The Installation and Commissioning of the IPNS Third Cavity

The Fourth CW and High Average Power RF Workshop

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Intense Pulsed Neutron Source

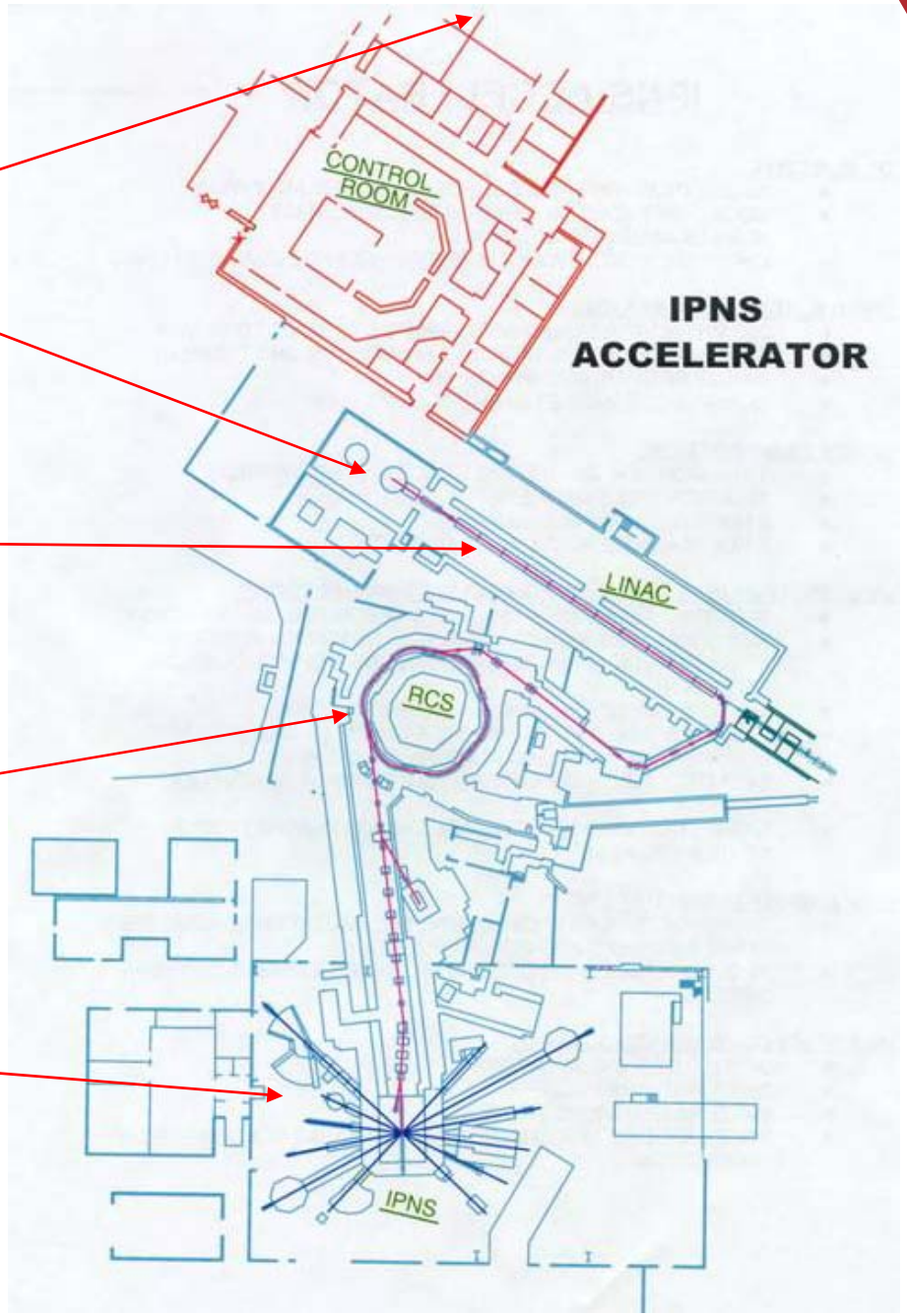
You are here

750 keV Cockcroft Walton Injector

50 MeV Linac

450 MeV Rapid Cycling Synchrotron

Target



Outline

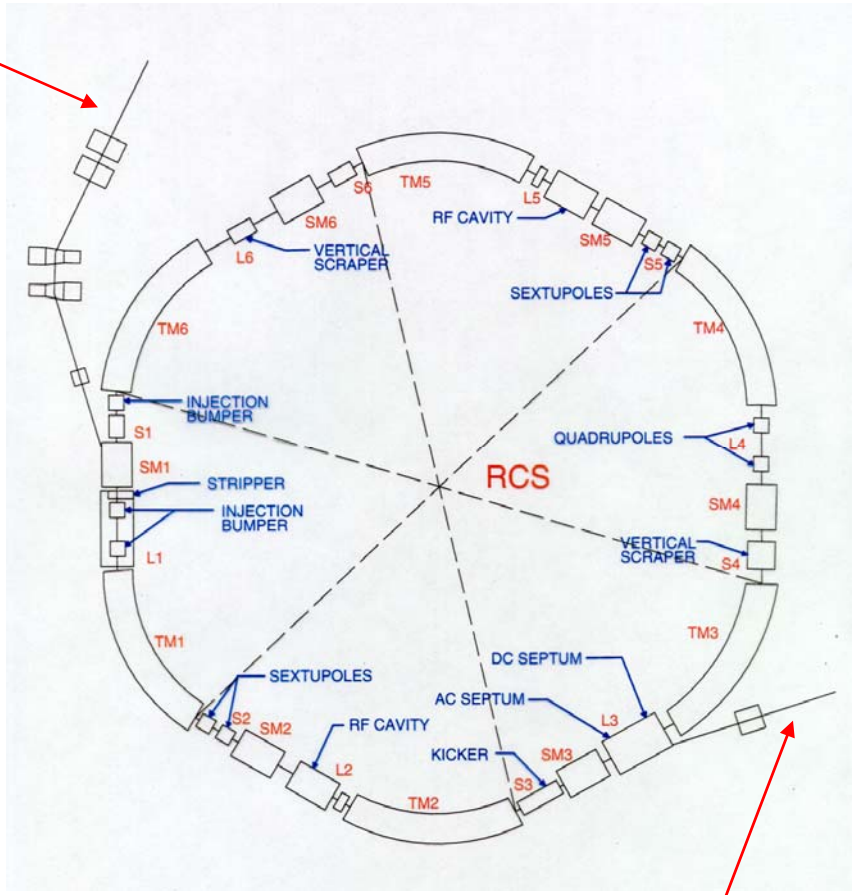
- Motivation
- Description of the Original IPNS RCS RF System
- Description of the Third Cavity RF System
- Installation and Commissioning of the Third Cavity RF System
- Plans for Operating Third Cavity at the Second Harmonic

Motivation

- Early indications suggested that the RF system was voltage limited.
- A third cavity would provide operational flexibility and possibly contribute to increased reliability.
- A third cavity would provide a platform for 2nd harmonic studies.

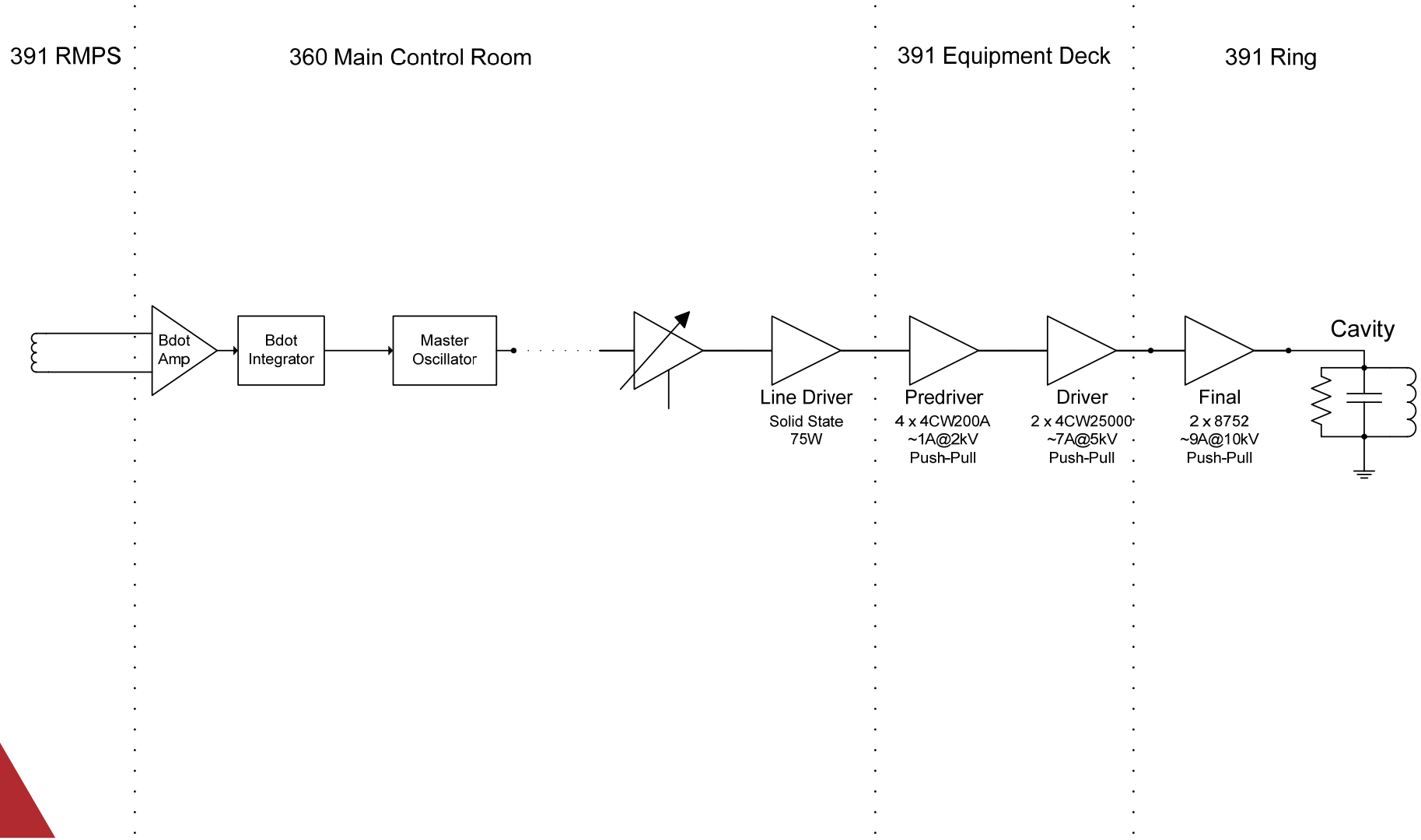
Original RCS RF System: RCS Machine Parameters

- Circumference = 42.9 m
- f_{inj} ~ 2.21 MHz, E_{inj} = 50 MeV
- f_{ext} ~ 5.14 MHz, E_{ext} = 450 MeV
- ~3.7x10^{12} protons injected
- ~3.2x10^{12} protons extracted
- Harmonic number = 1
- Repetition rate = 30 Hz
- Typical average beam current ~ 15uA
- Cavities located in the L2 and L5 straight sections
- ~21kV total accelerating voltage w/2 cavities



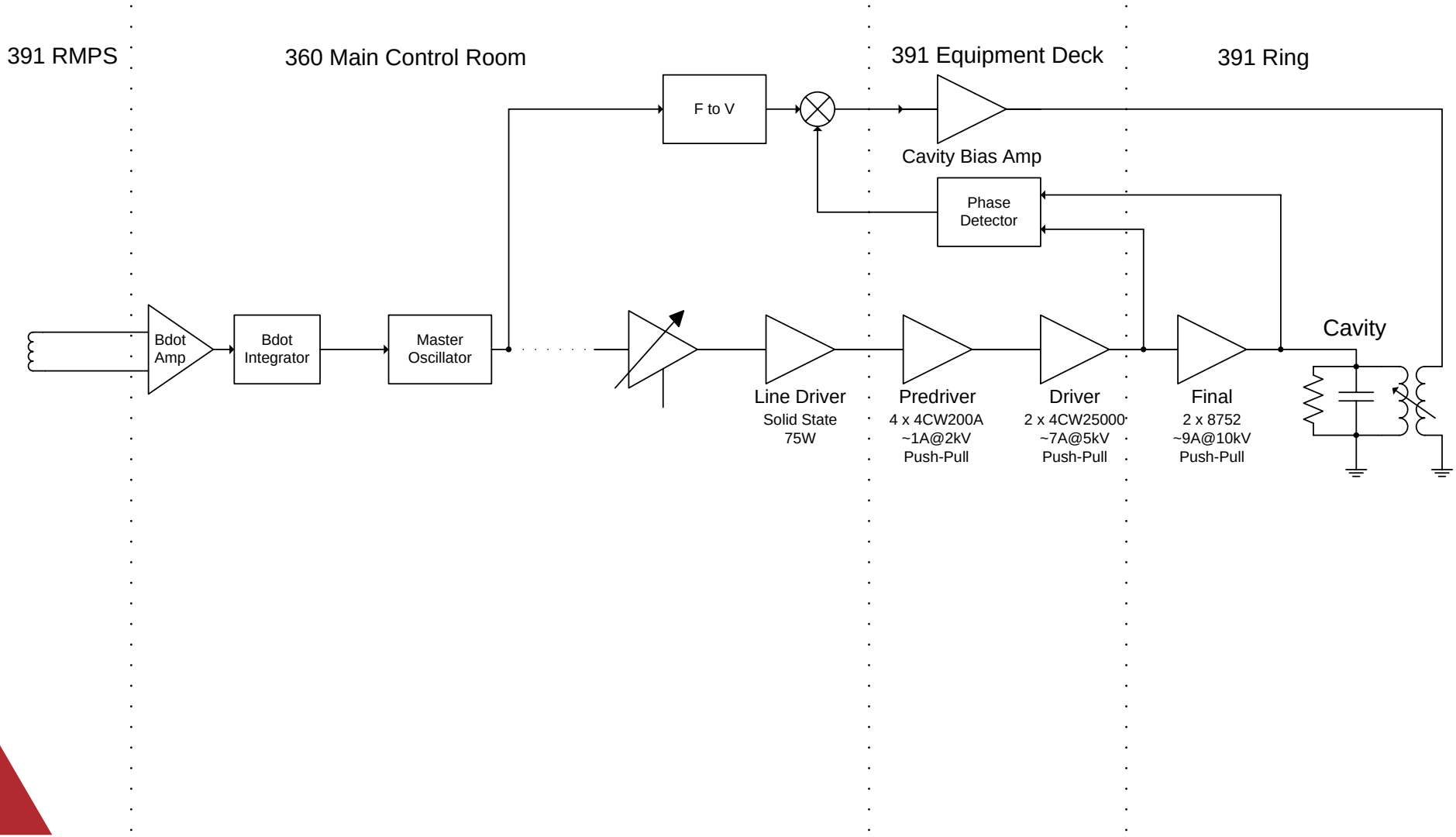
Original RCS RF System: Typical RF System

- Amplifier Chain



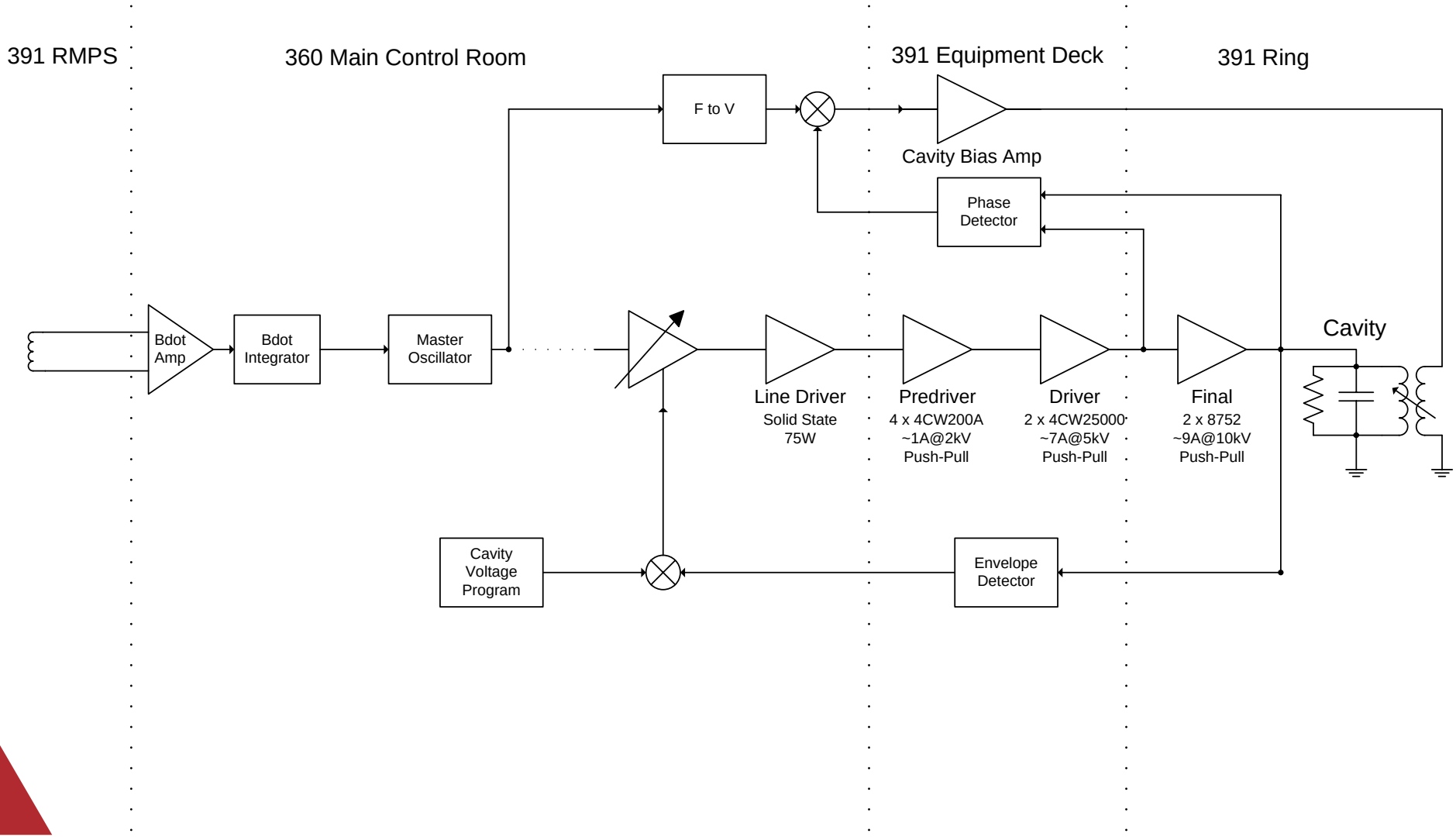
Original RCS RF System: Typical RF System

- Cavity Tuning



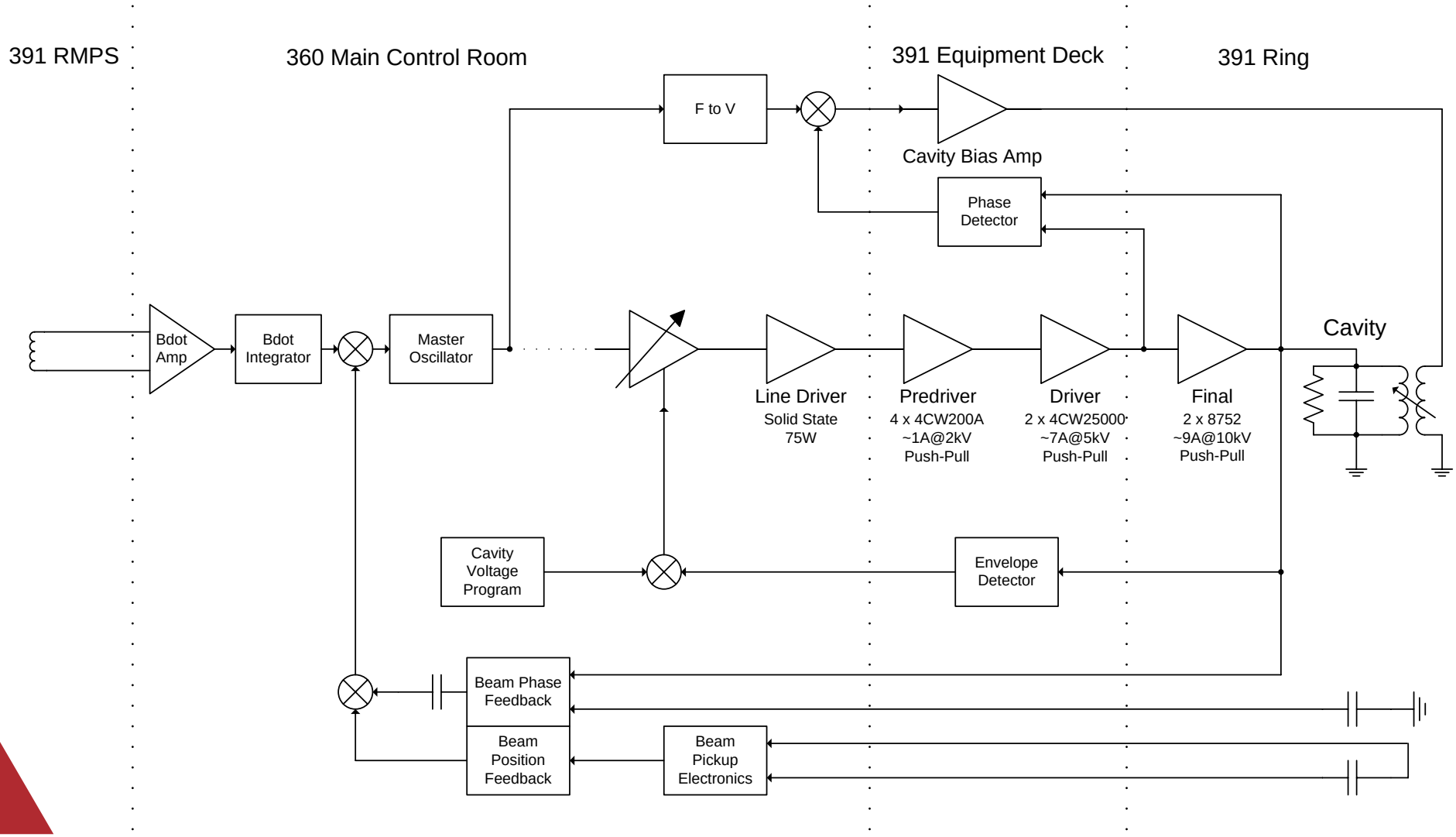
Original RCS RF System: Typical RF System

- Amplitude Control



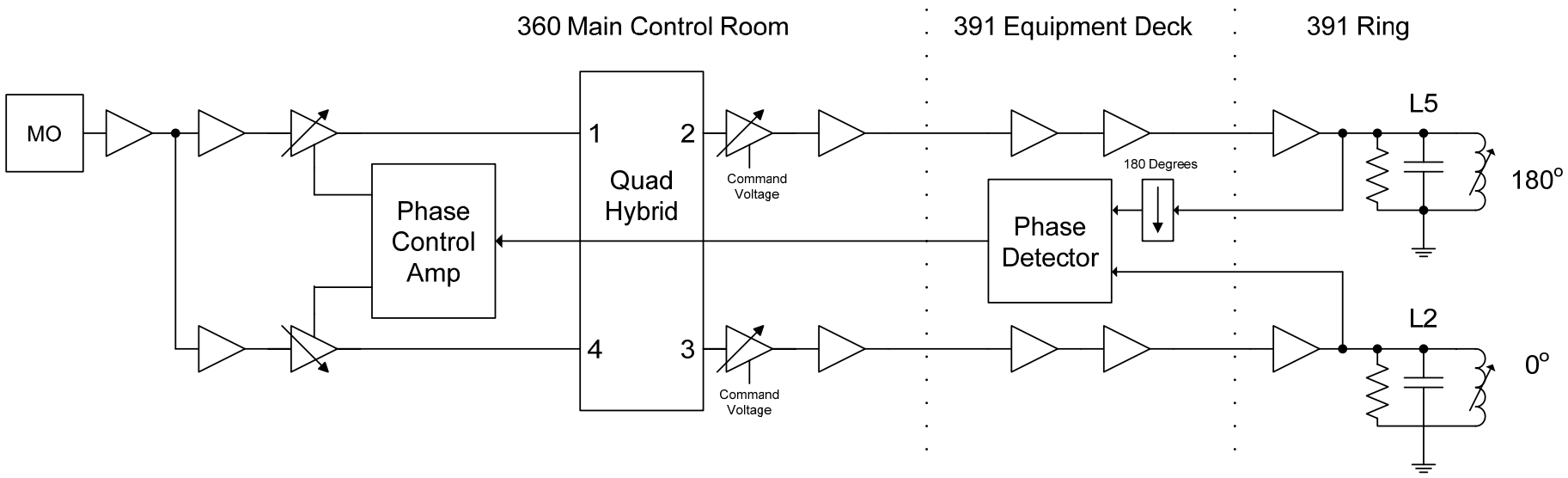
Original RCS RF System: Typical RF System

- Beam Position and Phase Control



Original RCS RF System: Typical RF System

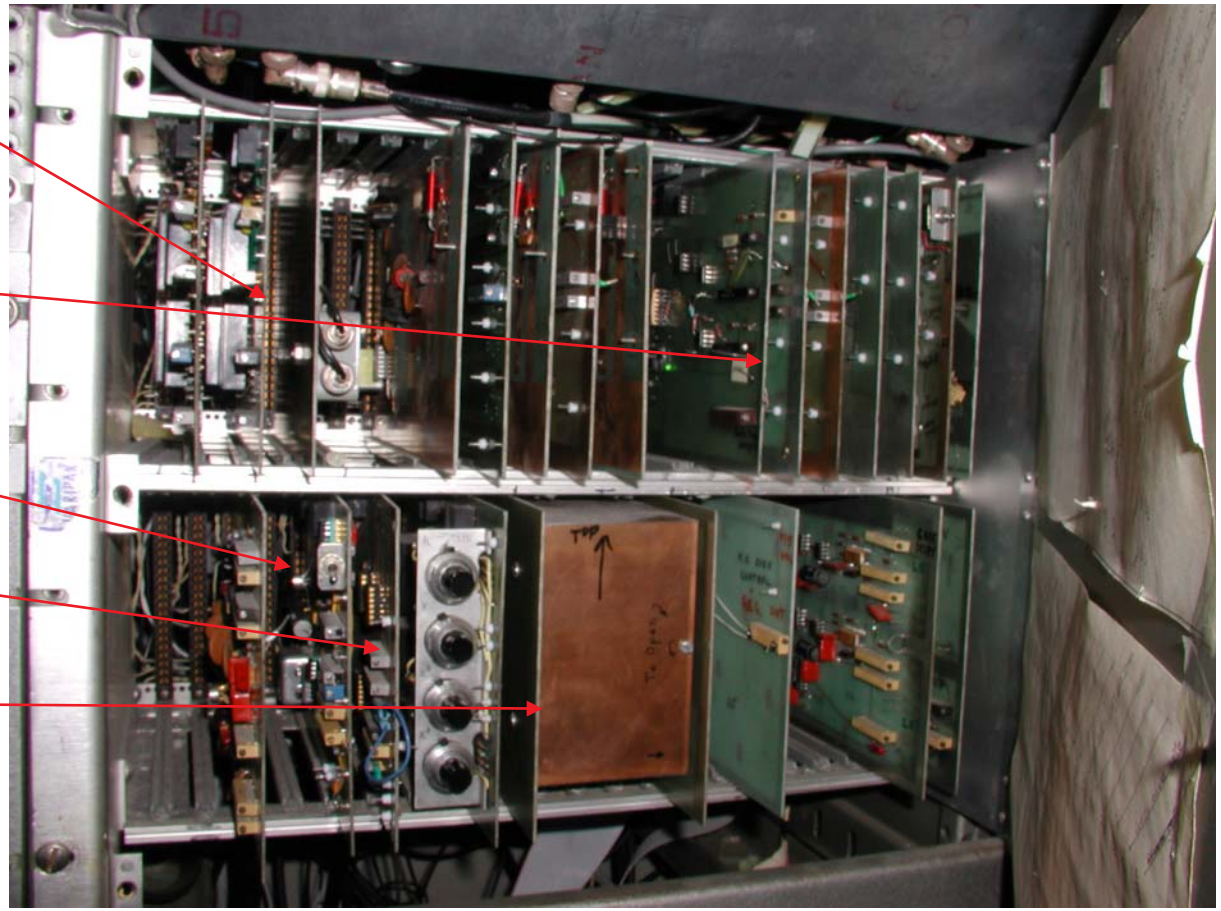
- Cavity to Cavity Phase Control



Original RCS RF System: Typical RF System

- Low Level RF Electronics

- **Cavity to cavity phase control**
- **Amplitude control**
- **Bdot integrator**
- **B offset and scaling**
- **Master oscillator**



Original RCS RF System: Typical RF System

- Predriver, Driver and Cavity Bias Supply

- **Predriver/Driver Cabinet**
- **Predriver Plate Supply, ~1A@2kV**
- **Driver Plate Supply, ~7A@5kv**

Original RCS RF System: Typical RF System

- Predriver, Driver and Cavity Bias Supply

- **Cavity Bias Supply, 0 – 1000A, 30VDC**
- **Grid and Screen Supplies, Interlock Status and Control**
- **Predriver/Driver Cabinet**

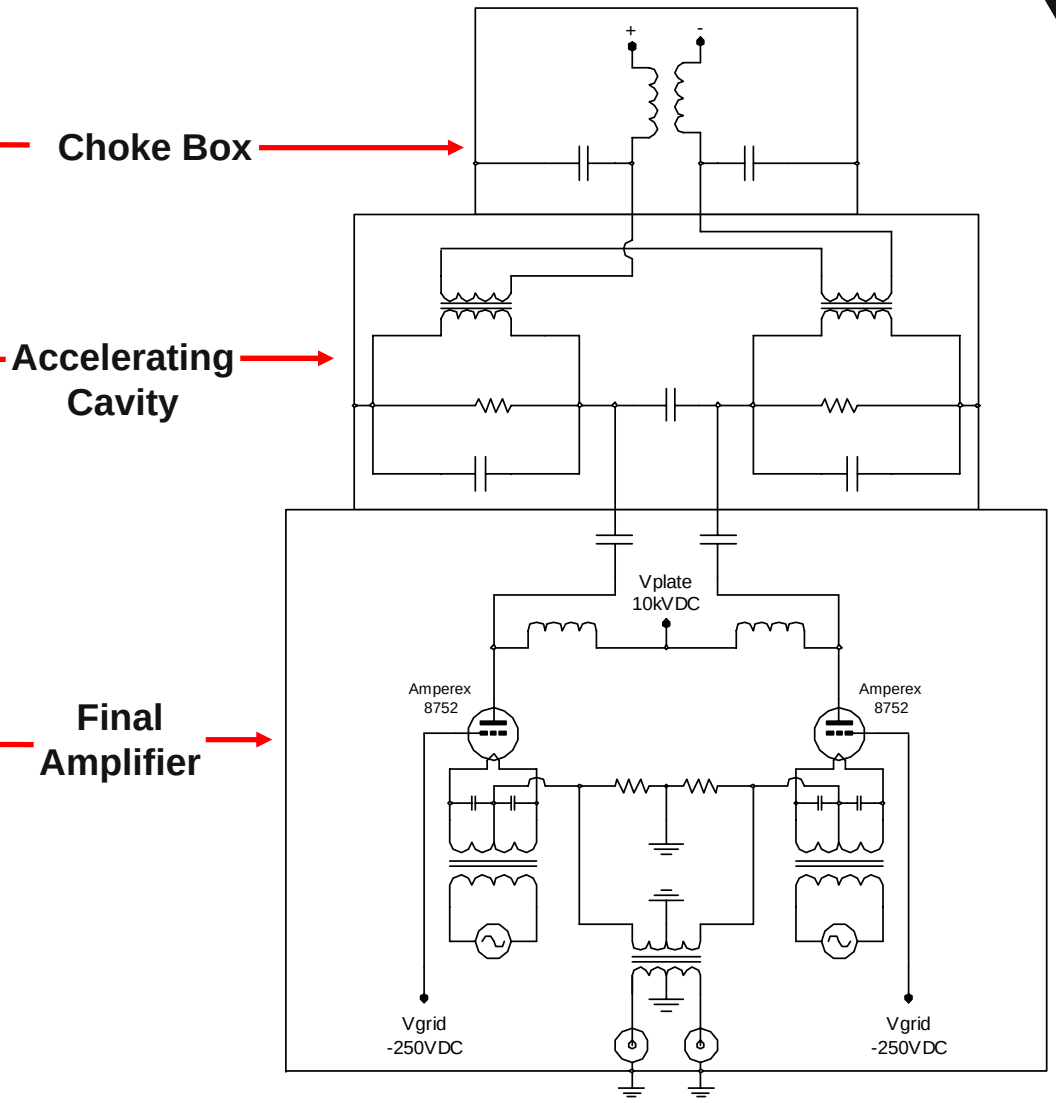
Original RCS RF System: Typical RF System

- Final Plate Supply (the “Reeves”)

- **Single Supply provide plate voltage to L2 and L5 finals.**
- **~18A@10kV total.**

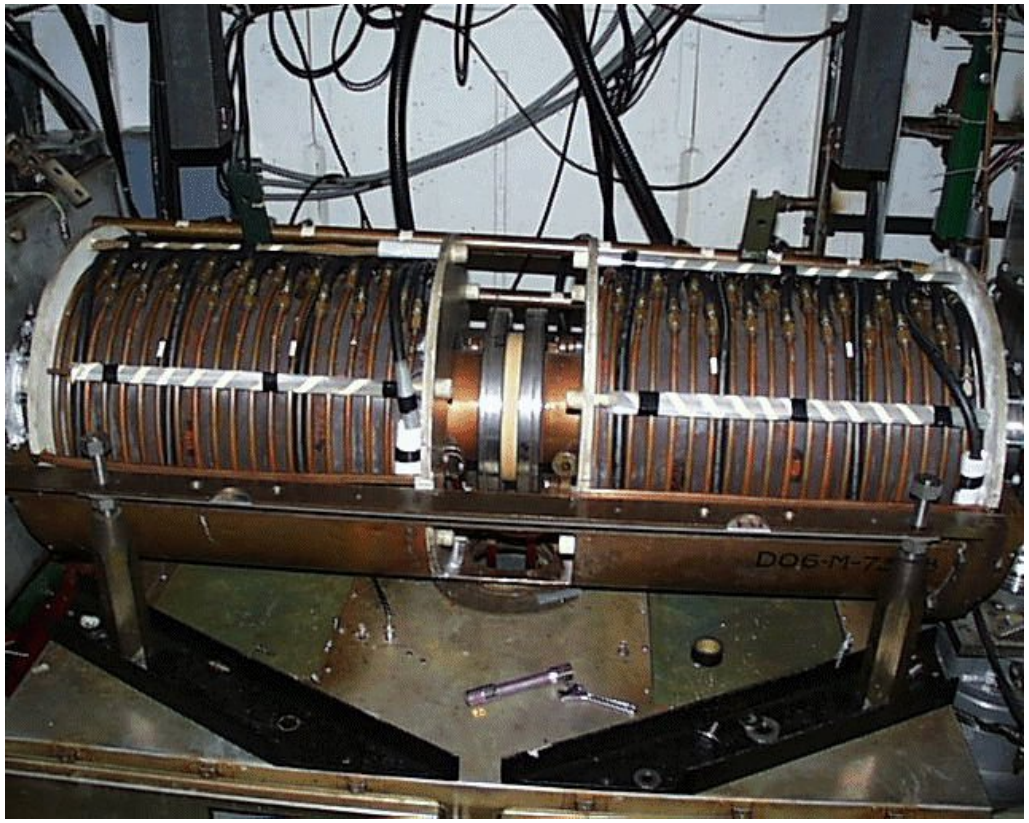
Original RCS RF System: Typical RF System

- Final, Cavity and Cavity Bias Choke Box



Original RCS RF System: Typical RF System

- Ferrite-Loaded, Coaxial Cavity



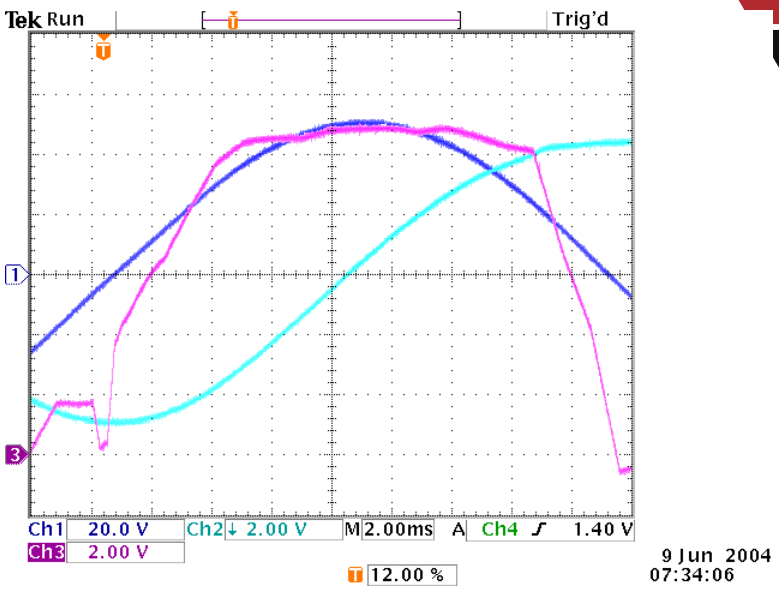
- **Cavities are ferrite-loaded, coaxial structures, with the accelerating gap in the center.**

- **Cavities are tuned by magnetic biasing of the ferrite.**
- **Each cavity contains two ferrite stack modules that are each ~20 inches long and ~14 inches in diameter.**
- **Each stack is made up of 20 Philips type 4H ferrite torroids (mu ~ 350), with edge-cooled copper cooling disks, insulating end pieces.**
- **Two figure-eight, parallel-connected, water-cooled conductors provide for biasing.**
- **The gap is formed by a ceramic spacer shunted with glass-vacuum capacitors.**
- **The cavity is a balanced device and driven push-pull.**

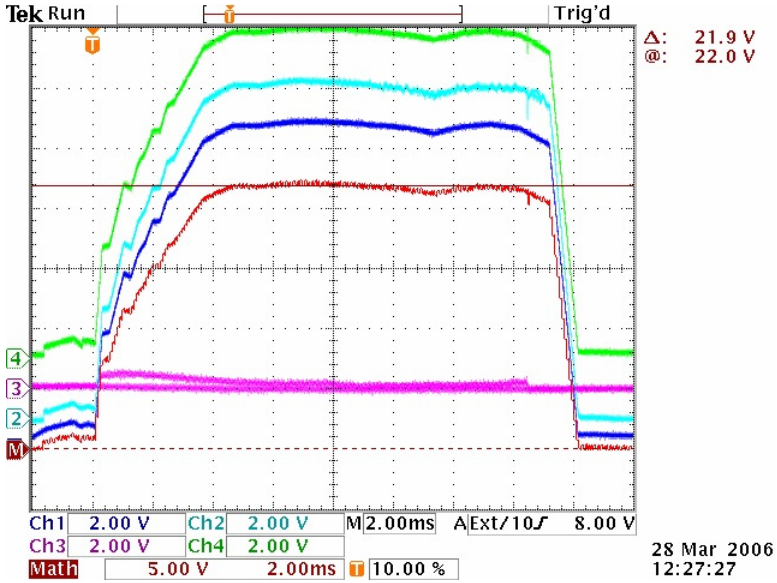
Original RCS RF System: Typical RF System

- Typical Two Cavity Operation

  - **Cavity gap voltages are driven at RF frequency which is modulated from ~2.21 MHz at injection, to ~5.14 MHz at extraction.**

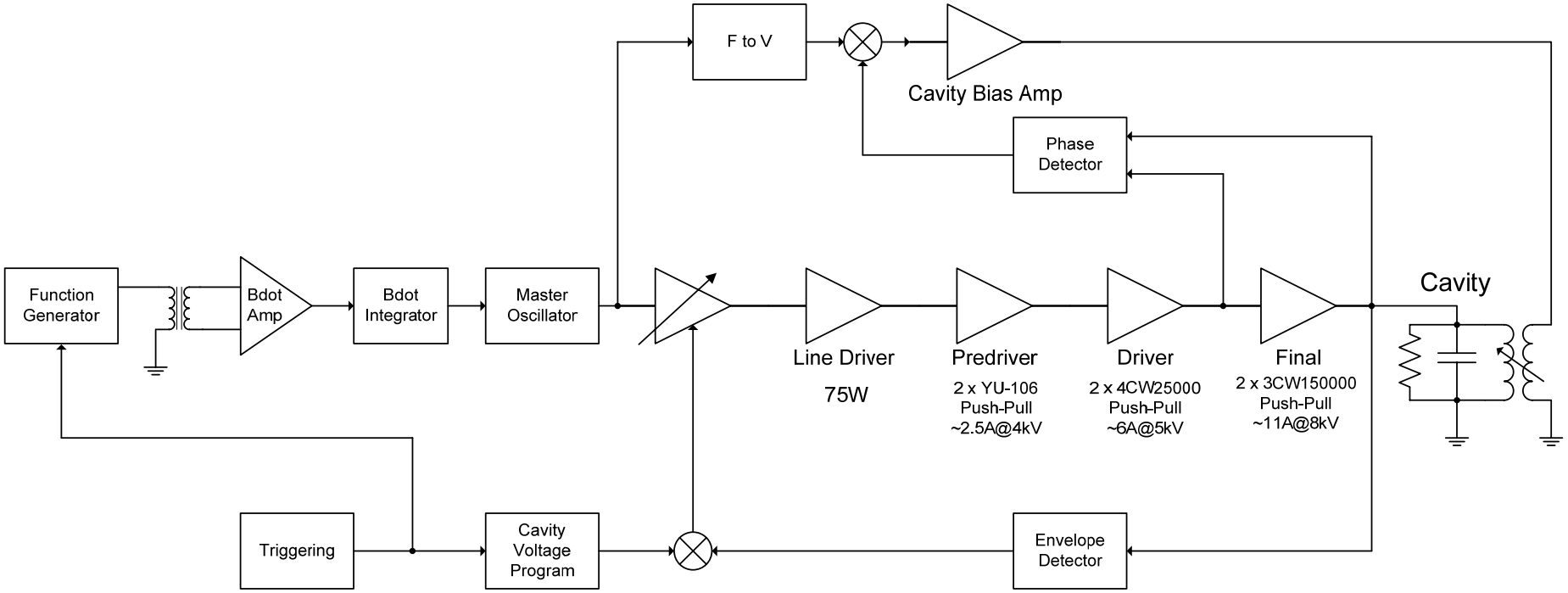


  - **Cavity gap voltages are amplitude modulated from a few hundred volts at injection, to ~10kV per gap at Bdot max.**



The Third Cavity RF System

- Third Cavity Test Stand



The Third Cavity RF System

- Time Line

June 1 – 16, 2005:

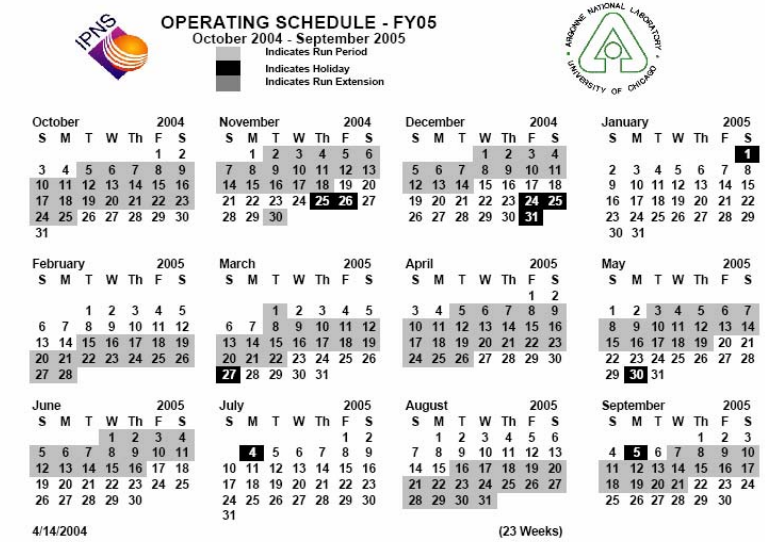
Two week around-the-clock operation in swept-frequency mode at ~11kV gap voltage.

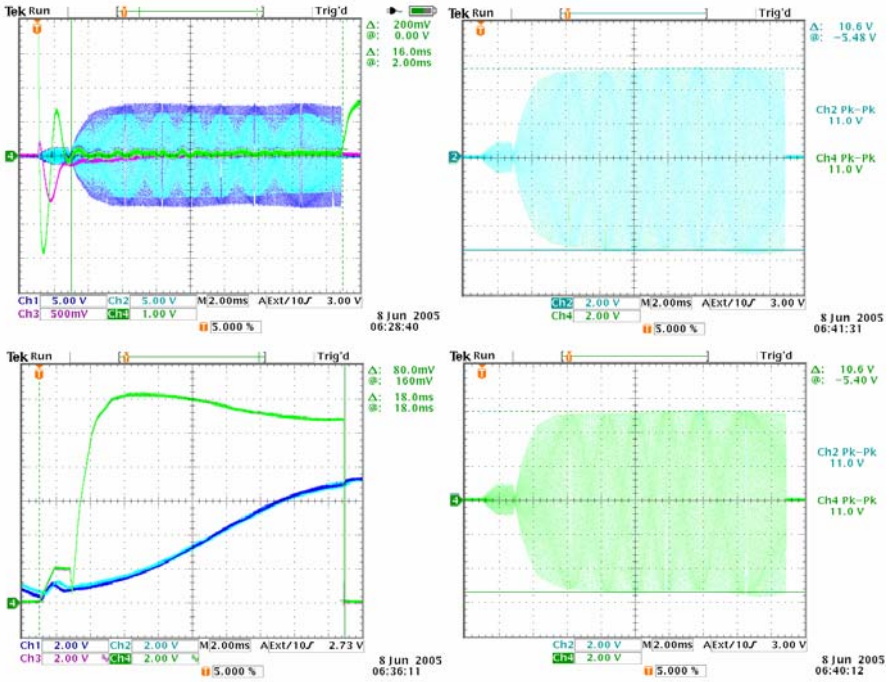
June 17 – August 15, 2005:

Disassembled equipment and moved major components into place.

August 16, 2005:

Typical operating schedule started after summer shutdown, limiting access to working areas.





The Third Cavity RF System

- Construction Photos: Test Stand

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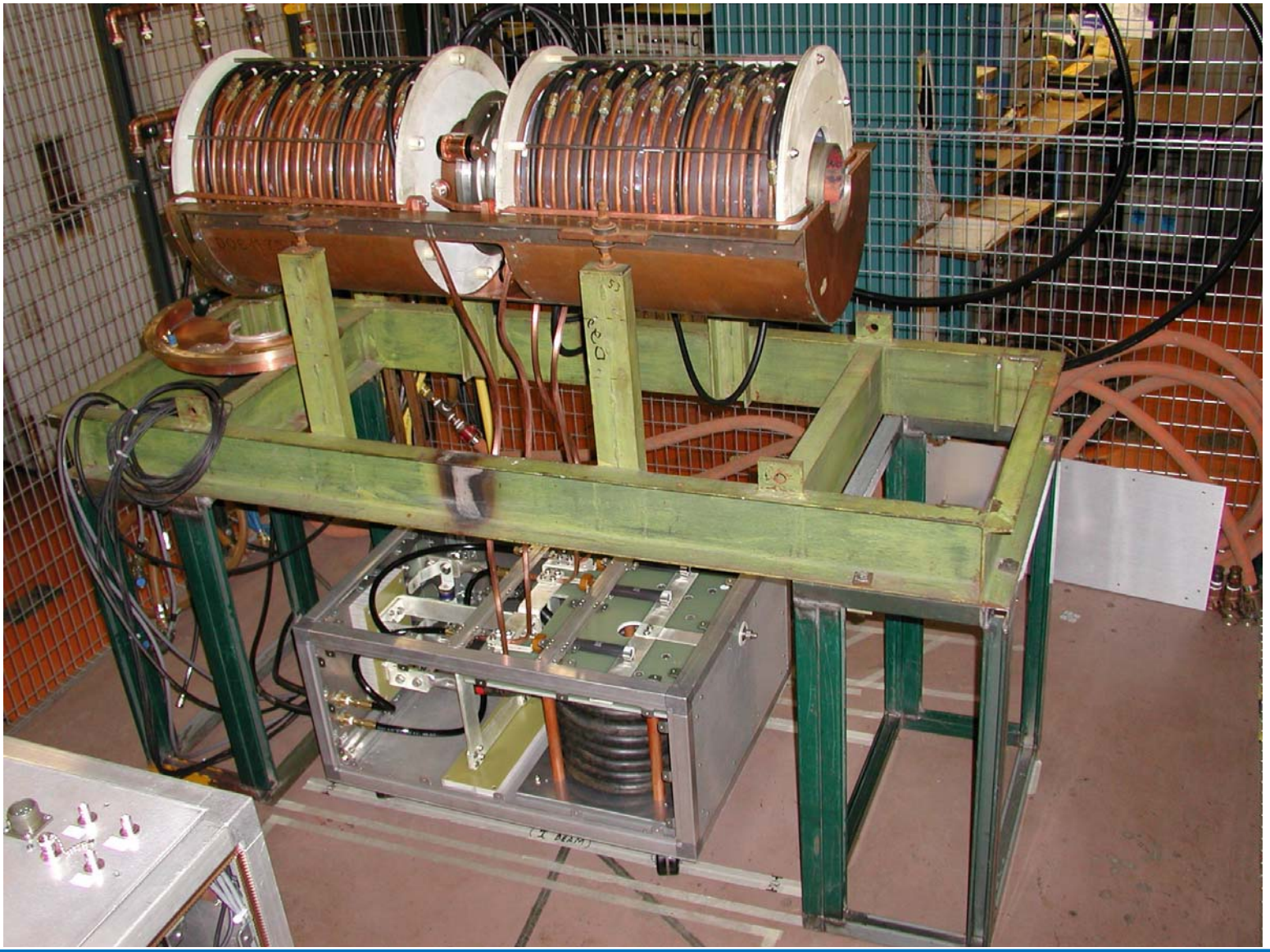
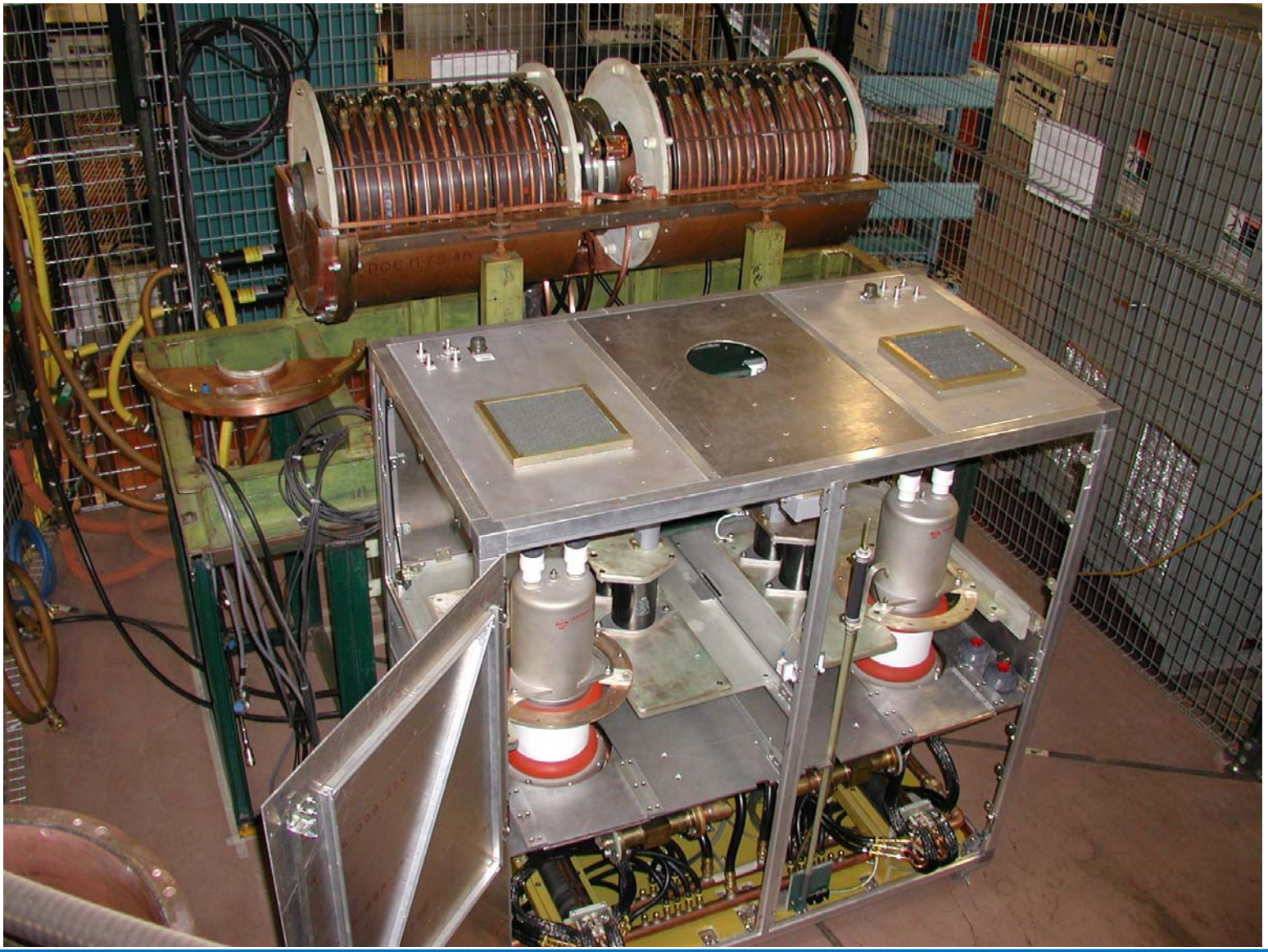


The Third Cavity RF System

- Construction Photos: Test Stand



The Third Cavity RF System

- Construction Photos: Test Stand

The Third Cavity RF System

- Predriver and Driver

- **Amplitude and Phase Detection Electronics**
- **Driver**
- **Predriver**

The Third Cavity RF System

- Cavity Bias Supply, Final Grid and Filament Supply Cabinet

- **Cavity Bias Supply, 0 – 1000A, 15VDC**
- **Final Grid and Filament Supply Cabinet**

The Third Cavity RF System

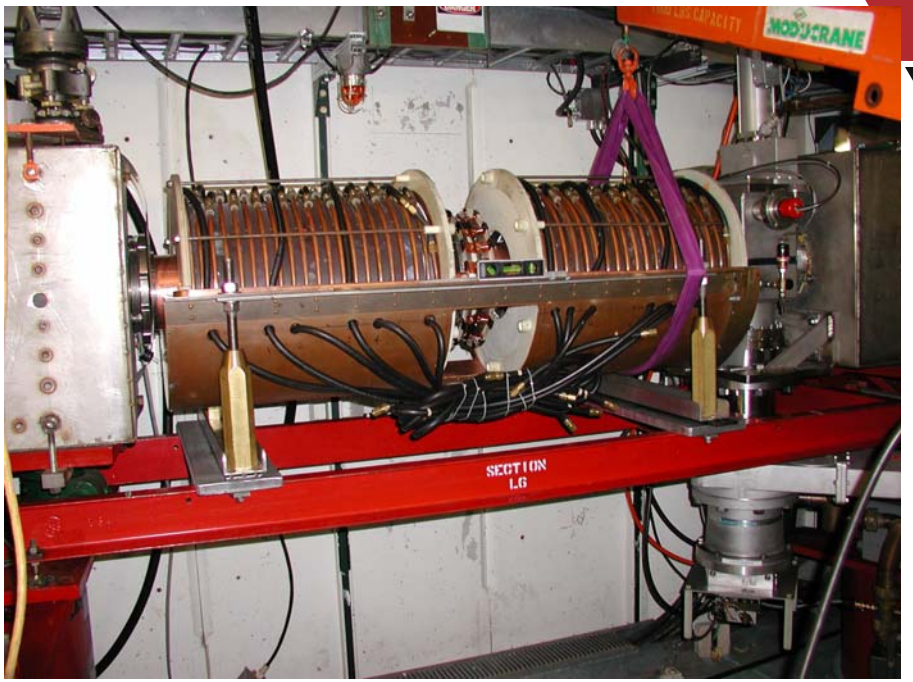
- "NWL" Final Plate Supply

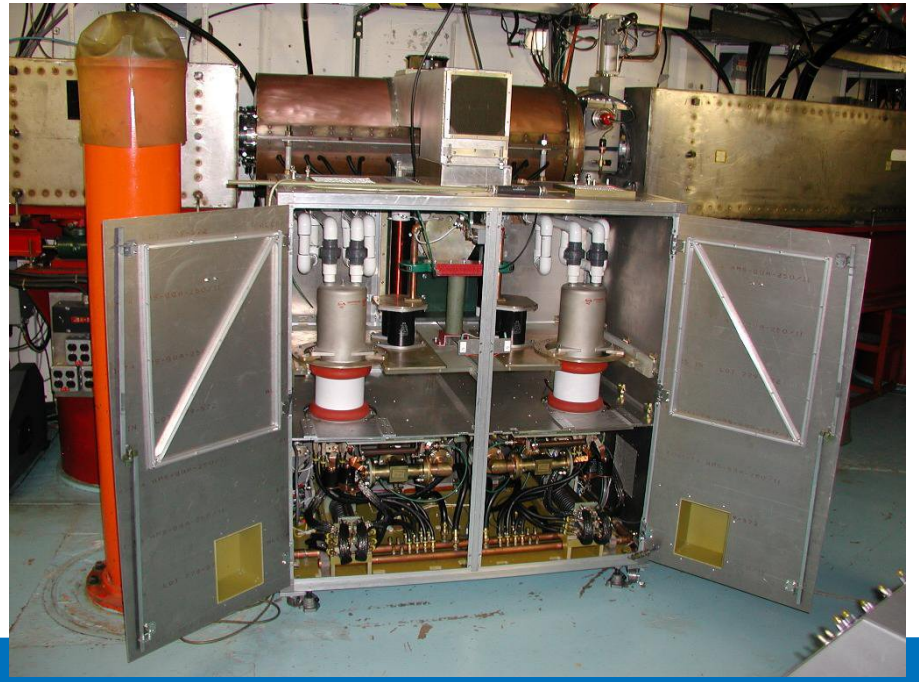
- **24A@7kV or 12A@14kV T-R Set**

- **Modified to include soft start and crowbar**

The Third Cavity RF System

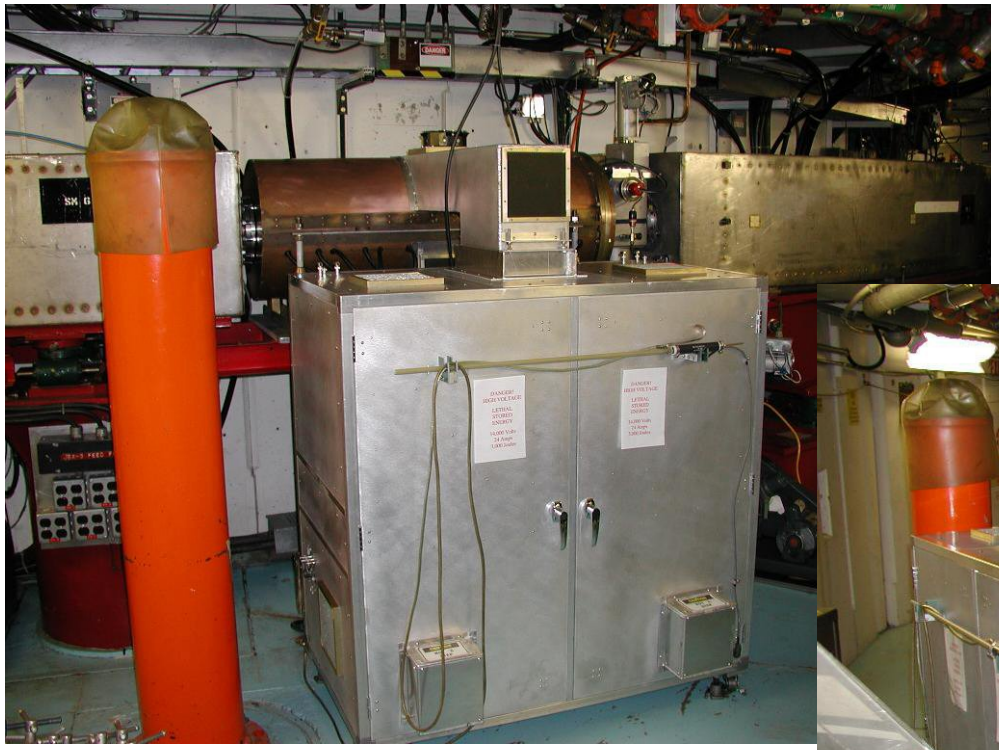
- Installation

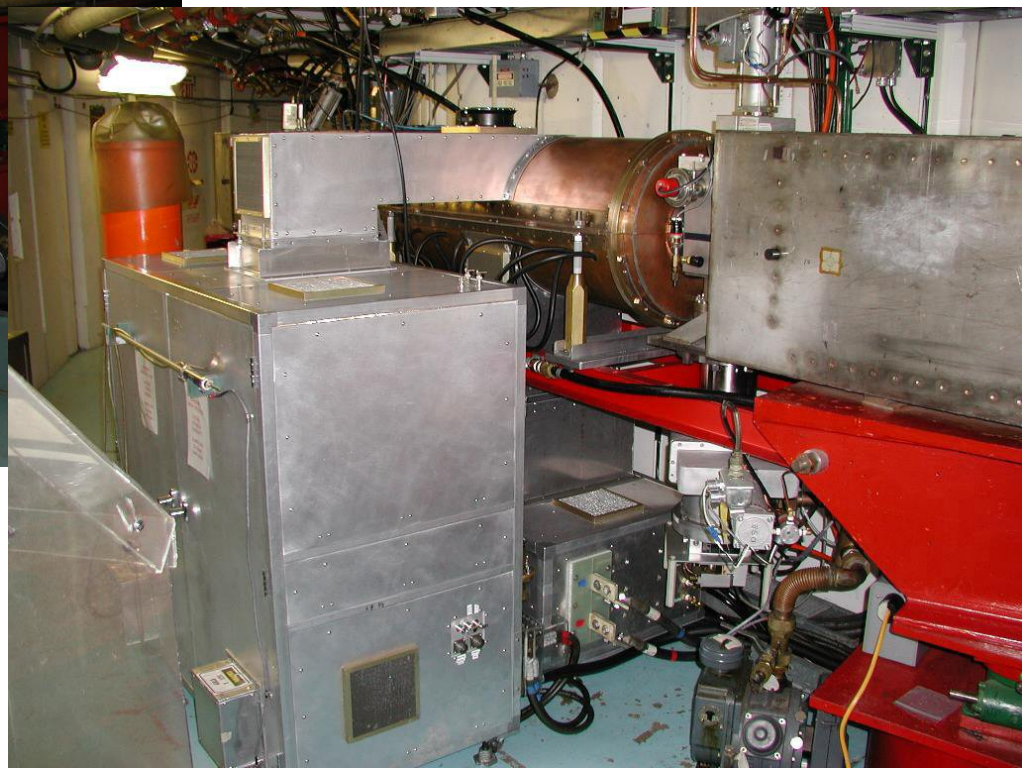




The Third Cavity RF System

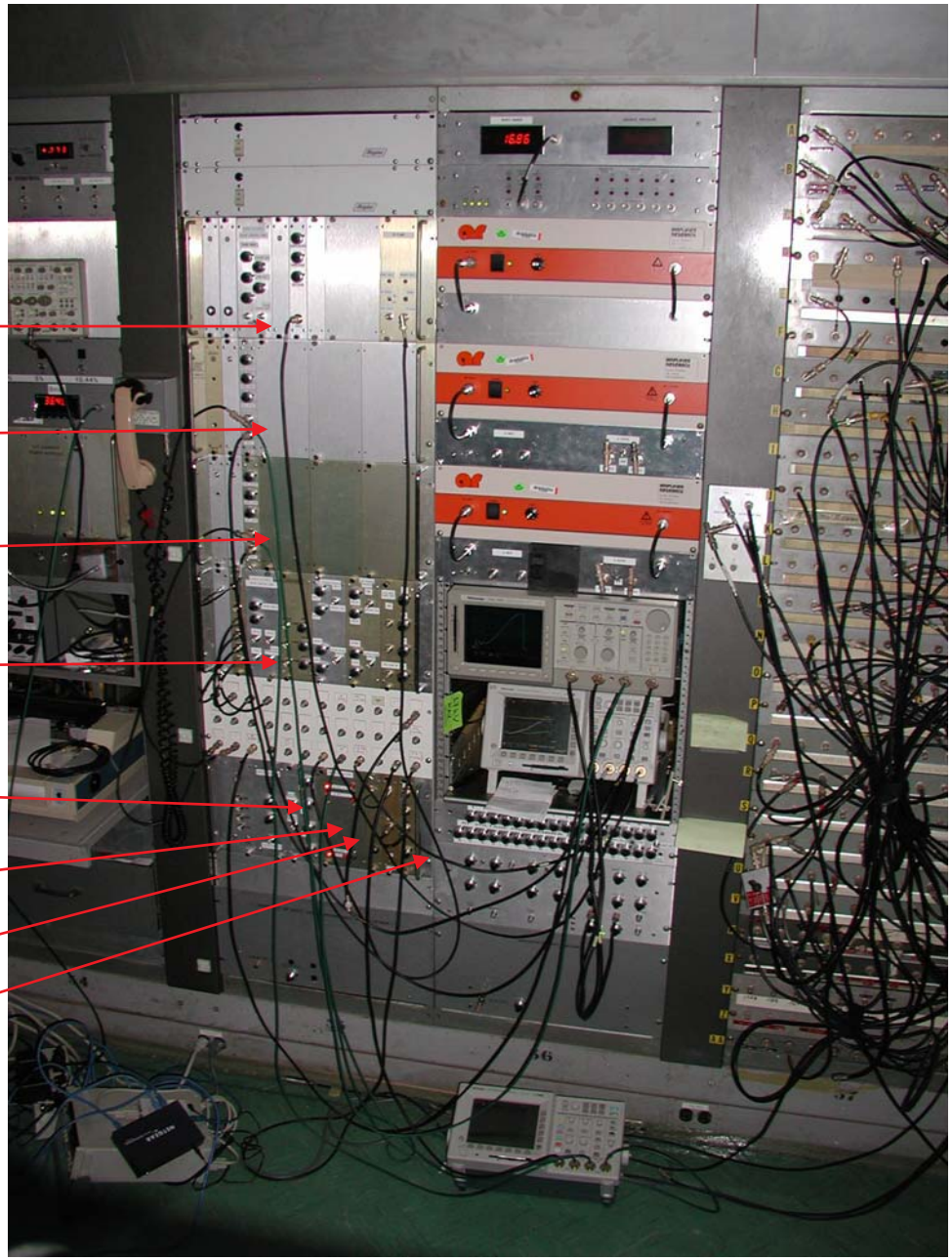
- Installation





The Third Cavity RF System

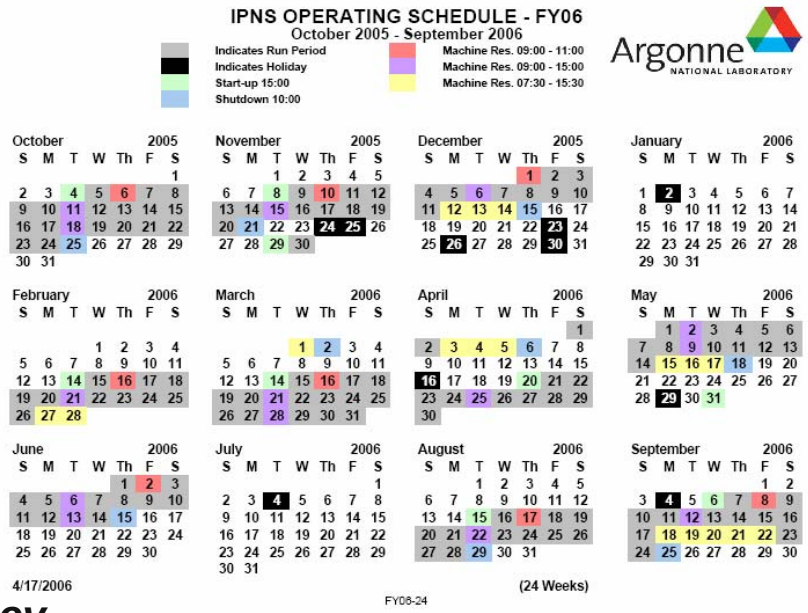
- Low Level Electronics



- **L6 Amplitude Control**
- **L5 Amplitude Control**
- **L2 Amplitude Control**
- **Cavity Phase Control**
- **Bdot Integrator**
- **B Offset and Scaling**
- **Master Oscillator**
- **Cavity Bias**

The Third Cavity RF System

- Time Line (continued)

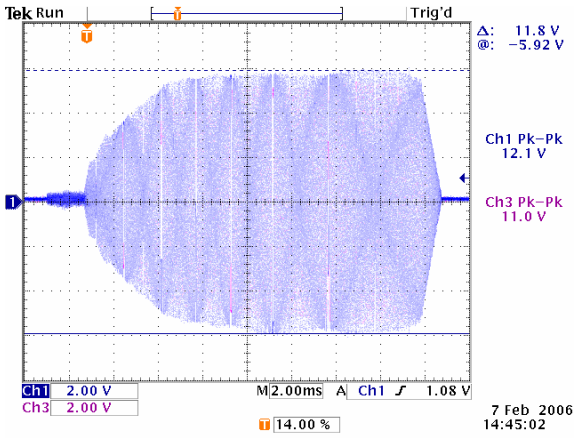


December 14, 2005 – February 3, 2006:

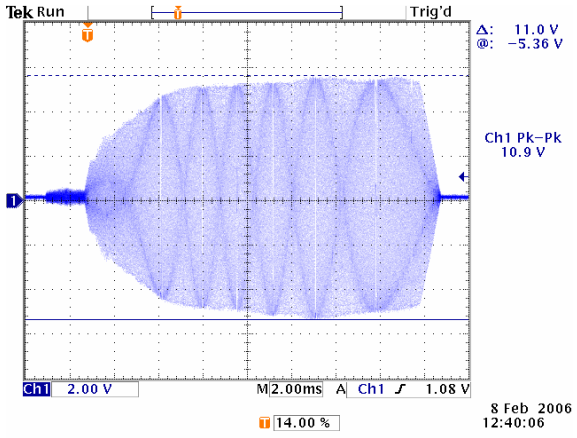
Plumbed in utilities, pulled cables, checked interlocks, performed safety reviews, performed crowbar test, powered on equipment, checked out amplifiers.

February 7, 2006:

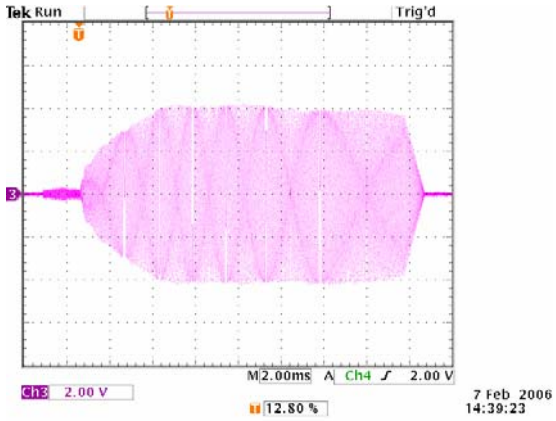
Operated all three cavities in swept frequency mode to full voltage (> 30kV total) without L2-L6 cavity phase control.



L2 Cavity Upstream Gap Voltage, 1kV/volt



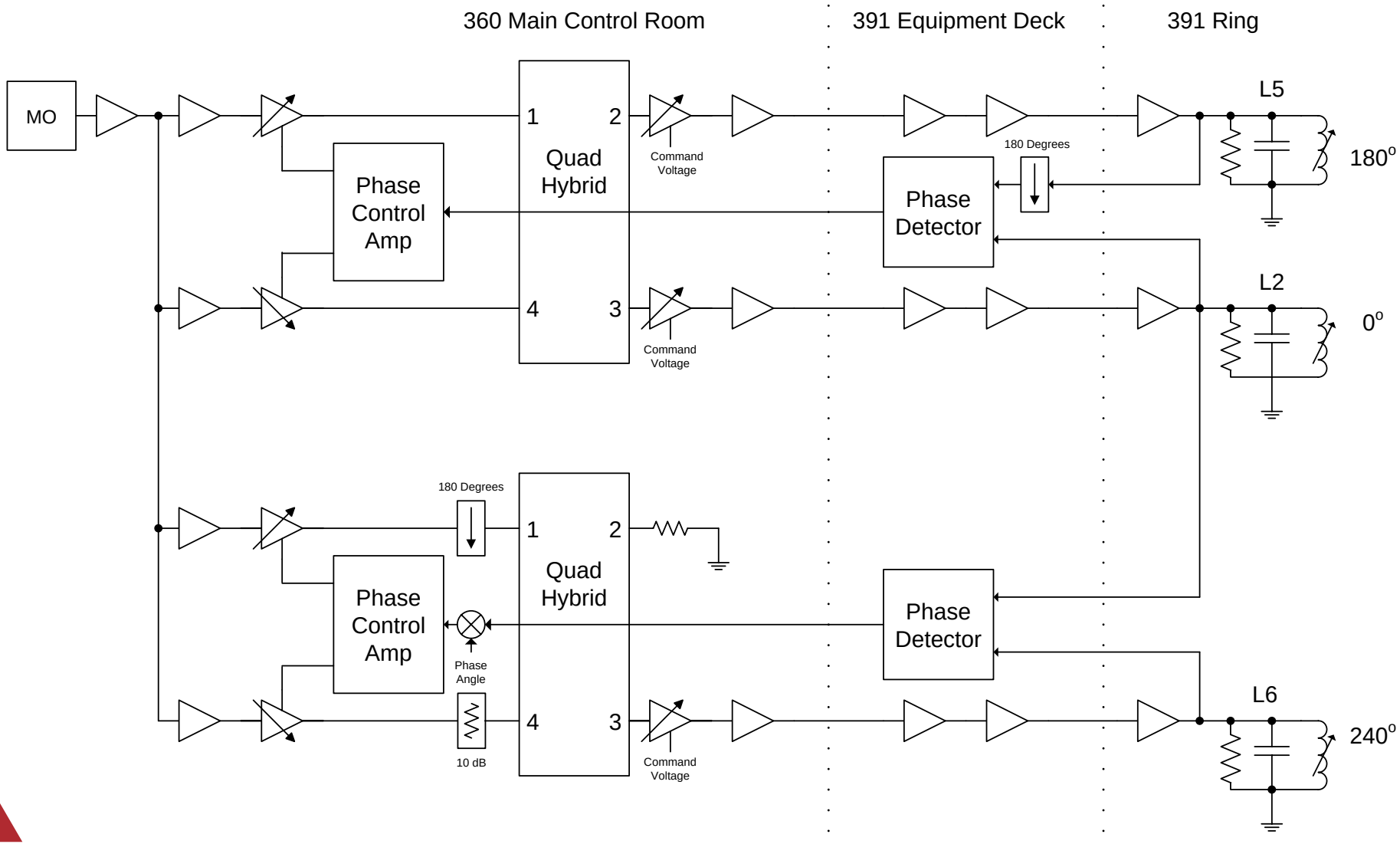
L5 Cavity Upstream Gap Voltage, 1kV/volt



L6 Cavity Gap Voltage

The Third Cavity RF System

- Cavity to Cavity Phase Control



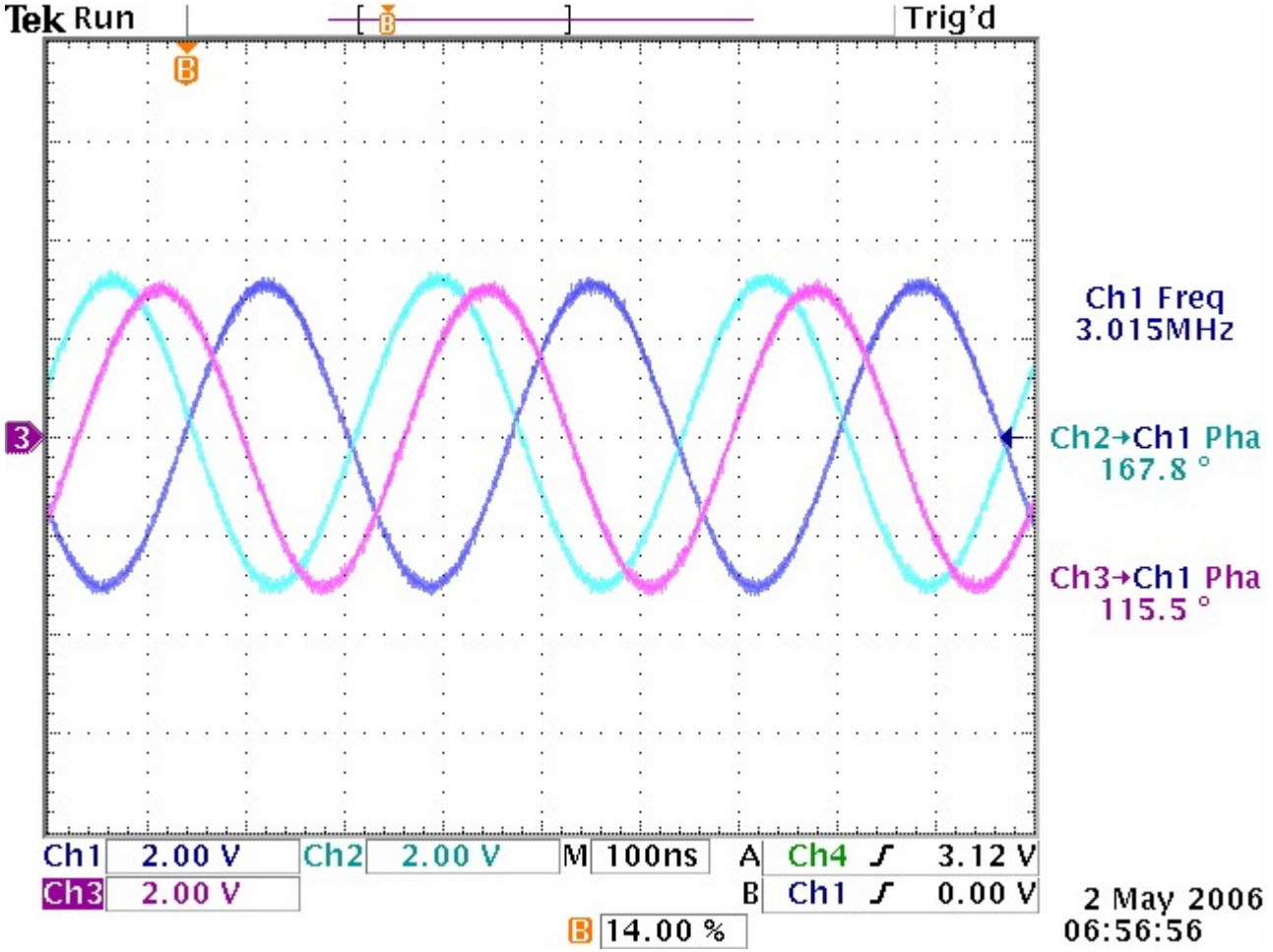
The Third Cavity RF System

- Cavity to Cavity Phase Control

CH1: L2 Gap Voltage

CH2: L5 Gap Voltage

CH3: L6 Gap Voltage

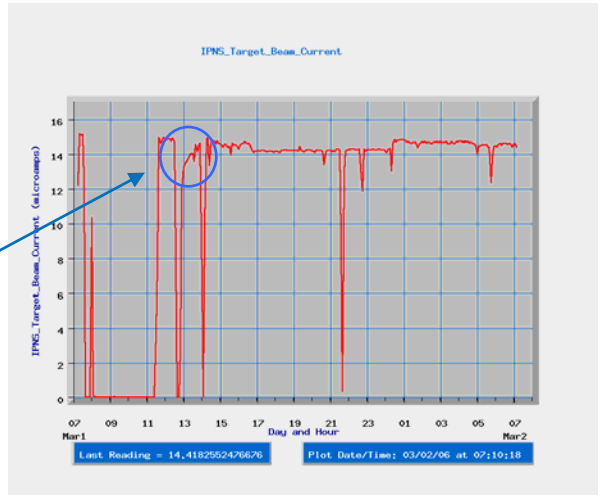


The Third Cavity RF System

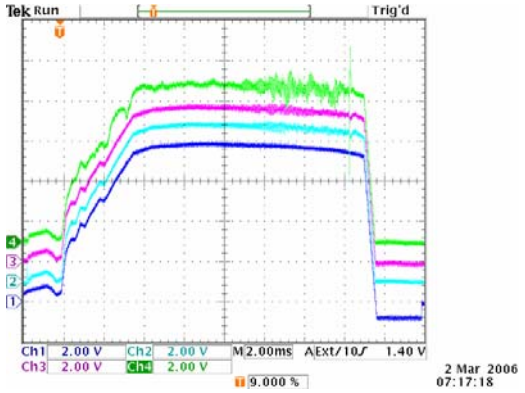
- Time Line (continued)

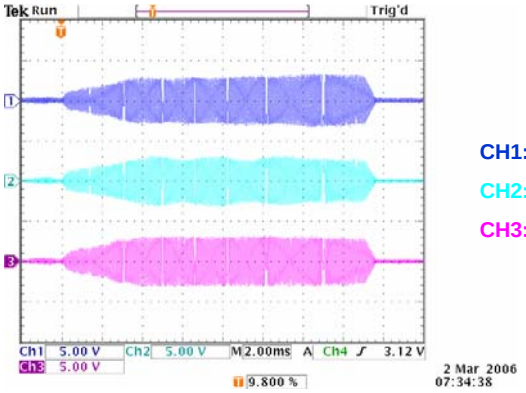
March 1, 2006:

Implemented L2-L6 cavity phase control and operated all three cavities with beam (> 24kV total).



Before retuning

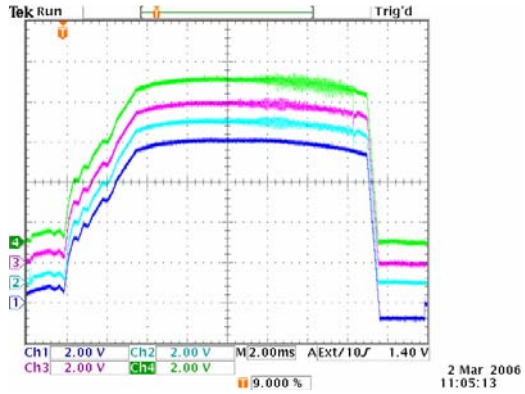


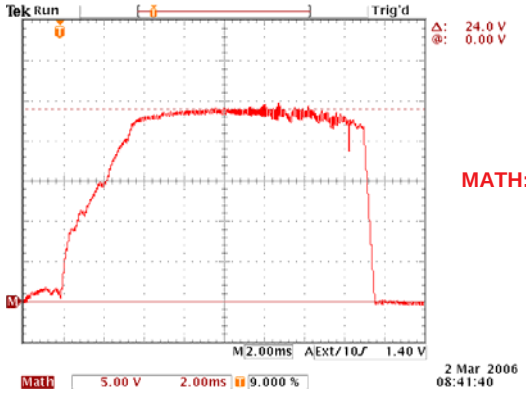


CH1: L2 Gap Voltage
CH2: L5 Gap Voltage
CH3: L6 Gap Voltage

CH1: Gap Voltage Program
CH2: L2 Rectified Gap Voltage
CH3: L5 Rectified Gap Voltage
CH4: L6 Rectified Gap Voltage

After retuning





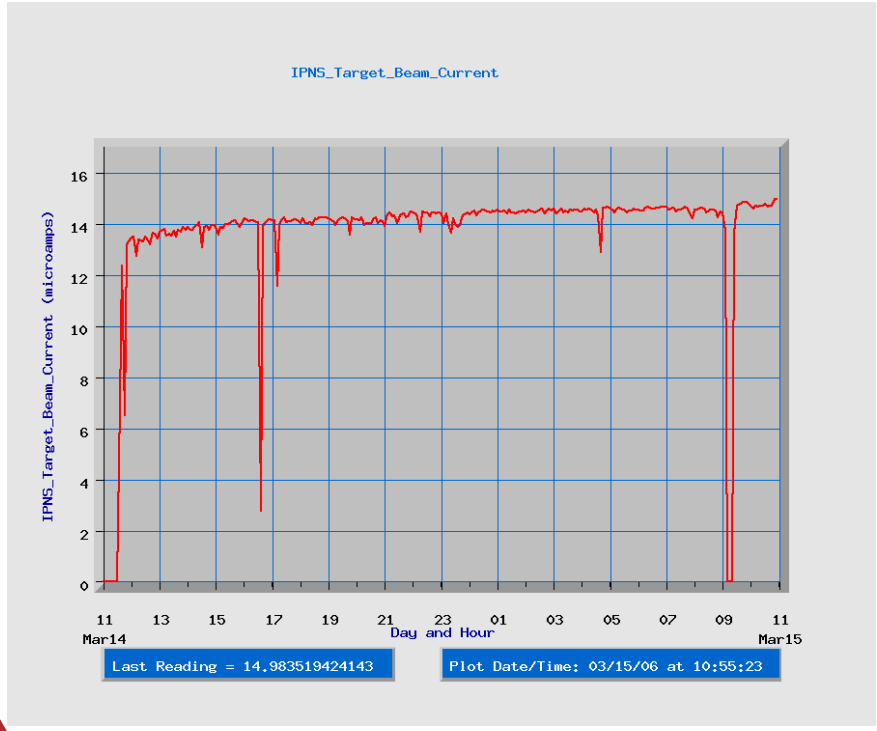
MATH: Total Gap Voltage

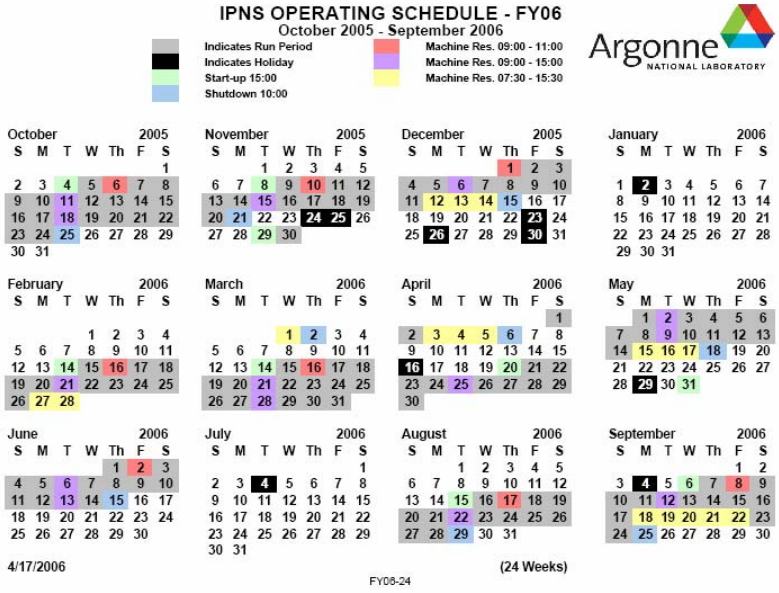
The Third Cavity RF System

- Time Line (continued)

March 14 – April 7, 2006:

Three cavity operation.



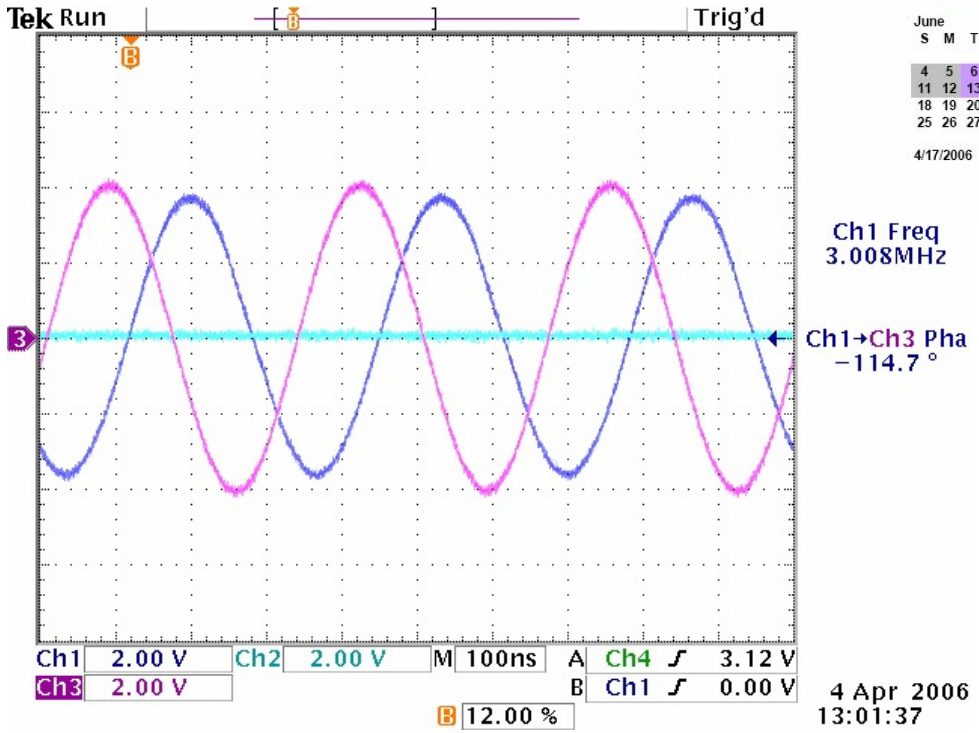


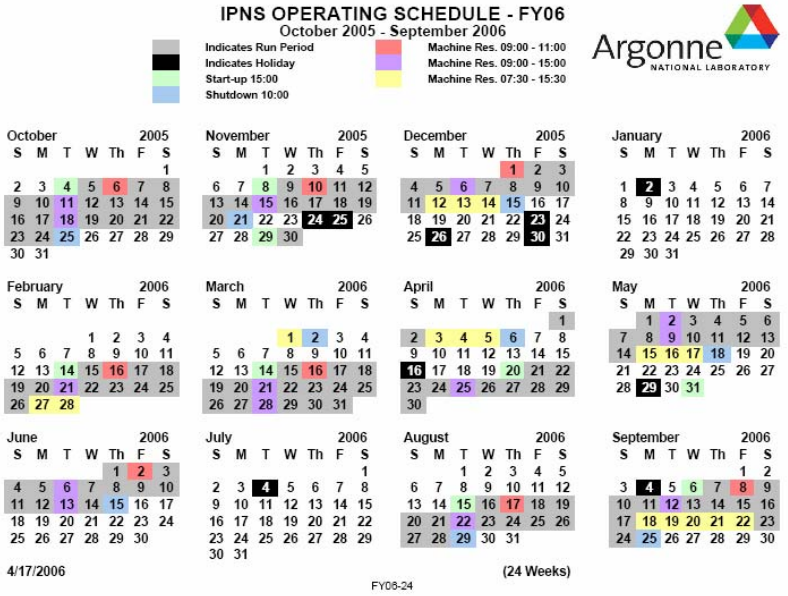
The Third Cavity RF System

- Time Line (continued)

April 4, 2006:

L2 – L6 operation with beam (~13.5uA).





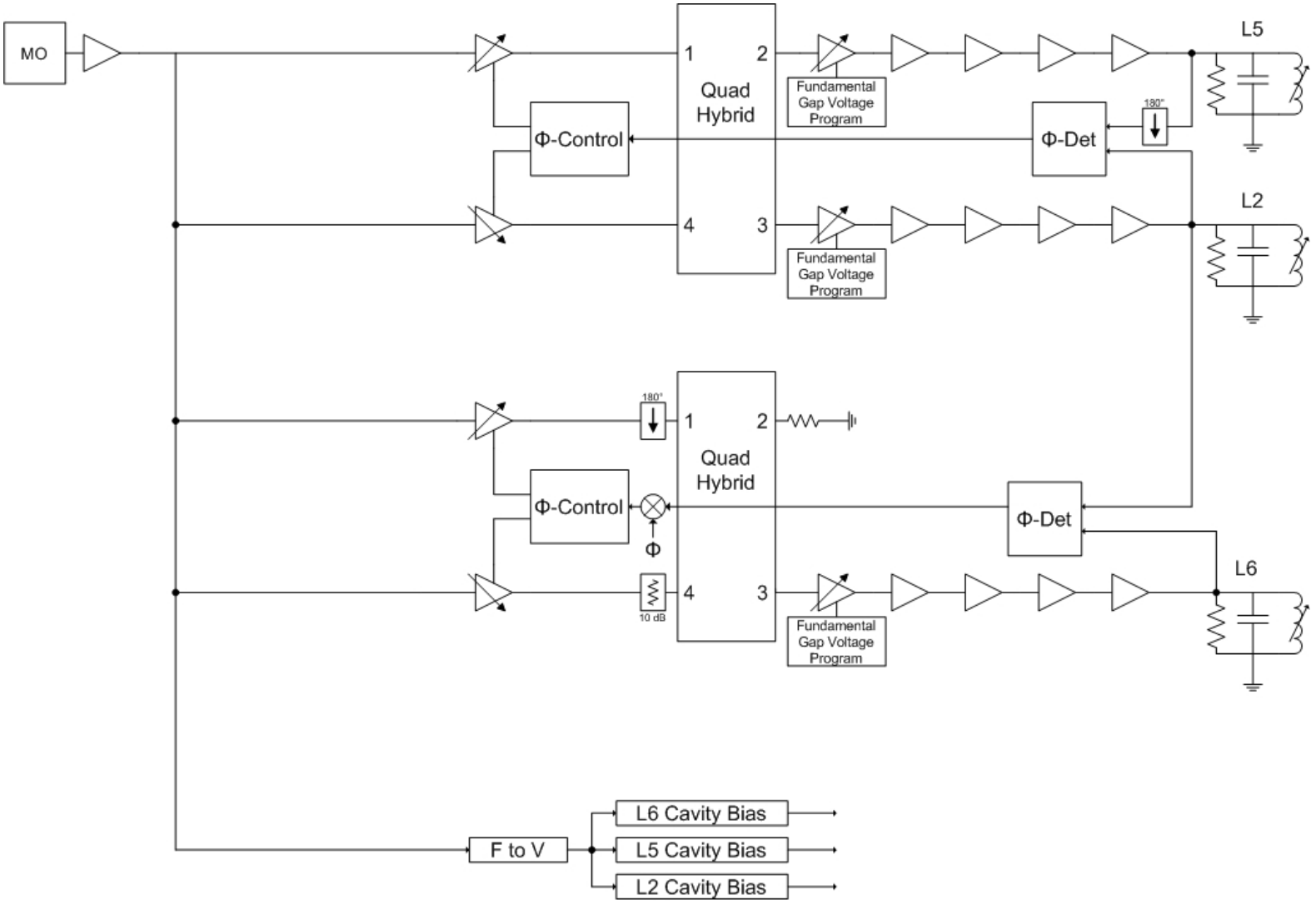
CH1: L2 Gap Voltage

CH2: L5 Gap Voltage

CH3: L6 Gap Voltage

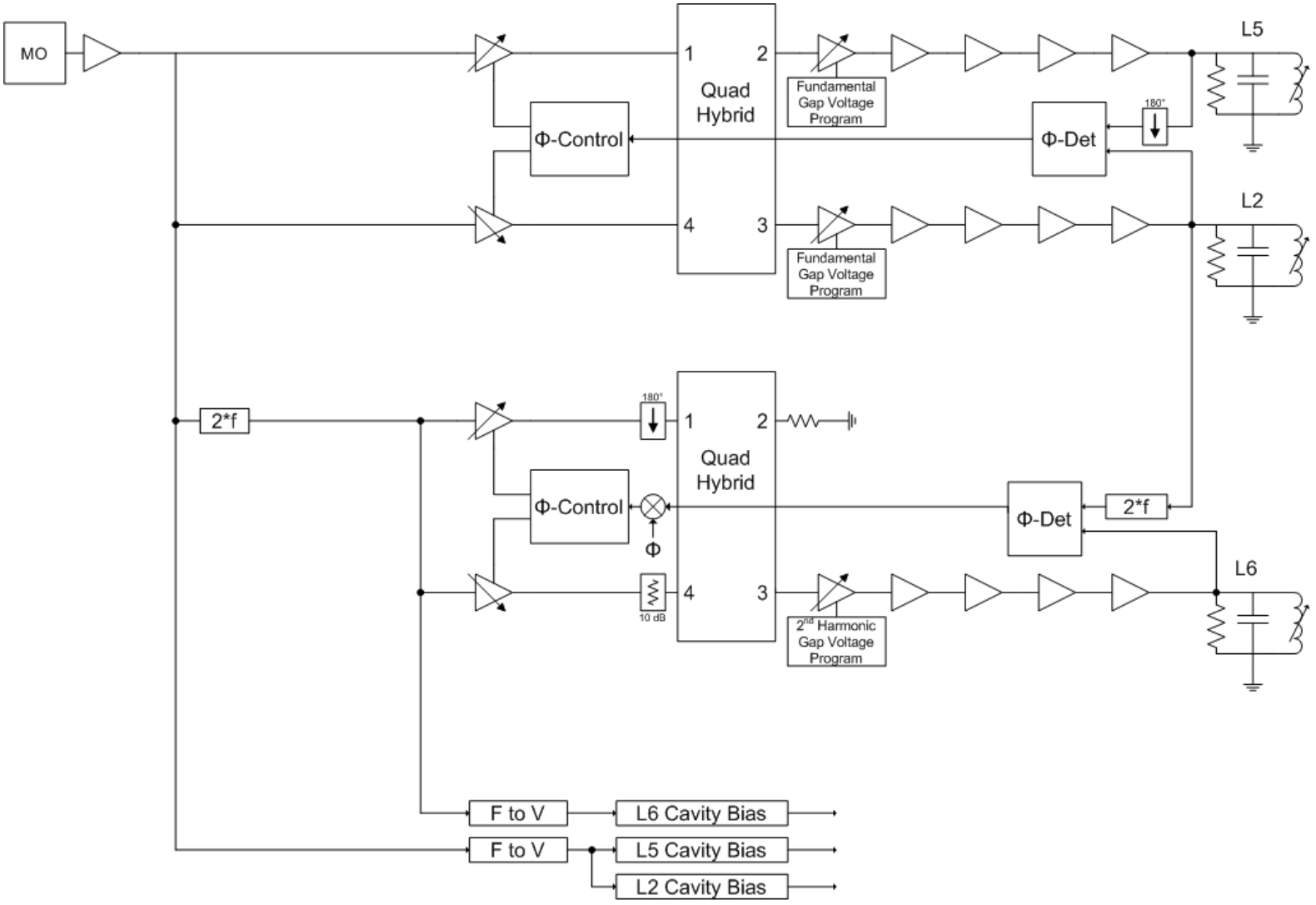
2nd Harmonic

- Fundamental Three Cavity Operation



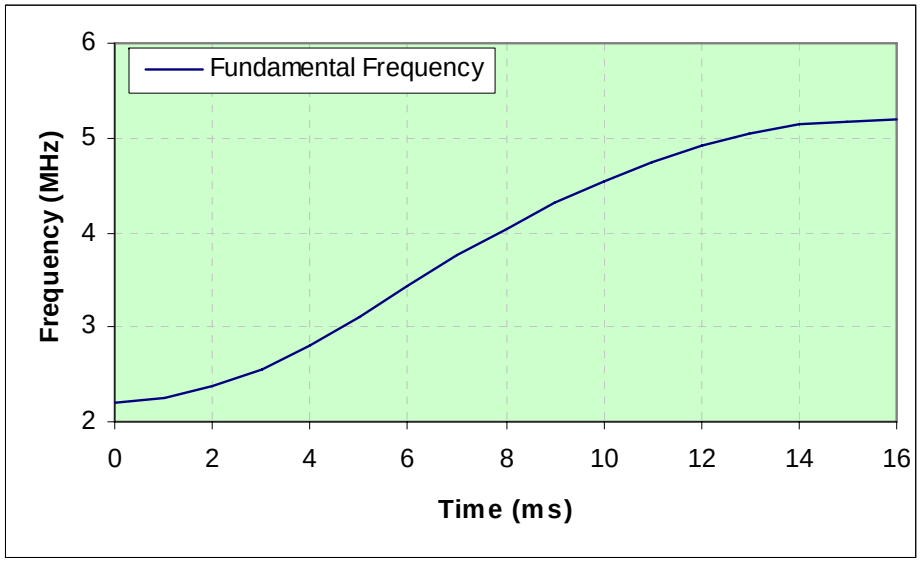
2nd Harmonic

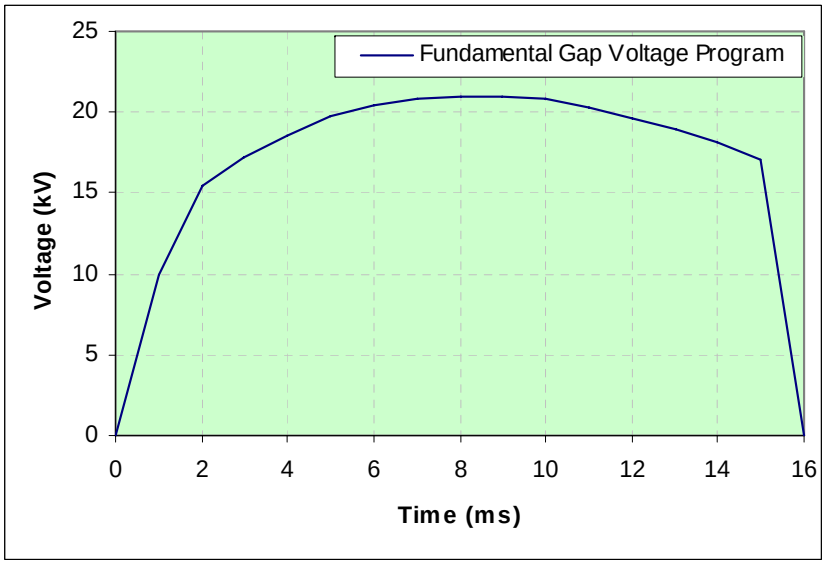
- Minimum Second Harmonic Operation

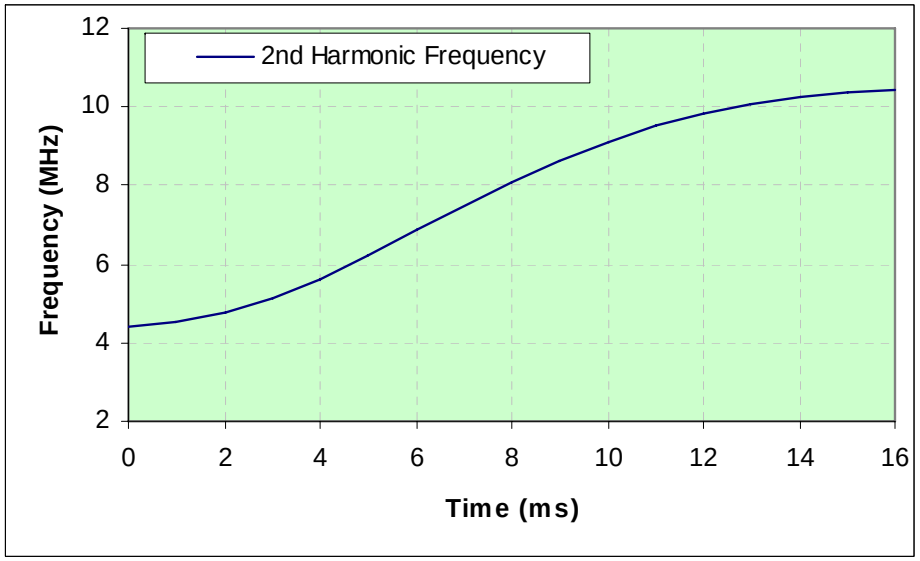


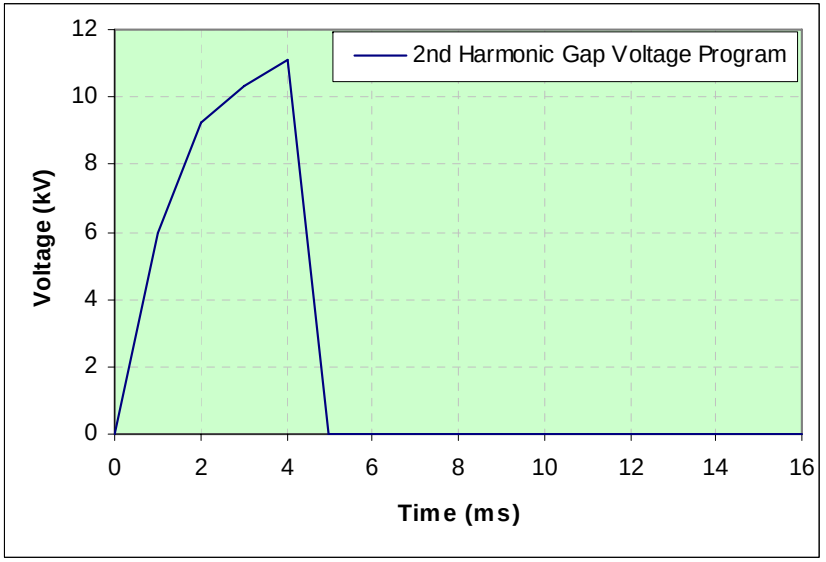
2nd Harmonic

- Minimum Second Harmonic Operation



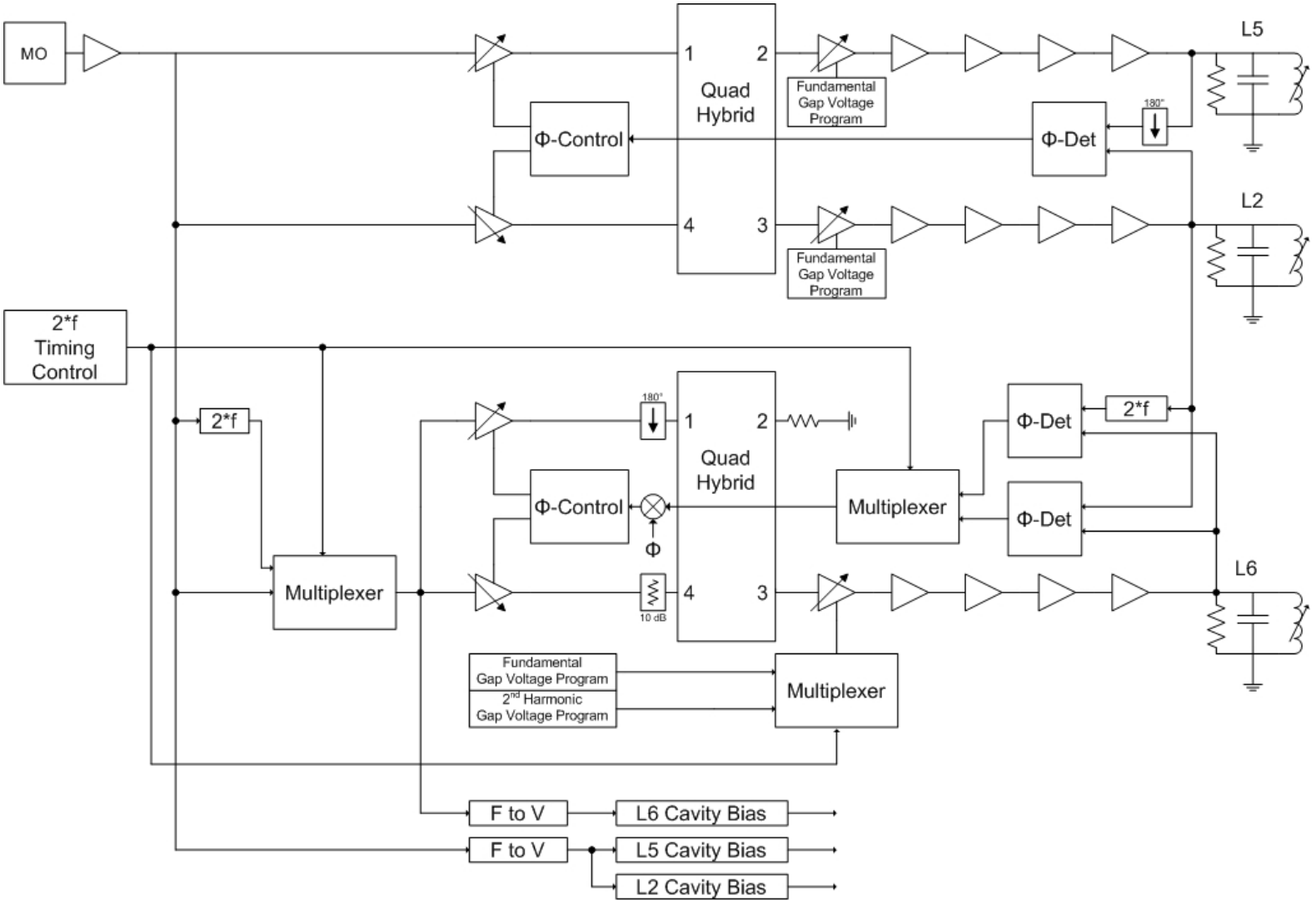






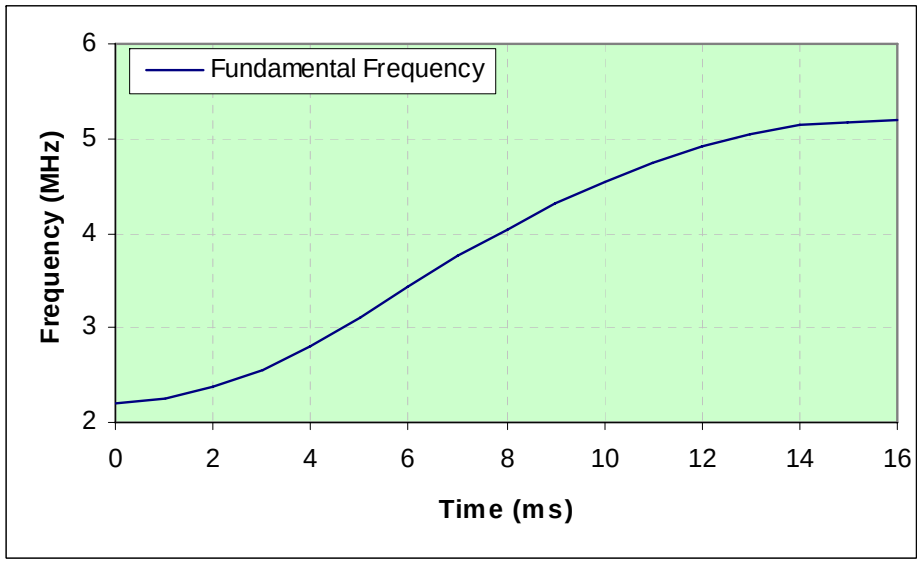
2nd Harmonic

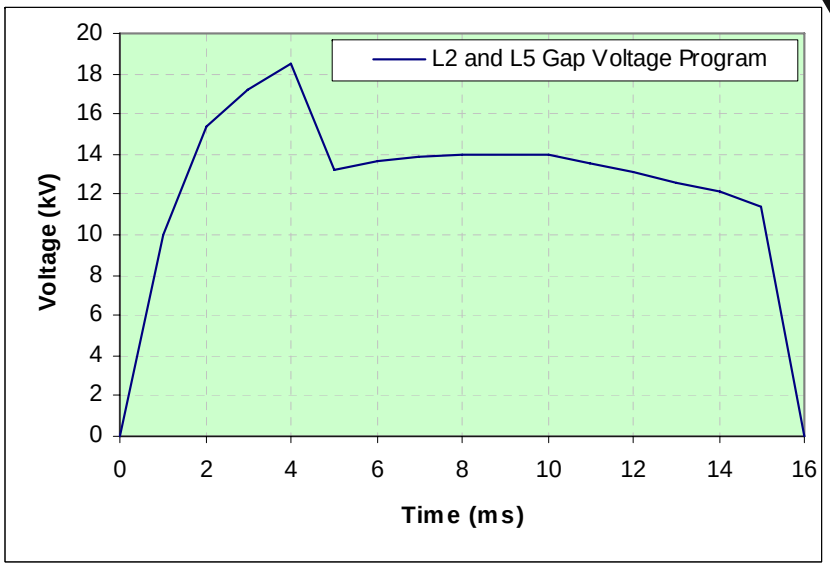
- Second Harmonic Operation

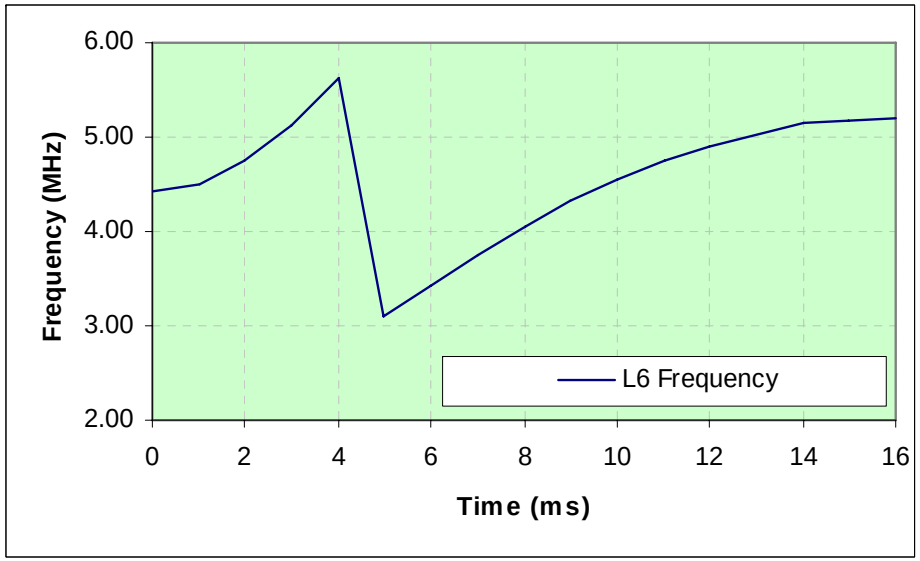


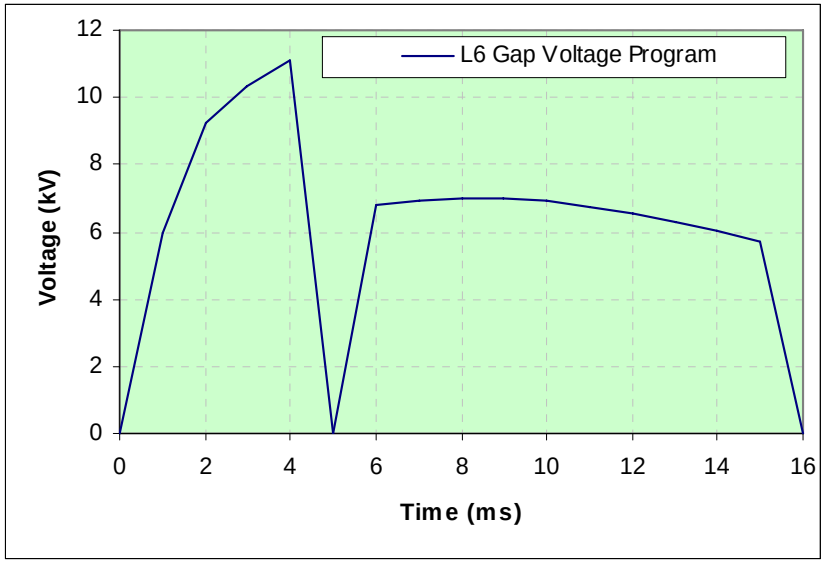
2nd Harmonic

- Second Harmonic Operation









Summary

- The third cavity has been installed and is operational.
- L2 – L6 cavity operation has been demonstrated, although not to satisfactory beam performance levels.
- L5 – L6 cavity operation has yet to be demonstrated.
- We have a platform for 2nd harmonic studies and hardware is being built.