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Long Pulse and Positive Polarity Operation of a Reflex Triode at the Saturn Accelerator

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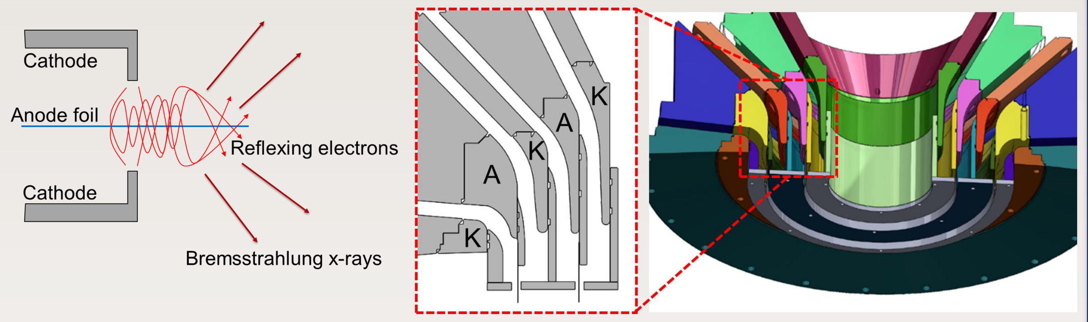
Experiment goal

- Run a longer power pulse on Saturn into the LANTERN source in an attempt to increase the x-ray dose rate

The LANTERN source

- Large Area Nested Triode with Electron Reflexing eNhancement
- Electrons emit from cathode tips and reflex several times through the thin anode foil allowing; lower self absorption than than the standard bremsstrahlung diodes for enhanced lower energy x-ray fluence



Motivation

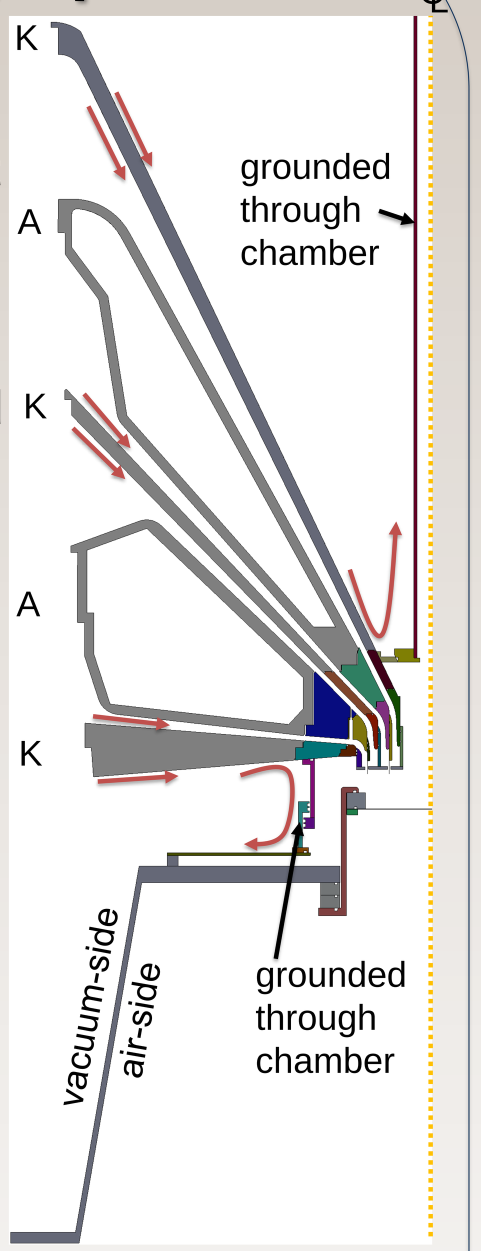
- Higher x-ray total dose and dose rate than were obtained on LANTERN reflex triode experiments run using Saturn's typical short pulse would be useful
- The reflex triode requires shifting the anode to positive polarity, reducing the available current on Saturn by shunting lines carrying 1/3 of the potential current

Why try a long power pulse?

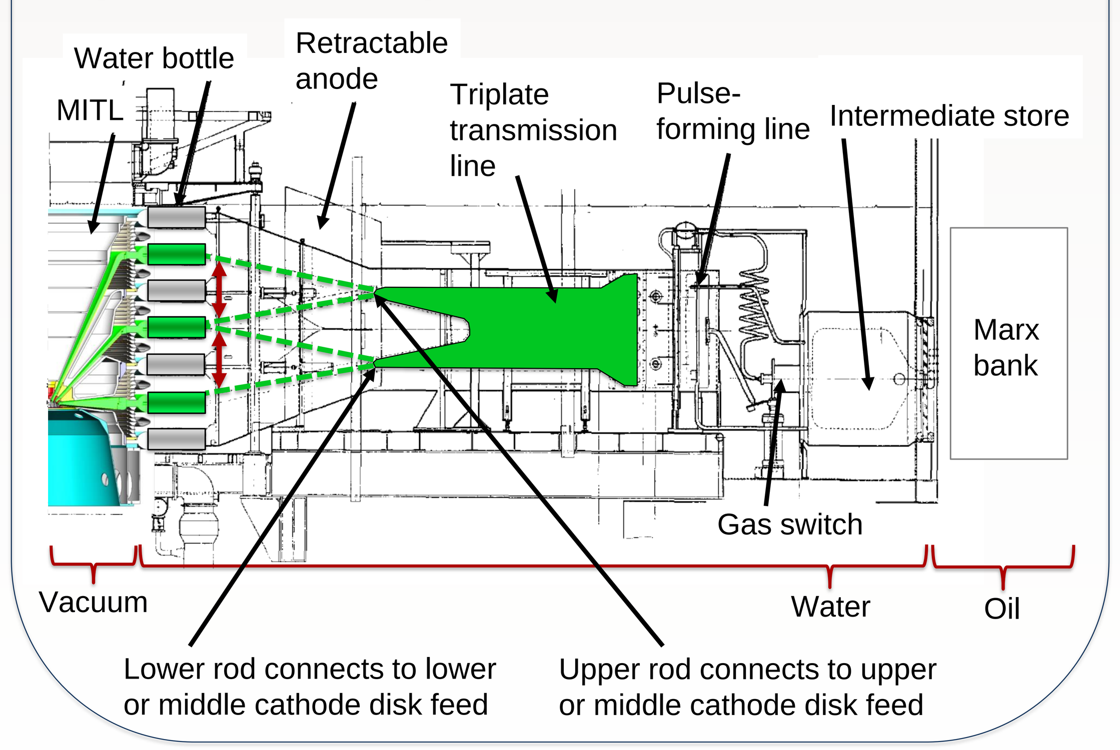
- The cylindrical reflex triode geometry is resistant to premature gap closure and so may hold up for a longer power pulse to produce an enhanced radiation pulse
- Long pulse drive has been used successfully with z-pinch sources on Saturn
- Long pulse drive may allow more of Saturn's current in positive polarity to be used for radiation production

Positive polarity operation

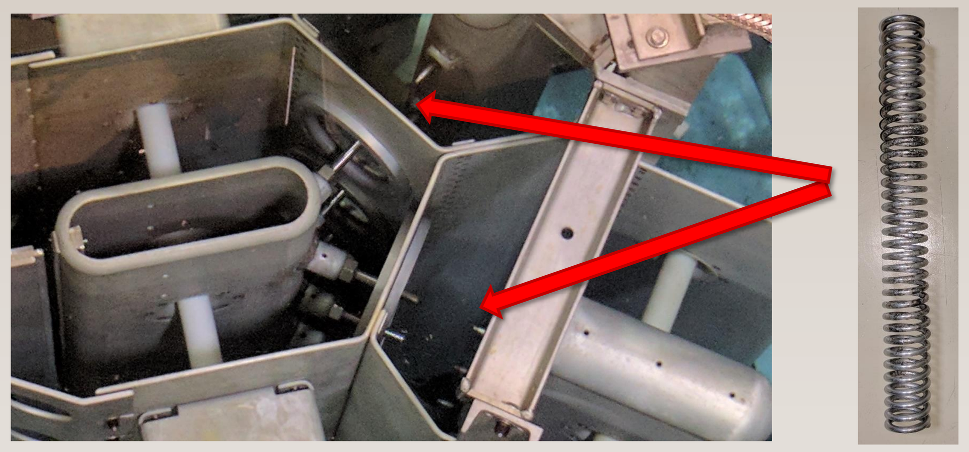
- Saturn driver cannot be easily configured for positive polarity → must shift polarity inside the vacuum stack
- Power flowing on the outside of the upper and lower cathodes is shunted to ground through the chamber acting as a ballast inductor
- The power pulse down the two outer MITLs drives the two anodes positive
- The anodes are transit time isolated from ground through the water section



- The power pulse on the central two MITLs in turn drives the center cathode to ground
- When the power pulse on the upper and lower lines sees the shunt, it is reflected
- The reflected pulse cannot go down the other lines until it goes back around the water bottles, which takes ~36 ns – after the pulse in short pulse mode



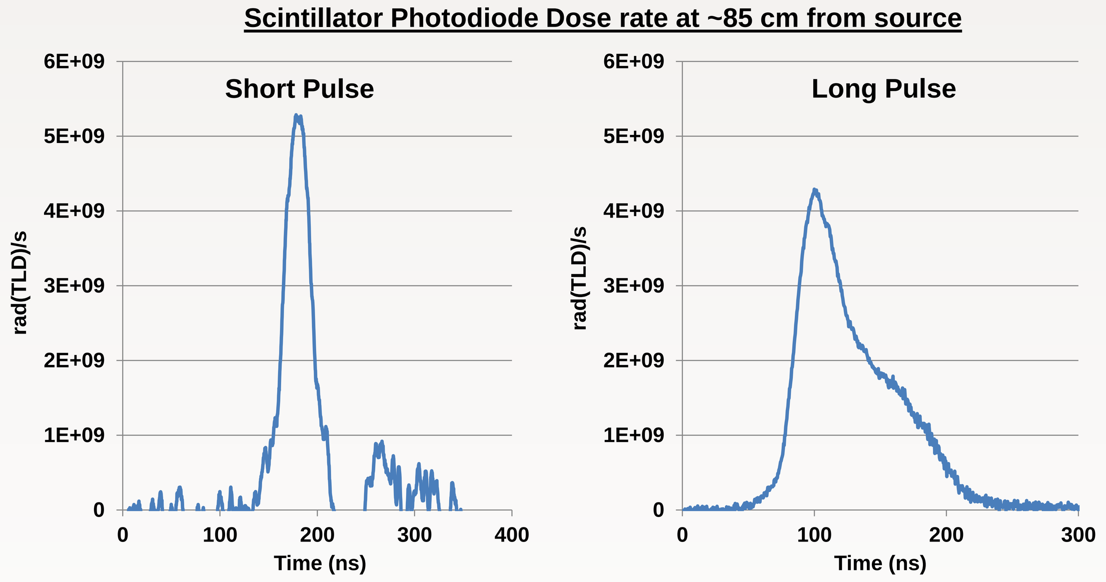
Machine configuration



Saturn's pulse forming line. Arrows point toward the self-break water switches where the springs are inserted.

- Long pulse mode achieved by shorting out the pulse forming line's self-break water switches with springs
- 72 Transmission line rods (2 for each of Saturn's 36 lines) split evenly with 24 to the bottom, middle and upper cathodes
- Prepulse gaps in standard configuration

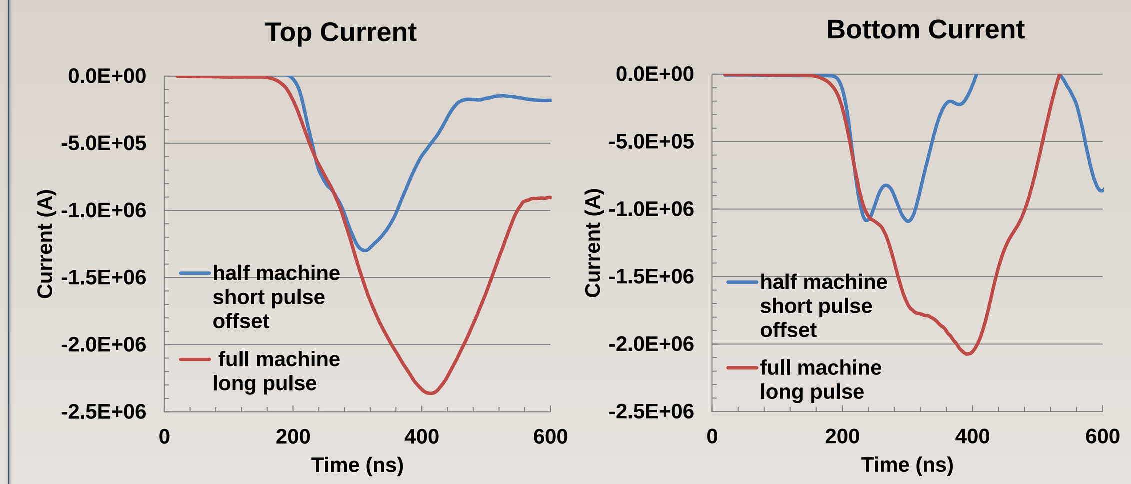
Comparing Saturn's long and short pulse modes

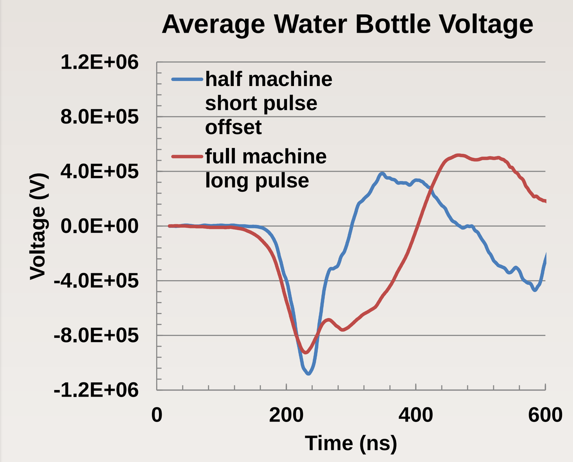


	Rise time ns	FWHM ns	Integral rads
Short pulse	24	32	193
Long pulse	24	53	293

- Long pulse dose reduced ~30% by additional polyethylene vacuum window
- Radiation for long pulse starts about 80 ns earlier with an increase in total dose by ~50%

Why is the radiation pulse rise time so similar?





- Full machine long pulse mode results in stack voltages approximately the same as the half machine short pulse mode
- The rise time is similar to short pulse likely because it is controlled by the transmission line and stack inductances
- During the rise, this drives similar currents and voltages in the vacuum section, resulting in a initial radiation pulse similar to the short pulse mode
- Later in time, the long pulse mode continues to drive current into the vacuum section, but by this time the diode gap has closed substantially, so the diode voltage is low and the radiation production is low
- A-K gap closure is ~3 cm/μs which is consistent for both 5.5 mm and 4.5 mm (shown here) gaps. Peak radiation occurs at a gap of ~3.2 mm on the outermost gap and ~2.2 mm on the innermost gap

Take away

- Long pulse results in same dose rate but increased total dose
- The benefit of operating LANTERN in a long pulse mode is reduced by diode closure

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NNSA National Nuclear Security Administration

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