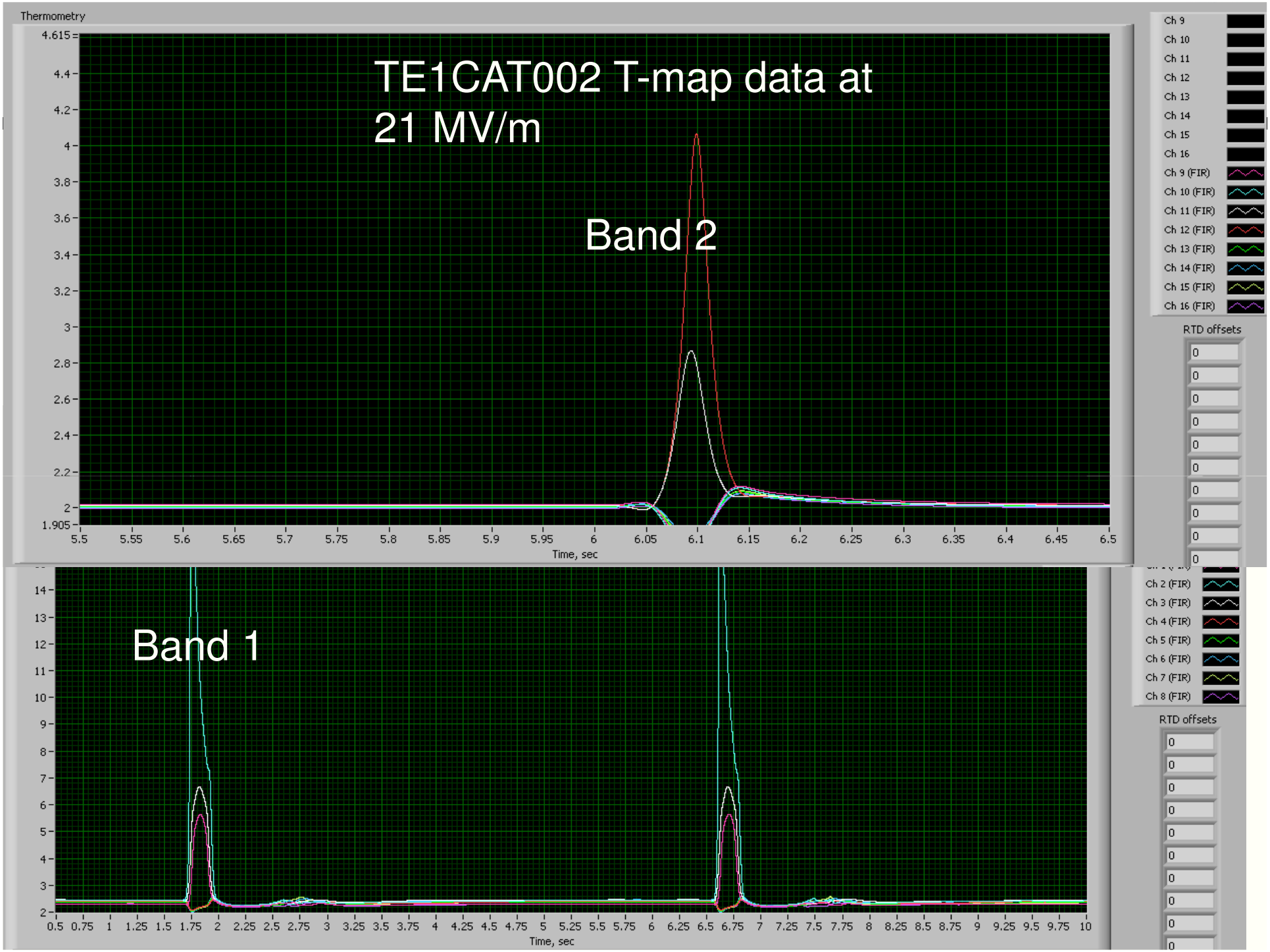
- For the diagnostic purpose, total 16 temperature sensors (cernox) were a mounted near each side of the equator. (8 x 2 bands)
- Strongest quench (temp) signal was on sensor #2, band1.
- Next strongest was on sensor #4 of band 2,
- Then sensor #3 of band 2.



Cavity preparation for testing : Temp sensor mounting

Equator Cartoon




Thermometry
TE1CAT002 T-map data at
21 MV/m
Band 2
Band 1
Time, sec
Time, sec
Ch 9
Ch 10
Ch 11
Ch 12
Ch 13
Ch 14
Ch 15
Ch 16
Ch 9 (FIR)
Ch 10 (FIR)
Ch 11 (FIR)
Ch 12 (FIR)
Ch 13 (FIR)
Ch 14 (FIR)
Ch 15 (FIR)
Ch 16 (FIR)
RTD offsets
Ch 2 (FIR)
Ch 3 (FIR)
Ch 4 (FIR)
Ch 5 (FIR)
Ch 6 (FIR)
Ch 7 (FIR)
Ch 8 (FIR)
RTD offsets

Discussions on cavity inspection

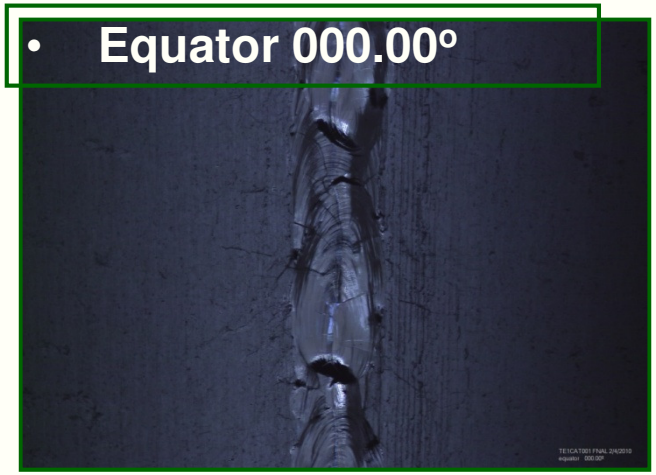
The weld bead , Centrifugal polishing & test results

The results were discussed and it was decided to take TE1CAT002 for EP (at ANL facility) and perform CBP (tumbling) on TE1CAT001 before EP.

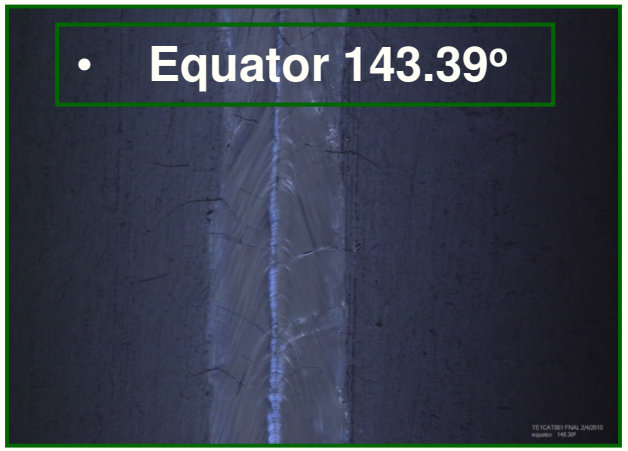
Optical inspection …

TE1CAT001
Under optical inspection

- Equator 000.00°



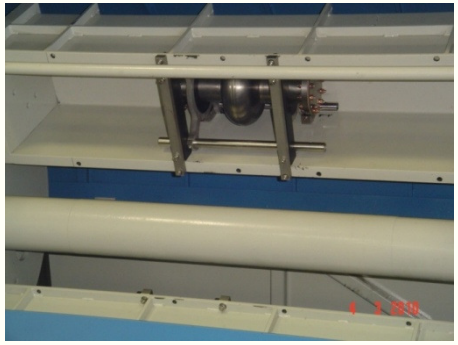
- Equator 143.39°



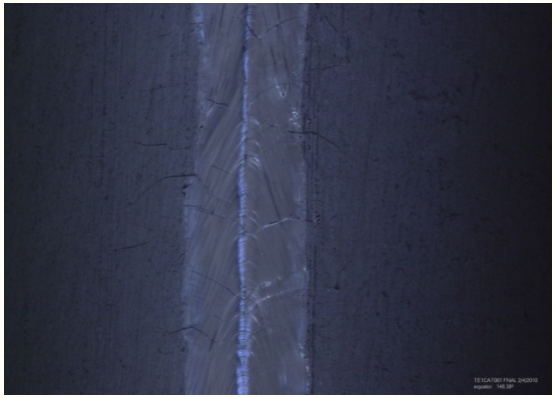
Internal weld bead examination using camera on Equator

Centrifugal Barrel Polishing

Single cell mounted on CBP machine



TE1CAT001_equator_ Equator 143.39°



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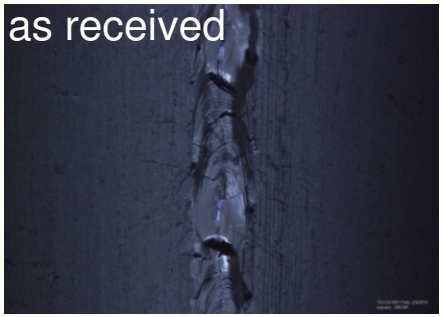
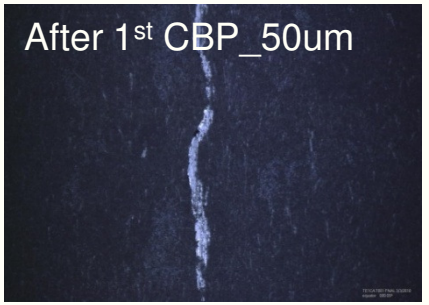
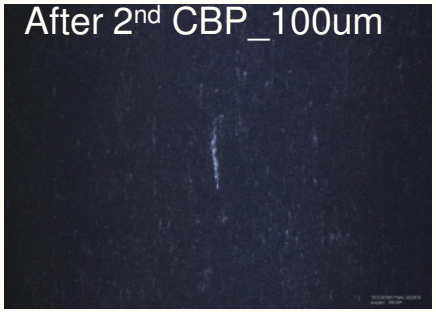
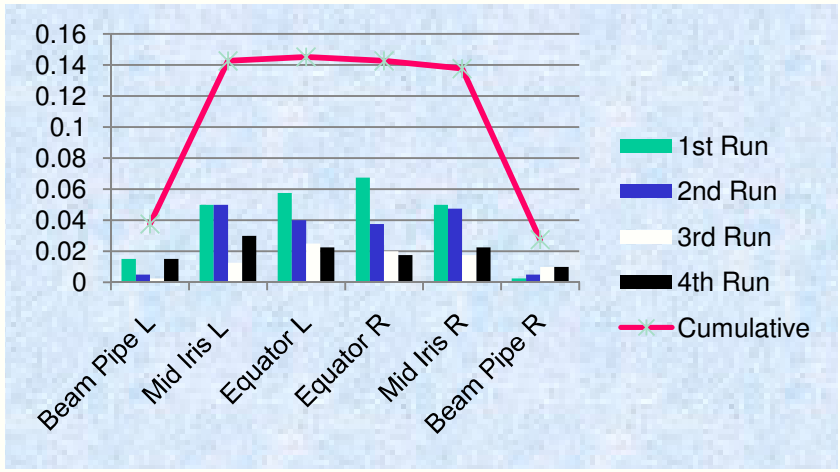








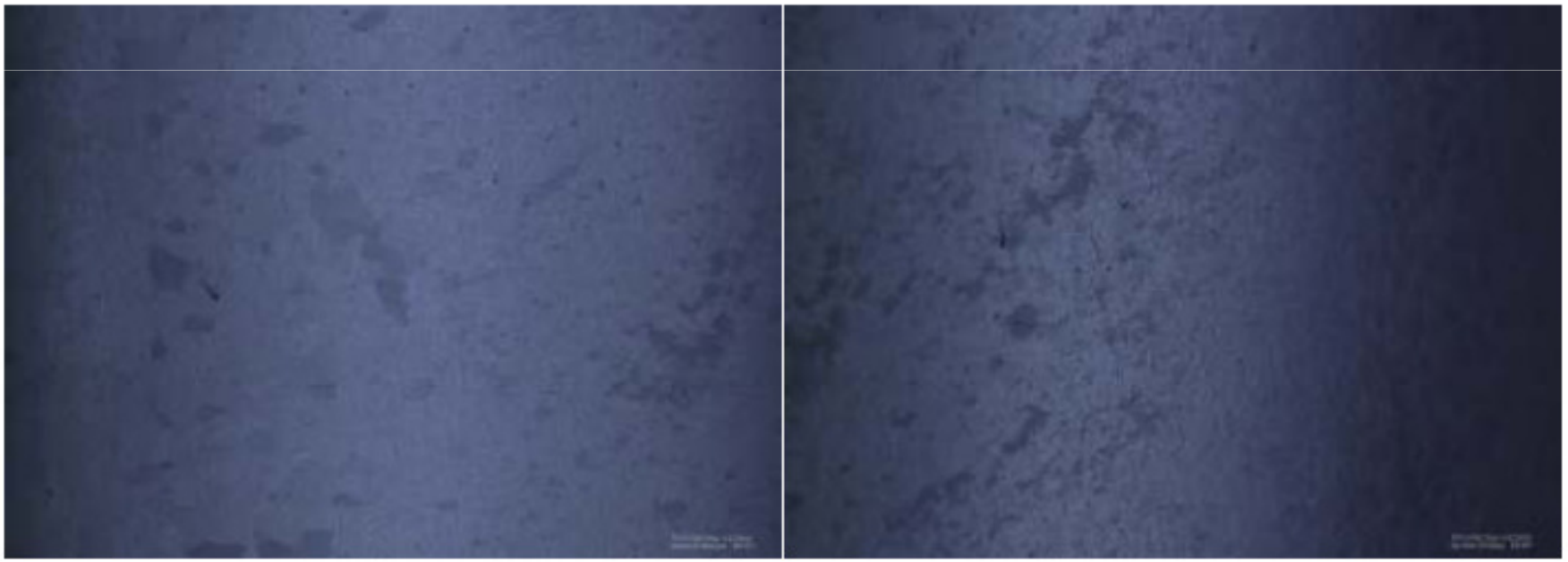
Discussion of the test results from two prototype cavities

1.3GHz single-cell cavity TE1CAT001 optical inspection report

Mingqi Ge and Genfa Wu

After we received the cavity from India colleagues, it was tumbled at Fermilab IB3, and was EP'd 30μm, after RF cold test, the cavity achieved 19MV/m. After that test, the cavity was carefully inspected. During the optical inspection by Kyoto system, several features were found on equator from 244deg to 276deg, but none of them caused cavity quench, while the quench location looks smooth and no obvious geometry defect was found.

Quench location:



Corelation to weld quality & quench location ??

Cavity performance Guaranteed ?

Making Multicell cavity
to perform at desired accelerating gradient is
Highly Complex, Toll order & Challenging

- No vendor is giving guarantee of gradient
- All SC cavities are built to design
- Not built to performance
- Else the costing is different and very high
- Some recent test result (August 2010) discussion

Achieving high gradient - Discussion

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9 September 2010

China reaching the target gradient

A 1.3-gigahertz TESLA-type nine-cell niobium superconducting cavity, named PKU3, as the third nine-cell cavity fabricated by the superconducting radiofrequency (RF) group at Peking University, Beijing, China, achieved an accelerating gradient of 28.6 megavolts per metre (MV/m) at an unloaded quality factor of 4×10^9 in its second vertical test at Jefferson Lab (JLab), USA on 9 August 2010. This cavity is the first nine-cell cavity with end group components in China reaching a gradient usable for the ILC.

PKU3, the first nine-cell cavity in China reaching a gradient usable for the ILC, in JLab clean room before vertical test. *Image: Fumio Furuta*

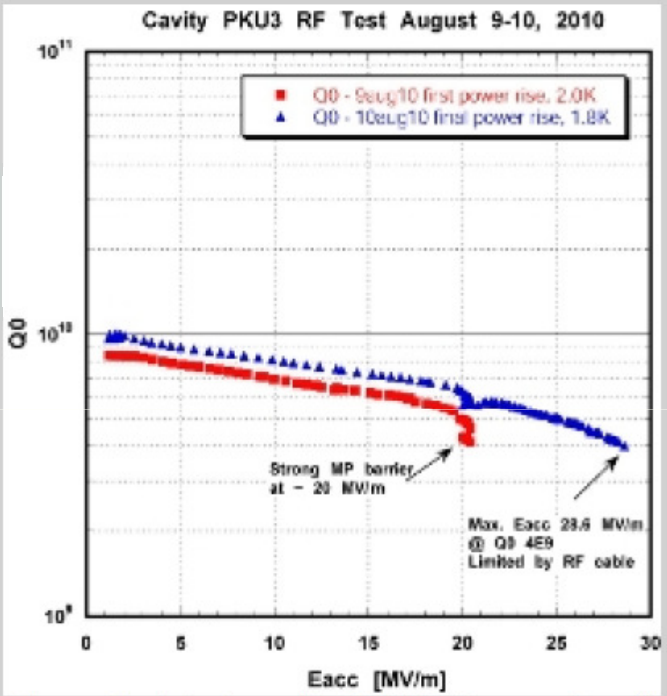
The cavity is made of high-purity niobium from Orient Tantalum Industry Corp. (OTIC), Ningxia, China. The fabrication of the cavity was finished in the middle of 2009. After field flatness pre-tuning with the Peking University tuning facility, PKU3 was sent to JLab in April 2010 for performance evaluation.

Superconducting cavities (including PKU3) fabricated by Peking University since 2005. *Image: Peking University*

After optical inspection of electron-beam welding seams, the cavity was ultra-sonic cleaned and etched for 10 micrometres of inner surface removal by buffered chemical polishing, followed by field flatness tuning in May. The flatness was 95.5 percent, which shows no degradation of cavity mechanical dimensions due to transportation. Successful bulk electropolishing of PKU3 was made on 15 June. Furnace vacuum heat treatment was applied to the cavity at 800 degrees Celsius for two hours on 23 June. After the field flatness was tuned to 97.9 percent, a light electropolishing of 25 micrometres was done on 13 July. After high-pressure rinsing and clean room assembly, the first RF test was done on 30 July. The maximum accelerating gradient was 20 MV/m at an unloaded quality factor of 2.3×10^9, limited by field emission. After partial disassembly, additional high-pressure water rinsing was done, followed by the second RF test on 9 August. The maximum accelerating gradient reached 28.6 MV/m at an unloaded quality factor of 4×10^9, limited by RF cable heating. The observed decrease of quality factor versus the gradient (Q slope) might be due to the field emission by the sharp edges in the iris electron-beam welding regions. The cavity will be re-inspected for further improvement.

Achieving high gradient - Discussion

The achievement of PKU3 is a major milestone in superconducting RF technology development in China. PKU started the R&D work on this technology from the late eighties in cooperation with JLab and Cornell University in the US, DESY in Germany, and KEK in Japan. The group has accumulated extensive experiences in the field of superconducting RF science and technology. In 1994, PKU produced the first Chinese niobium cavity. Since 2005, great efforts have been extended to develop high gradient superconducting cavities in close collaboration with DESY and JLab. PKU produced a series of superconducting cavities including single-cell, two-cell, 3.5-cell, five-cell and nine-cell cavities, using fine-grain and large-grain niobium from China. PKU has also signed a memorandum of understanding with Fermi Laboratory in the US for cooperation on superconducting RF technology. "The achievement of PKU3 is a great encouragement for the superconducting RF group at Peking University. More efforts have to be made on further development of high gradient nine-cell cavity in the future," said Jiaer Chen, academician of Chinese Academy of Science.

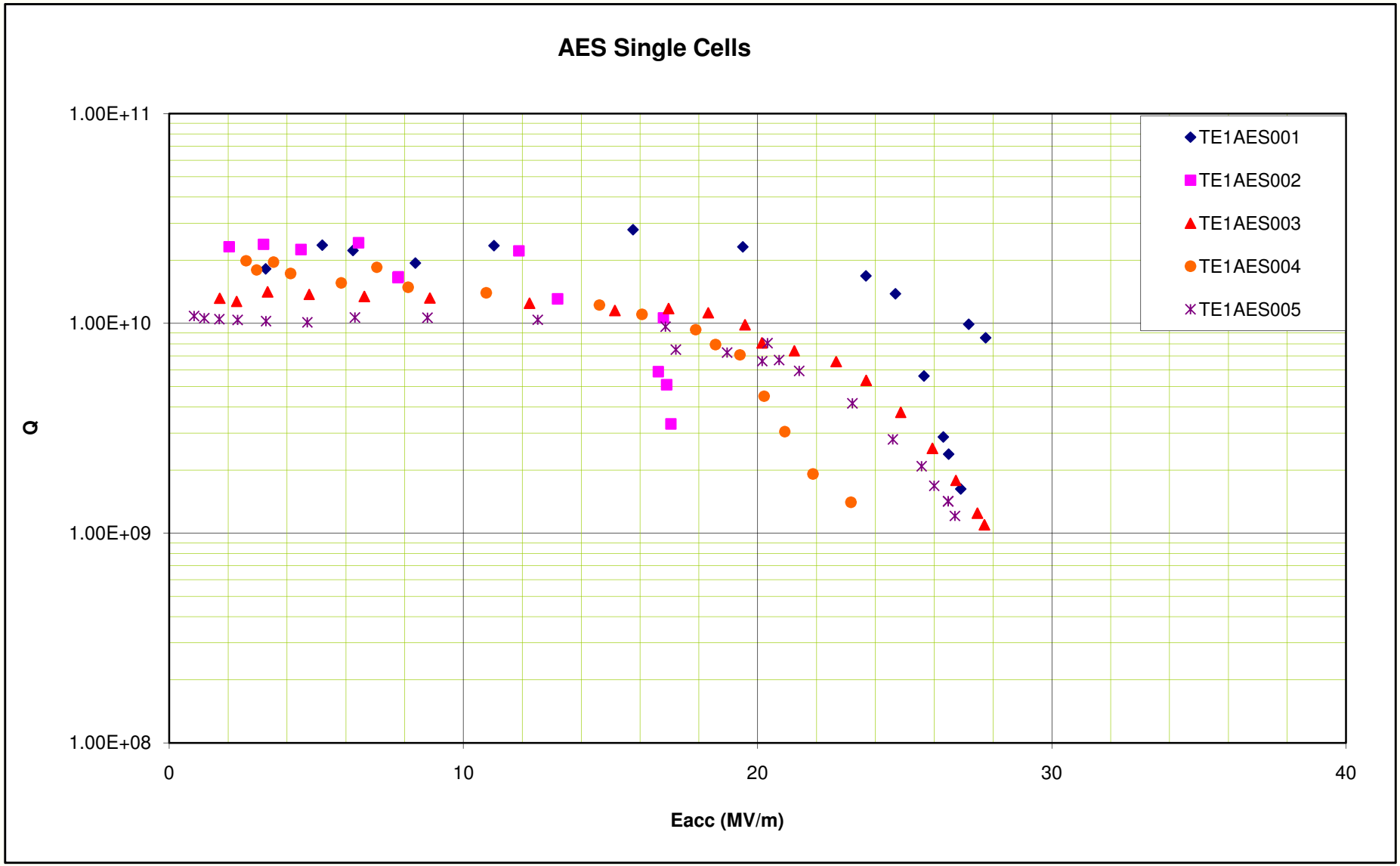


The vertical test result of PKU3. *Image: Rongli Geng*

"The achievement of PKU3 is very exciting and it is a very important milestone to both of Chinese superconducting technology development and the global cooperation for ILC activities. We are very much impressed to hear of this exciting news and would send our sincere congratulation for the PKU team and the global cooperation", said Akira Yamamoto, on behalf of the ILC Global Design Effort Project Managers. Jie Gao, chair of Asia Linear Collider Steering Committee also indicated that: "It is very good news for the ILC Asian collaboration. Asia's participation and contribution to the ILC will be more and more balanced in the future".

-- Jiankui Hao, Peking University

Discussion- IIFC meet



Discussions

- **X-Ray inspection & data analysis**
  - What does the X-ray report tell us ?
  - Any analysis report based on those pictures ?
  - X- Ray inspection of a good quality weld bead (for comparison)
  - How much a defect like porosity deep inside the weld affect the performance ?

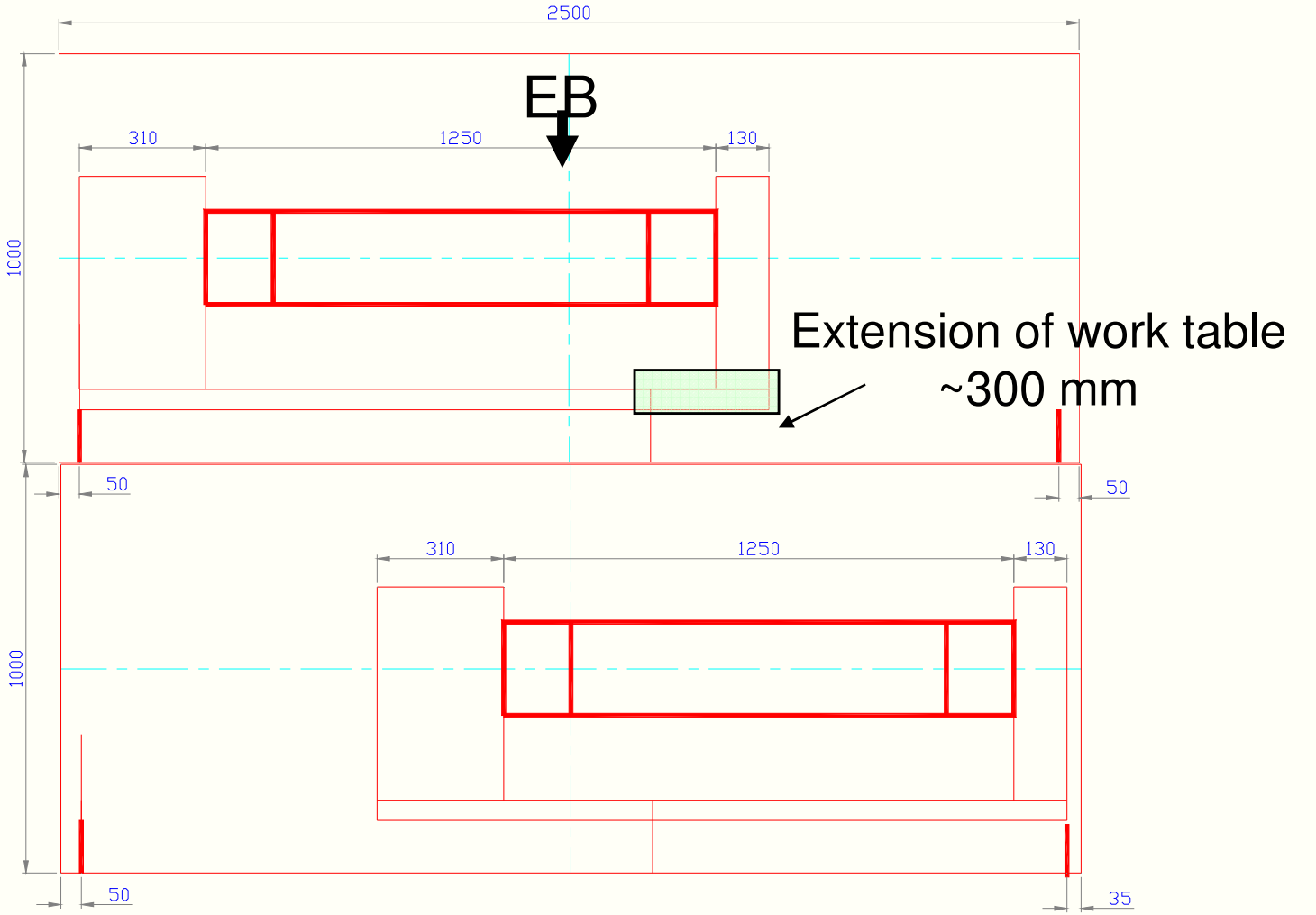
Improved Single cell cavity

- Beam Oscillations
- Vacuum level during welding & Quality of vacuum
- 20 µm bulk BCP etching or EP
- Coolant / lubrication during machining
- Any more ??

Discussions

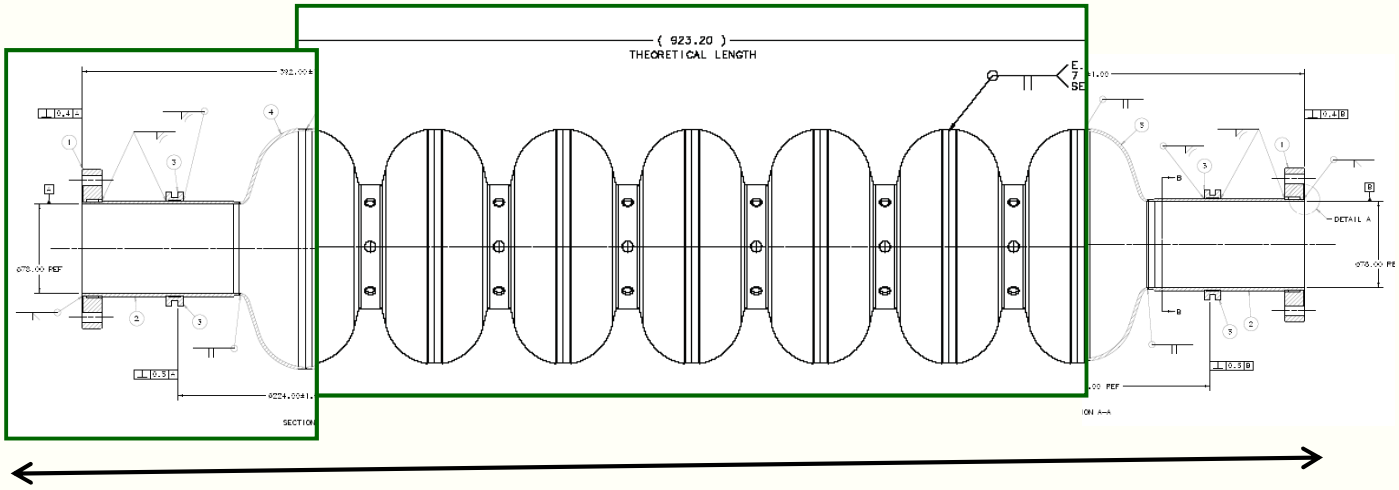
- **1.3 GHz Aluminum / Copper cavities for thin film deposition R&D at FNAL**
  - **Does the need of Aluminum Single cell cavity still exists ?**
  - **FNAL / ANL plans for those**
  - **Sealing / Flange material ?**

IUAC EBW Facility Layout



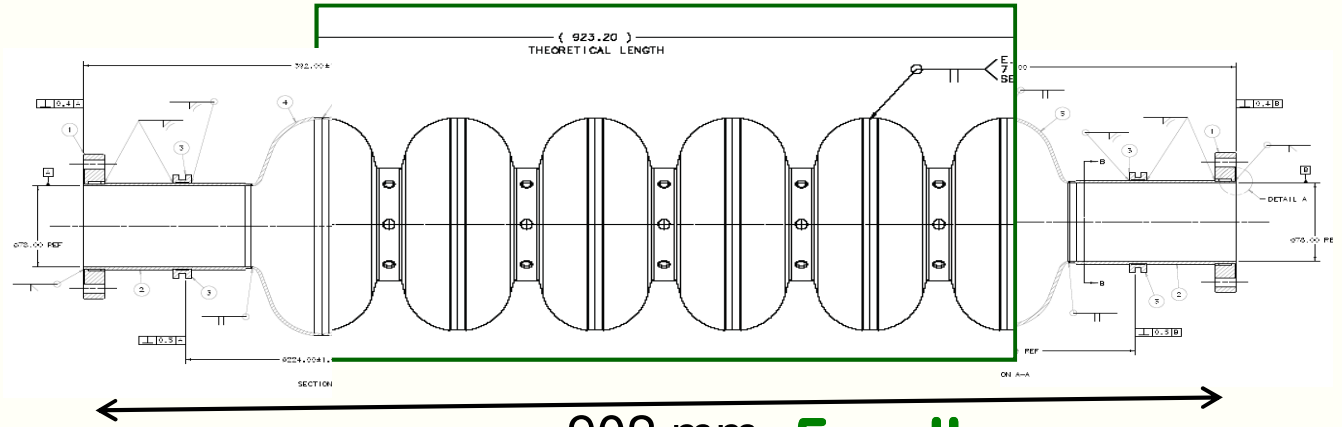
Modifications needed to fit 1.3 GHz 9 cell cavity or 650 MHz Five cell cavity with present facility

Proposed Multicell configuration



1017 mm **7-cell**

Should we focus 5/6/7 cell cavity ?



902 mm **5-cell**

650 MHz β=0.9 Discussions

A. β = 0.9, 650 MHz Cavity (1-cell cavity Q4 2011)

Looks possible

B. 1st 5-cell cavity in Q4-2012 in collaboration with IUAC

Need to develop 1.3 GHz multicell cavity for capacity building

Need modifications in the EBW set up

Likely delay 3~4 Months

C. 4 + 1 Spare cavity Q2-2014

To be reviewed based on the progress on item # A & B.

- Feed back from 1-cell and 5 cell cavities,
- RRCAT EBW set up (during 2012)
- Utilization of Industrial infrastructure
- Progress on other associated infrastructure, sub system, technology etc..

Schedule discussion

Link to schedule

Discussion- IIFC meet

Summary of discussion