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Expansion of the Radiographic Linear Transformer Driver (LTD) to 2.5 MV

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† This work was performed under the auspices of an agreement between CEA/DAM and NNSA/DP on cooperation on fundamental sciences

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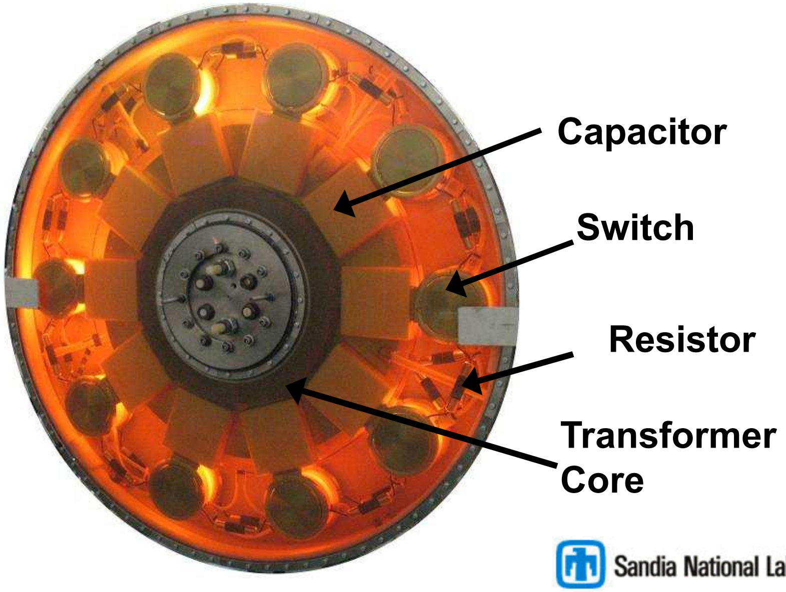
Outline

- Review of the 1-MV LTD
- Upgrade to 2.5 MV
- New component testing
- Current status of the upgrade
- Future plans

The Sandia 1-MV LTD for radiography

- Originally built in Tomsk, Russia at IHCE
- Moved to Sandia in 2004
- The 1-MV LTD consists of seven series cavities.
- Original design incorporated peaking capacitors in each cavity
- Without peaking capacitors, peak voltage is about 800 kV
- Voltage from the seven cavities adds along a coaxial vacuum transmission line.
- Testing includes:
  - Over 600 full system shots
  - Over 1900 single cavity shots



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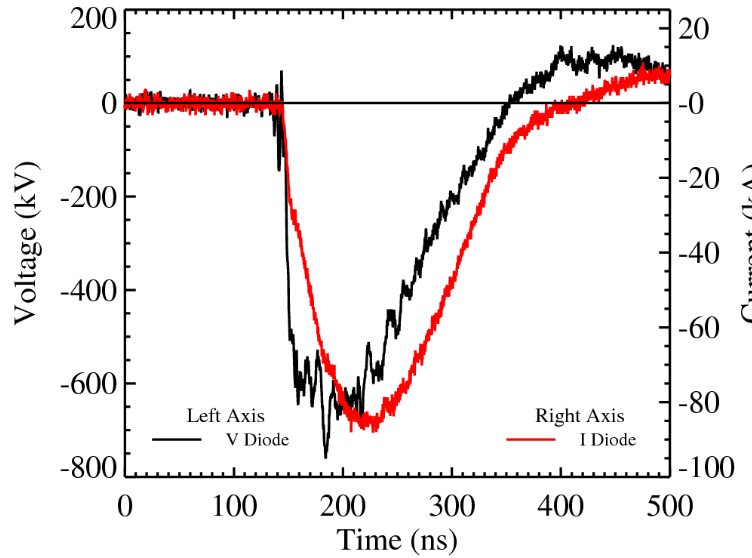
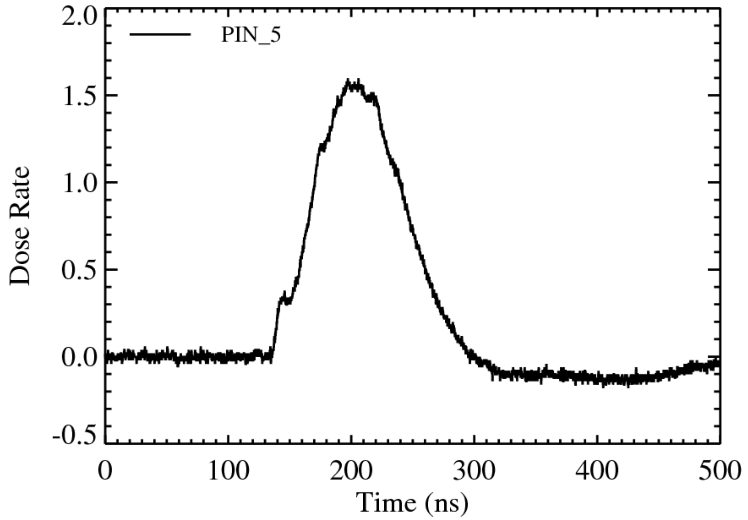
Output of the 7-cavity LTD

- The 7-cavity testing includes:
  - Negative and positive polarity with large area diode (LAD) load
  - Negative polarity with SMP load
- Data shown here is for Negative polarity LAD
  - Zdiode ~ 8 ohms
  - Vdiode ~ 650 kV
  - Voltage pulse width (FWHM) ~ 100 ns
  - X-ray dose rate pulse width (FWHM) ~ 80 ns





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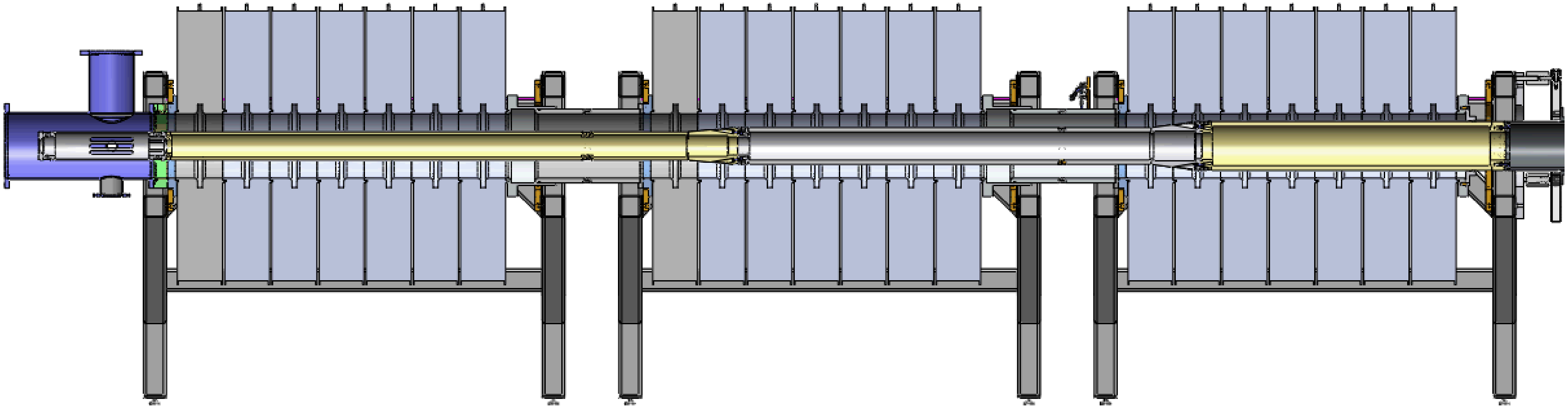
Requirements for LTDs designed to drive electron beam diodes

- Drivers for radiographic e-beam diodes require narrow pulses (<100ns) and high voltages (2-8 MV)
- Cavities are coupled to a magnetically insulated transmission line (MITL) with electron sheath flow
- Diode impedance is dynamic and varies with type of diode

- The 7-cavity LTD cannot address all of these research areas

The Sandia LTD for Radiography is being upgraded from 1 MeV to 2.5 MeV

- Upgraded system has 21 cavities
- Cavities are assembled in groups of 7
- Total of 210 switches and 420 capacitors
- 7.5m long and 1.5m wide
- Output voltage pulse width of about 100ns
- Output line vacuum impedance of 50 ohms



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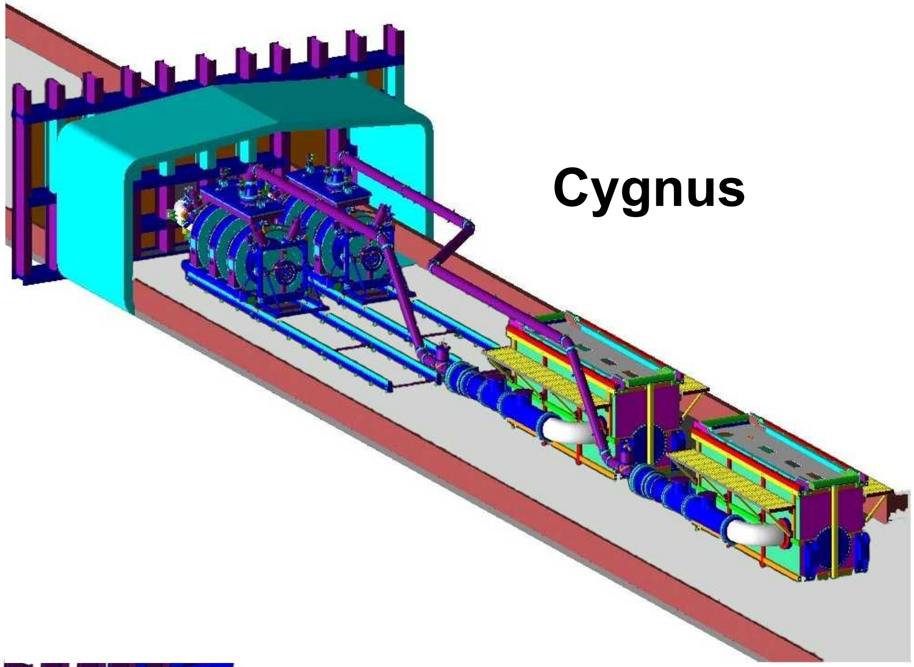
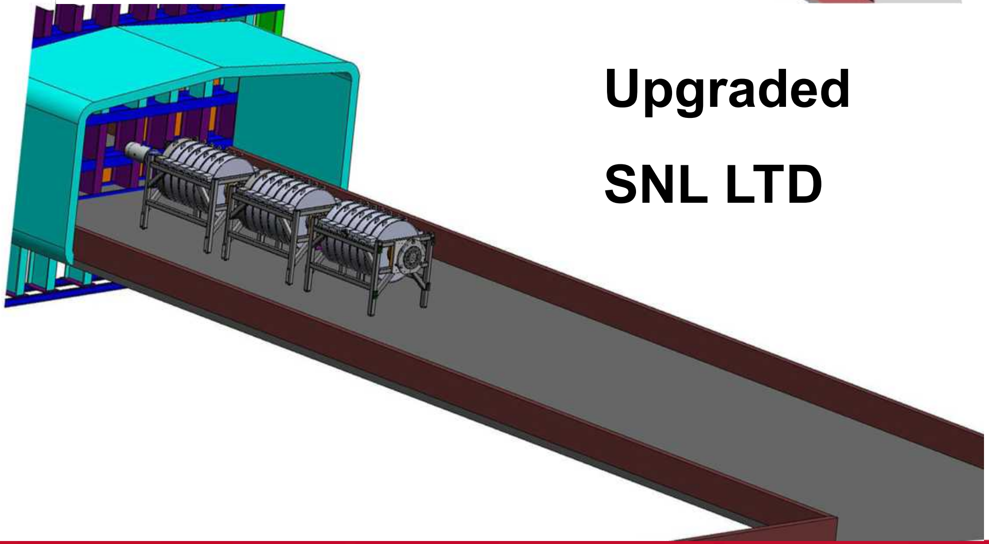
Upgraded LTD will produce similar output as the Cygnus accelerators at the Nevada Test Site

- Cygnus accelerators produce 2.25MV and about 4 rad@1m from a Rod-pinch diode
- 21-cavity LTD will produce similar output from a much smaller footprint
- Experimental results from the 21-cavity LTD will validate computational models.
- Will provide sufficient data for scaling to a large scale accelerator (7-8 MeV, 200 kA)



Cygnus



Upgraded

SNL LTD

Design of the 21-cavity LTD

- **Cost and time schedules dictated that the design build on the existing 7 cavities with minimal change**

- **Design changes include**
  - **Metglas cores instead of Si-steel**
  - **Switches built by L-3 Pulse Sciences (San Diego)**
  - **Higher voltage trigger generator (increased from 80kV to 150kV output)**

Three switches have been tested in the radiograhic LTD cavities

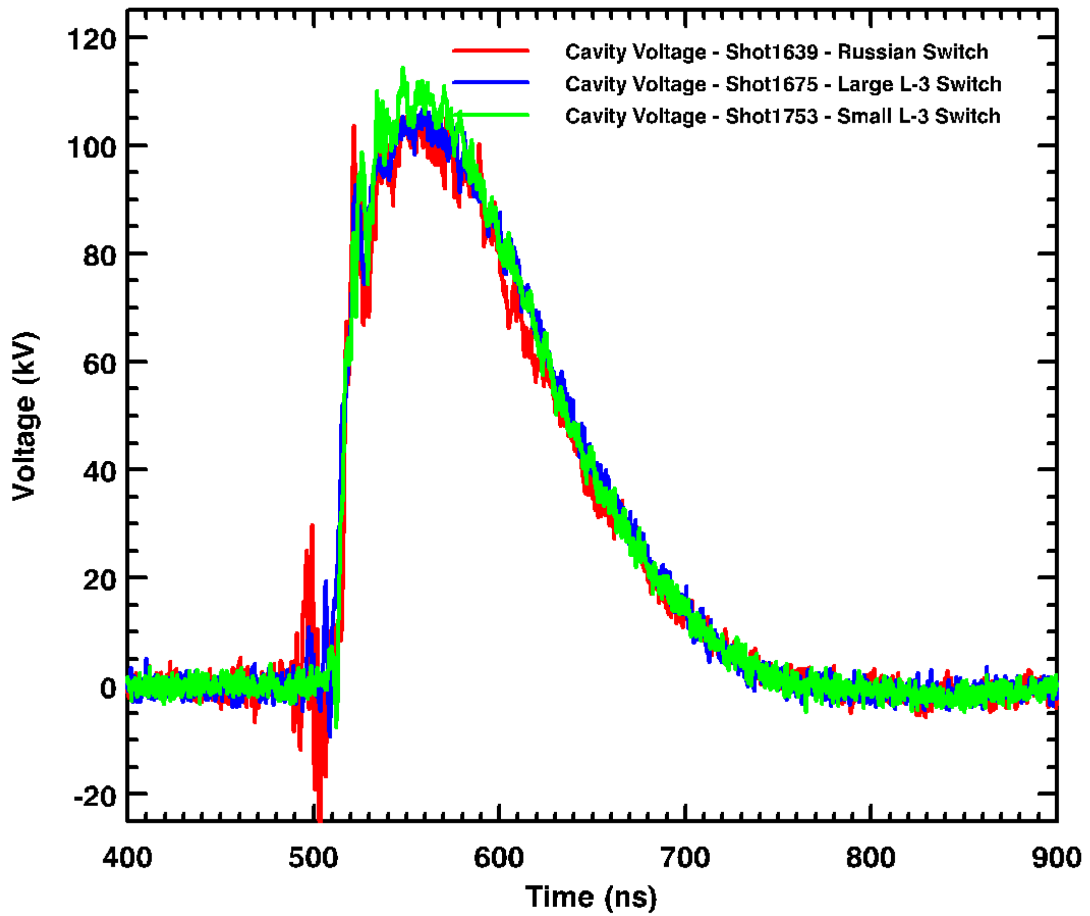
- The seven cavities built at the IHCE in Tomsk use the IHCE multi-gap switch.
- The large L-3 switch was tested in a single cavity.
- The 14 new LTD cavities will use the small L-3 switch which was developed by L-3 and Sandia.
- The small L-3 switch has about 15% lower inductance than the IHCE switch*.

Small L-3 Large L-3 IHCE

* J. Woodworth, et. al. “Low-inductance gas switches for linear transformer drivers,” Phys. Rev. ST Accel. Beams, vol. 12, 060401, 2009.

Switch test results show similar performance of the three different switches

- Each of the three switches was tested in a 10-switch cavity.
- These three tests use the same load, charge voltage, and trigger generator.
- The test with the small L-3 switch produced slightly higher peak voltage.
- No significant difference in risetime or pulsewidth is seen in the cavity voltage of the three switch types.



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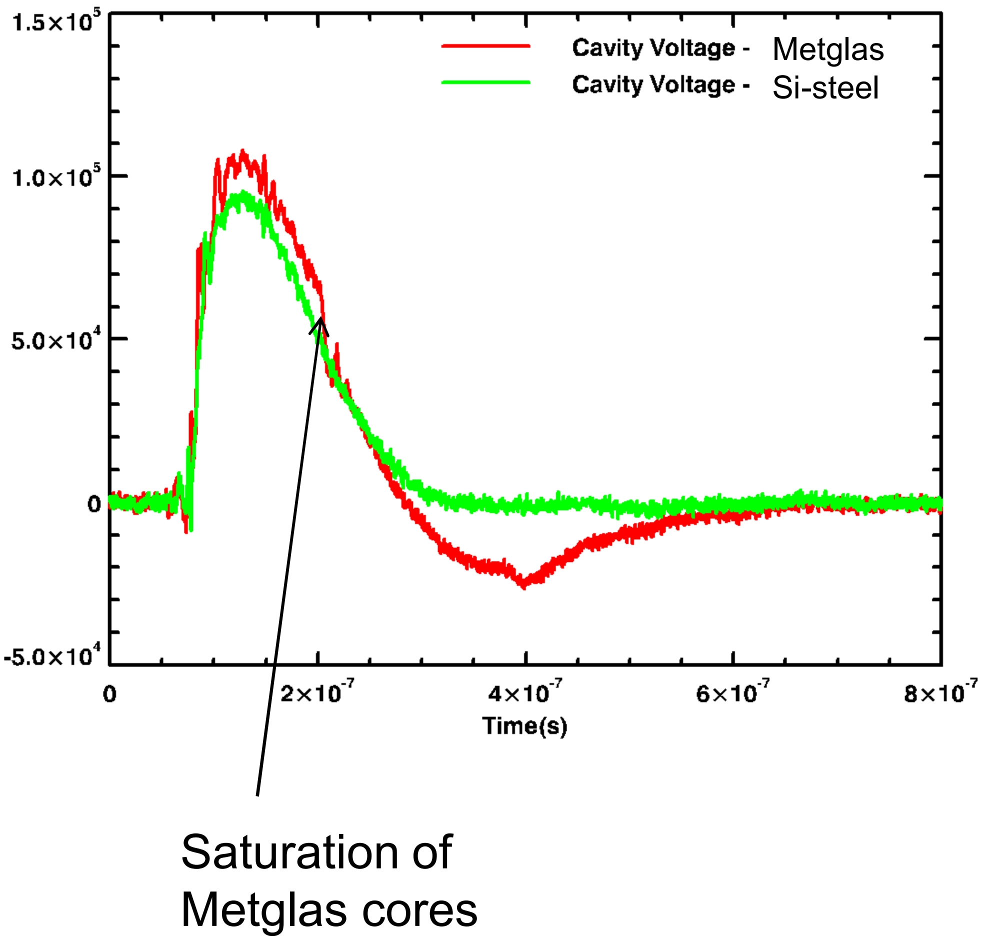
Cavity jitter with the small L-3 switch is similar to the IHCE switch

- Voltage monitors measure the cavity output voltage. There are not monitors for each switch to determine individual switch jitter.
- Jitter is measured for each cavity by comparing the rising edge of the output voltage to the timing of the trigger pulse.
- Jitter is reported here for sets of 20 consecutive shots with 7 cavities triggered simultaneously.
- Russian multi-gap switches
  - Single cavity jitter (1-sigma) ranged from 2.1ns to 2.7ns
- Small L-3 switches
  - Single cavity jitter (1-sigma) ranged from 1.7ns to 3.0ns

The new cavities will use lower loss transformer cores

- The seven original cavities use transformer cores made from 80-micron thick silicon steel ribbon with mylar insulation between layers
- The transformer cores for the new cavities use Metglas 2605Co material
- Single cavity tests with both cores show that the Metglas material reduces loss current, increasing the peak output voltage of the cavity
- The first set of cores manufactured by Metglas did not have sufficient material to prevent the cores from saturating before the end of the pulse. Additional cores have been built that should correct this error.



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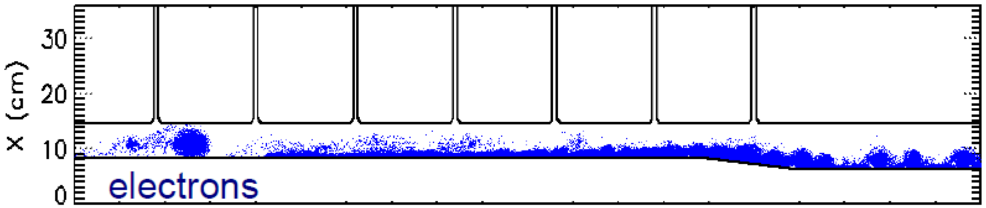
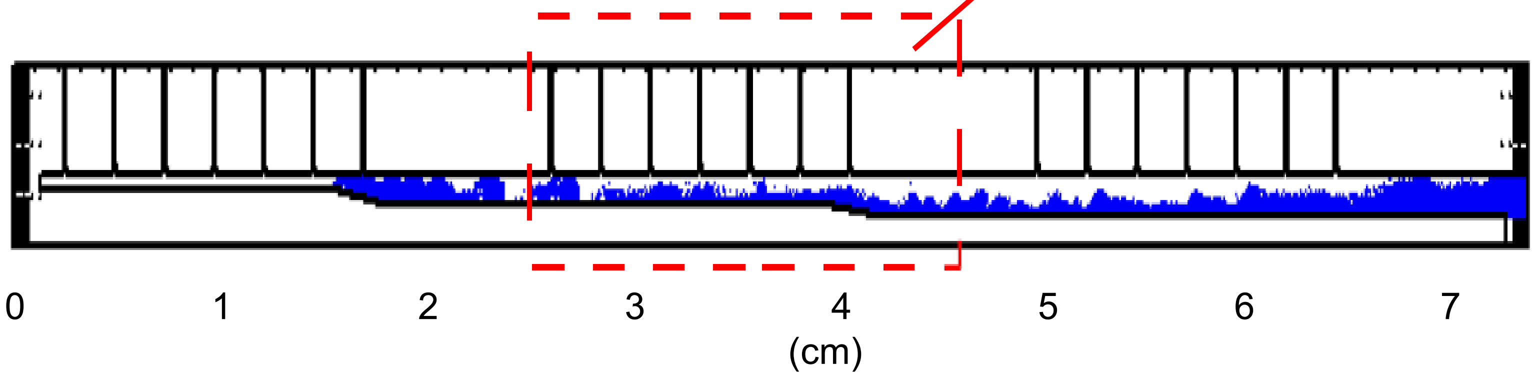
21 cavity power flow simulations

- **The MITL has impedance transitions after the 6th and 13th cavities.**
- **With a high impedance diode the peak load voltage is 2.5 MV with 50kA bound cathode current and 22kA sheath current.**
- **PIC simulations predict 3kA loss current throughout pulse.**
- **The impact of loss current on insulator operation must be investigated.**

Cavity	MITL Zvac (Ω)
1-6	16.6
7	Transition
8-13	33.5
14	Transition
15-21	50.0





Status of the LTD upgrade

- Assembly of the 21-cavity LTD began this month.
- The three new stands have been aligned
- The original 7 cavities have been installed in the new stand
- The first new cavity has been assembled and is being tested
- The MITL center stalk has been assembled
- Cavity assembly will continue for the next 6-8 weeks

Timeline and future plans

- Summer 2010 – complete assembly of 21-cavity LTD
- Fall 2010 – Spring 2011
  - Testing with large area diode (LAD) and Self-magnetic pinch (SMP) diode
  - Detailed analysis of MITL power flow
  - Experiments and simulations of coupling to high and low impedance diodes.