Present Status of Infrastructure Facilities for SCRF Cavity Development

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Development of Superconducting Cavities and Associated Technologies for High Energy Accelerators and their Applications

Objectives :

- Technology development and setting up of an infrastructure for the SCRF cavity fabrication, chemical processing, cleaning, assembly and testing at required accelerating gradient for accelerator applications

- To establish Cryogenic Infrastructure to operate large systems operating at liquid helium environment

- Experimental research in bulk and thin film superconducting materials for building accelerating cavities with high gradient and high quality factor

New Facilities Planned at RRCAT

SCRF cavity fabrication Facilities:
120 Ton Hydraulic Press, Nb machining, EBW Machine etc.

Chemical & thermal processing facilities
EP/BCP/CBP, HPR & Annealing Furnaces etc.,

Cavity Inspection Facilities
3-D CMM, UTM, Optical inspection bench, 3-D confocal microscope, SIMS

Cavity RF Measurement & Tuning Facility
Half Cell, dumbell and multi-cell cavity frequency measurement
Cavity Frequency & field tuning machine (under design)

Assembly & testing set up.
Clean-room, Test cryostats, RF sources etc.

Cavity Fabrication Facility

Development work done on Forming & Machining

Forming

Inspection

120 T – HYDRAULIC PRESS

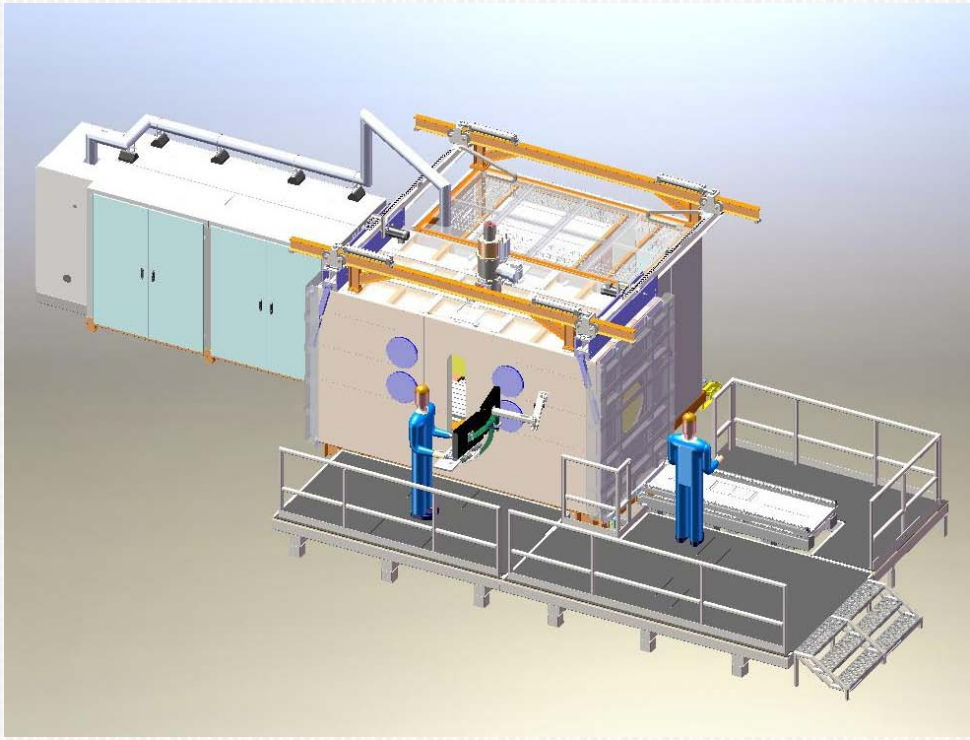
Machining

Formed Niobium Half cell

Electron Beam Welding Machine

Major specifications of EBW Machine

Beam power	15 kW
Gun Voltage	90 to 150 kV
Duty cycle	100%
Beam current range	100 mA
Beam current setting resolution	0.1 mA
Beam oscillations	1 – 1000 Hz or more
Beam focus diameter	0.25 mm
Inner size of chamber	3650 x 1500 x 1800 mm^3
X-Y table size	1780 m x 710 mm
Vacuum ready pressure	< $1x10^{-4}$ mbar in 15 min
Ready for welding pressure	< $1x10^{-6}$ mbar in 60 min



Inspection, Measurement & Cavity Test Facility

3D CNC Coordinate Measuring Machine

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Applications :

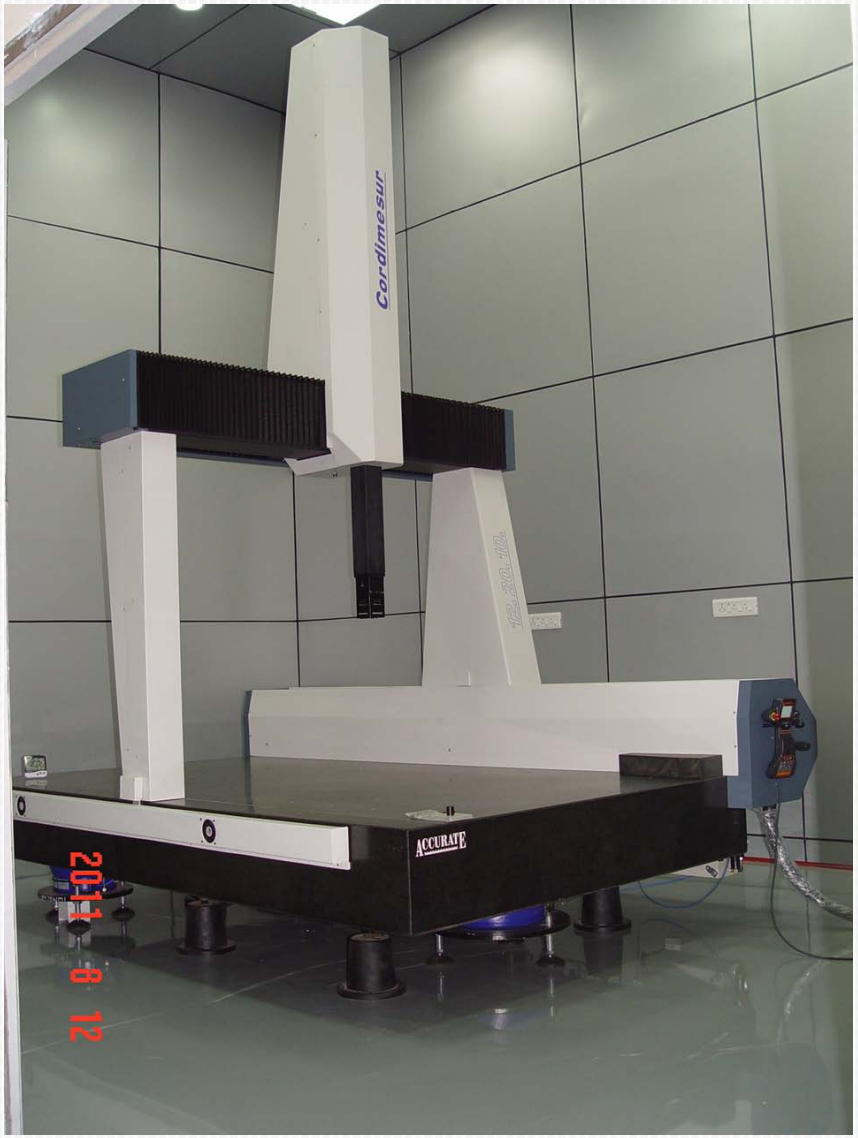
Dimensional inspection of SCRF cavity components like half cells, dumb-bells, multi-cells etc

Accuracy :

1.6 + L/400 microns

Commissioning :

In progress



Universal testing machine for evaluation of mechanical properties

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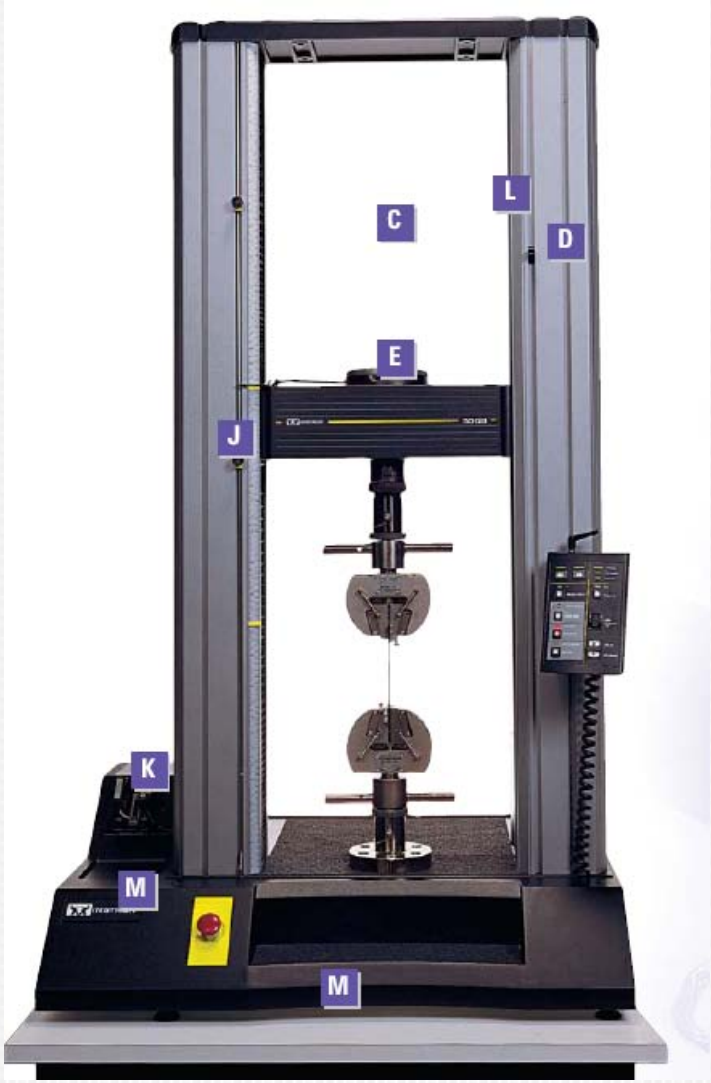
Instron UTM Model: 5569

- Load: ± 50 kN
- Testing speed: 0.001 – 500 mm/min
- Accuracy of Load: ± 0.5% for 0.5 – 50 kN
- Strain measurement Accuracy: ASTM E 83 Class B or better
- Total cross head travel: 1500 mm



Measurements:

•Yield strength, ultimate tensile strength

•Elongation

•Plastic strain ratio, Strain hardening exponent.

•Cavity Stiffness measurement

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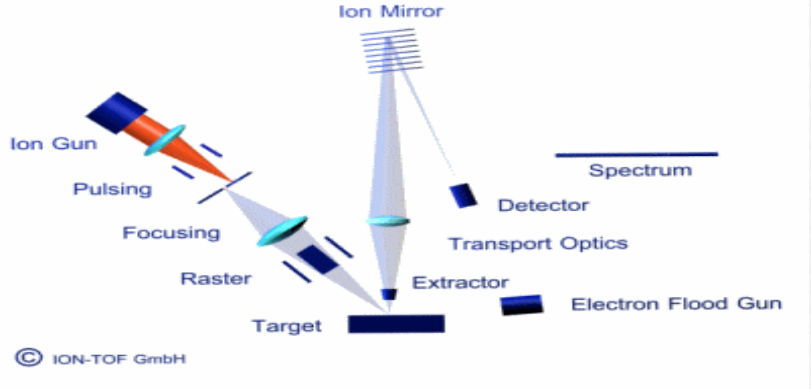
Secondary Ion Mass Spectrometer (SIMS)

To develop understanding of impurity distribution near the top layer (~100 - 200 nm) of niobium by 2-D, 3-D ion mapping of the impurities.



Quantification of the elemental impurity distribution using niobium standards .

SIMS has been commissioned Nov – 2011.

3D Laser scanning confocal microscope

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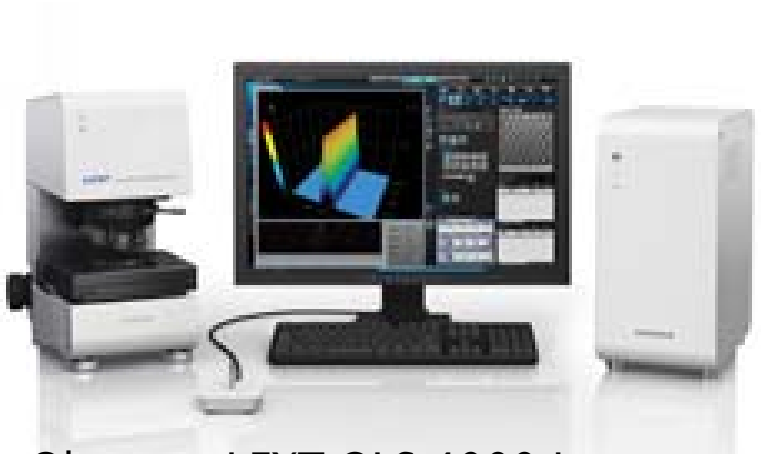
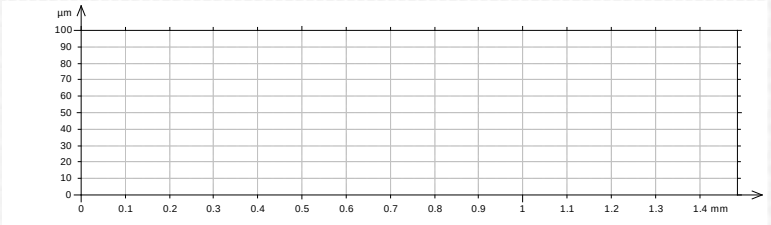
Imaging Method	3-D Laser Scanning Confocal system
Z - Resolution (Depth)	≤ 10 nm
Z - Measurement repeatability	12 nm
Z – measurement range	10 mm
X-Y Resolution	0.12 μm



Olympus LEXT OLS 4000 Laser scanning confocal microscope



Cavity Optical Inspection

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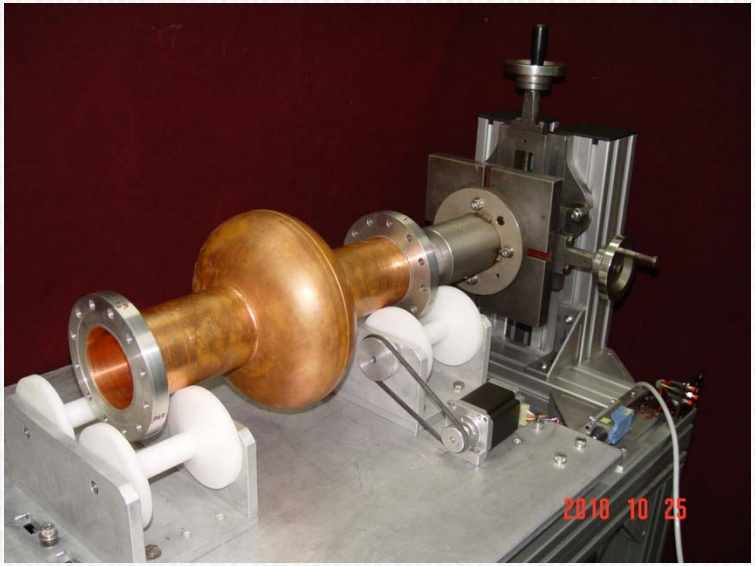
Cavity internal surface measurement using a small digital CCD camera with magnification 10X-200X

Motorized Optical inspection bench for cavity internal inspection for1.3 GHz -9 cell SCRF cavity



RF MEASUREMENT SETUP

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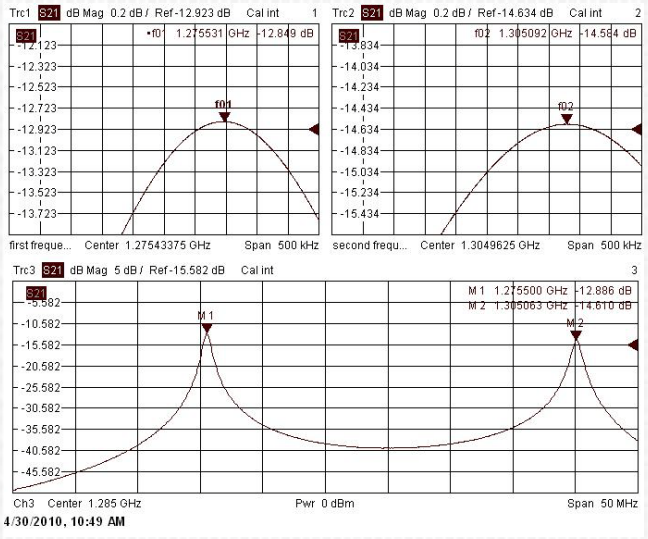
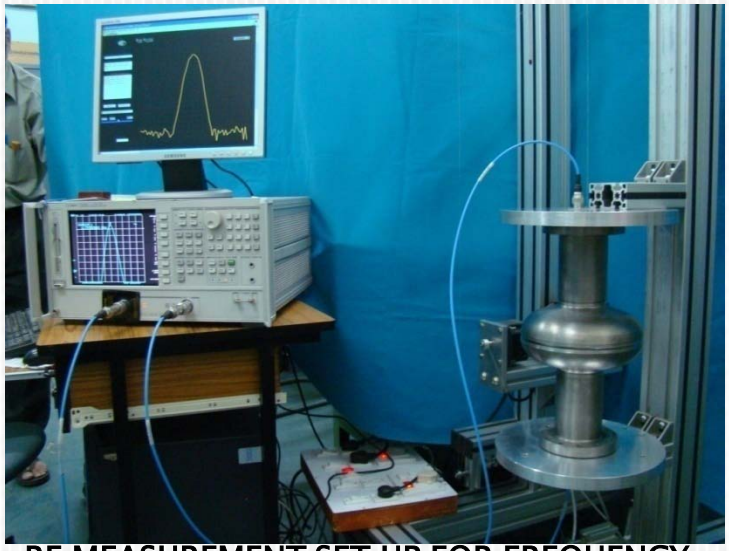
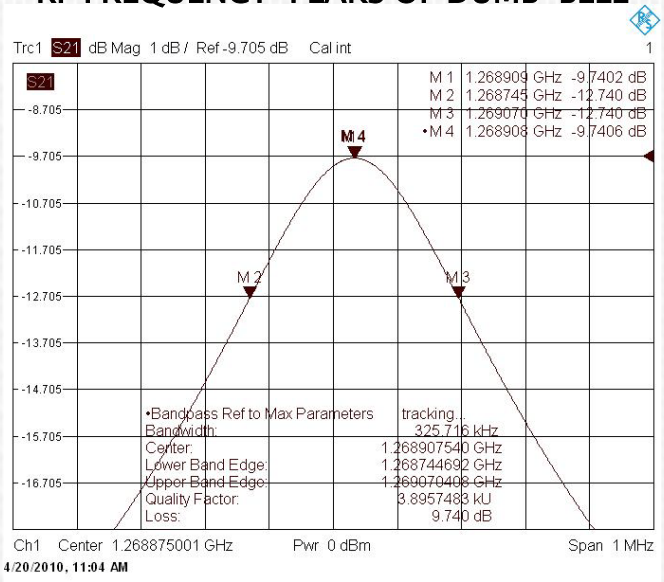
RF FREQUENCY MEASUREMENT SETUP



RF FREQUENCY PEAKS OF DUMB-BELL



RF MEASUREMENT SET UP FOR FREQUENCY AND FIELD DISTRIBUTION



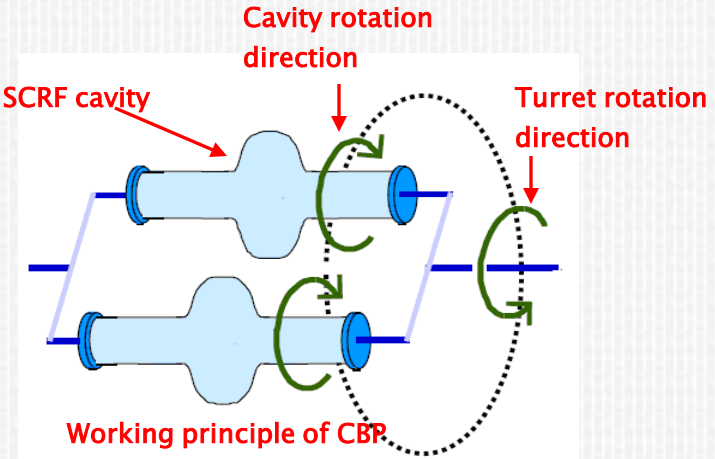
RF FREQUENCY PEAKS OF SINGLE CELL CAVITY

Cavity processing facility

Centrifugal Barrel Polishing (single Cell)

Main features of CBP machine

- ❖Turret and Barrel rotate in opposite direction
- ❖Turret speed – 0 – 200 rpm (variable)
- ❖Barrel speed – 0 – 200 rpm (variable)
- ❖Barrel size – 320 X 320 X 500 mm



Working principle of CBP

Cavity ready for mounting in CBP m/c

Cavities mounted in CBP machine

Initial Trial Results of CBP

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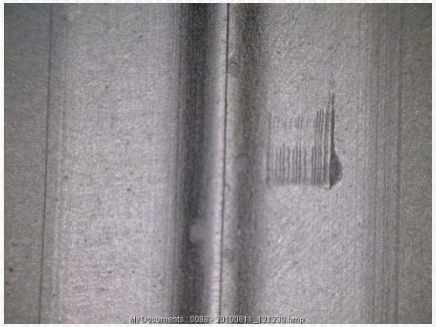
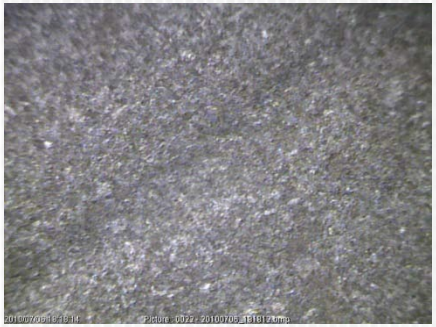
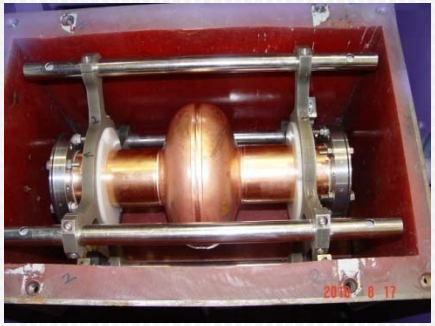
ALUMINUM CAVITY





COPPER CAVITY



Ultrasonic cleaning facility

Ultrasonic cleaner for single cell cavity & small components

Ultrasonic cleaner for 9 cell cavities

Development of Electro polishing setup

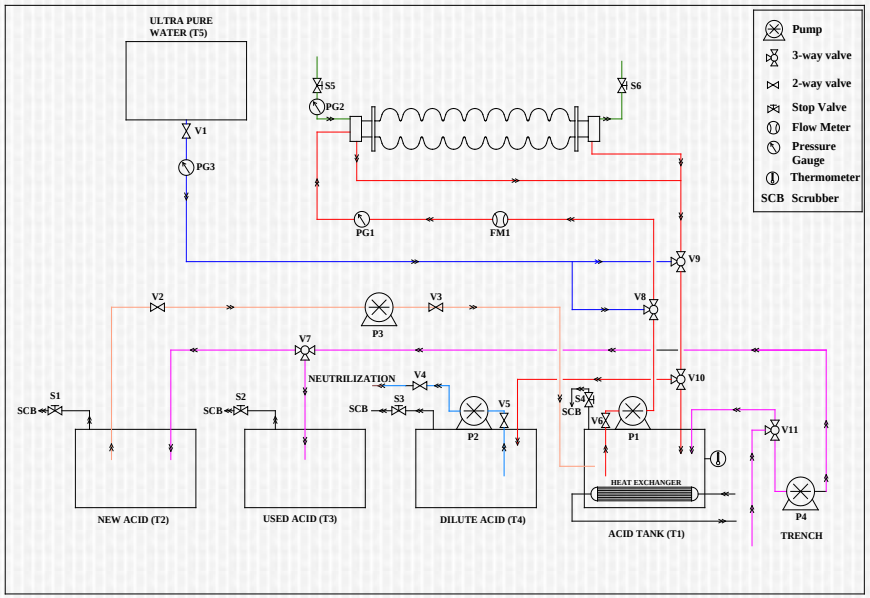
- Bench for electro-polishing of SCRF cavity has been developed, it can process 1.3 GHz -9 cell cavity.

The stand is capable of :

- Rotating the cavity at 2-10 rpm.
- Holding the cavity in horizontal position during processing & in vertical position during draining/ rinsing and for loading the cathode
- connect power supply using Slip ring with 4 carbon brushes

The flow circuit has been assembled and tested.

A 25V – 1000A DC Power supply has been procured.



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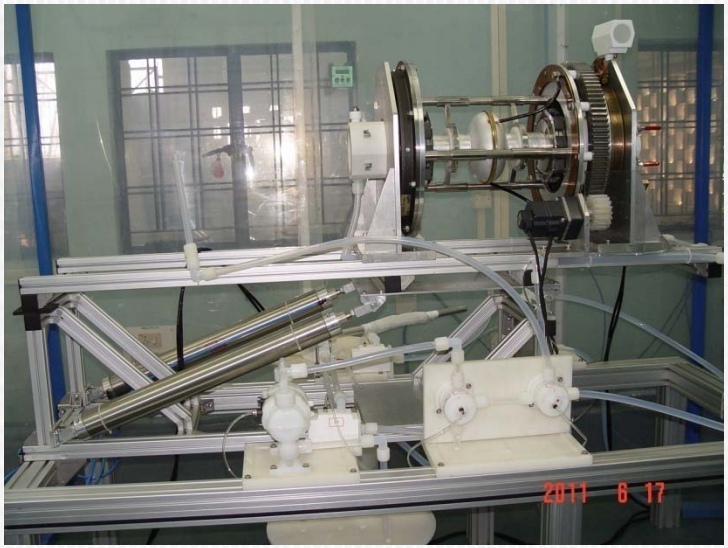
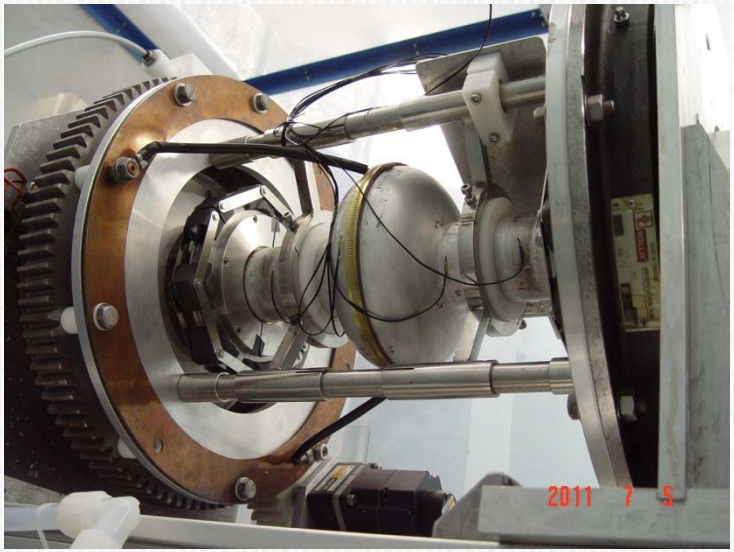
Electro-polishing of Single cell Aluminium cavity





After fabrication (without any processing)

After Barrel polishing

After 30 micron Electropolishing

Surface roughness of 50nm was obtained in the beam pipe after electro-polishing

High Pressure Rinsing Setup

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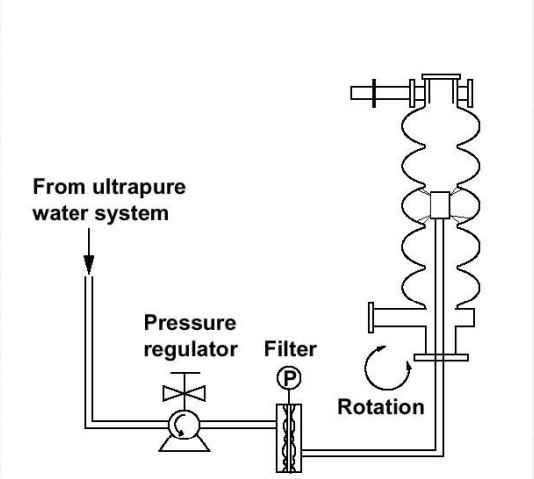
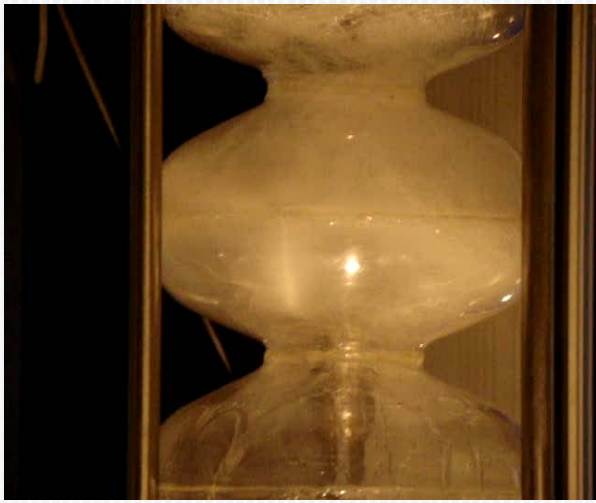
Features:

- Cavity / wand Rotational speed: 2-20 RPM
- Vertical Stroke: 1300 mm
- Vertical movement speed: 60 mm/min
- Ultra-pure water jet. pressure: 80 – 100 bar

Ultra Pure Water Plant

High Pressure Rinsing Set up in Clean enclosure (Class 100)





High Pressure Cleaning of dummy cavity

THERMAL PROCESSING OF CAVITIES

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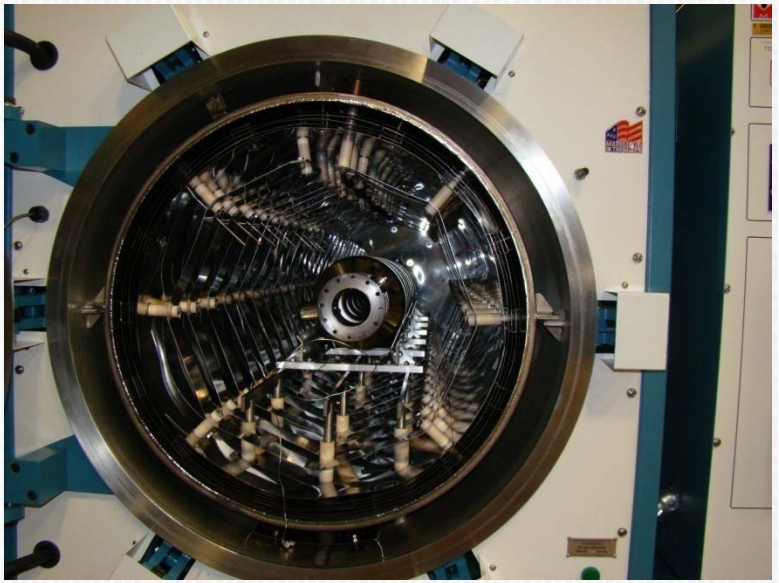
Specification of High Vacuum Furnace	
Orientation	**Horizontal**
Temperature range	**1400°C Max**
Working Vacuum	**<1 x 10^{-7} mbar (600°C -1000°C) <1 x 10^{-6} mbar (> 1000°C)**
Working Volume	**Diameter 825mm Depth 1500mm**



The furnace is under procurement

SCRF Cavity Tuning Machine

Tuning of SCRF Cavity

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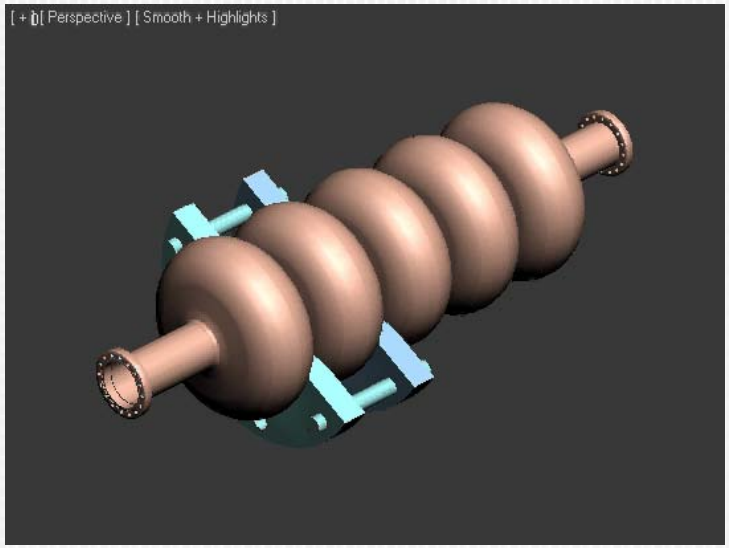
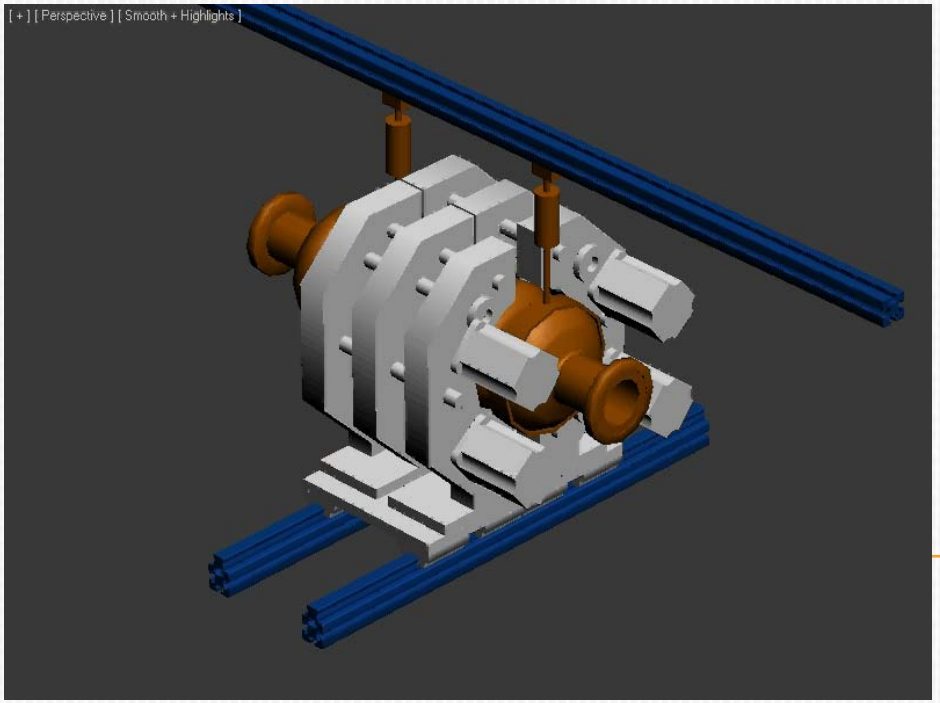




- A multicell elliptical accelerating cavity requires a “flat” electrical field profile at the target π-mode frequency
- Emin/Emax>0.98

- Cavity requires cell to cell tuning due to shape deformation during fabrication, material removal at various stages of polishing & also deformation during thermal processing.
- Cavity must be straight & requires an alignment

Building to House SCRF Cavity Infrastructure Facility

Building for SCRF Cavity Development

Cavity Fabrication, Assembly & Processing Building

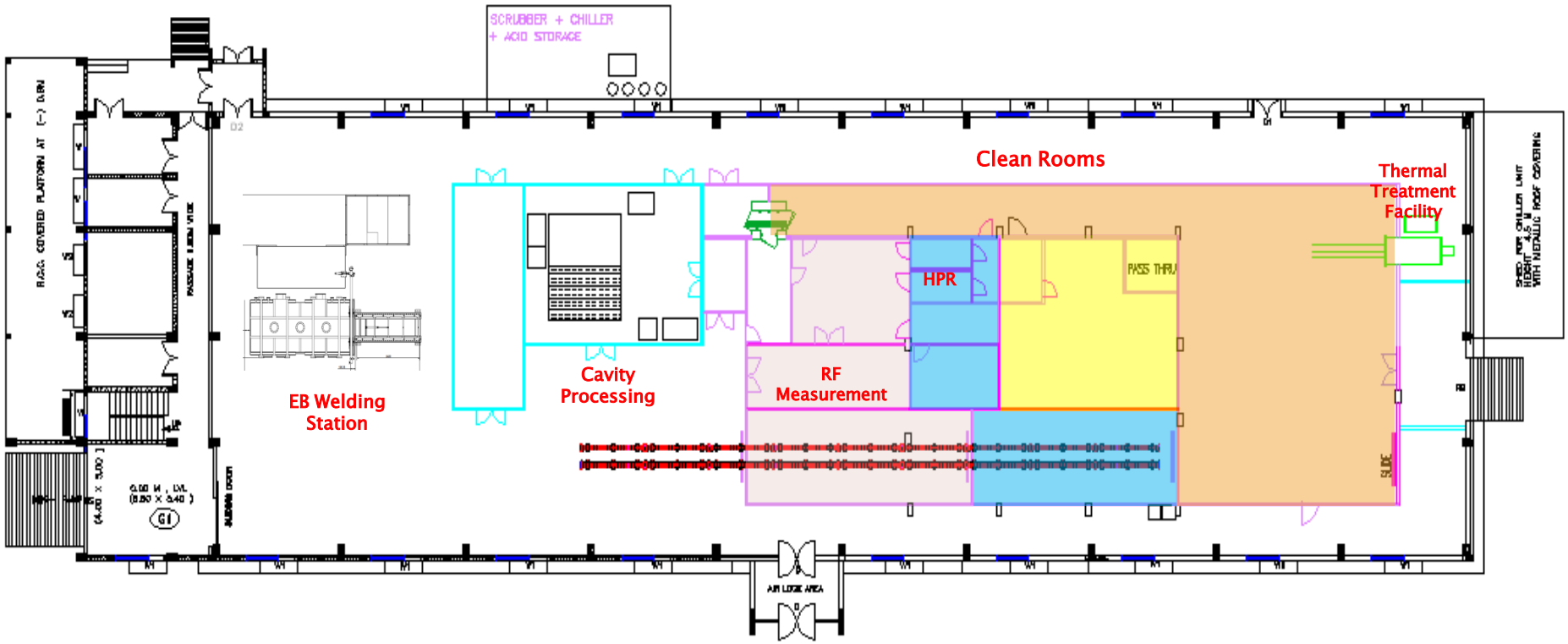
•The building will house clean rooms, Electron Beam welding machine. High Vacuum Annealing Furnace, Electro-polishing setup, Centrifugal barrel polishing machine, RF measurement etc.

•Building is ready.

Lab Building

• Facility being set up: CMM, SIMS, material testing facility, thin film deposition facility etc .

SCRF Cavity Processing Building (Equipment Layout)



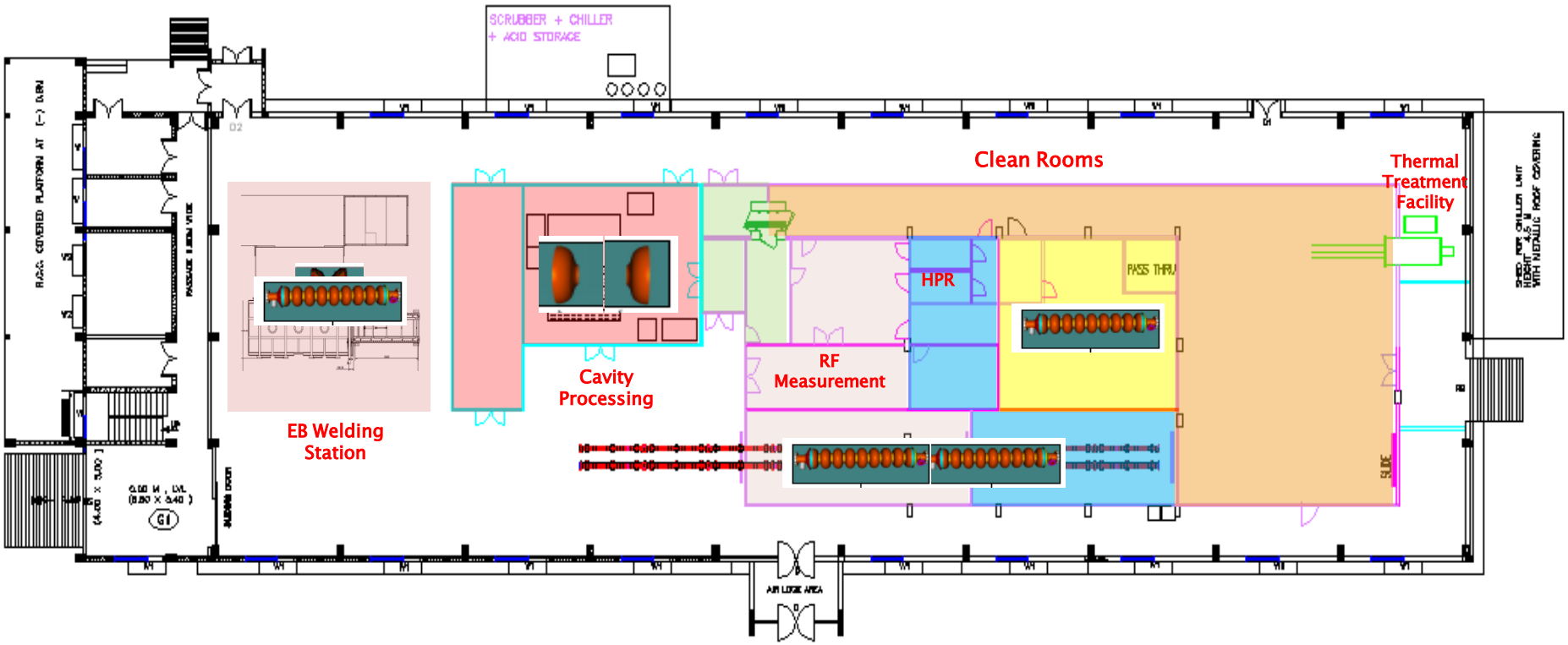
SCRF Cavity Movement in SCRF Building

After EB welding – To RF Measurement and for fabricating single cell cavity

After string assembly – To Cryomodule Assembly

bells

Building

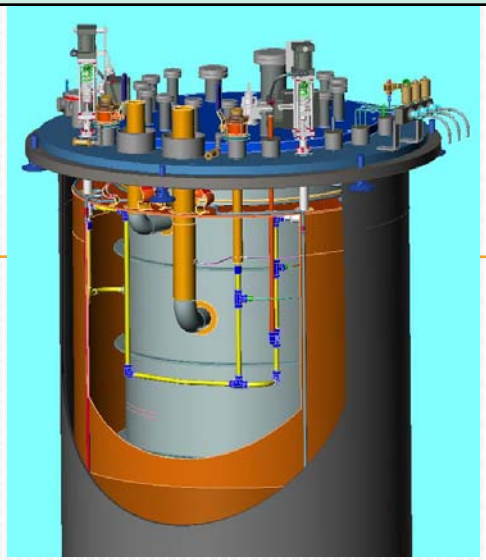


Cavity testing facility

Development of 2K Vertical Test Stand

- Single & 9-cell Tesla-style cavities (2 – 6 cavities)
- Single Spoke Resonator cavity 325 MHz
- Triple Spoke Resonator Cavity 325 MHz
  - Measure Q vs. T (T_{min}~1.5 K)
  - Measure Q vs. E_{acc} at 2 K
- cryogenic capacity ~250 W at 2 K
- Magnetically shielded cryostat
  - External (room-temperature) Amumetal® (80% Ni alloy) and internal Cryoperm 10® magnetic shield, designed to attenuate field to <10 mG at cavity
- Radiation shielding to maintain "Controlled Area" status
  - < 5 mrem in an hour immediately outside the shielding

Outside diameter of Vacuum Vessel + outside magnetic shield	≤ 58 inches
Length of Vacuum Vessel (from top flange to crown of head)	211.375 inches
Clear aperture of the Helium Vessel	34 inches
Length of Helium Vessel (from top flange to crown of head)	191.35 inches
80K Shield sits in space between Helium Vessel OD & Vacuum Vessel ID	



Work was taken up under IIFC

Development of 2K Cryostat for VTS

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RRCAT carried out design of various components of 2K VTS Cryostat:

- Liquid Helium Vessel
- 80K shield
- Vacuum Vessel
- Top Insert Plate
- Magnetic shielding (2K + room temperature)
- Piping layout for liquid helium
- 3-D model of the complete VTS-2 assembly

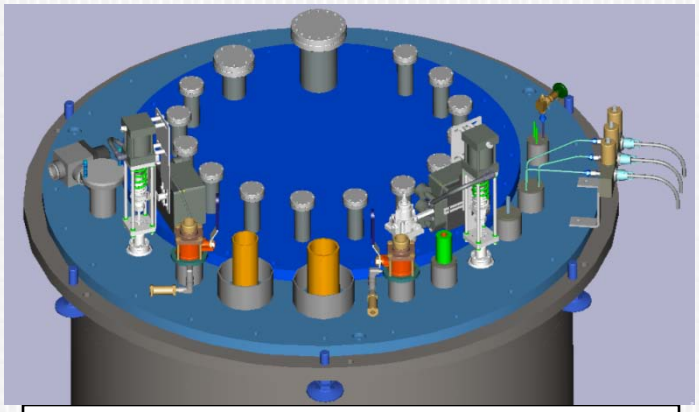
Three VTS cryostats are under fabrication at US vendor under joint supervision of engineers from Fermi Lab and RRCAT.

Expected delivery schedule : March 2012.

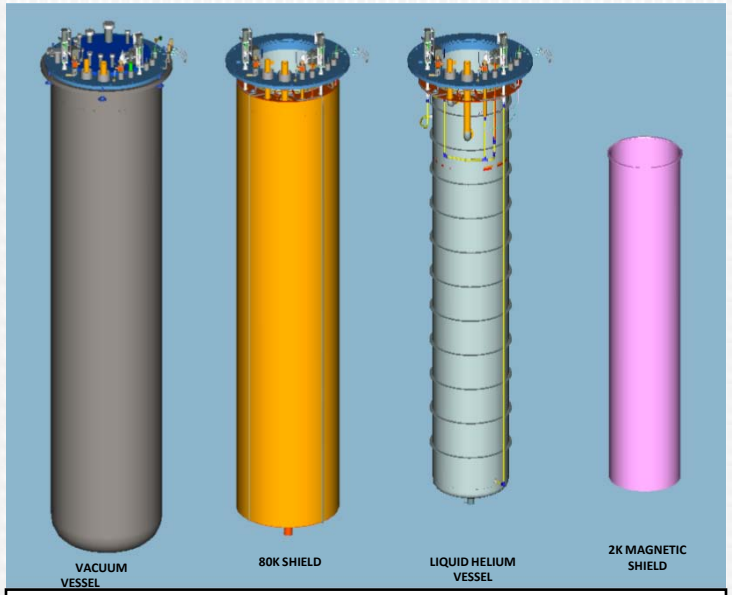
Building to house VTS at RRCAT is under construction and expected to be ready by December 2011

Cryogenics system under process (P K Kush &Team)

Components of RF and DAQ system fro RRCAT VTS is under process and expected to be ready by Dec 2011.
(P Shrivastava & Team – RF and T A Puntambekar & Team – DAQ)



VTS-2 TOP PLATE – CRYOGENIC & VACUUM INSERTS



3-D MODELS OF VTS-2 VESSELS

Pictures of VTS under fabrication at manufacturer (in USA)

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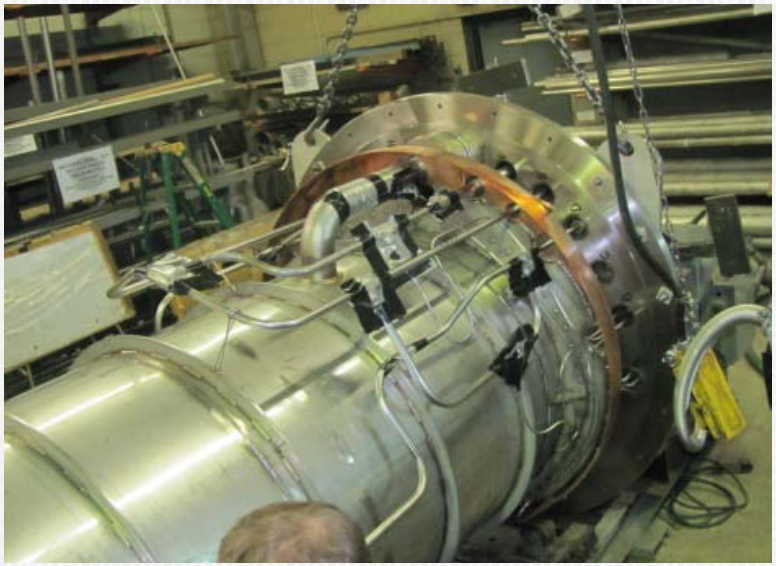

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Thank You