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Plasma Power Station

Quasi Spherical Direct Drive Capsule for Fusion Yield
Inverse Diode for Driver-Target Standoff
Magnetically Insulated Linear Transformer Drivers

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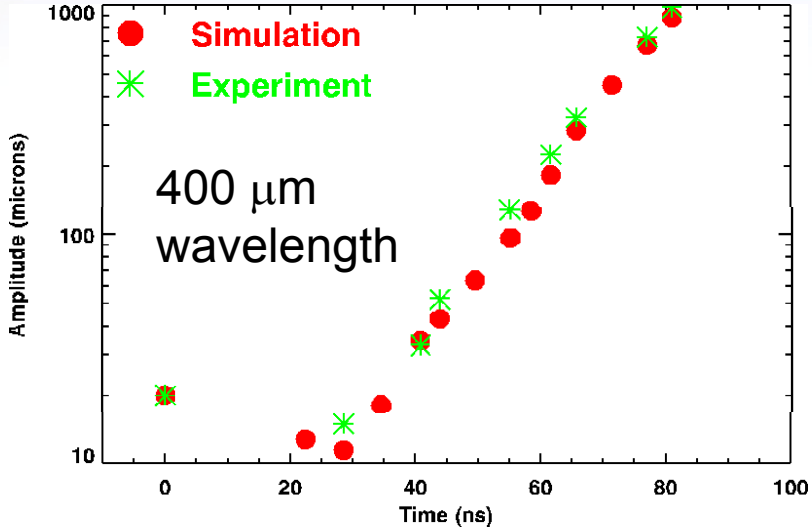
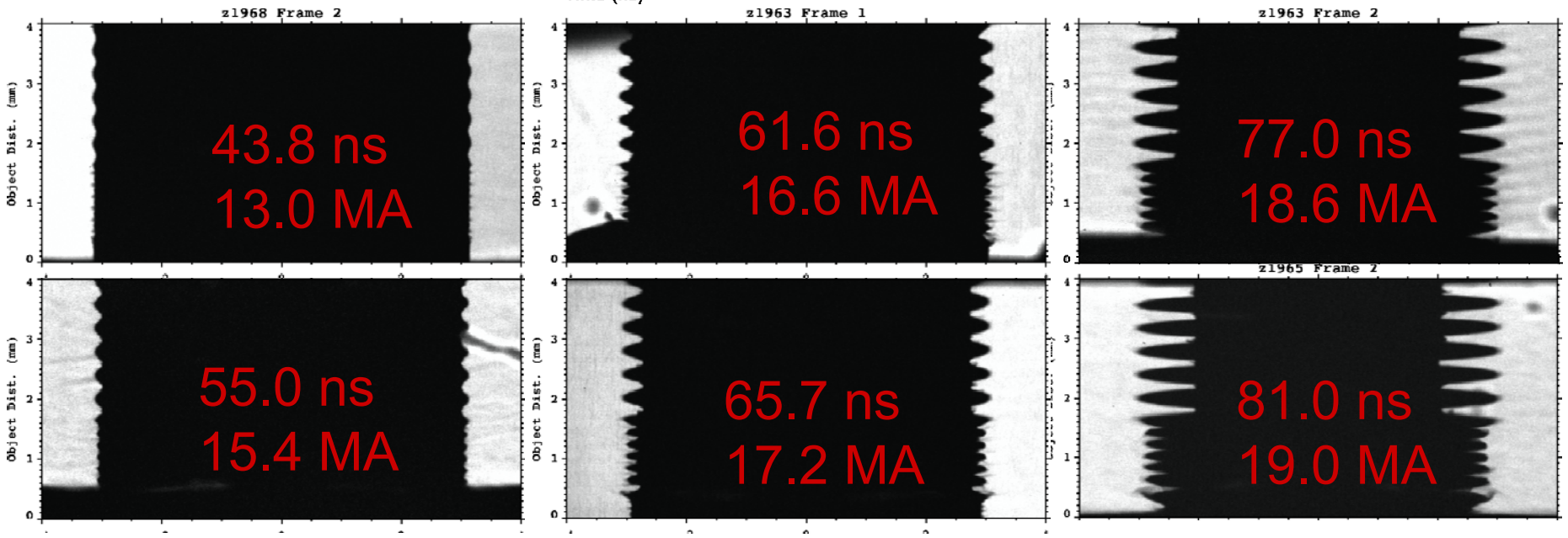
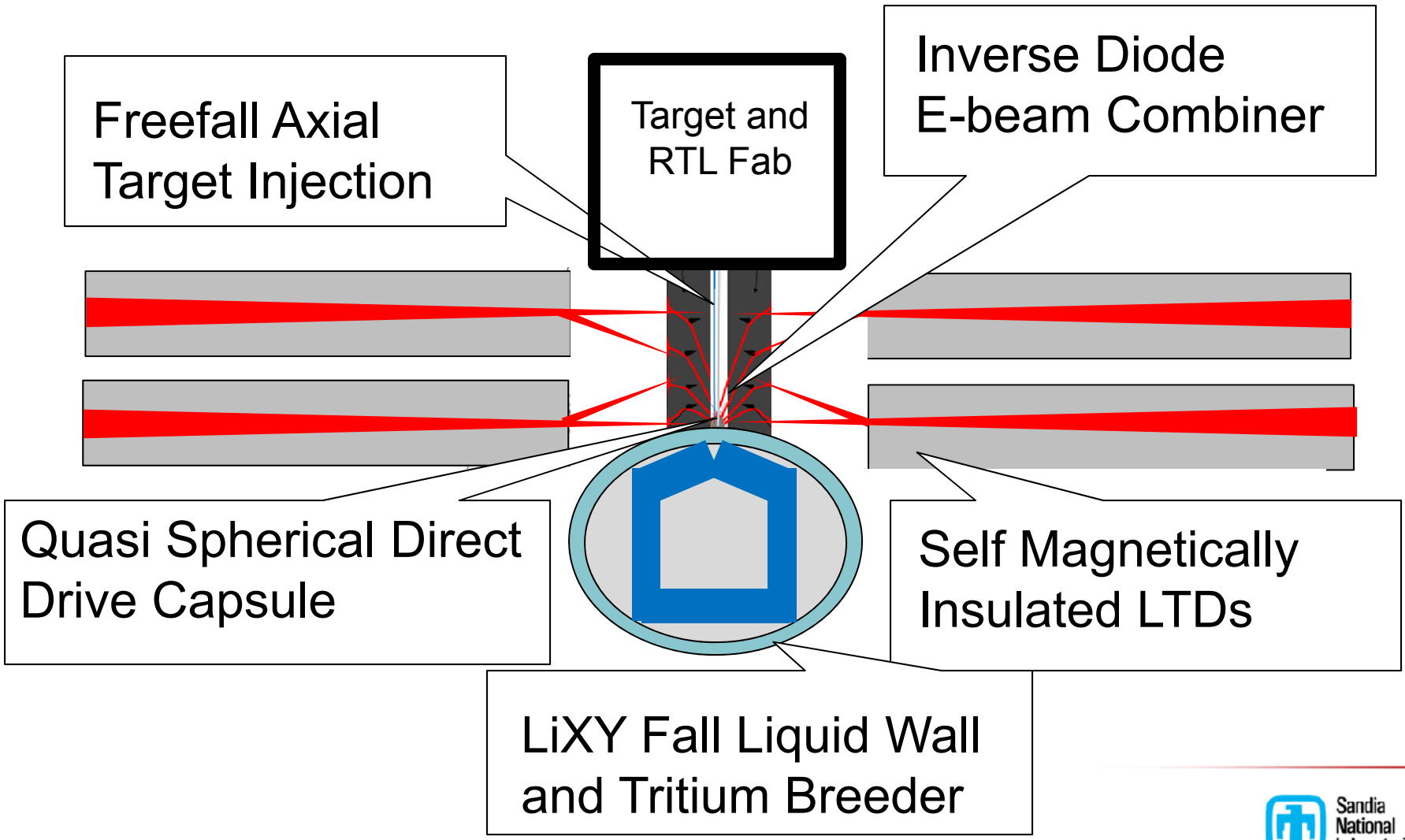
Experiments have validated LASNEX simulations of Magnetic Rayleigh Taylor (MRT) Instability.



- D. Sinars et al. PRL **105**, 185001 (2010) and Physics of Plasmas **18**, 056301 (2011)
- Longer wavelengths compared well.
- Shorter wavelength growth less than 2D predictions.



PPS now targets 3 Hz operation to produce power at Meir-Mohr Model COE of 7.6 cents/kW-hr.



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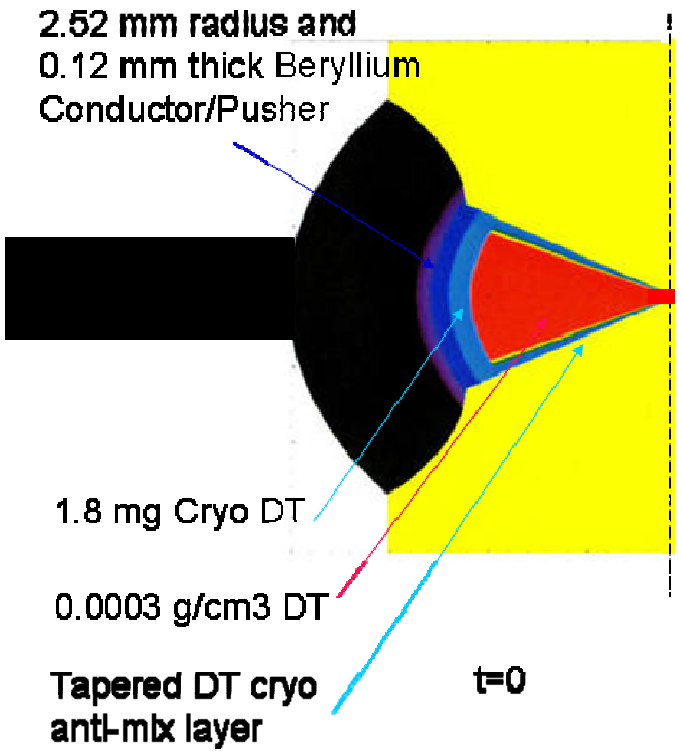
Quasi Spherical Direct Drive capsule offers 500 MJ yields with 85 MJ energy store.



Many issues are mitigated with a higher dI/dt.

- **Uniform Initiation**
- **Less growth of Magnetic Rayleigh Taylor instability**
- **Lower driver energy**
- **Higher ηG**
- **Lower Cost of Electricity**

2D yield is currently limited by a wall instability.
Three possible solutions are being examined with LASNEX.

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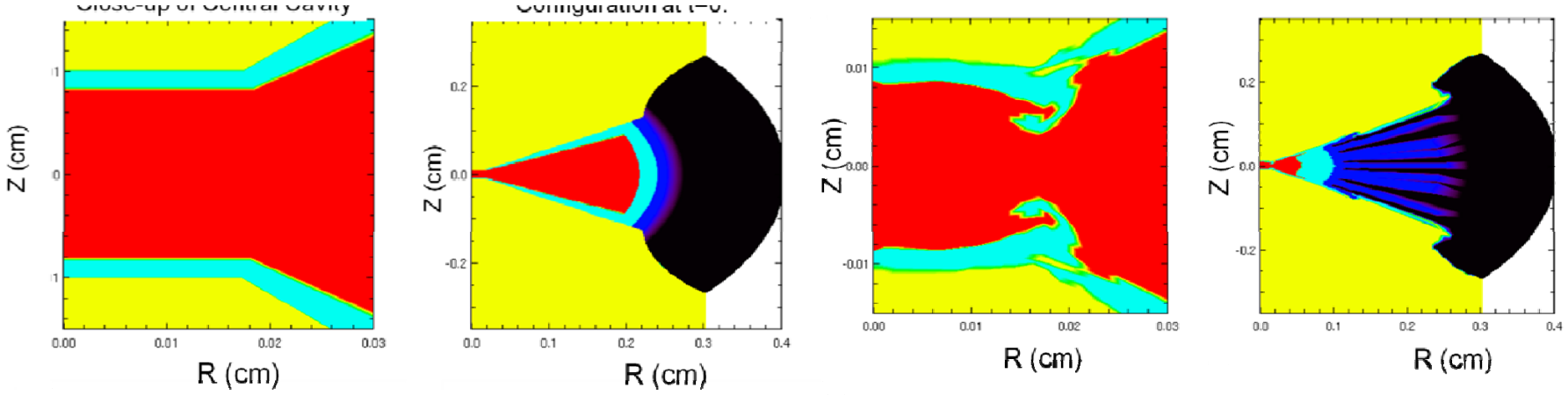
LASNEX Simulations show MRT Instability is benign for R_o/δ_o = 21 and 1 MJ yield in 1D and 2D at 38 MA.

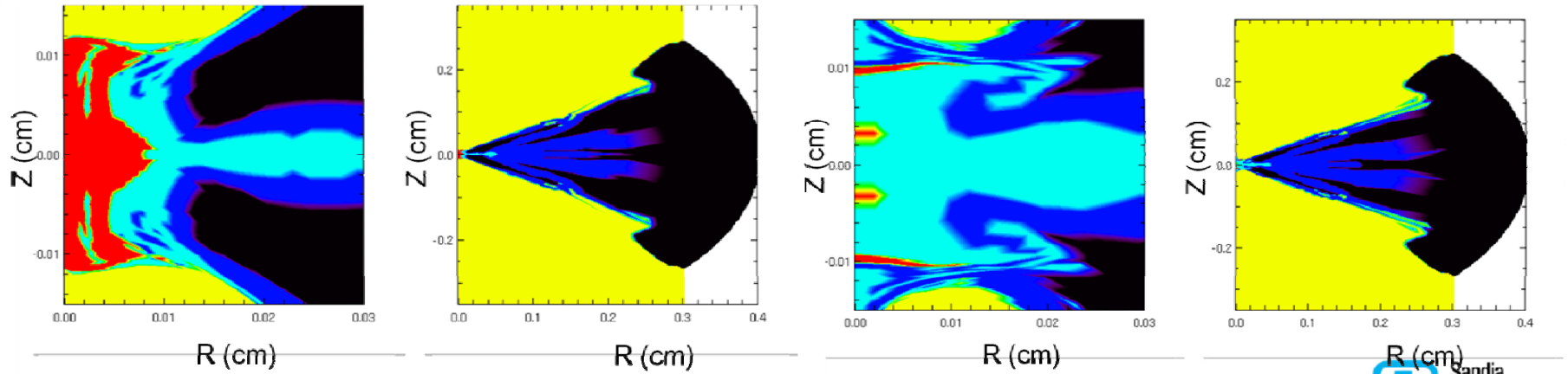
t=0 ns

t=39.1 ns



t=41.6 ns

t=41.9 ns



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Simulations reveal seven features that motivate QSDD.

1. Quantum Molecular Dynamics make design less uncertain than laser plasma interaction, wire initiation, and opacities make x-ray drive.
2. >6 times more energy in the fuel than x-ray drive.
3. Peak magnetic pressure >10 times ablation pressure of x-ray drive.
4. Internal pulse shaping automatically provides hot spot heating and adiabatic compression of main fuel.
5. Metal conductor tamps expansion during burn.
6. >4.5 MA current penetration into fuel gives alpha trapping and reduce $\rho r_{ignition}$ by a factor of 5 .
7. Possibility of MJ yields on a 40-ns, Z-class driver.

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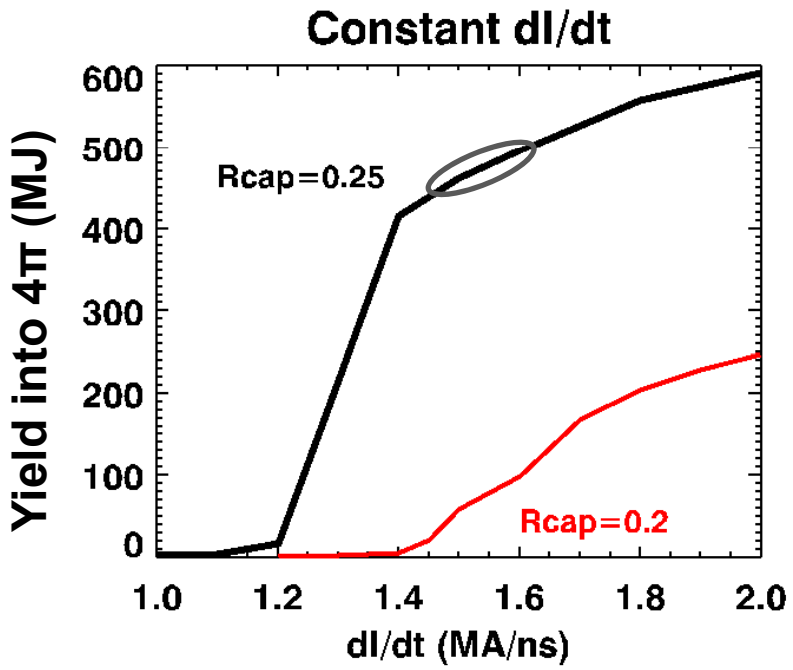
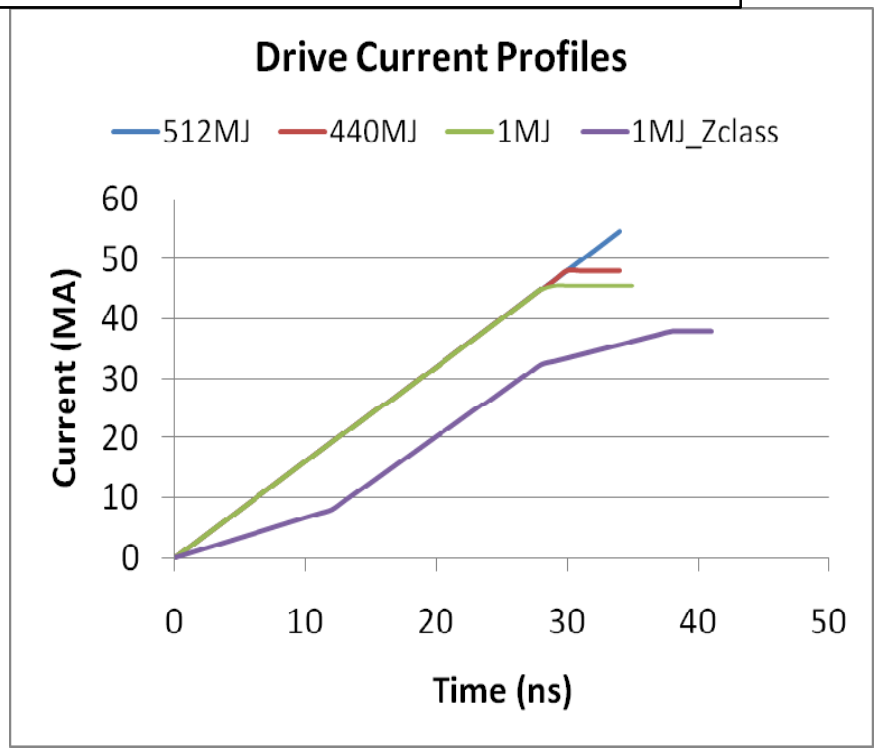
Projected drive current is ~ 38 MA for ignition on Z-class driver and ~48 MA for high-gain on PPS.

Magnetic Rayleigh-Taylor instability
allows initial aspect ratio of $R_o/\delta = 21$.





Producing $dI/dt = 1.5 \times 10^{15}$ A/s in a 2.5 mm radius capsule requires a new technology.

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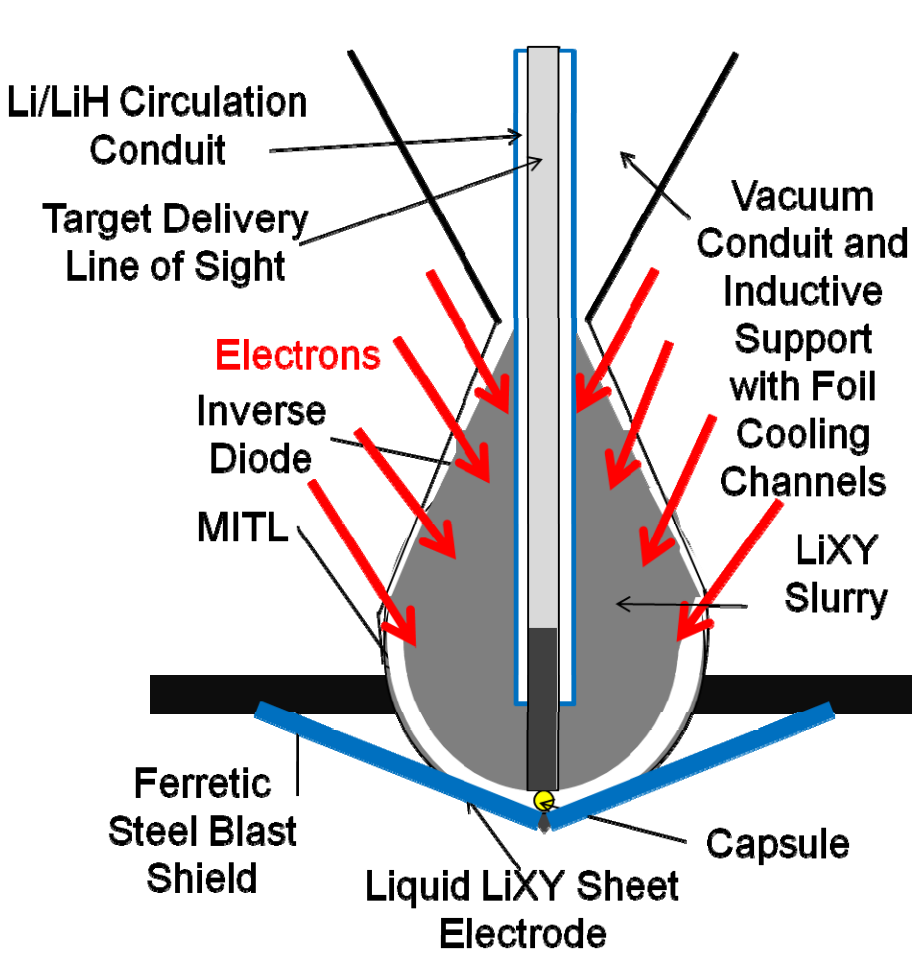
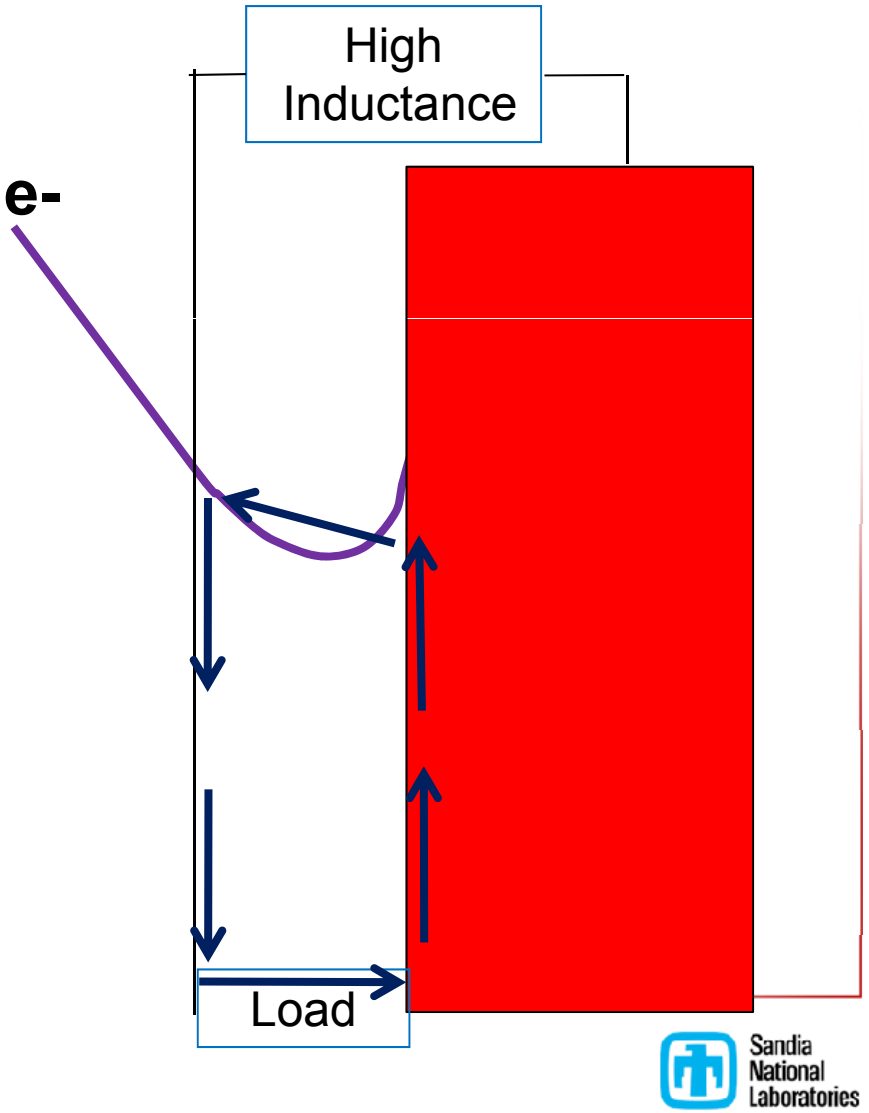
RTL and Inverse Diode couple the capsule to the driver.





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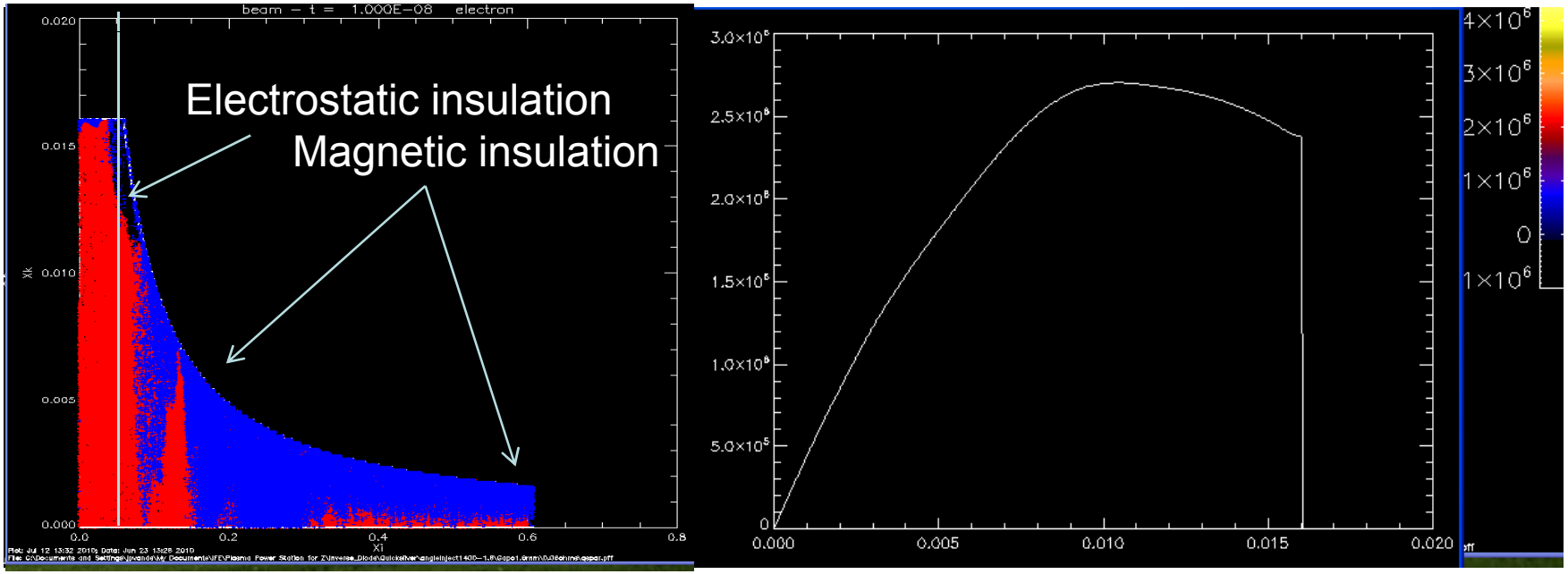
Space charge distribution prevents secondary electrons from neutralizing injected current.

Red: Injected electrons
Blue: Electrons emitted from cathode

Potential distribution across AK gap at r=0.05 m shows E-field reversal at cathode.



40 MA at 4 MeV injected and 33 MA at 2 MV at load without optimization

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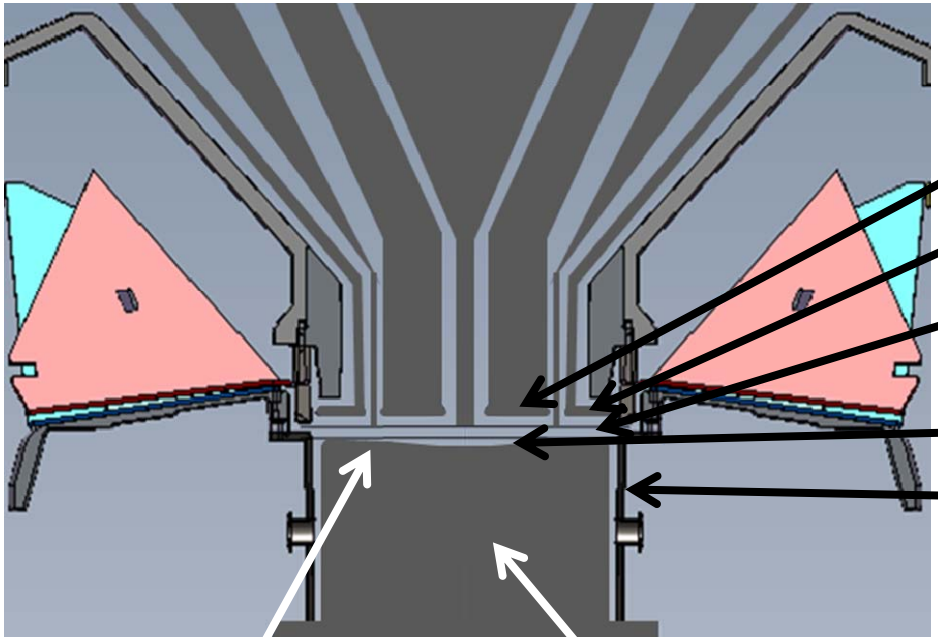
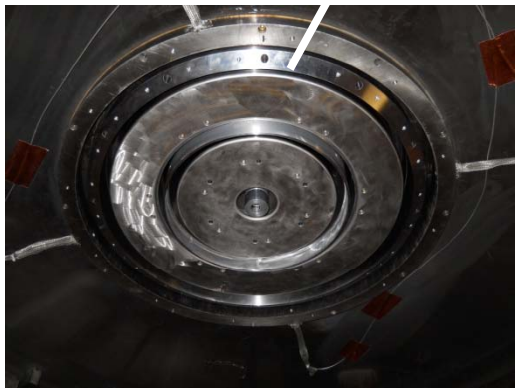
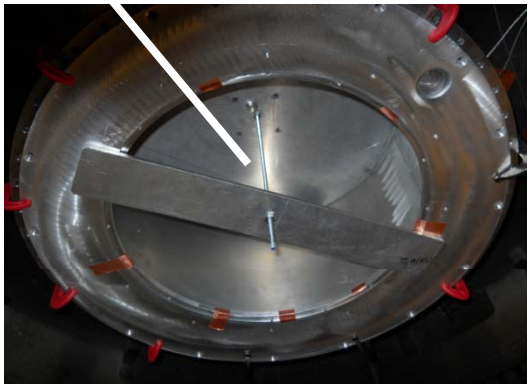
Saturn experiment supports the feasibility of the Inverse Diode for the PPS—in some key parameters.







- Inner MITL Cathode
- Outer MITL Cathode
- Post Accelerating Gap (PAG)
- Inverse Diode Gap
- Voltage Monitoring Inductor

Saturn	PPS
1,3 MV	11 MV
2 kA/cm^2	0.5 kA/cm^2
2.5 MA	50 MA

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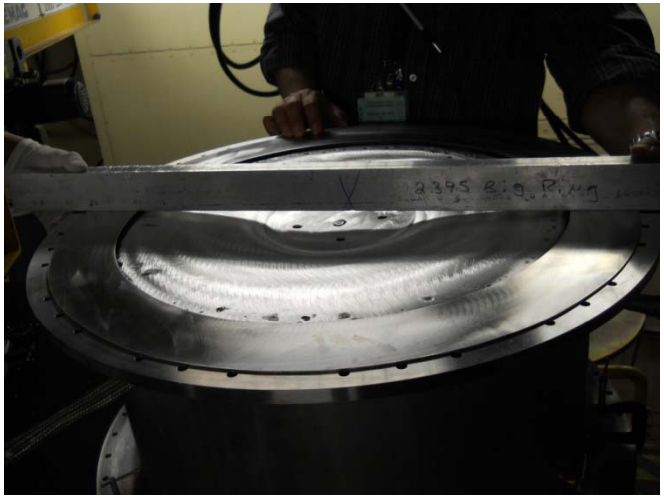
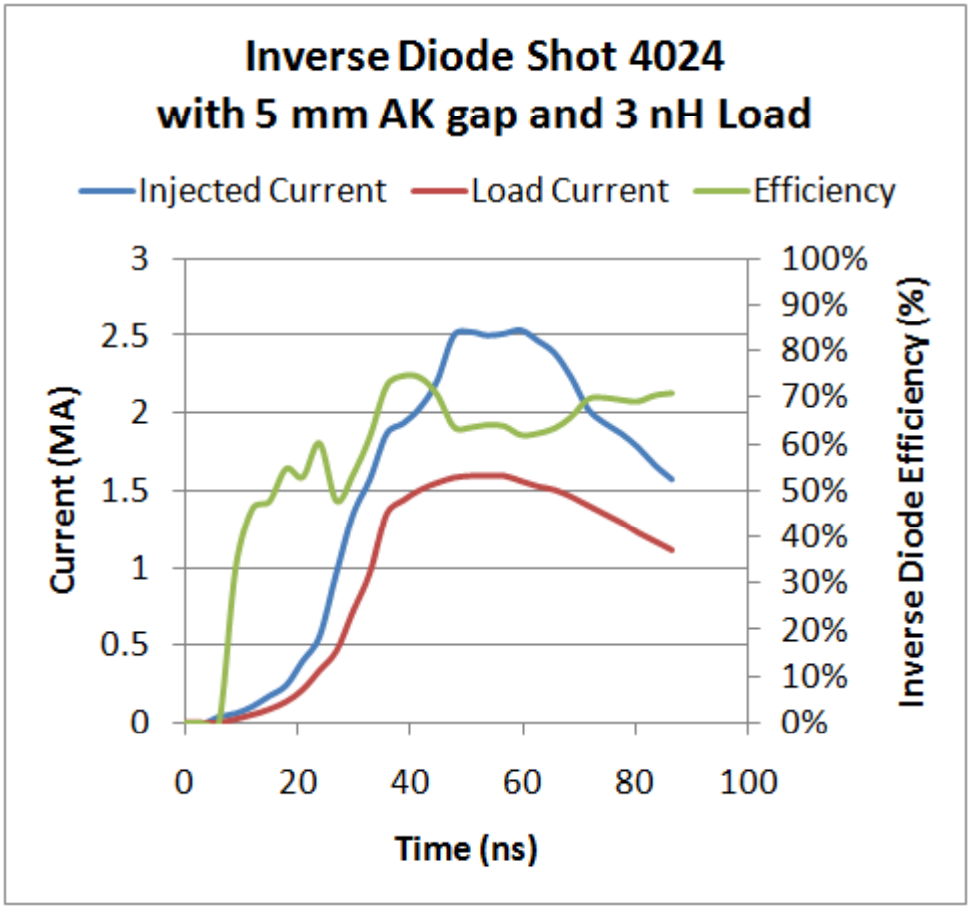
Unoptimized Inverse Diode had ~65% collection efficiency on Saturn.





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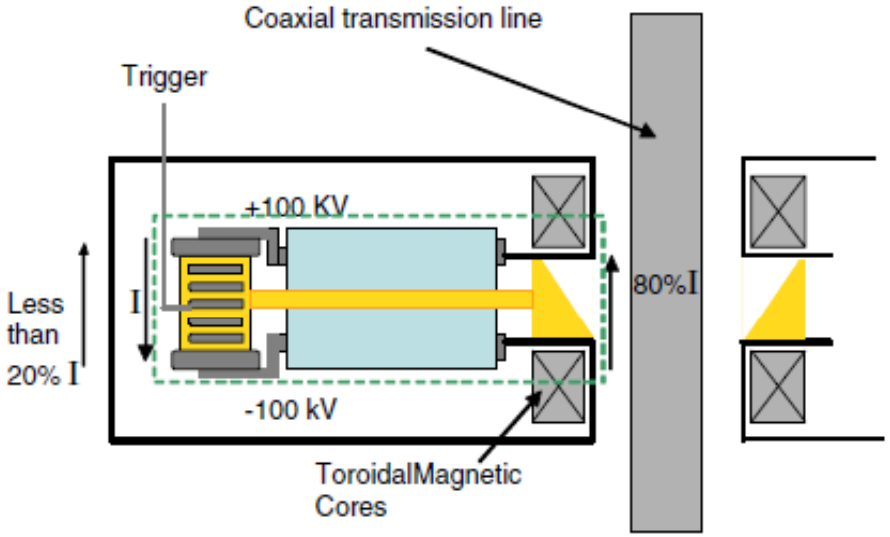
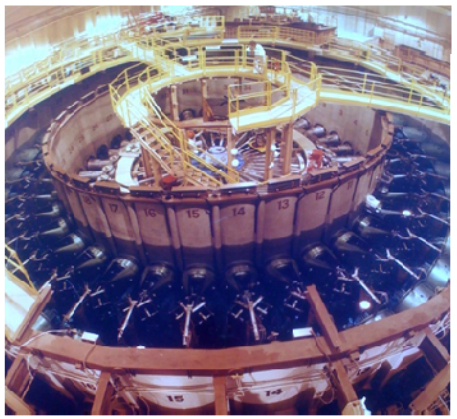
Magnetically Insulated, Linear Transformer Driver (MI-LTD) provides the modular e-beams.



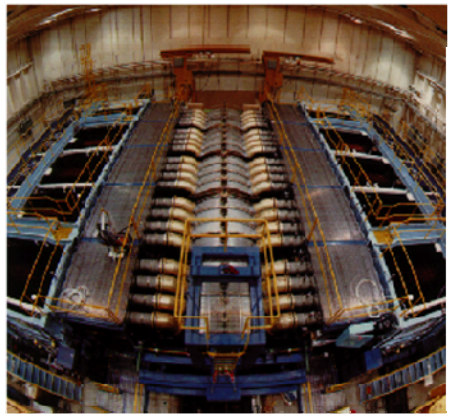
MYKONOS LTD Driver Test Bed

Prototype costs are:
$11/Joule
~10^{-4} cents/peak watt

PBFA-I, 2 MV, 12 MA



Hermes III, 18 MV, 0.7 MA



RHEPP II, 120 HZ

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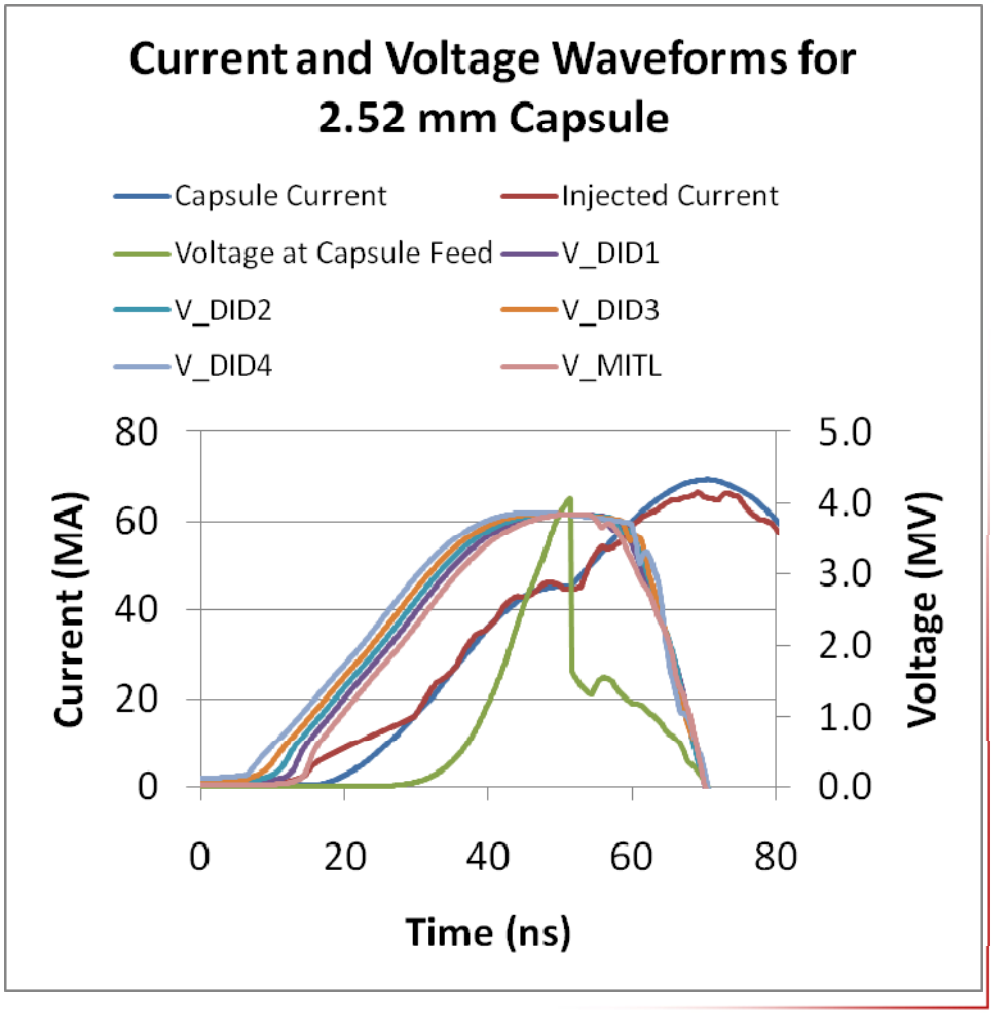
45 MA at 1.5x10^{15} A/s in QSDD capsule drives the design of the rest of the PPS.

- Direct Inverse Diode
  - 1 meter radius
  - 560 A/cm^2 injected electrons
  - 1 mm to 2mm minimum AK gap for 7.5 to 15MeV injected electrons
- MITL and Capsule
  - 1mm to 2 mm AK gap
  - 2.5 to 3.5 mm QSDD capsule

MITLs with 1 mm to 2 mm AK gaps must not short out.



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PPS targets 3 Hz operation to produce power at Meir-Mohr Model COE of 7.6 cents/kW-hr.

First Units with 10% Cost of Capital and 1.85 MIT 2009 Study Factor to 2007$ gives 14.9 cents/kw-hr.

Input: Nc=number of chambers	1.00
Input: RR=rep rate in shots per chamber per second	3.00
Input: Discount or Hurdle Rate for attracting capital	**10.00%**
MIT Escalation Factor	**1.85**
Approximation to Pe (MW)	866
Eta=thermal to electrical	0.44
$/Joule for Bank Energy	2.00
Energy Store (MJ)	85.0
ηG_bank	7.5
Net Electrical Power (MW)	651
Output: COE in $/KWH	0.149
Y(E)=yield per chamber (MJ)	641
M=Energy multiplication factor	1.15
Net Electric Power (MW)	651

Proven Units with 7.8% Cost of Capital and 1.0 MIT 2009 Study Factor to 2007$ gives 7.6 cents/kw-hr.

Input: Nc=number of chambers	1.00
Input: RR=rep rate in shots per chamber per second	3.00
Input: Discount or Hurdle Rate for attracting capital	7.80%
MIT Escalation Factor	1
Approximation to Pe (MW)	866
Eta=thermal to electrical	0.44
$/Joule for Bank Energy	2.00
Energy Store (MJ)	85.0
ηG_bank	7.5
Net Electrical Power (MW)	651
Output: COE in $/KWH	0.076
Y(E)=yield per chamber (MJ)	641
M=Energy multiplication factor	1.15
Net Electric Power (MW)	651

QSDD Capsule, Cylindrical RTL, Survivable Inverse Diode, Magnetically Insulated LTD.

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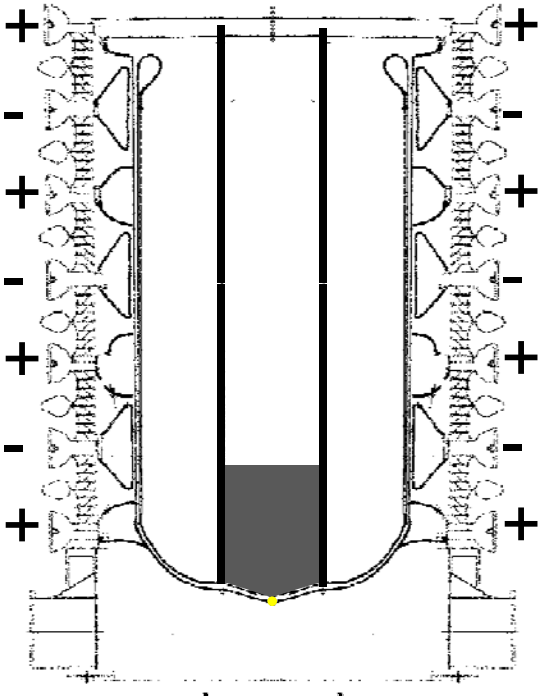
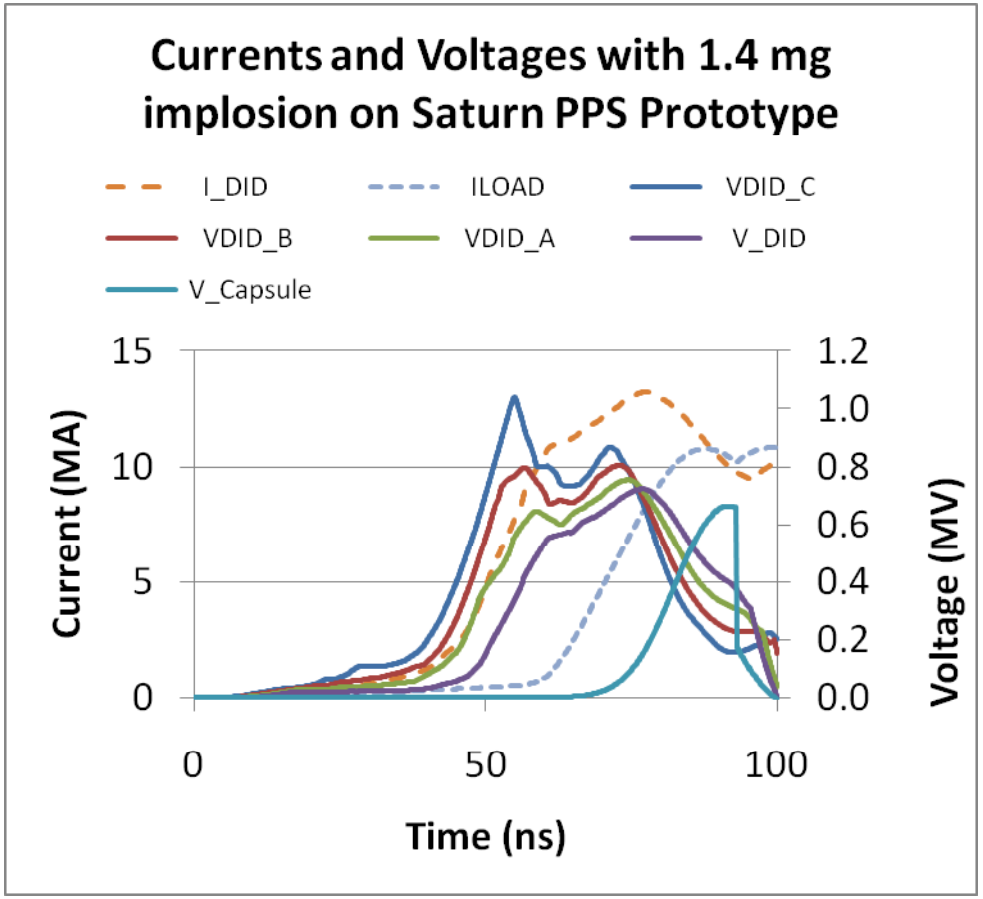
Saturn could prototype the PPS Inverse Diode, RTL, and QSDD Capsule.





QSDD baseline with 17.5 mg mass has 4 cm/ μs velocity.
QSDD surrogate with 1.4 mg mass has 22 cm/μs velocity.

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Many issues need to be addressed.

- Better mitigation of wall instability
- Experimental demonstration of QSDD performance
- High-resolution Gorgon, LASNEX, or Hydra simulations at 500 MJ yield with dI/dt ~1.5×10^{15} A/s
- Experimental demonstration of > 90% current efficiency with Direct Inverse Diode (DID)
- Survivable anode at 560 A/cm^2 electron injection
- 2D simulations of blast and radius for survivability
- Simulation of chamber recovery for 3 Hz operation
- LiXY working fluid with <3×10^{-5} Torr vapor pressure at 400 ^{o}C
- Liquid metal MITL anode
- Ignition on short pulse modification of Z

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