SRF Cryomodule Construction and Photocathode Prototyping at AES

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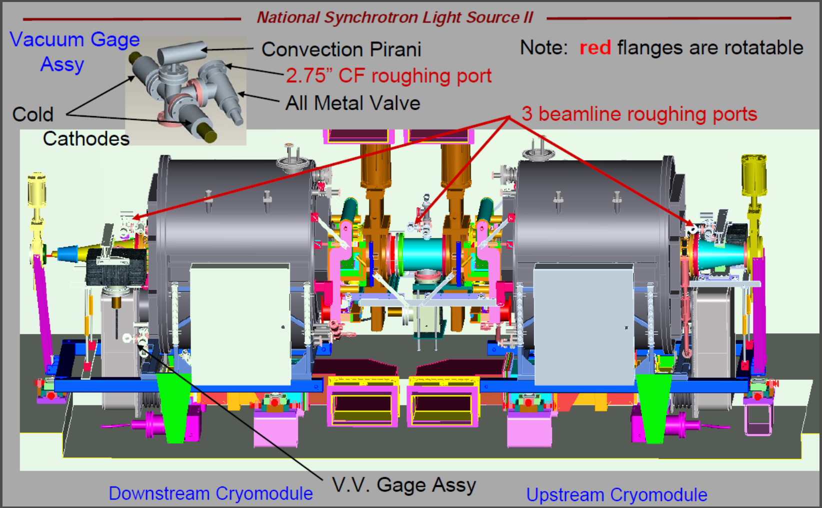
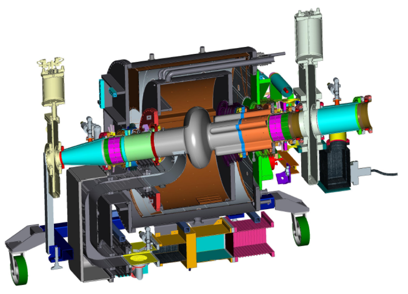
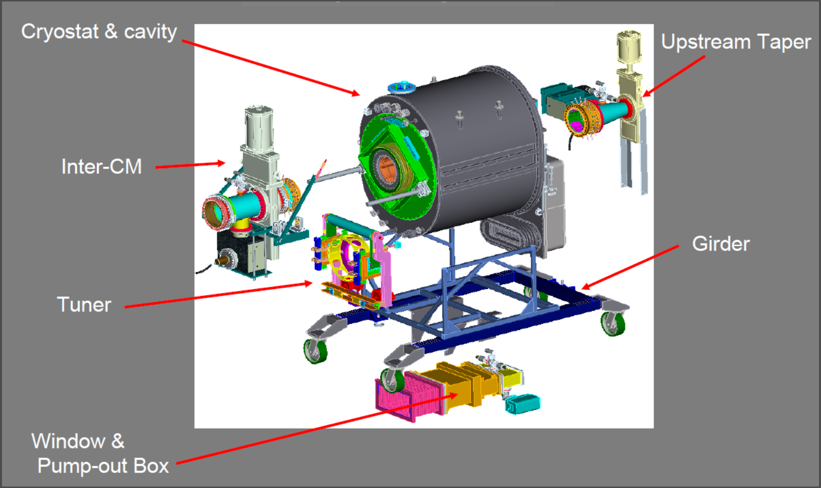

National Synchrotron Light Source II
Vacuum Gage Assy
Convection Pirani
2.75" CF roughing port
All Metal Valve
Cold Cathodes
Note: red flanges are rotatable
3 beamline roughing ports
V.V. Gage Assy
Downstream Cryomodule
Upstream Cryomodule

Performance Requirements



- $Q_{ext} = 6.5\text{E}4$
- V = 1.84 MV nominally (depends on power limitations)
- $Q_0 > 7\text{E}8$
- Static Heat Load < 37.5 W
- Dynamic Heat Load < 60 W

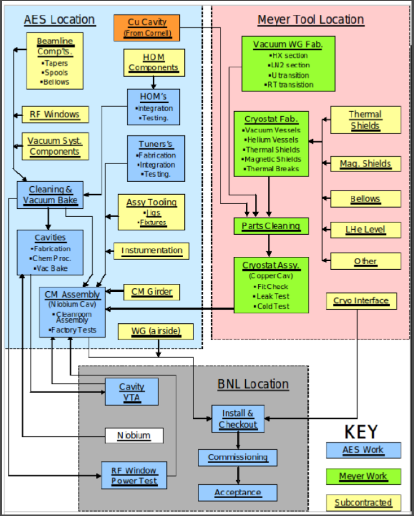
Acceptance Tests Required for All Major Sub-Assemblies



Acceptance Tests Required for All Major Sub-Assemblies

- HOM load tile testing
    - HOM load total absorbtion > 7 kW
- RF Window Conditioning
    - 300 kW 80% duty cycle TW
    - 120 kW CW SW
- Nb Cavity Vertical Testing
- $E_{\mathrm{acc}} > 10$ MV/m, $Q_0 > 5\mathrm{E}8$
- Cryostat
    - nitrogen cold test
    - pneumatic pressure test of He vessel to 1.15 MAWP

BNL Contract with AES, Meyer Tool is the Primary Sub-Contractor



AES Location

Cu Cavity (From Cornell)

Beamline Comp'ts.
- Tapers
- Spools
- Bellows

HOM Components

HOM's
- Integration
- Testing.

RF Windows

Vacuum Syst. Components

Tuners's
- Fabrication
- Integration
- Testing.

Cleaning & Vacuum Bake

Assy Tooling
- Jigs
- Fixtures

Cavities
- Fabrication
- Chem Proc.
- Vac Bake

Instrumentation

CM Assembly (Niobium Cav)
- Cleanroom Assembly
- Factory Tests

CM Girder

WG (airside)

Meyer Tool Location

Vacuum WG Fab.
- HX section
- LN2 section
- U transition
- RT transistion

Cryostat Fab.
- Vacuum Vessels
- Helium Vessels
- Thermal Shields
- Magnetic Shields
- Thermal Breaks

Thermal Shields

Mag. Shields

Bellows

LHe Level

Other

Parts Cleaning

Cryostat Assy. (Copper Cav)
- Fit Check
- Leak Test
- Cold Test

Cryo Interface

BNL Location

Cavity VTA

Niobium

RF Window Power Test

Install & Checkout

Commissioning

Acceptance

KEY

AES Work

Meyer Work

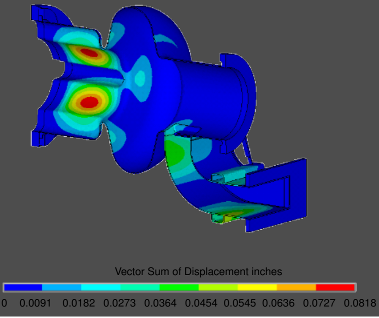
Subcontracted

AES-BNL SRF Processing Facility

- newly installed class 100 clean room for cryo-module assembly at AES
- recently stamped 500 MHz half-cells under SBIR contract
- NSLS-II cavity fabrication currently in process at AES

AES Cavity Design Changes for ASME Compliance

- Design by Analysis 2007 Section VII Division 2
- when collapse has occurred in the past, it occurred at the Nb waveguide
- NSLS-II cavity and waveguide wall thickened
- cavity is stable against collapse up to MAWP = 1.55 Bar
- satisfies requirements of ASME Pressure Vessel Code

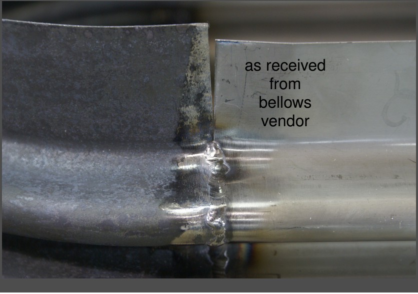


Cryostat Construction and Testing at Meyer Tool

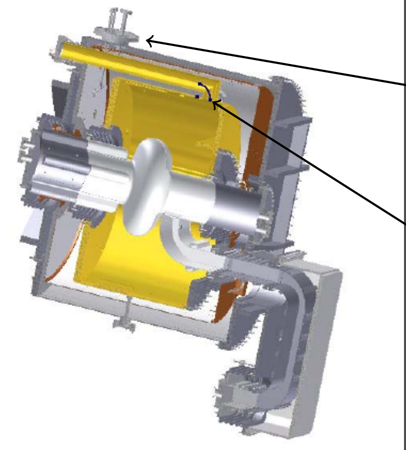
- both He vessels ASME code-tested and leak-tested
- both thermal/magnetic shields completed
- all laser cut waveguide and thermal transition parts being welded

Cryostat Construction and Testing at Meyer Tool

- racetrack bellows tolerances less than acceptable as received from bellows vendor
- Meyer Tool able to re-work bellows and mating weld preps to achieve functionality
- minimal impact to schedule as a result



Re-Design of He Vent Line and Cryo Lines



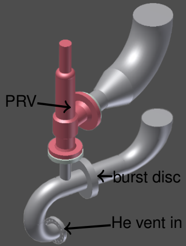
- LHe, cold He gas out, and LN2 in lines are now routed through the top of the cryostat instead of the side
- larger pipe OD to increase flow during venting from over-pressurization

BNL Numerical Analyses

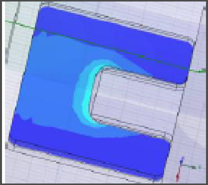
The tuner functions properly with the thicker cavity walls

(Loading movie...)

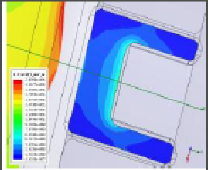
- critical fault scenario is air leak into the cavity vacuum, producing 70 kW heat load
- PRV, burst disc, and bends sized to keep back pressure accumulation below 21% above MAWP



BNL Numerical Analyses



Cornell coupling tongue



BNL coupling tongue

- Cornell Q_{ext} = 2E5
- BNL Q_{ext} = 6.5E4

RF Window Power Limitations

β = RF input coupling coefficient

	$\beta \approx 1$ travelling wave	$\beta \gg 1$ standing wave
Cavity Voltage	V_c	V_c
Forward Power	P_f	$\frac{P_\mathrm{f}}{4}$
RF Window Limit	550 kW	150 kW

$$V = \left(\frac{2\beta}{1+\beta}\right)\sqrt{\frac{R}{Q} Q_\mathrm{ext} P_\mathrm{f}} \Longrightarrow V_\mathrm{BNL} = 0.57 V_\mathrm{Cornell}$$

Temperature gradient across the ceramic determines window power limit

variation in TiN coating produces a range of power limits

3-stub tuning can vary effective Qext

Not obvious how much window heating will be reduced

Historical Problems

- cryo-pumping/multipacting in cold waveguide sections
- He leaks to cavity vacuum
- insulation vacuum leaks
- poor adhesion of copper plating
- catastrophic failure of non-interlocked components

Historical Problems

Resistive Heaters Protected from Overheating

thermometers will be attached to resistive heaters in the helium vessel for use with interlocks

Copper Plating Adhesion is Tested

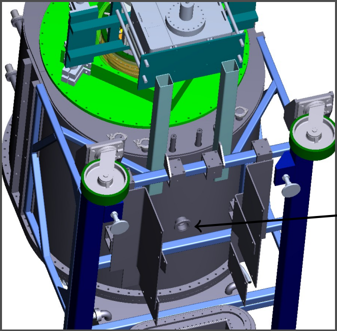
priority for QA and test pieces used to qualify the plating

blemishes due to
unpolished substrate,
not copper plating

Historical Problems

Insulation Vacuum Leaks not a show stopper

Annoying but able to limp along in practice by active pumping with a turbo pump



K40 port for possibly connecting a turbo pump

Historical Problems

He Leaks to Cavity Vacuum a real show stopper

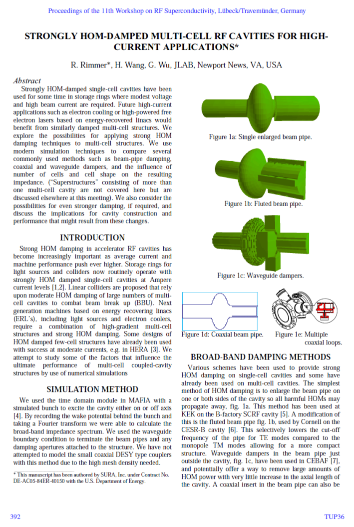
- The cryo-modules are leak-checked at 10% He fill prior to installation
- FBT indium seal seems prone to leaks, possibly due to challenges of assembly

Historical Problems

Cryo-Pumping/Multipacting Waveguide is a constant challenge

- Periodic warm-up is required to outgas adsorbed gas
- multipacting supressing magnetic field coils can help

Fluted or Re-Entrant Beam Tube?



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STRONGLY HOM-DAMPED MULTI-CELL RF CAVITIES FOR HIGH-CURRENT APPLICATIONS*

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Abstract

Strongly HOM-damped single-cell cavities have been used for some time in storage rings where modest voltage and high beam current are required. Future high-current applications such as electron cooling or high-powered free electron lasers based on energy-recovered linacs would benefit from similarly damped multi-cell structures. We explore the possibilities for applying strong HOM damping techniques to multi-cell structures. We use modern simulation techniques to compare several commonly used methods such as beam-pipe damping, coaxial and waveguide dampers, and the influence of number of cells and cell shape on the resulting impedance. ("Superstructures" consisting of more than one multi-cell cavity are not covered here but are discussed elsewhere at this meeting). We also consider the possibilities for even stronger damping, if required, and discuss the implications for cavity construction and performance that might result from these changes.

INTRODUCTION

Strong HOM damping in accelerator RF cavities has become increasingly important as average current and machine performance push ever higher. Storage rings for light sources and colliders now routinely operate with strongly HOM damped single-cell cavities at Ampere current levels [1,2]. Linear colliders are proposed that rely upon moderate HOM damping of large numbers of multi-cell cavities to combat beam break up (BBU). Next generation machines based on energy recovering linacs (ERL's), including light sources and electron coolers, require a combination of high-gradient multi-cell structures and strong HOM damping. Some designs of HOM damped few-cell structures have already been used with success at moderate currents, e.g. in HERA [3]. We attempt to study some of the factors that influence the ultimate performance of multi-cell coupled-cavity structures by use of numerical simulations

SIMULATION METHOD

We used the time domain module in MAFIA with a simulated bunch to excite the cavity either on or off axis [4]. By recording the wake potential behind the bunch and taking a Fourier transform we were able to calculate the broad-band impedance spectrum. We used the waveguide boundary condition to terminate the beam pipes and any damping apertures attached to the structure. We have not attempted to model the small coaxial DESY type couplers with this method due to the high mesh density needed.

Figure 1a: Single enlarged beam pipe.

Figure 1b: Fluted beam pipe.

Figure 1c: Waveguide dampers.

Figure 1d: Coaxial beam pipe.

Figure 1e: Multiple coaxial loops.

BROAD-BAND DAMPING METHODS

Various schemes have been used to provide strong HOM damping on single-cell cavities and some have already been used on multi-cell cavities. The simplest method of HOM damping is to enlarge the beam pipe on one or both sides of the cavity so all harmful HOMs may propagate away, fig. 1a. This method has been used at KEK on the B-factory SCRF cavity [5]. A modification of this is the fluted beam pipe fig. 1b, used by Cornell on the CESR-B cavity [6]. This selectively lowers the cut-off frequency of the pipe for TE modes compared to the monopole TM modes allowing for a more compact structure. Waveguide dampers in the beam pipe just outside the cavity, fig. 1c, have been used in CEBAF [7], and potentially offer a way to remove large amounts of HOM power with very little increase in the axial length of the cavity. A coaxial insert in the beam pipe can also be

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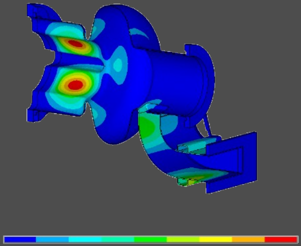
RF advantages to fluted beam pipes...

- Flutes generally provide stronger coupling to HOMs
- Q_{ext} 46% lower for strongest monopole HOM
- Q_{ext} < 5% lower for first two dipole HOMs

Fluted or Re-Entrant Beam Tube?

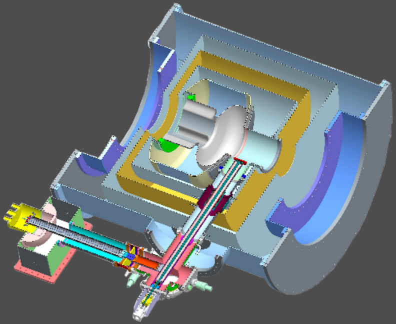
but there are advantages to round beam tubes, too.

- Risk of He-to-cavity leak may be mitigated by replacing indium sealed fluted flange with a circular Conflat flange
- a cylindrically symmetric tube would stiffen the mechanically weakest area of the cavity



AES/BNL Phase 1 SBIR Study

- 500 kW through power
- variable coupling
- smaller He vessel volume
- compact
- easier to suppress multipacting



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