NSLS I : Challenges and upgrades on 30 year old high power RF systems

Aditya Goel

Brookhaven National Laboratory

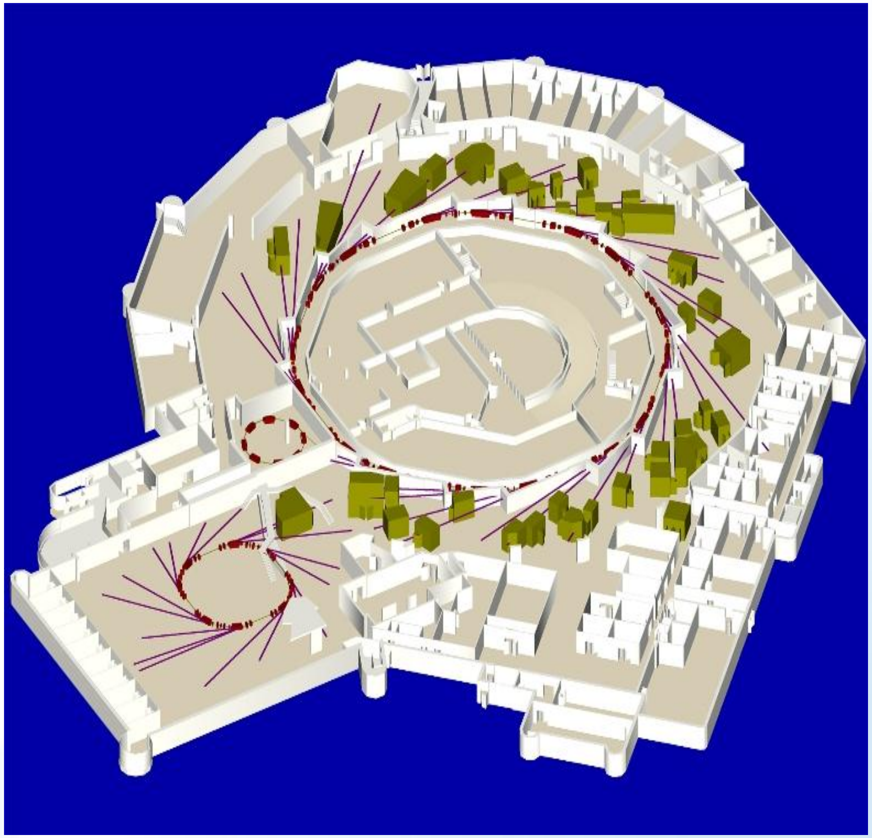
08 May 2012

Summary

- Current description of the system.
- Upgrades
- Challenges
- Questions

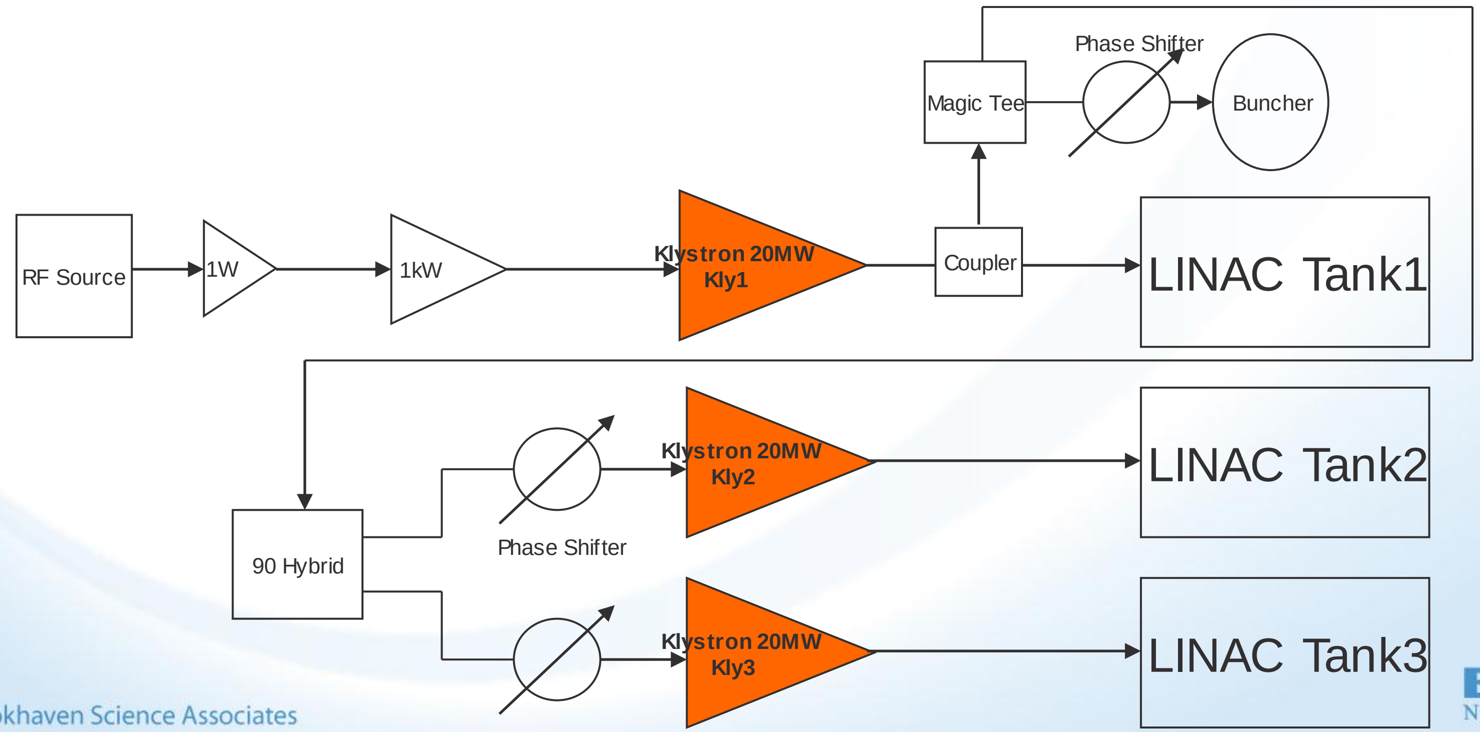
System Overview

- Four electron beam accelerators
  - Injector Systems – Linac and Booster
  - Ring Systems – VUV and X-Ray
  - Typical uptime of 97%



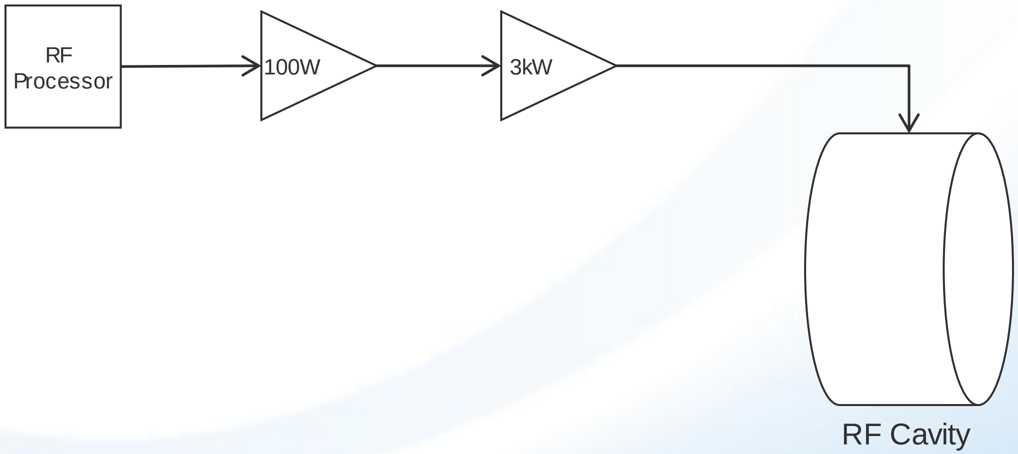
System Overview: LINAC

- 3 Accelerating structures
- 3x20 MW Pulsed Klystrons 2.856 GHz



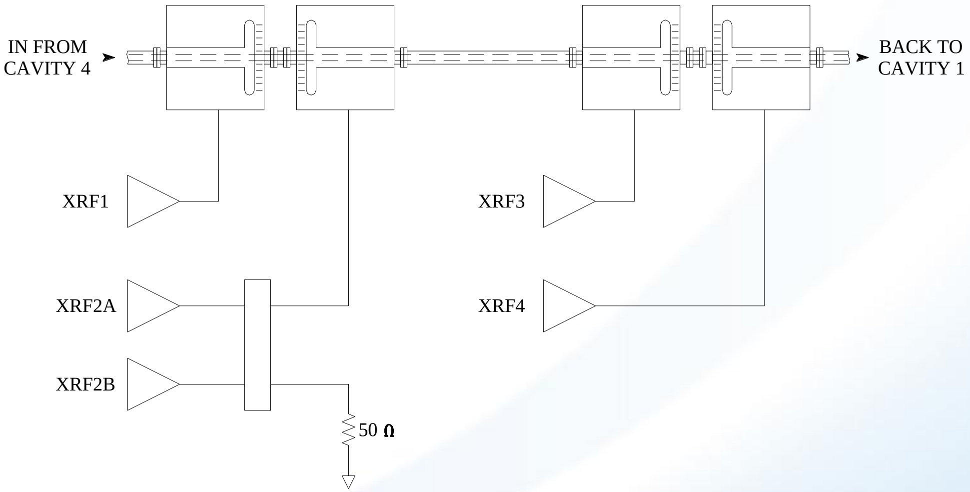
System Overview: Booster

- 1 Accelerating Cavity
- 3 kW CW Tetrode based @ 52.8875 MHz



X-Ray Ring: System Overview

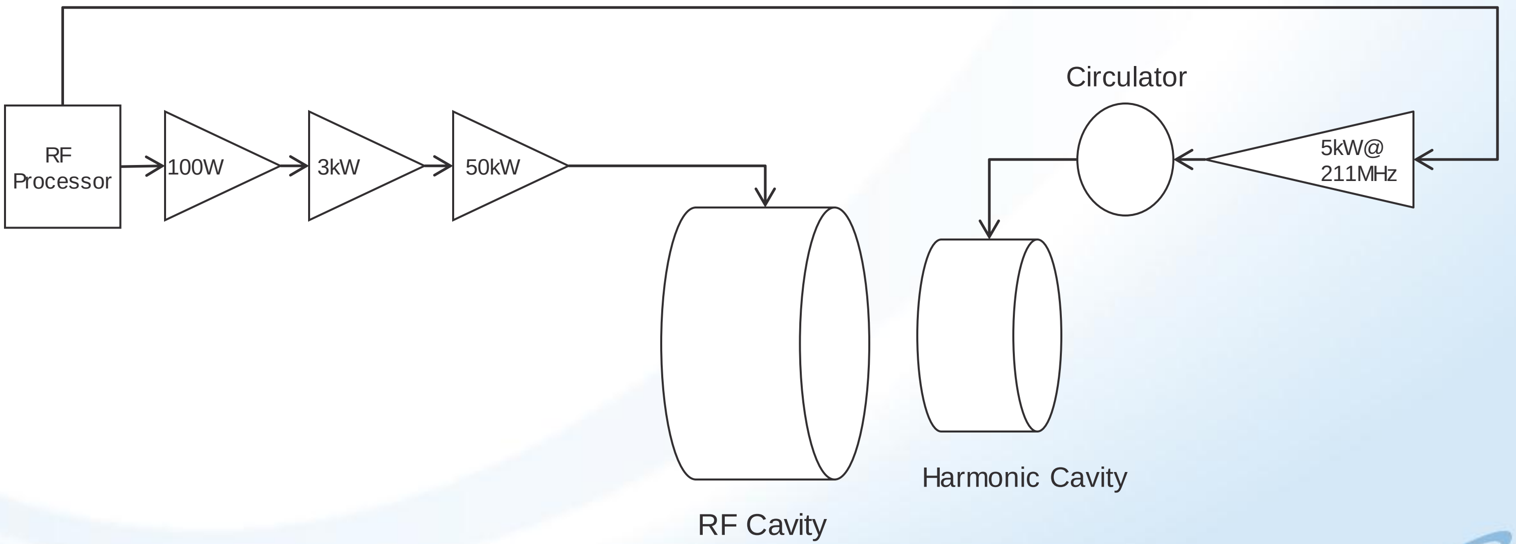
- 4 Accelerating Cavities
- 5x125kW CW Tetrode based @ 52.8875MHz
- XRF2 System combines 2x125kW systems using a hybrid
- Beam Current and Energy – 300mA @ 2800 MeV



BROOKHAVEN NATIONAL LABORATORY

System Overview: VUV Ring

- 2 Cavities – Fundamental and Harmonic
- 50kW Tetrode Based System @52.8875 MHz
- 5kW Solid state based system @211 MHz (4th Harmonic)
- Beam Current and Energy – 1000mA @800 MeV



Challenges and Upgrades

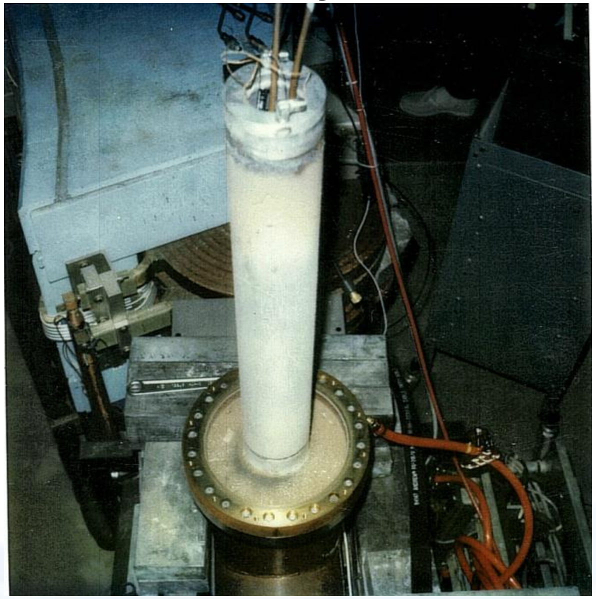
- Driving Factors
  - Reliability
  - Obsolescence
  - Fatigue and aging
  - Soft challenges

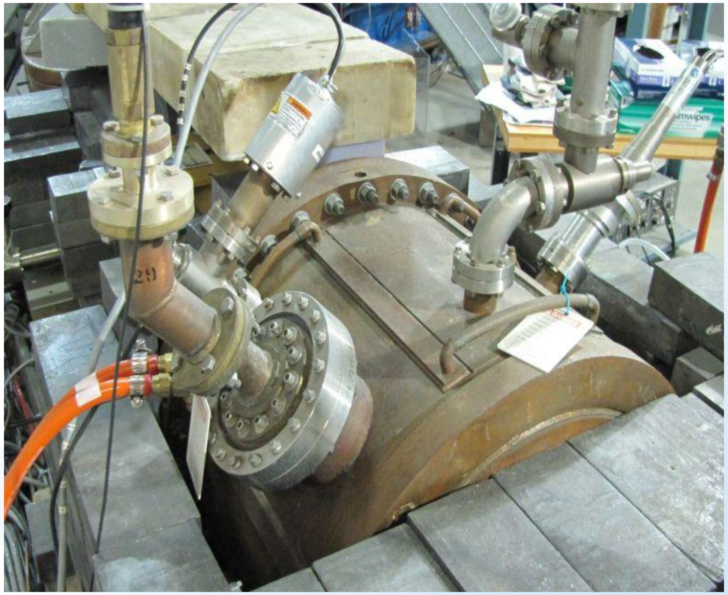
Reliability

- Major driver for upgrades
- 24x7 facility with strong emphasis on uptime
- DOE mandates 90% uptime BNL aims for 95%
- Regular maintenance and upgrades needed to maintain high reliability.
- Several upgrades over last 30 years.
- Major upgrades affecting RF systems covered here

Reliability: Booster

- Booster Cavity Upgrade
  - Original cavity was a coaxial T cavity design
  - The cavity was prone to arcing & vacuum leaks
  - New cavity installed in 1989





Reliability: X-Ray

- Highest power CWRF systems at facility
- Several upgrades to improve reliability of systems
- Original amplifier design by RCA
- Unsatisfactory performance and evaluation of alternative vendors yielded Eimac as the second provider of amplifiers.
- Significantly improved stability, power output and tube lifetime prompted decision to change all amplifiers to Eimac

Reliability: X-Ray

- Eimac improvements
  - Gradual improvements over last 25 years
  - Better high power contact area
  - Better Thermal Management
  - Ferrite tiles to get rid of 1GHz mode
  - All these improvements have greatly increased system stability

Reliability: X-Ray

Heat-sinks to better combat temp rise

Thicker silver plated contact area

Plate line chimney water cooling

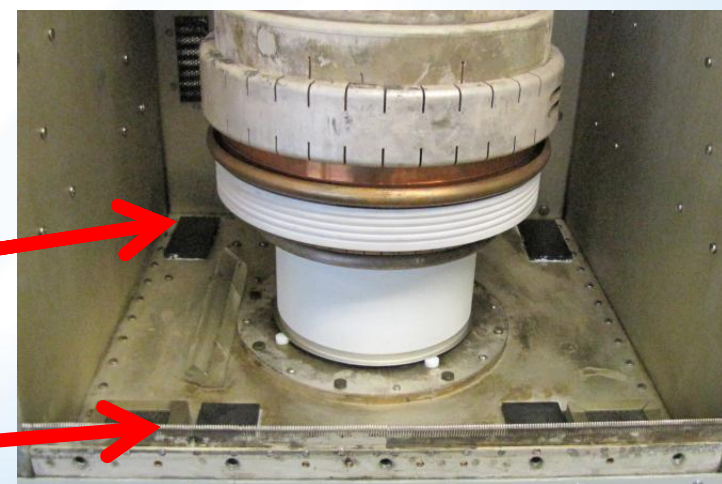
Stiffen sides to prevent bowing

Knife edge on the certain high current contacts

Boron-nitride window to cool coax inner conductor at amplifier output

Ferrite Tiles to get rid of 1GHz mode

spring fingers on amplifier front door

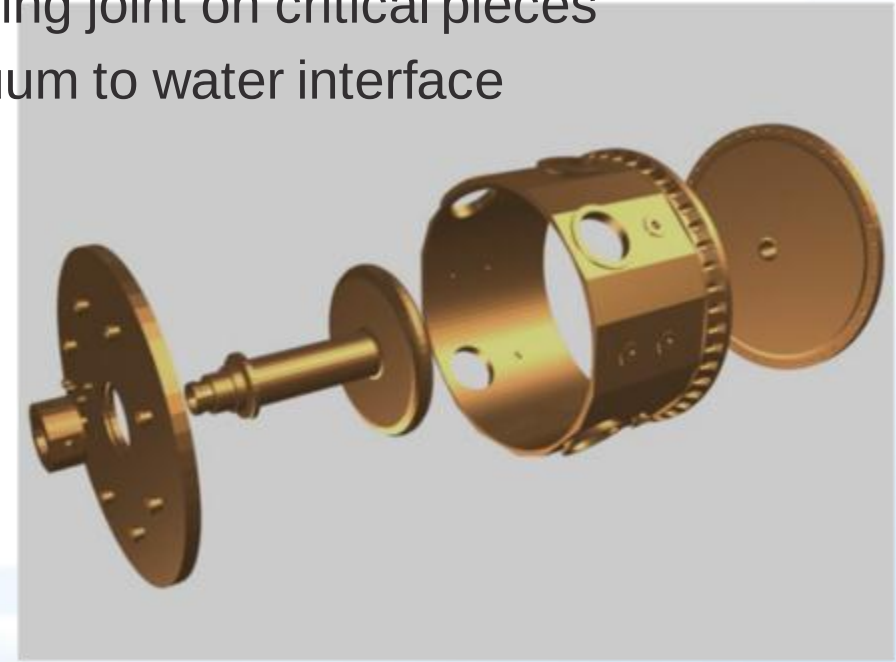


Reliability: X-Ray

- Addition of hybrid system on XRF2 amplifier
  - Original intention was to reduce loading on other amplifiers
  - Better isolation between cavity and amplifier
  - Better cavity input coupler re-designed for higher power acceptance
  - Beryllium Oxide window on cavity input
  - However decision was made to go to 2.8GeV
  - Despite complicated controls and near double the amount of equipment, XRF2 system reliability has been comparable to a single amplifier system.
- Modular Solid State driver amps and circulators on 3 systems
  - Reduced amount of equipment and spares
  - Reduced maintenance and troubleshooting time.

Reliability: X-Ray

- Upgrade to full Copper cavities
  - Original cavity copper clad steel
  - Original cavity had problems with multi-pactoring and vacuum leaks
  - No welding joint on critical pieces
  - No vacuum to water interface



Reliability: VUV

- VUV 50kW amplifier
  - Original design installed in xray ring amplifier
  - Tube lifetime was short
  - Severe problems with drift, oscillations and sparking inside the tube.
  - Cooling design was not adequate
  - No other viable alternative – at that time
  - Decision was made to redesign tube since it was being used on X-Ray and UV ring systems

Reliability: VUV

- VUV 50kW tube redesign
  - Joint effort between BNL and vendor (RCA)
  - Redesign of grid structure for better mechanical and thermal stability
  - Blackening of anode for better thermal conductivity

Reliability: VUV

- Upgrade of 211 MHz VUV harmonic cavity amplifier
  - Original Townsend amplifier prone to drifts, overheating and controls problems
  - Replaced by a multi module Solid State amplifier in 1996
  - Only SS amplifier powering a cavity directly (through circulator)
  - Performance has been satisfactory compared to previous amplifier

Obsolescence

- Second major reason for upgrades
- Usually forced upgrade to ensure future maintainability.
- Currently we see more problems with low level controls and diagnostics
- For vacuum tubes it is difficult to find vendors that provide good tube rebuild services.
- Rebuilders committing to “best effort” services only. Does not instill confidence in future availability of services.

Obsolescence

- Quality of rebuilds is a major issue – recent rebuilds on our X-Ray tubes have required very drastic changes to operating parameters to extract satisfactory performance
- Our recent klystron rebuild failed twice before we received a working spare.
- Manufacturers phasing out entire product lines makes spares availability very difficult. Requires us to stock a large inventory of spares.
- Due to industry evolution and acquisitions locating documentation and technical support has become a major challenge.
- Frequently vendors will end support or refuse to support product lines of acquired companies.

Fatigue and Aging

- Usually results in catastrophic failure
- Even with proper PM's and replacements some equipment will fail prematurely.
- Thermal and mechanical fatigue of High power components is a major failure mode
  - Recently we had to "patch" a vacuum leak in our high power RF window on XRF System
  - We found loose coaxial bullets with arc marks in high power feed-lines.

Fatigue and Aging

- Age related HV insulation failure
  - Not very easy to spot and troubleshoot
  - We notice more failures on pulsed systems compared to our CWRF systems
- In general we have had to increase our inspection and scrutiny as the systems have aged
  - Tube sockets are a prime candidate

Soft Challenges

- Usually driven by changes in policy or management
- Safety and Regulatory changes
  - Equipment and devices acceptable 30 years ago are no longer viable
  - Ban of PCB's required us to redesign our modulators and filtering capacitors
  - Ignitron devices using mercury had to be addressed
  - Safety and LOTO procedures had to be reviewed and re-written.
  - Adoption of new fire safety rules also required us to implement fixes

Soft Challenges

- Budget constraints
  - Cuts in operational time and maintenance activities
  - Funds availability scarce for upgrades
- Loss of expertise
  - Personnel Changes
  - Retirements
  - Retraining

Acknowledgements

- Roy D' Alsace
- Gloria Ramirez
- Joseph Papu
- Peter Davila
- James Rose
- Douglas Durfee
- Christopher Sorrentino
- Kenneth Pedersen
- Michael Fulkerson

Questions?