
Load Line Evaluation of a 1-MV Linear Transformer Driver (LTD)

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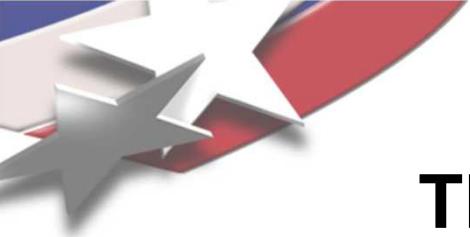
† This work was performed under the auspices of an agreement between CEA/DAM and NNSA/DP on cooperation on fundamental sciences



Introduction

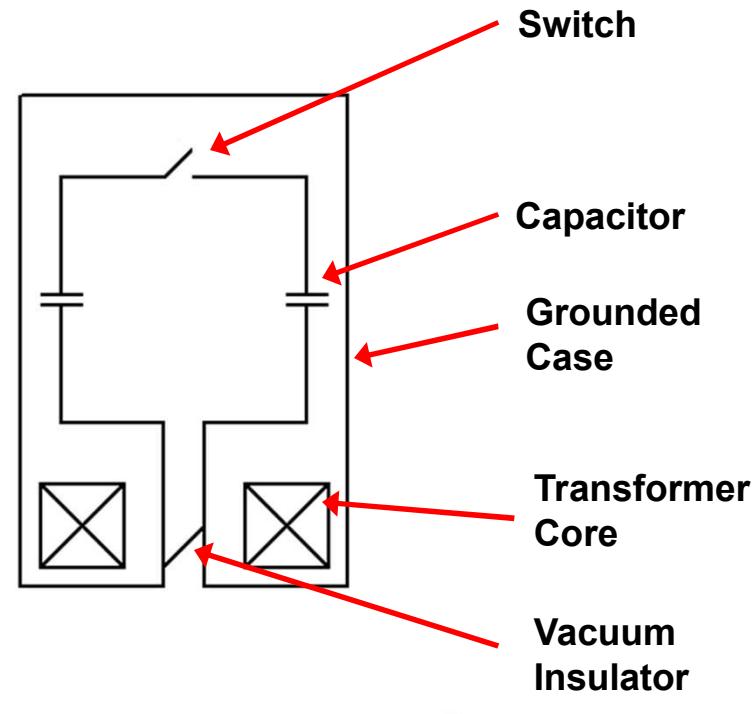
- **Pulsed power driven radiography systems routinely operate in the rage:**
 - 2-10 MeV
 - 100-200 kA
- **LTD based accelerators can be designed to provide similar radiographic capability as inductive voltage adder (IVA) drivers with:**
 - Smaller footprint
 - Lower cost
 - Potentially mobile
- **Radiography systems are optimized for voltage rather than current because x-ray dose is determined by the equation:**

$$\text{Dose} \propto IV^x \quad (2 < x < 3)$$



The basic building blocks of an LTD

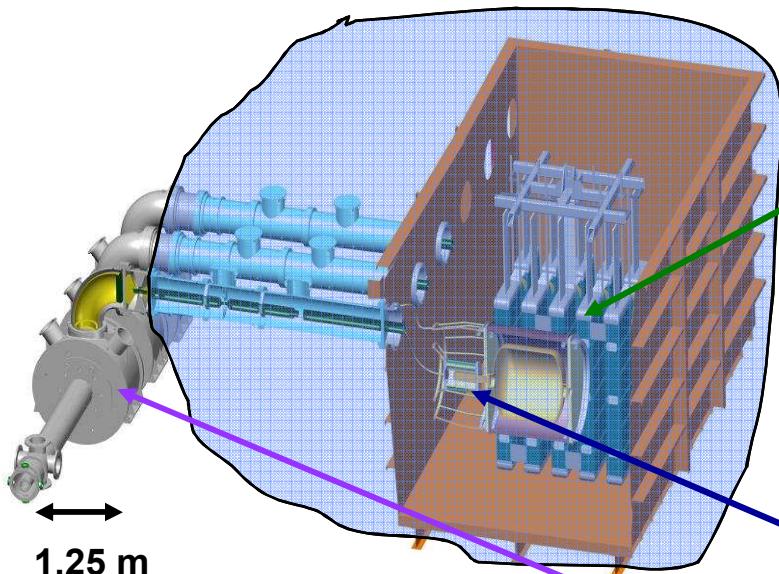
- The basic building block of an LTD circuit, the “Brick,” is a single stage Marx generator with two capacitors and one switch.
- A “Cavity,” is a single LTD stage with several parallel brick elements.
- LTD cavities are typically encased in a grounded metal case with inductive isolation.
- Cavities are stacked in series to form a voltage adder.





The LTD is much more compact than conventional IVAs

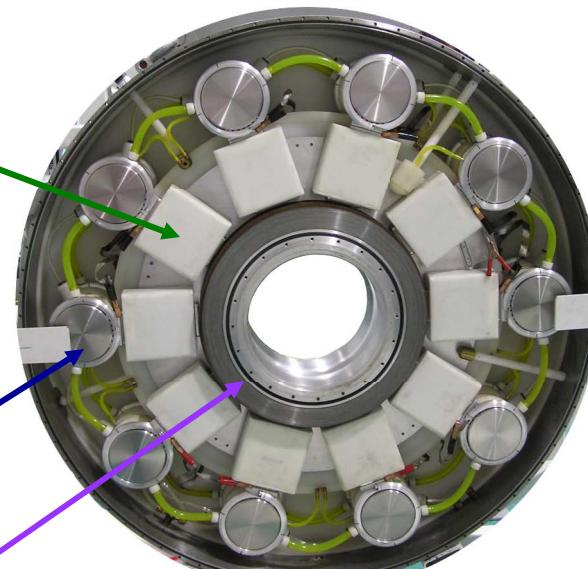
Inductive Voltage Adder (IVA)



Remove pulse formation and compression hardware

10 m

Linear Transformer Driver (LTD)



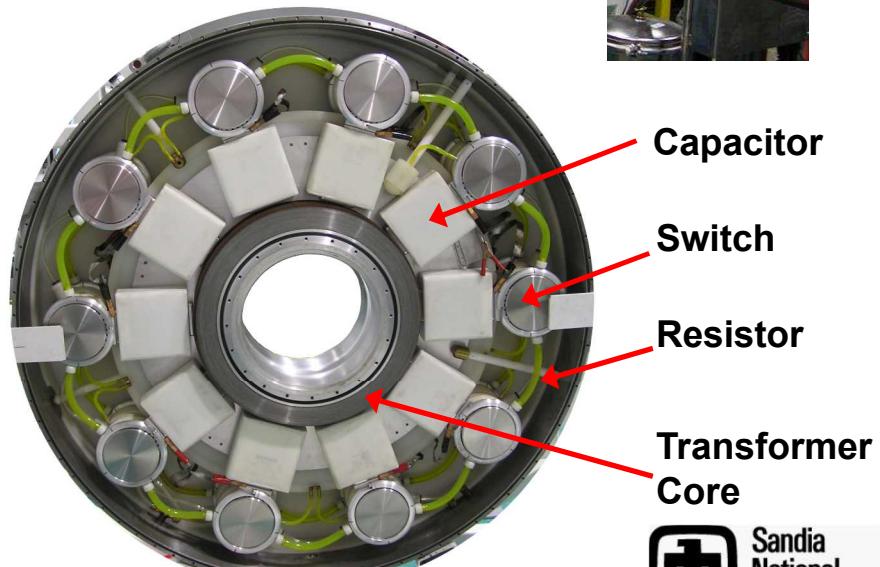
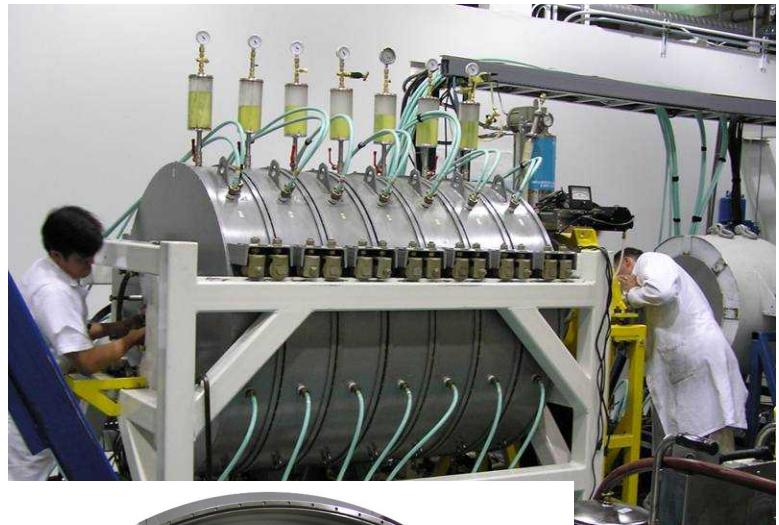
Inductive isolation

1.25 m



A 1-MV LTD has been tested at Sandia

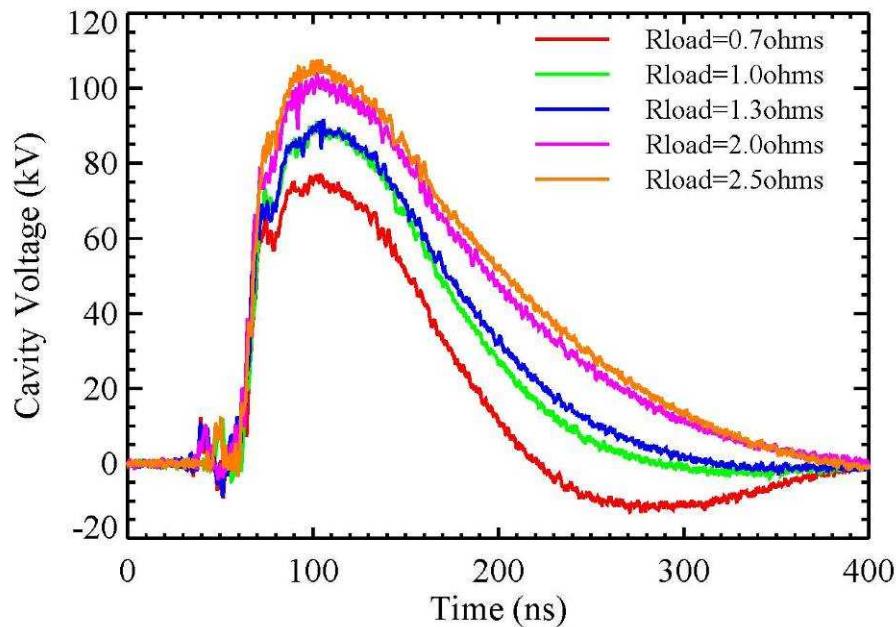
- The 1-MV LTD consists of seven series cavities
- Voltage from the seven cavities adds along a coaxial vacuum transmission line
- The system was built in Russia and assembled at Sandia in 2005.
- Testing of individual cavities resumed in July '07 using a resistive load.
- Testing of full 7-cavity system resumed in Sept '07 with e-beam diode
- In total we have fired more than 400 full system shots and more than 1000 single cavity shots.

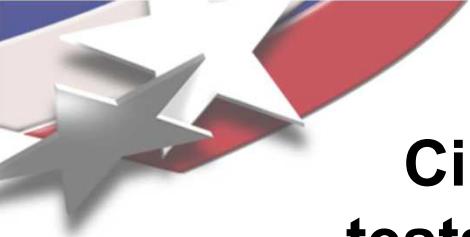




Individual cavities have been tested with a resistive load

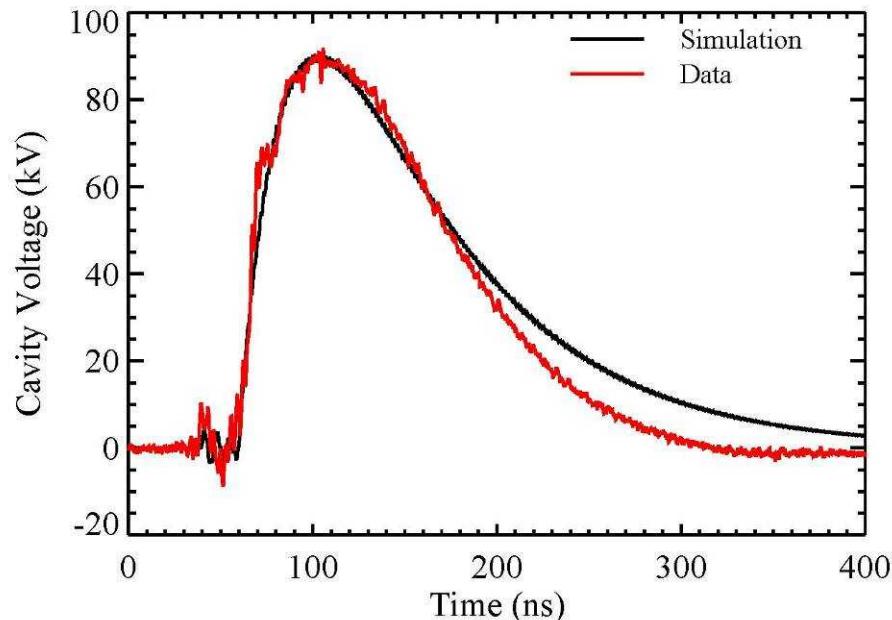
- Cavity voltage data shown here is for +/- 80 kV charge.
- Tests were performed with a liquid filled load resistor with varying resistance.
- Voltage measurements were recorded using a resistive voltage divider.
- Results indicate that the circuit is approximately matched with a 0.7ohm load per cavity.





Circuit simulations have been compared to tests of individual cavities with a resistive load

- Circuit simulations of the LTD cavities match the approximate output pulse shape, but not the amplitude.
- The simulation shown here has been normalized to the peak measured voltage.
- Further work will include careful calibration of voltage monitors, characterization of the load, analysis of switch inductance and resistance.
- These efforts should improve the cavity circuit model.

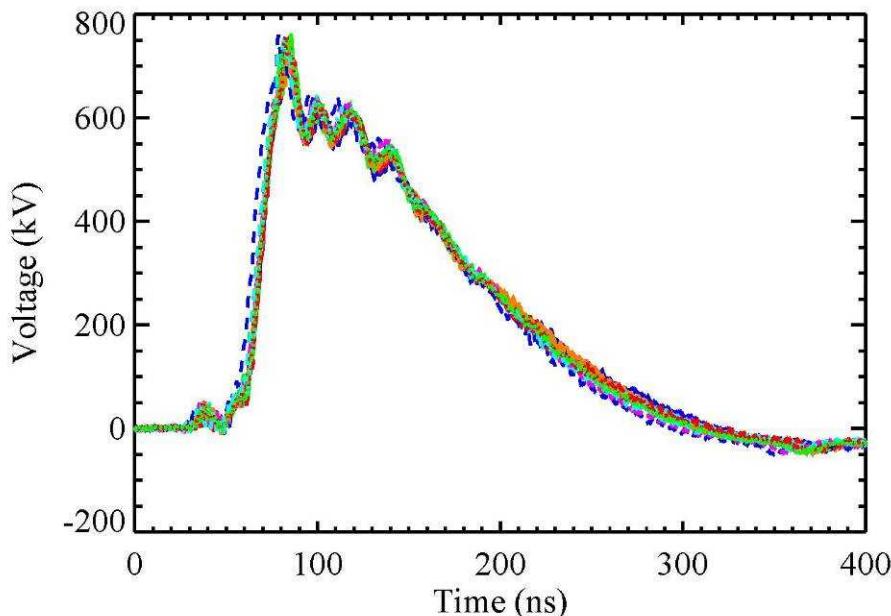




The output pulse of the seven cavity adder is very repeatable

- This plot shows 15 shots of the full 7-cavity system into an electron beam load with $\pm 80\text{kV}$ charge.
- The individual cavity 1-sigma jitter is 1.4-2.7ns
- The load voltage 1-sigma jitter is about 1.9ns.
- The spike at the beginning of the pulse is caused by delayed turn-on of the diode load. Circuit simulations support this conclusion.

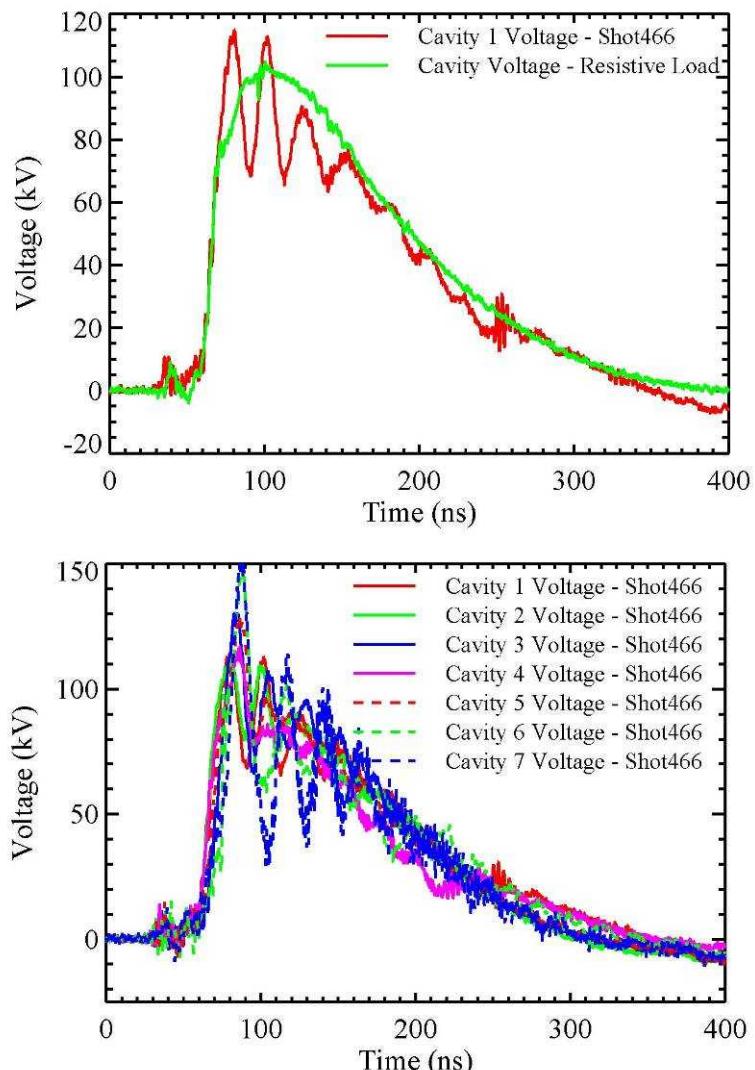
Load Voltage for 7-cavity test with e-beam load





Tests with a dynamic load are important to predicting future system performance

- Most testing of individual bricks and LTD cavities has been done with resistive load.
- Radiographic diodes have time varying impedances that start very high before transitioning to a nominal impedance of $40-200\Omega$.
- Experiments with seven series cavities coupled to a large area electron beam diode load result in large cavity voltage oscillations that are not seen in resistive load tests.
- The cavity oscillations vary greatly with cavity position in the adder.





We plan to expand the LTDR to a 3-MV adder over the next two years*

- The LTD will be moved to a larger lab at the end of the summer.
- We will have space and adequate shielding available to expand the system to 2-3 MV if funding permits.
- Data acquisition will move into a screen room (STF screen room).
- Testing at 1-MV produces very limited electron emission in the MITL and only at the end of the accelerator.
- Expanding to 2-3 MV would allow us to study MITL power flow on an LTD system.
- A 2-3-MV LTD would replicate the voltage produced by the Cygnus accelerators (Cygnus is a 2.25-MV dual-axis pulsed power radiography system based on IVA technology and fielded at the Nevada Test Site).
- The expanded LTD could be used to study coupling to radiographic diodes including Rod Pinch and Self Magnetic Pinch (SMP) diodes.

* Pending available resources



LTD for radiography development path*

Scope/yr	'08	'09	'10	'11	'12
Accelerator R&D	Move 1 MV LTD to RITS Hi-Bay	2 MV LTD	3 MV LTD		→
Source R&D	Component and diode studies	Rod-pinch diode	MITL power flow coupling. Rod-pinch and self-pinch diodes	Scale design to 8 MeV	→



* Pending available resources