A Compact Portable Plasma Radiation Source Generator at Idaho Accelerator Center:

approach and design possibilities

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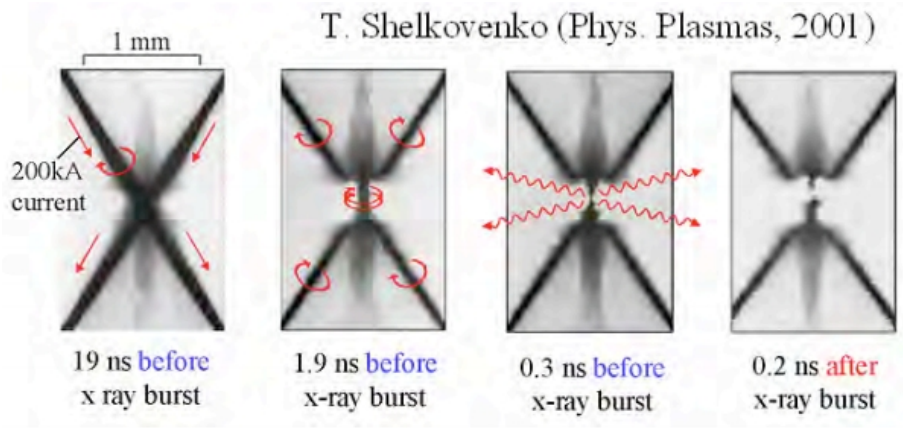
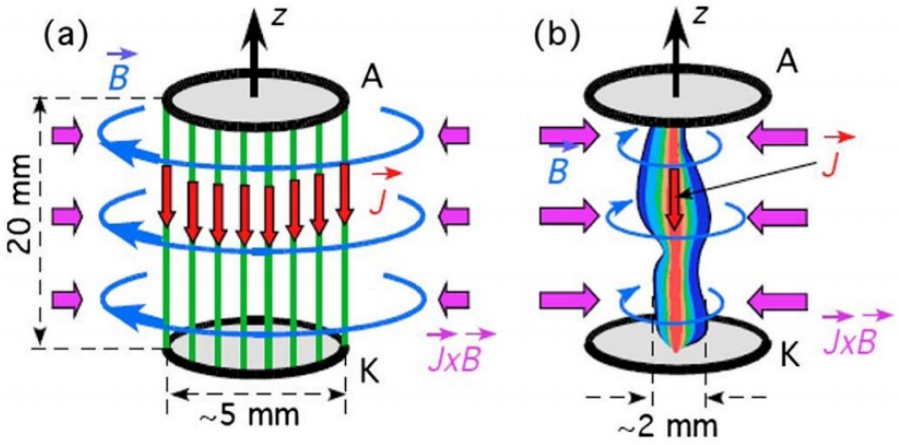
What is X - Pinch / Z - Pinch?





* two or more 5 – 100 um metal wires crossed at one point

* **Current pulse:**
  ≥ 100 kA , ≥ 1 kA/ns

* **X-Ray pulse:**
  short pulse (< 1 ns)
  small size (few um and less),
  bright (hundreds of mJ and more)

* cylindrical one or more metal wire array

* **Current:**
  1 MA and higher

* **X-Ray pulse:**
  short pulse
  hundreds of TW

a)b) J. L. Giuliani and more, J.L. IEEE Transactions on Plasma Science 40, 3246 - 3264 (2012)

Why is X - Pinch / Z - Pinch?

X - Pinch Appliocations:

* high resolution x-ray radiography
* phase-contrast imaging of low opacity object
* fast diagnostic tools for rapidly evolving small system
* exploding wire, hot/warm plasma experiments
* weapon effect testing experiments *... and more*

Z - Pinch Applications

* wire initiation, ablation, implosion, stagnation research
* Dynamic – Hohlraums study
* Pulsed Fusion Energy (Z-Machine) *... and more*

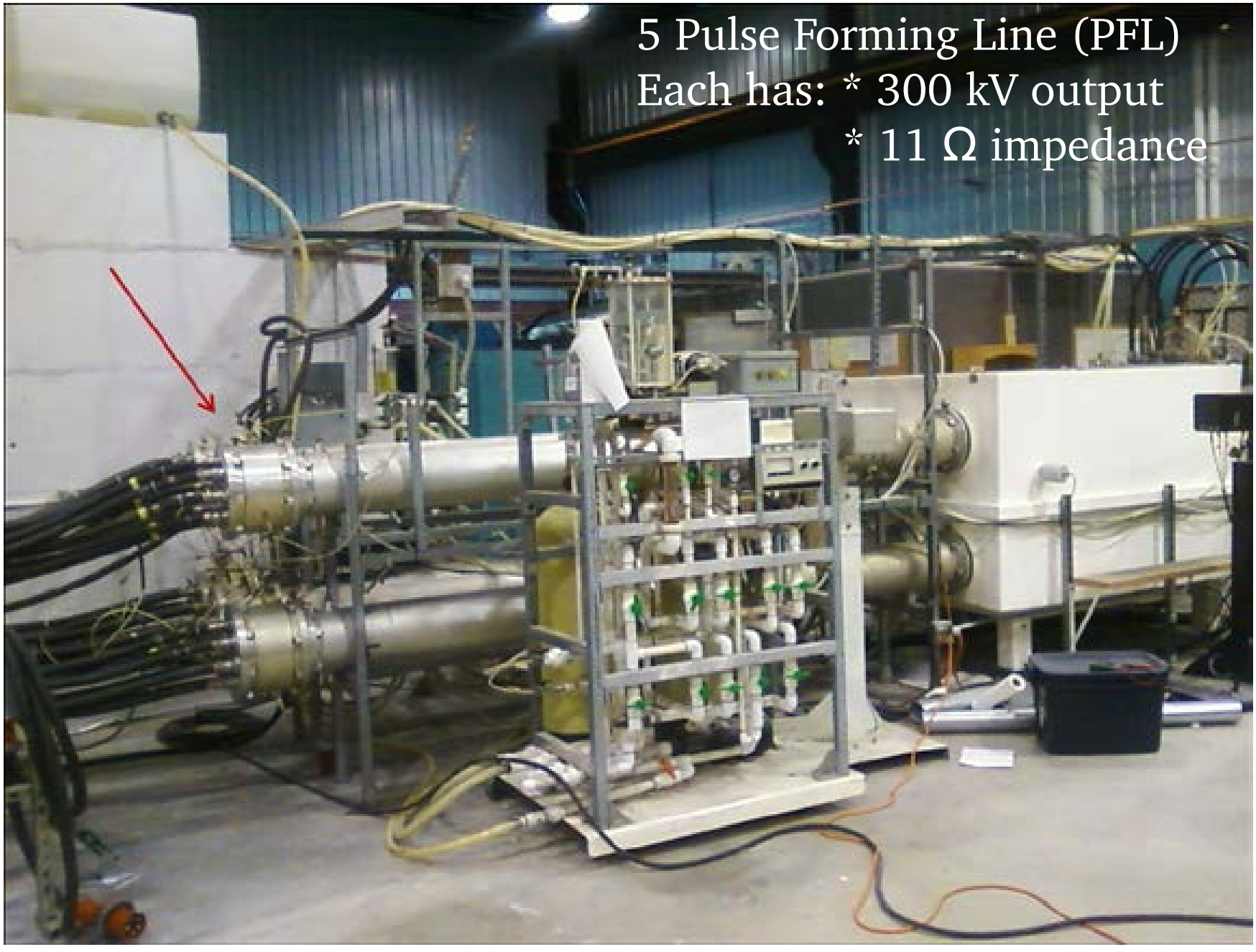
X/Z - Pinch Fundamental Physics

* High Energy Density Physics (HEDP) Research
* Basic Plasma Physics Science (EOS, radiation mechanism, radiation transport, spectral properties, instabilities) *... and more*

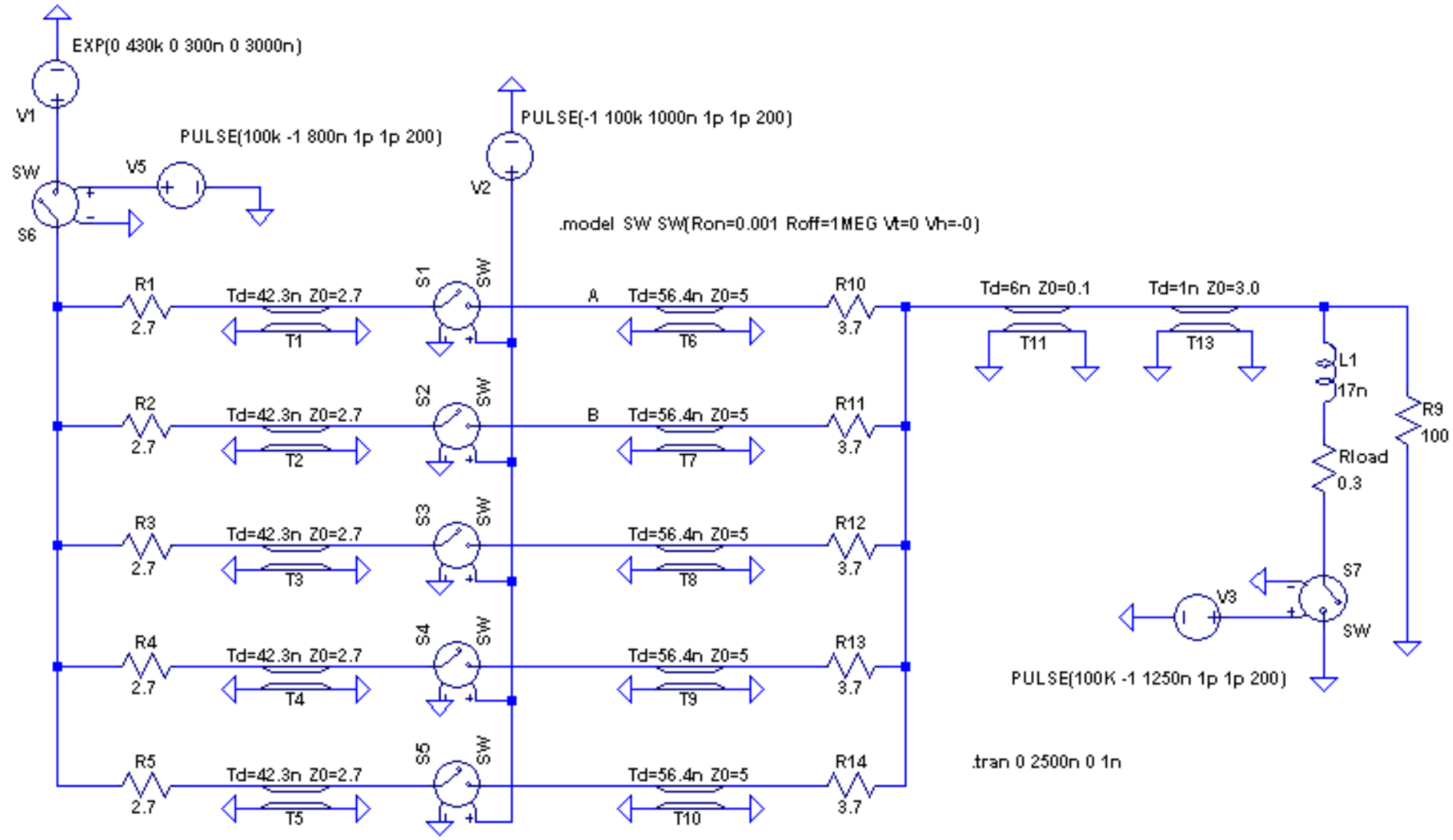
1st possible design for X - Pinch Driver:

Modification of
Idaho State Induction System (ISIS)
Induction Cell Driver (ICD)

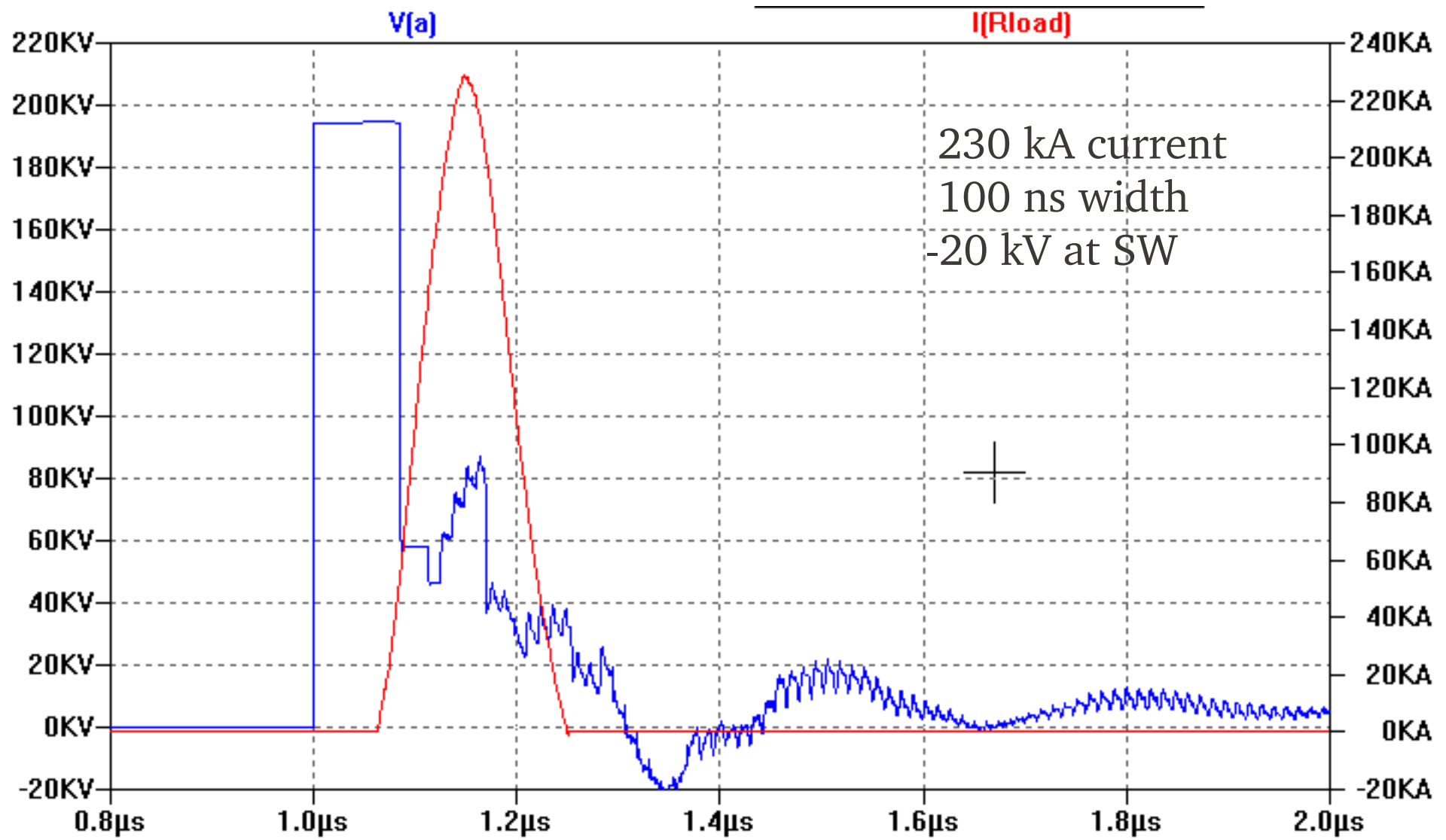
Idaho State Induction System (ISIS) Induction Cell Driver (ICD)



1st Plan: Model



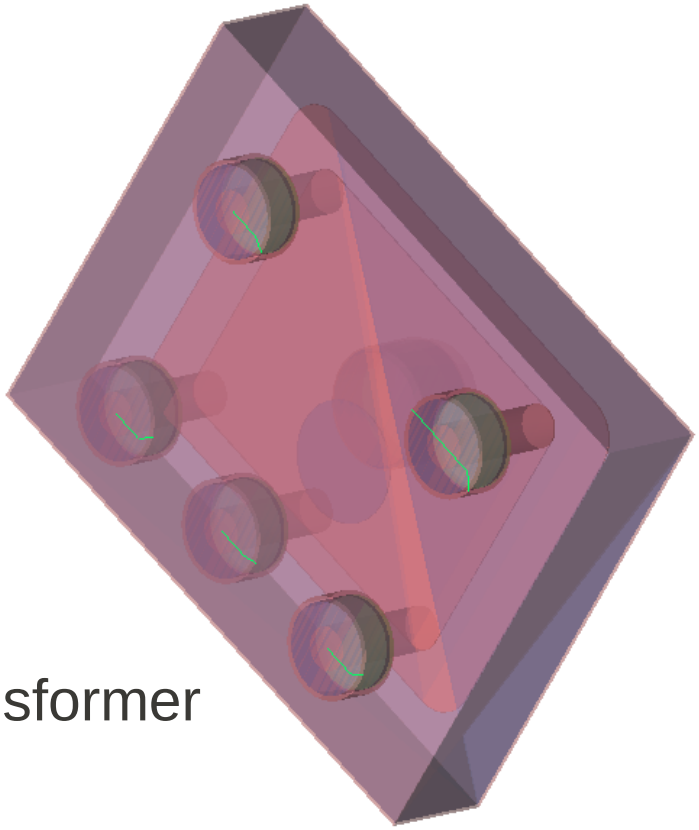
1st Plan: simulation results



1st Plan: Transformer Design

$T = 6$ ns

$Z_0 = 0.1\ \Omega$



Transformer Length:

30 cm/ns * 6 ns = 180 cm (in vacuum)
180 cm / 9 = 20 cm (in water)

We can do 20 cm long water filled transformer

Transformer Impedance:

Z = L/C

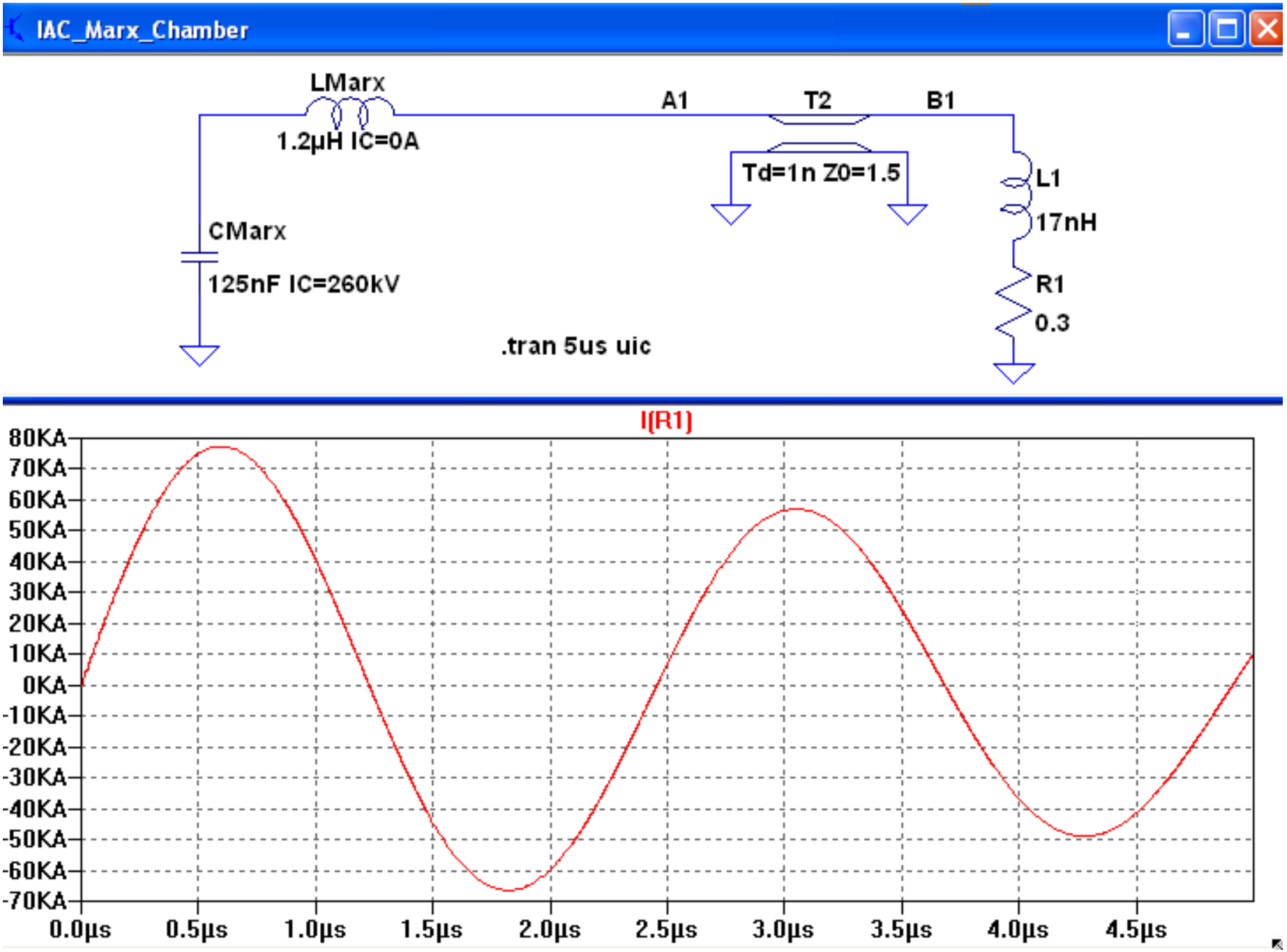
Remcom Xfdtd software

2nd possible design of X-Pinch Driver:

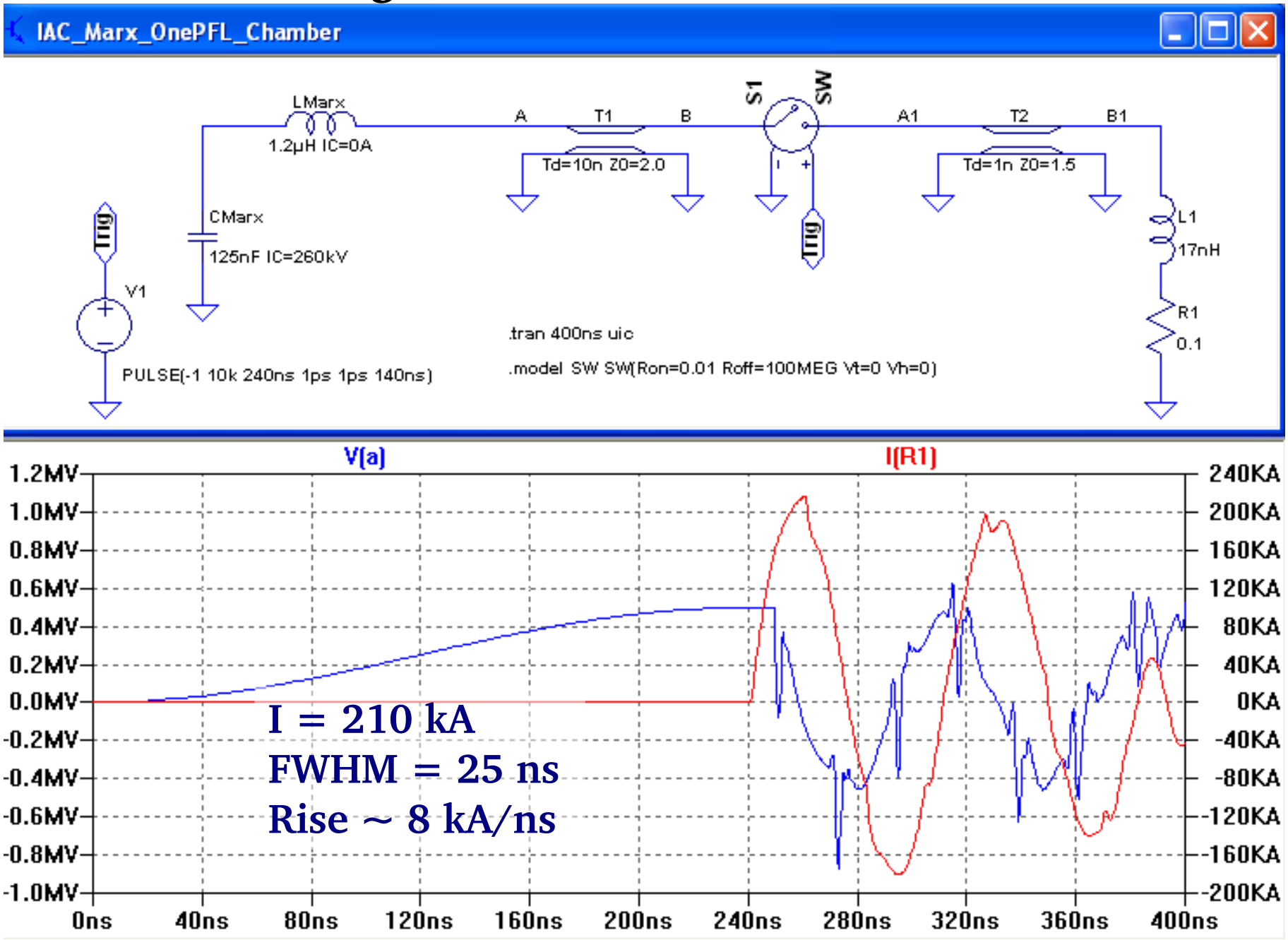
Construct separate Marx generator

with Pulse Forming Line

2nd Plan: Marx generator without transmission lines



2nd Plan: Marx generator with one transmission line



3rd possible design of X-Pinch Driver:

Compact Portable
Plasma Radiation Source (PRS)
X-Ray Generator

no Marx generator

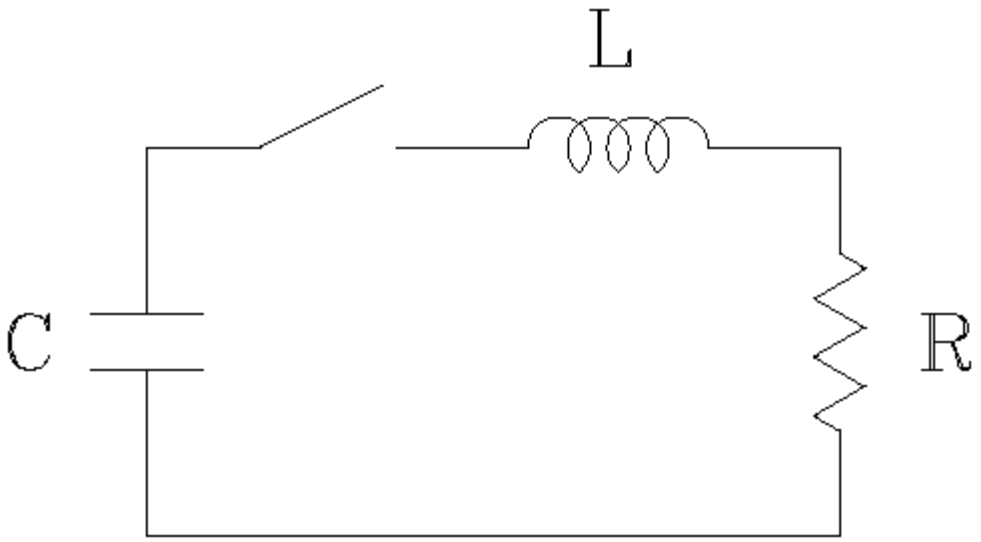
no Pulse Forming Lines

instead utilize new

high current low inductance

capacitors and switches

LRC circuit analysis*



$$L\,d^2i/d^2t + R\,di/dt + i/C = 0$$

"Damped"

$$R_1 = \sqrt{L/C}$$

$$v_{peak} = 0.55\,V_0$$

$$i_{peak} = 0.55\,V_0/R_1$$

$$t_{peak} = 1.21\sqrt{LC}$$

"Critical Damped"

$$R_2 = 2\sqrt{L/C}$$

$$v_{peak} = 0.74\,V_0$$

$$i_{peak} = 0.74\,V_0/R_2$$

$$t_{peak} = \sqrt{LC}$$

*M.G.Mazarakis, and R.B.Spielman "A compact, high-voltage E-beam pulser" 1999 IEEE

A total of four fast high current capacitors

Capacitor 35478: $C_c = 80\,nF,\ L_c = 10\,nH,\ V_0 = 100\,kV,\ I_c = 60\,kA$

Switch: $L_{sw} = 10\,nH$

With 4 such capacitors we can built 200 kA, 0.25 Ω generator

$I_{peak} = 200\,kA$

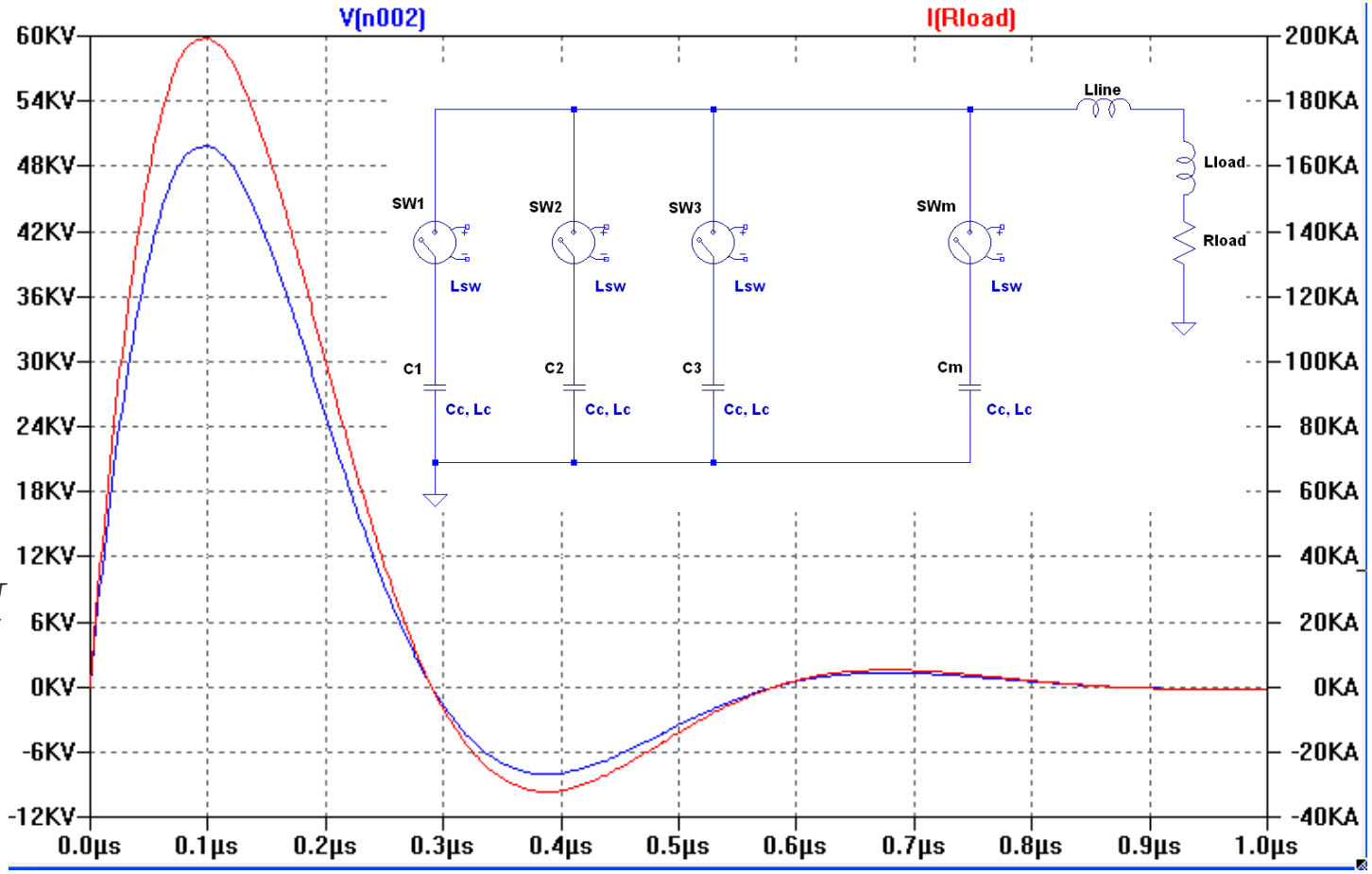
$V_{peak} = 50\,kV$

$t_{peak} = 97\,ns$

$2.06\,kA/ns$

$L_{load+line} = 15\,nH$

$R_{load} = 0.25\,\Omega$



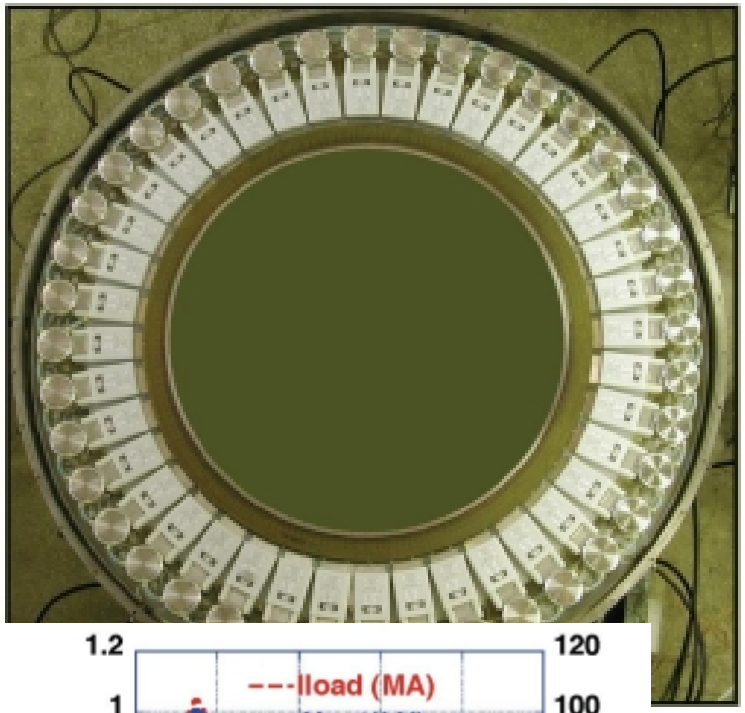
4th possible design of X-Pinch Driver:

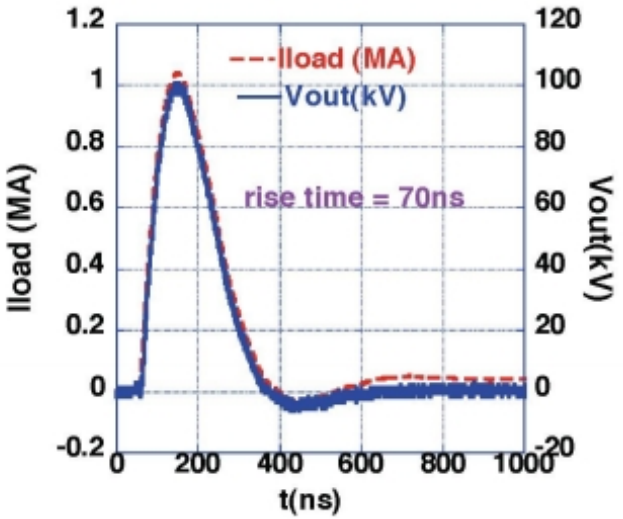
Acquire a complete

Linear Transformer Driver (LTD) Cavity

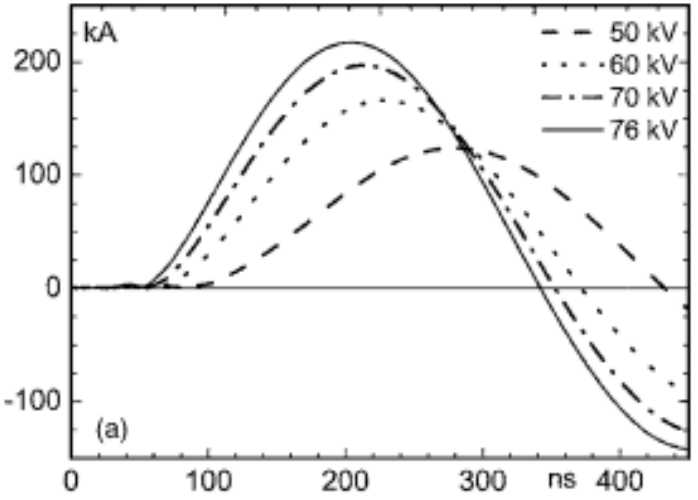
to build X/Z – Pinch Driver

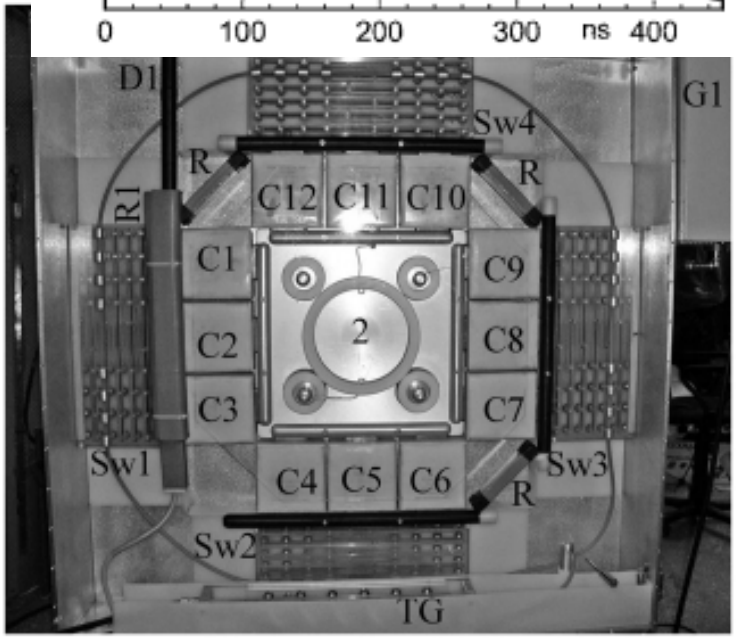
Sandia National Laboratory LTD Cavity *





Institute of High Current Electronics LTD Cavity **





* M.G. Mazarakis "High Current Fast 100-NS LTD Driver Development in Sandia Laboratory" 2005 IEEE
** A. V. Kharlov "Compact high current generator for x-ray radiography" Rev. Sci. Instrum. 77, 123501 (2006)

Conclusion

1. X /Z – Pinch Driver has many applications in different areas of research, starting from imaging, radiography and ending up with pulsed fusion energy research

2. We can actively participate in Pulsed Power Research by building one or more X/Z – Pinch Driver at IAC

3. At present moment, we have four different possibilities:

   * Modification of ISIS ICD
   * Construction of separate Marx generator + PFL
   * Utilize the new low inductance capacitor and switch technologies to build a compact PRS
   * Acquire complete LTD cavity for X/Z-Pinch study

THANK YOU

and, please, questions

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Z-Pinch/X-Pinch worldwide Installations

- Sandia National Laboratories, Z machine (1996), 18 MA 100ns [4]
- Sandia National Laboratories, ZR (Refurbished) (2006), 27 MA, 95ns
- Sandia National Laboratories, future ZN (Z Neutron), 20 and 30 MJ per short
- Sandia National Laboratories, future Z-IFE (Z-inertial fusion energy), 70 MA, 1 PetaWatt
- Sandia National Laboratories, SATURN, 8 MA
- Cornell University, USA: COBRA, 1 MA, 95-180 ns [5]
- Cornell University, USA: XP Pulser, 450 kA, 50 ns [6]
- University of Nevada, Reno: Zebra, 1MA, 100ns [7]
- University of California, San Diego: GenASIS, 210 kA, 150 ns [8]
- University of California, San Diego: X-Pinch Pulser, 80 kA, 50 ns [9]
- University of Michigan, USA: MAIZE, 1 MA, 100 ns [10]
- Florida A&M University: X Pinch system

- Pontificia Universidad Católica de Chile: Llampüdkeñ, 400 kA, 260 ns
- Pontificia Universidad Católica de Chile: GEPOPU, 180 kA, 120 ns

- Imperial College, London: MAGPIE, 1.4 MA, 240 ns [11]
- Imperial College, London: Table-top X-pinch, 40 kA, 30ns
- France?: PIAF, 250 kA, 180 ns

- Xi'an, China: QiangGuang-1, 1 MA, 50 ns
- Beijing, China: PPG-1, 400 kA, 100 ns
- CIAE, China: Light II-A, 200 kA
- Beijing, China: Table Top, 100 kA, 60 ns, 2m x 1.1m x 1.2m

- TRINITI, Russia: ANGARA-5-1, 4 MA, 100 ns [12]
- Institute of High Current Electronics, Russia: Compact Pulse Generator, 300 kA, 200 ns, 70 kg
- Institute of High Current Electronics, Russia: Compact submicrosecond, high current generator, 650 kA, 390 ns