"Single Cell SC Cavity Development in INDIA"

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(On behalf of IIFC collaboration)

Collaborators & Team members

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G Wu, ANL

Outline

1.3 GHz

- **Single cell cavity (1st prototype)**
  - Aluminum and Copper prototype (With Industry)
  - Niobium Single cell (IUAC Collaboration)
  - Processing & testing at ANL & FNAL.
- **Single cell cavity (2nd prototype)**
- **Multicell Cavity**

650 MHz (β=0.9)

- **Single Cell cavity**

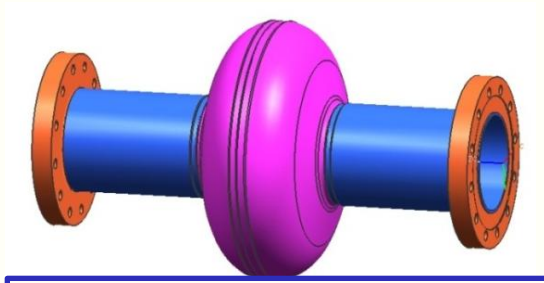
Introduction

- RRCAT has initiated R&D work on development of SCRF technology and associated infrastructure to support their future LINAC program.
- RRCAT is also a member of TTC and IIFC (Indian Institution Fermilab Collaboration).
- Under IIFC, we are working on design and development of different aspects of SCRF technology viz SCRF Cavity, Cryomodule, RF powering, Processing & Testing infrastructure etc.
- This presentation will report cavity development work.
- Initial focus of the work jointly with Fermilab was on ILC type β=1; 1.3 GHz SCRF cavities.
- 650 MHz (β=0.9) is the recent addition.

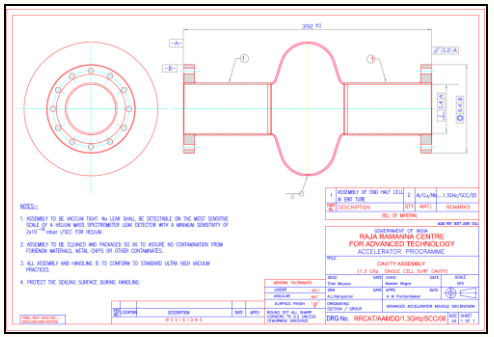
Single cell cavity development

- Single cell cavity is made based on TESLA shape design
- At RRCAT
  - Design & development Forming die & half cell forming
  - Design for manufacturing
    - 3-D Modeling – UGNX, Detail dimensions with tolerances to suit manufacturability
    - Design & development of various machining & welding fixture
    - Machining all the parts in-house
    - Development of manufacturing process and QA plan.
  - Design & development of RF measurement set up
  - Estimation of Frequency with temperature and K_{eq}
  - Regular WebEx meeting for progress review & technical discussions

Single cell cavity design activities



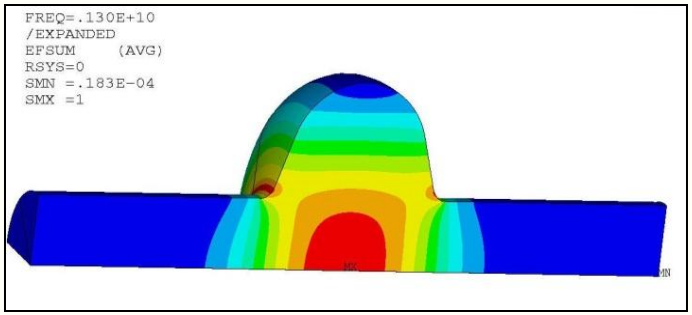
3-D design model of 1.3 GHz single cell Cavity (UGNX)

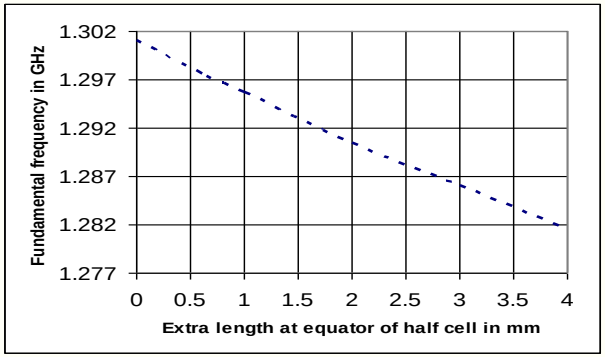


Fabrication drawing of 1.3 GHz single cell

Estimation of change in frequency with temperature

Material	RT Frequency	2K Frequency
Niobium	1297.8 MHz	1300.00 MHz
Copper		1303.81 MHz
Aluminium		1306.42 MHz



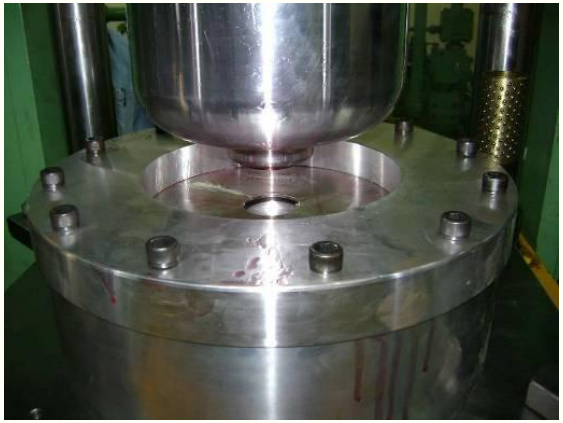


Estimation of equator sensitivity coefficient (K_{eq} – 5.2 MHz/mm)

1.3 GHz Forming tool development and half cells forming

- **Two sets of forming tools were developed.**
  - **One set of forming tooling was delivered to Fermilab.**
  - **This was used for vendor development.**
- **The second set was used for making cavities in India**

Long End Half Cell Tooling



Forming

Inspection

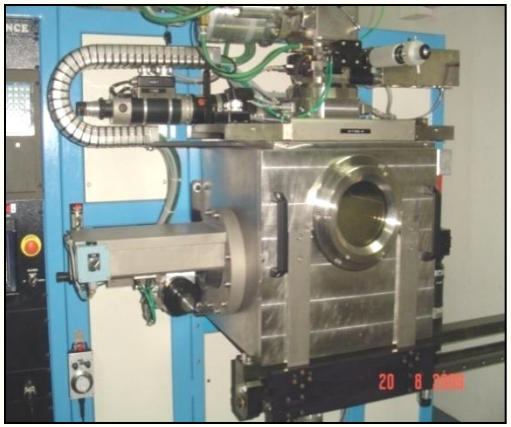
1.3 GHz Prototype Single cell Aluminum and Copper cavity with industry

- Technology development efforts started with Aluminum prototype cavities (No EBW , No Nb qualified vendor)

This has helped us to

  - Develop cavity manufacturing process
  - Test & qualify the welding fixtures
  - Understand various mechanical & RF qualification procedure

- Copper cavity was made as per request from FNAL for thin film R&D.
- Later on these cavities were useful in pre-commissioning of various cavity processing facility at RRCAT



EBW Machine : 6 KW, 60 kV, 450 x 450 x 500 mm chamber size, Vacuum < 5 x 10e-05 m-bar
M/s Laxmi Technology & Engineering Industry Coimbtour

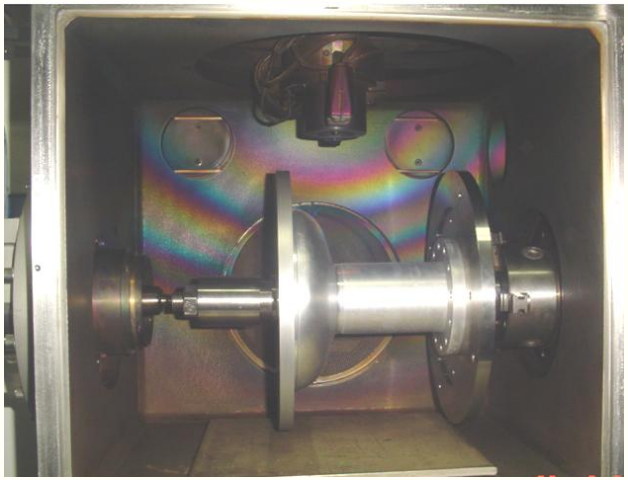
A lot can be learned making Non Niobium Cavities in a cheaper way

Aluminum and copper Prototype single cell cavities

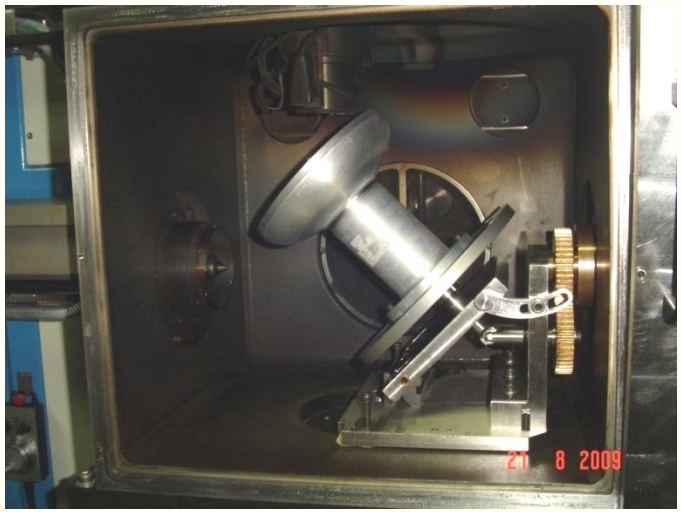
- We have been able to generate interest in Industrial units to participate in R&D projects.

1.3 GHz Prototype Single cell Aluminum cavity activities

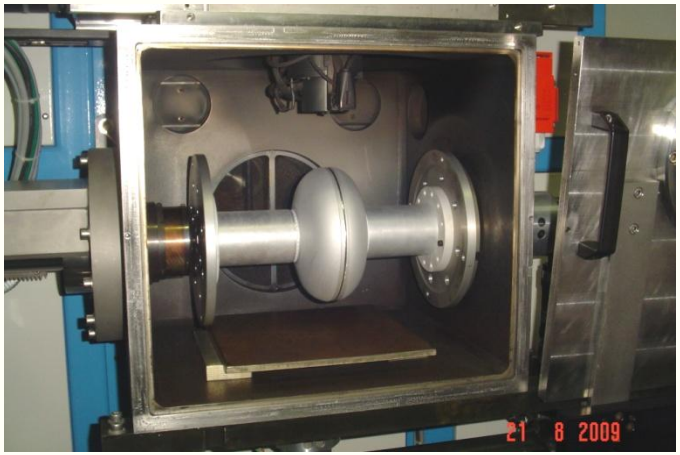
Beam pipe - Flange welding



Inside Iris weldig



Outer IRIS welding

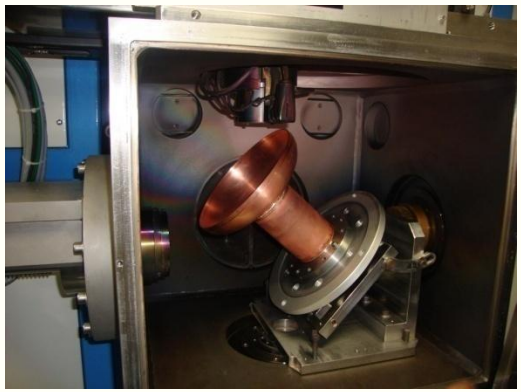


Final equator welding

1.3 GHz Prototype Single cell Copper cavity activities

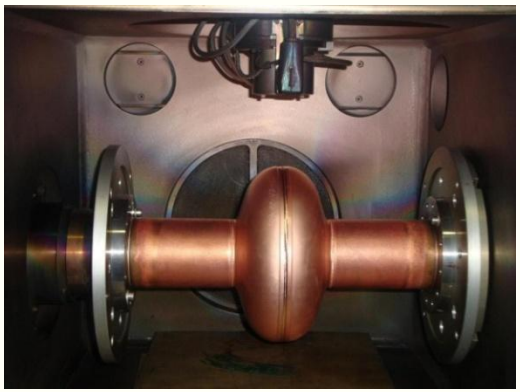
Beam Pipe Welding

Beam pipe - Flange welding



Inside Iris welding

Copper Half cell assembly



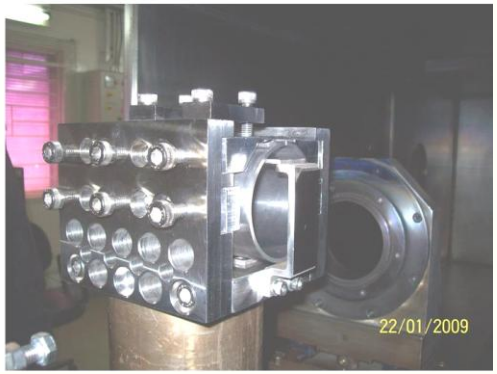
Copper prototype

Niobium single cell SCRF cavity IUAC Collaboration

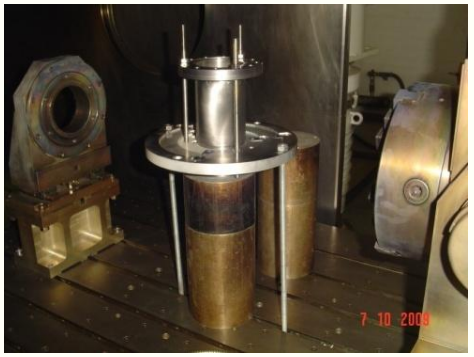
IUAC EBW Machine :
15 KW, 60 kV-250 mA, chamber size, 2.5 x 1 x 1 m
Vacuum < 5 x 10e-05 m-bar

Prototype Niobium single cell SC cavity progress with IUAC

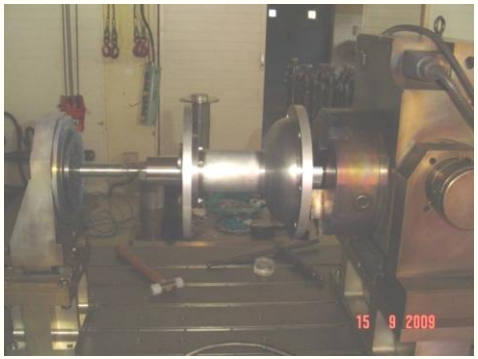
Beam pipe rolling



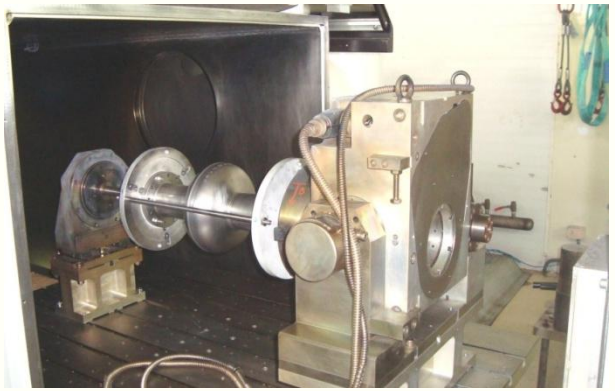
Beam pipe seam welding



Pipe Flange welding



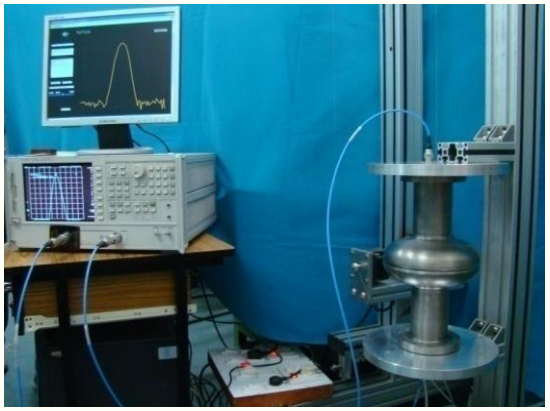
Iris welding



Equator welding

Qualification & testing at RRCAT

Mechanical inspection



RF measurements

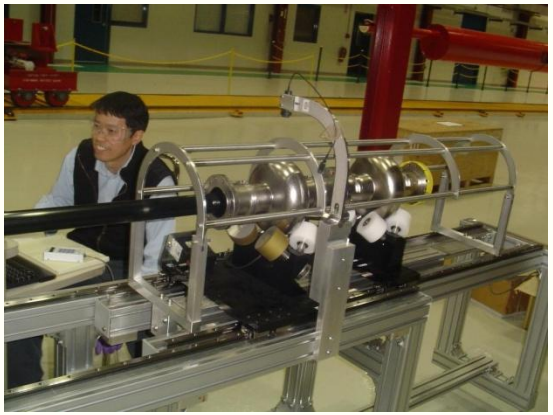
Leak testing

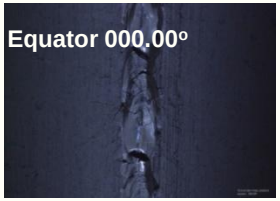
Cavity ID	Vacuum leak rate (mbar l/s)		RF Frequency (MHz)		Total length (392 1)	Shrinkage equator
	300 K	77 K	300 K(Vacuum)	77 K	(mm)	(mm)
TE1CAT001	< 1 X 10^{-12}	< 1 X 10^{-12}	1297.2666	1299.3333	393.52	0.47
TE1CAT002	< 1 X 10^{-12}	< 1 X 10^{-12}	1296.73333	1298.8666	392.97	0.42

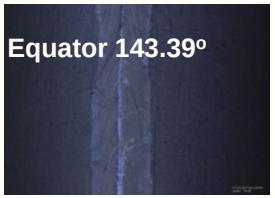
Processing & Qualification testing

After all pre-dispatch qualification these cavities were shipped to Fermilab for processing & qualification testing.

- **Incoming inspection at FNAL**
  - **Internal optical inspection**
  - **RF testing**







Optical Inspection

RF Measurement

Frequency	TE1CAT001	TE1CAT002
FNAL (23 C)	1297.031	1296.793
RRCAT (27 C)	1296.926	1296.675
'Q' factor		
FNAL (23 C)	9960.53	9917.766
RRCAT (27 C)	9076	9328

Processing & Qualification testing

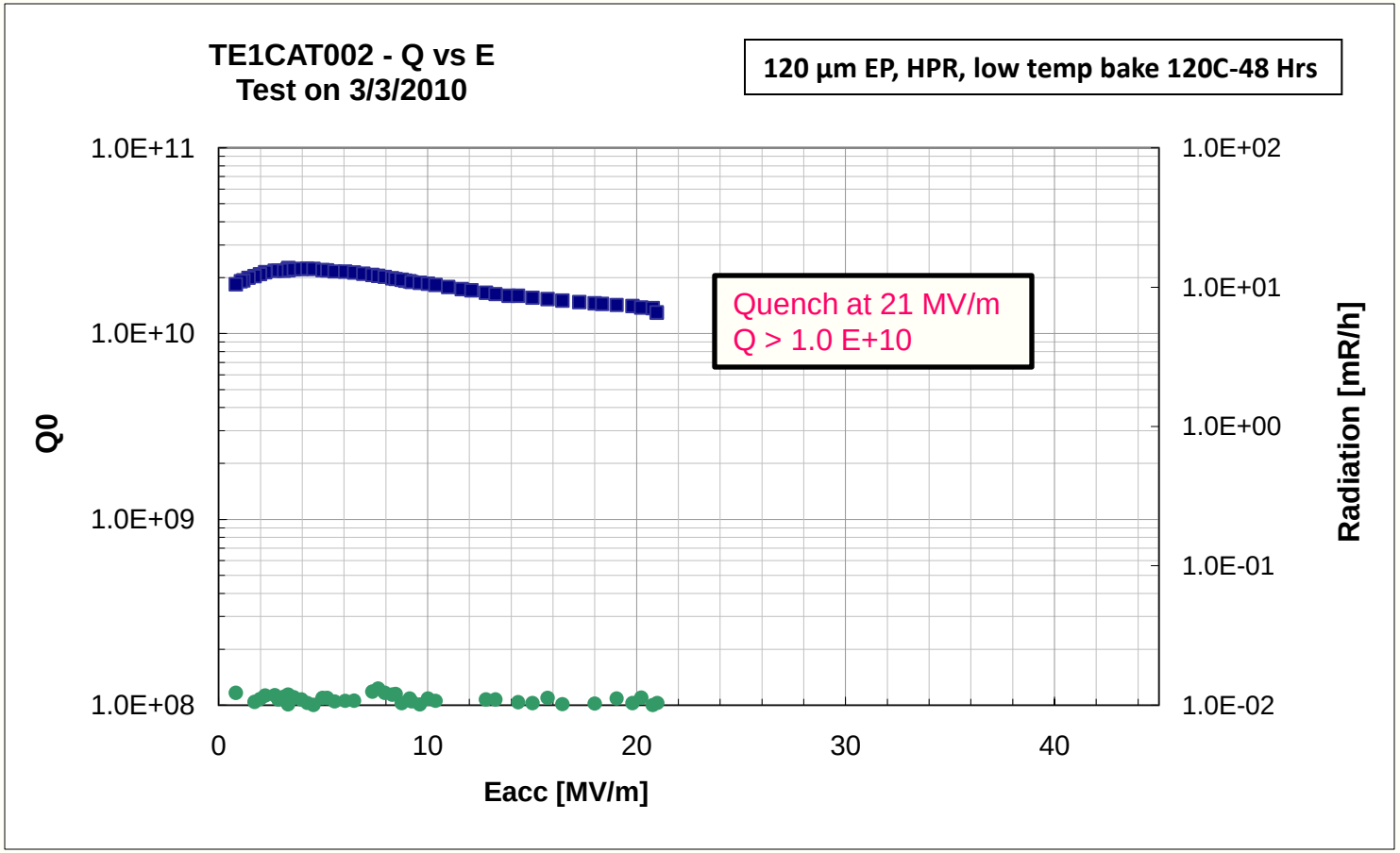
- **Processing steps**
  - **1st set of processing (TE1CAT002)**
    - Bulk EP ~ 120 µm
    - HPR 85 bar for 6 hrs followed by clean room assembly
    - Low temperature backing 120 °C - 48 hrs

EP @ ANL

HPR @ ANL

Low temp bake
120 °C - 48 Hrs @ FNAL

2 K Test results



Cavity was quench-limited to 21 MV/m. Cavity was FE-free.
Q was > 1.0 E10 with no significant "Q" drop

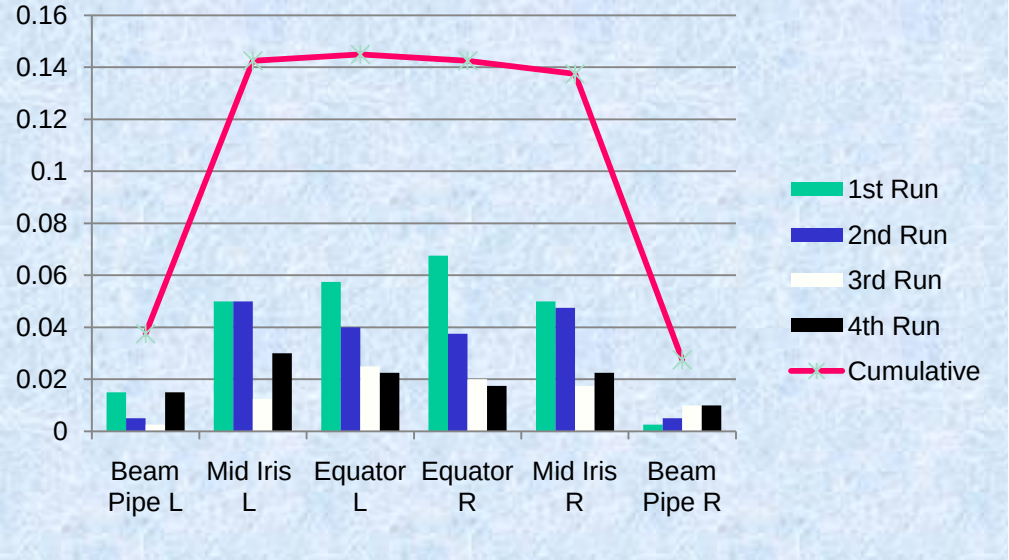
Processing & Qualification testing at FNAL

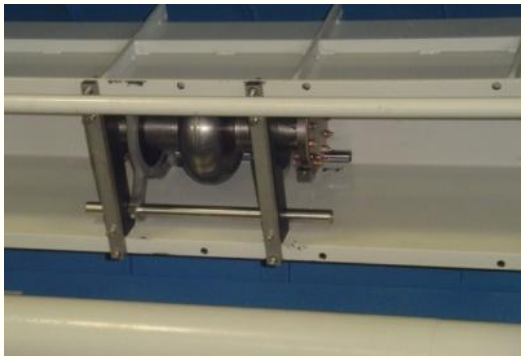
- **Processing steps**
  - **1st set of processing (for TE1CAT002)**
    - Bulk EP ~ 120 µm
    - HPR 85 bar for 6 hrs
    - Clean room assembly
    - Low temperature backing 120 C - 48 hrs
  - **2nd set of processing (for TE1CAT001)**
    - CBP ~ 140 µm
    - HT ~ 800 oC for 6 Hrs
    - Light EP ~ 20 µm
    - HPR 85 bar for 6 hrs
    - Clean room assembly
    - Low temperature backing 120 C - 48 hrs

To polish the special weld feature near equator

Centrifugal Barrel Polishing

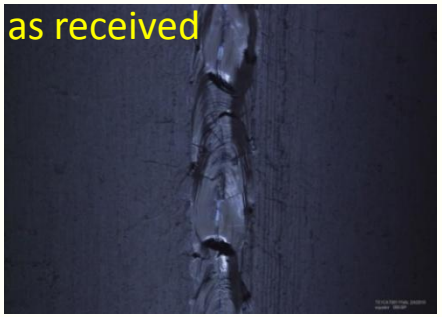
CBP process summary

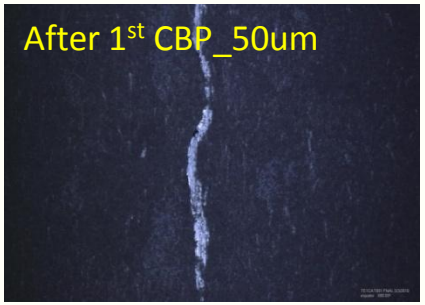


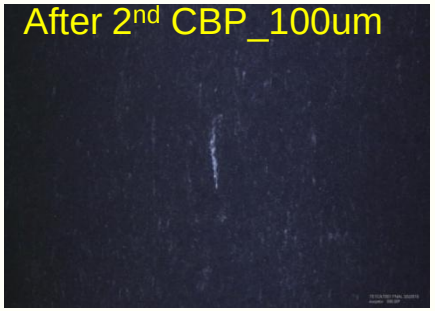


Single cell TE1CAT001 mounted on CBP machine

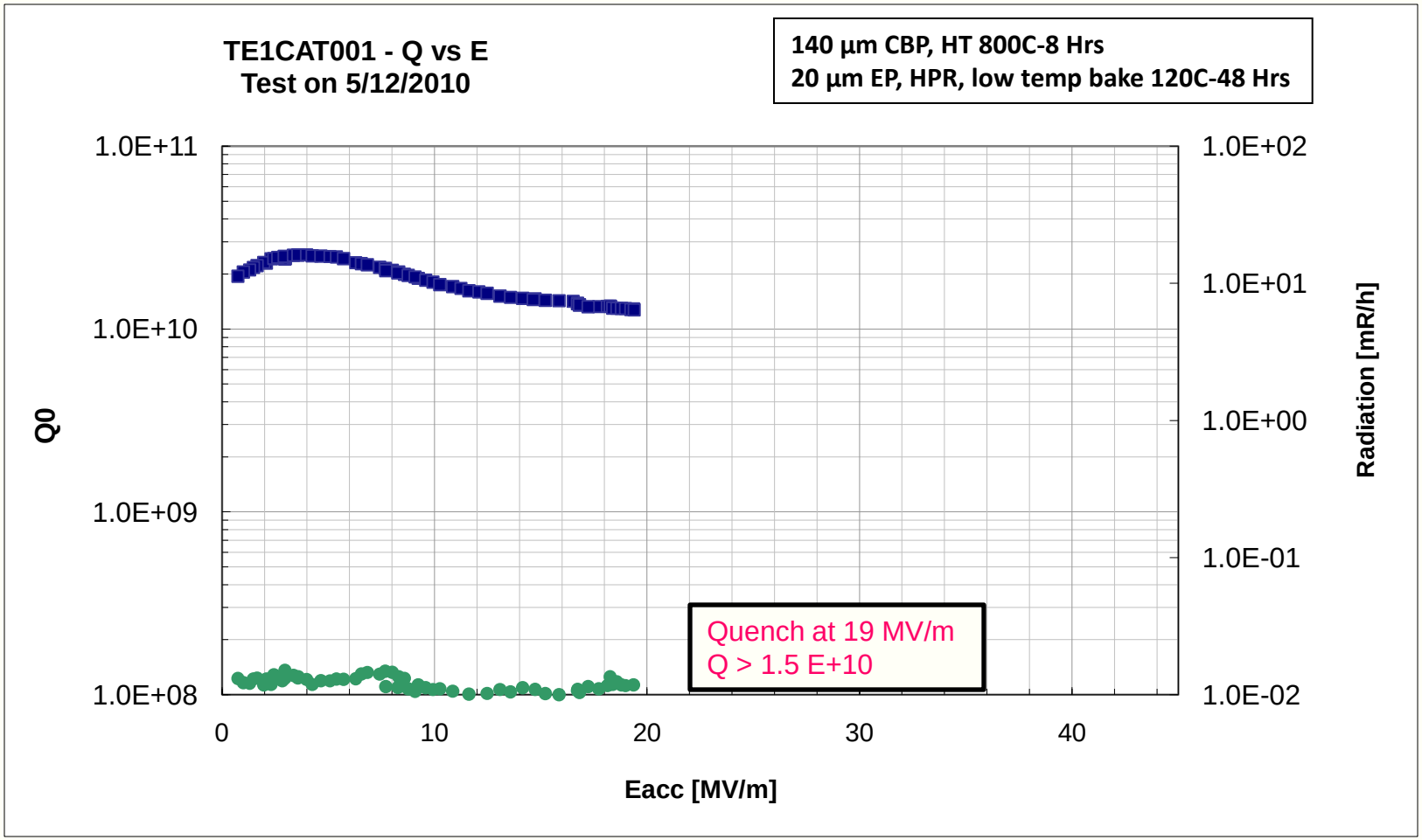
TE1CAT001_equator_000.00







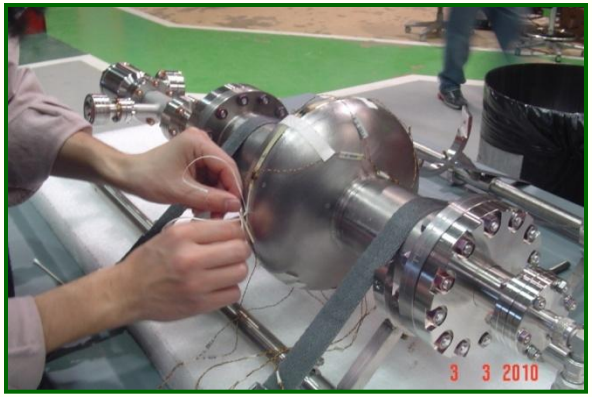
2 K Test results



Cavity was quench-limited to 19 MV/m. Cavity was FE-free. Q was > 1.5 E10 with no significant "Q" drop

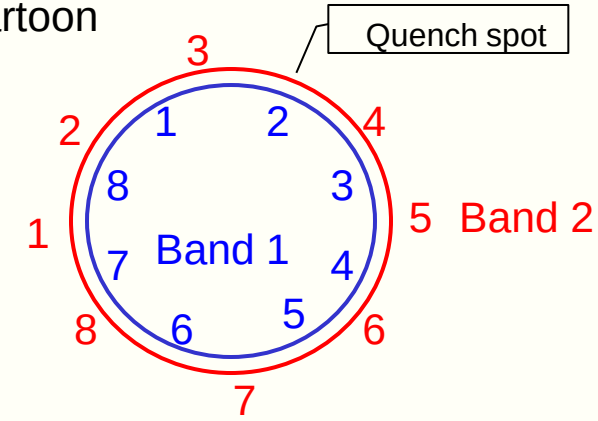
T-mapping & Internal inspection post 2 K testing

- 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.



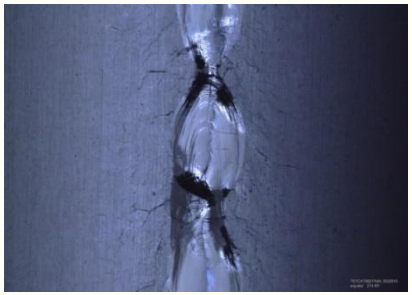
Temp sensor mounting

Equator Cartoon



Optical inspection was performed again on TE1CAT002 to see the quench spots and inner surface after EP.

Before EP



After EP

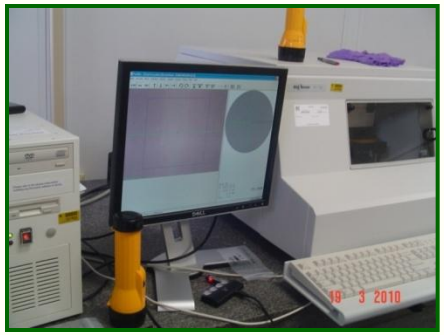
EP could not polish the weld undulations features

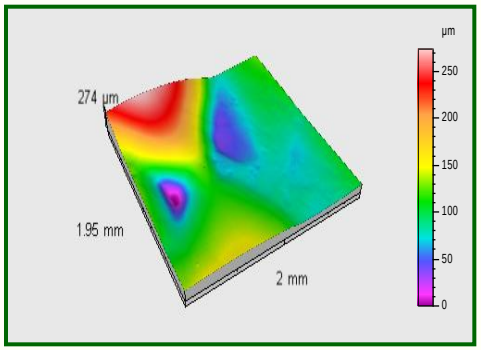
It was decided to do molding to investigate it further near the quench spots

Molding and Profilometry

Silicone mold making compound used
TRV 630 A & B (10:1 by weight)

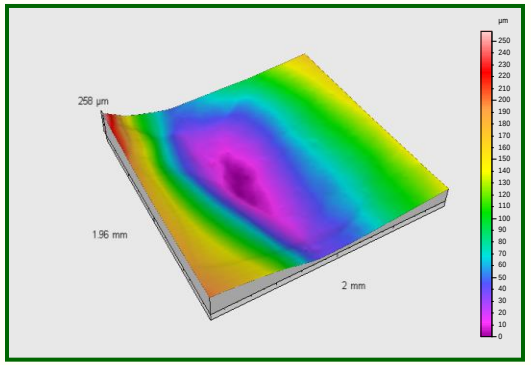
Profilometer inspection
KLA-Tencor P-16





- 2010-3-15 Equator 202

Profilometer inspection
KLA-Tencor P-16



- 2010-3-15 Equator 204

These results are in line with visual inspection.
Profilometry quantified the weld undulations, (274 µm, peak to valley)

Tumbling was carried out on TE1CAT002 also following the results discussions

TE1CAT002: Cavity 2nd test

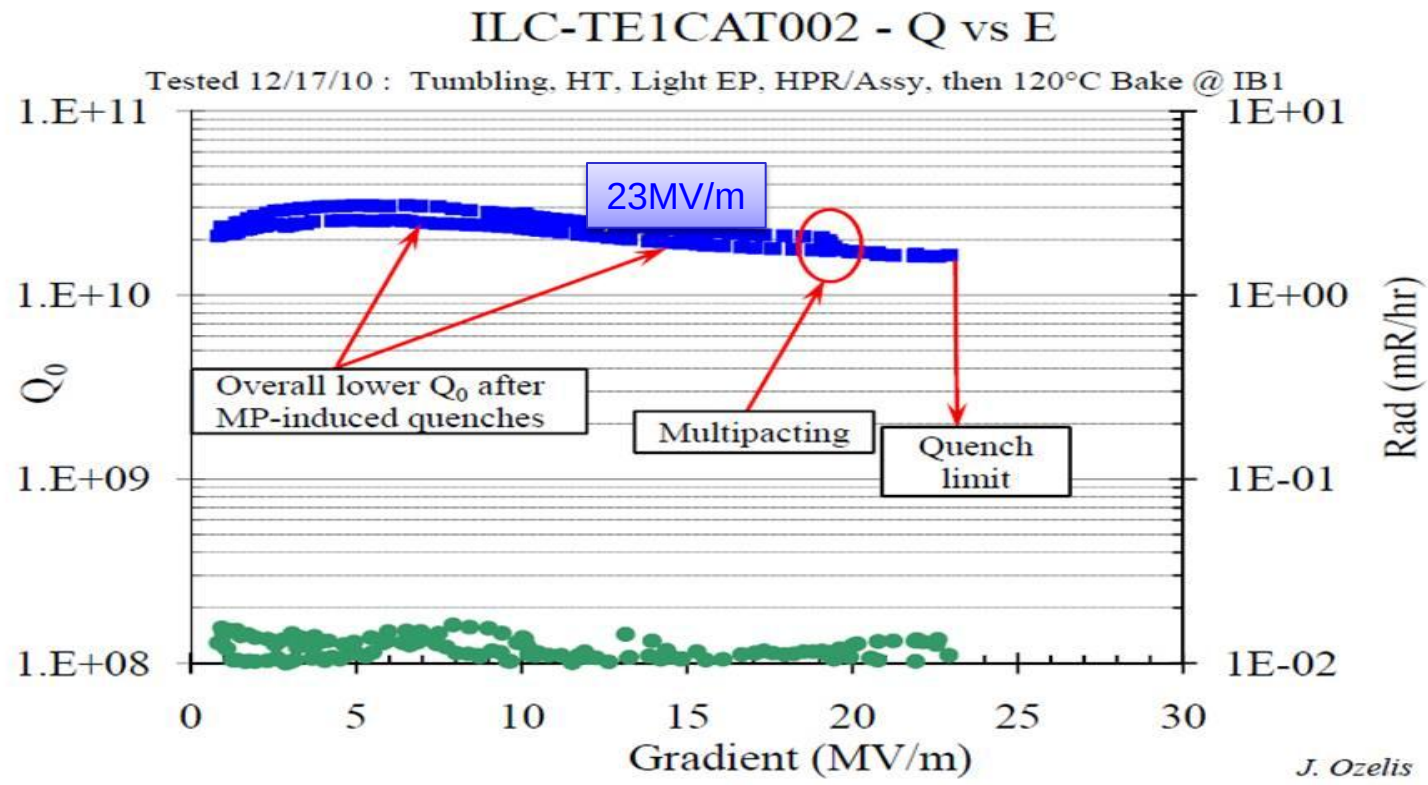


Figure 1. Q_0 vs E @ 2K.

- The cavity's gradient improved up to 23MV/m.
- There was no FE observed at any time, but some minor radiation levels were briefly observed accompanying the multipacting.
- Both low field and high field Q_0's were reasonably good – 2.5 x 10^{10} and 1.7 x 10^{10}, respectively.

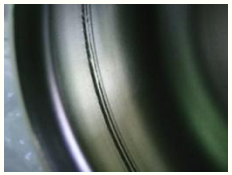
1.3 GHz Single Cell cavity (2nd prototype)

Based on the feedback from the inspection and test results for initial prototype cavities, we worked to make two nos (2nd prototype) single cell cavities.

- **Key improvements**
  - **A. Careful handling of Niobium components during all manufacturing Process.**
  - **B. 20 µm Bulk BCP etch**
  - **C. Further optimisation, including beam oscillation, of weld parameter for critical equator weld.**

BCP etching fixture with half cells

Equator welding trials



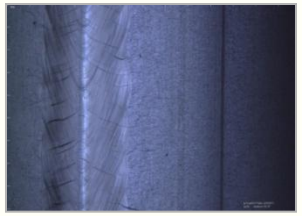
inner equator bead

Status: TE1CAT003 & 004

Two more single cell cavity (2nd prototype) have also been fabricated.

- **TE1CAT003 has been tested for Pre-dispatch qualification at RRCAT and sent to FNAL (May 2011)**
- **This has also undergone optical inspection, RF measurement at FNAL in June 11**
- **TE1CAT003 and also been EP'ed at ANL last week & is in Queue at 2 K test facilities at FNAL**

Optical inspection at FNAL TE1CAT003



Inner equator weld bead as welded

RF measurement data

Frequency	TE1CAT003	TE1CAT004
RRCAT	1299.871229	1299.
FNAL	1299.91538	to be measured
'Q' factor		
RRCAT	9463.7265	9237.3484
FNAL	10014.8086	to be measured

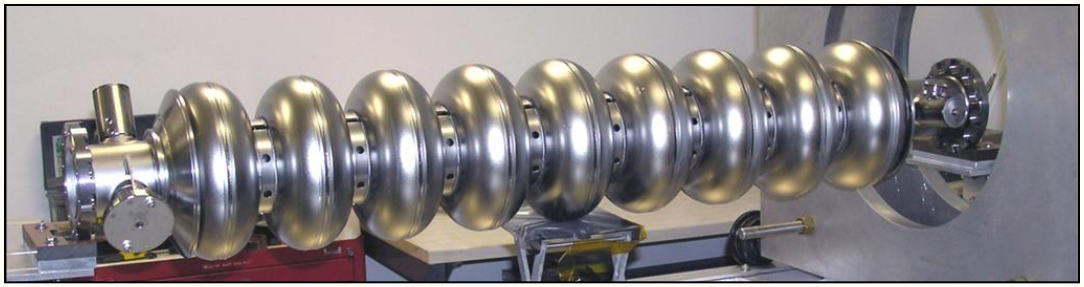
- **TE1CAT004 has also been fabricated (May 2011) and is getting ready for shipment to FNAL (August 2011)**

We hope to have test results for these cavities in coming months

TE1CAT003

TE1CAT004

Towards multicell cavity



1.3 GHz Nine cell cavity

- Plans to develop the dumbbells and simple 5 cell cavity.
- End group development in parallel

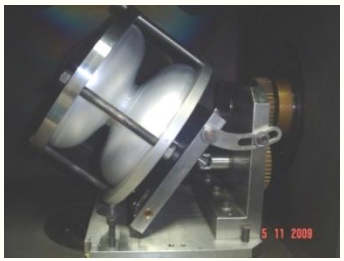
Progress on multicell cavity activity

1.3 GHz

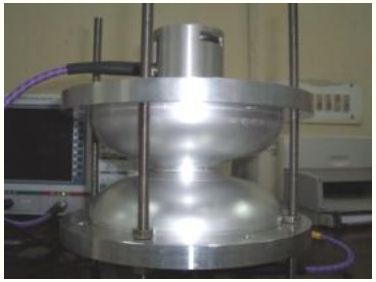
Development of prototype Dumbbell and their qualification.

After dumbbell qualification we plan to move to make 5 cells cavity with simple end group

Prototype Dumbbell



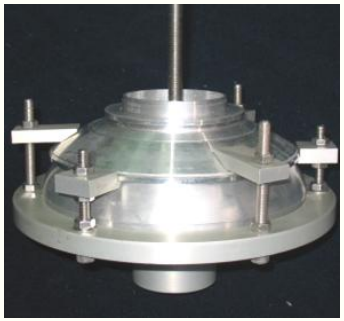
Dumbbell Welding



RF Qualification

Long & Short End Group in Aluminum

Stages of End group fabrication

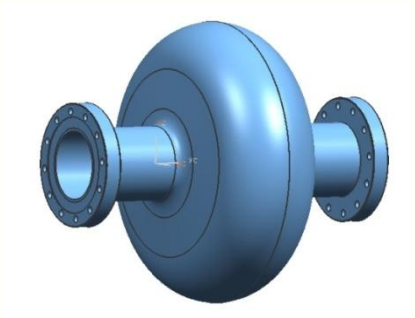


Long and short
End Group prototype

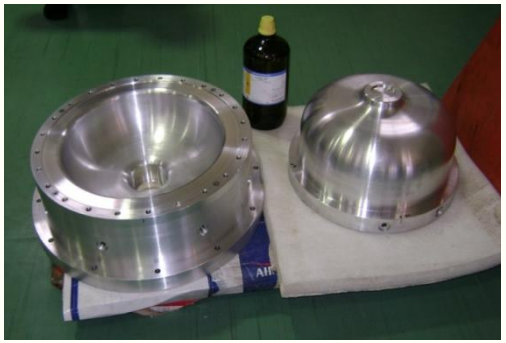
Parts machining & fixtures developed.
Niobium End group next

Initial activities on 650 MHz, β = 0.9 SRF cavity

- Design for manufacturing
- Design & development of various tooling & fixture
- Design and development of forming tooling



650 MHz β=0.9 single cell cavity 3-D Models



Die- Punch Set

Beginning of forming trials May-June 2011

- Awaiting arrival of Niobium Sheets
- We aim for the 1st prototype in 2011.

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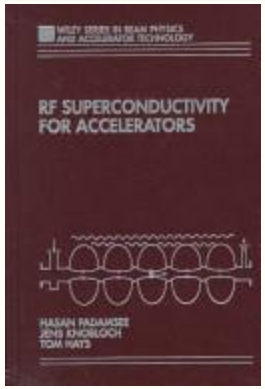
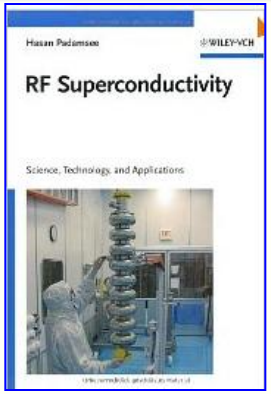
Hasan Padamsee

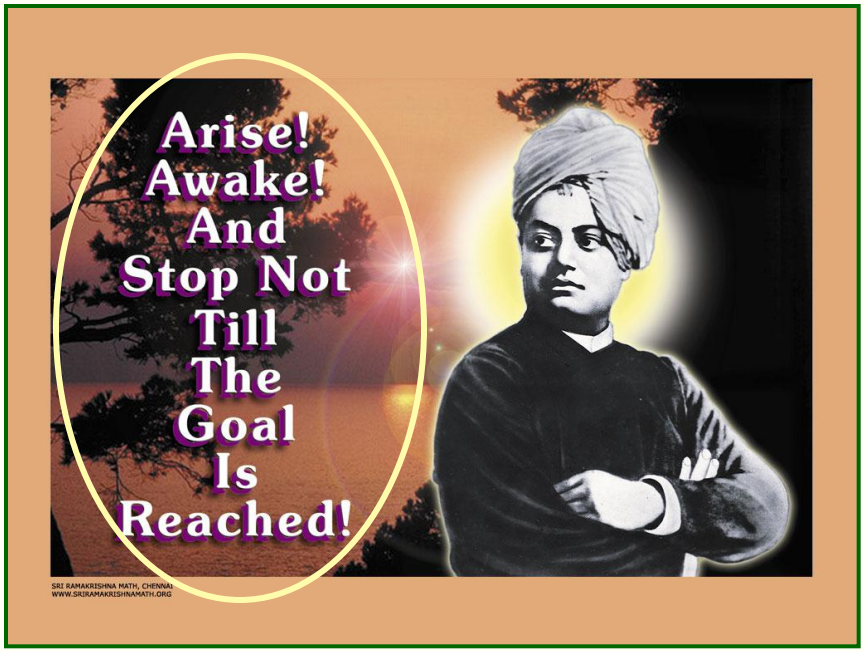




An interesting historical connections to Chicago City

Swami Vevekanand delivered the historical address at the "Parliament of the World's Religions" at Chicago in 1893

(More then 100 Years Ago!!)



http://www.youtube.com/watch?v=N8MRaedvfUU&feature=related

Thank You
for your kind attention