ISIS Induction-Cell Driver Modification to High Current X-Pinch Radiation Source

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IAC
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Overview: PPG-1 Tsinghua University, Beijing

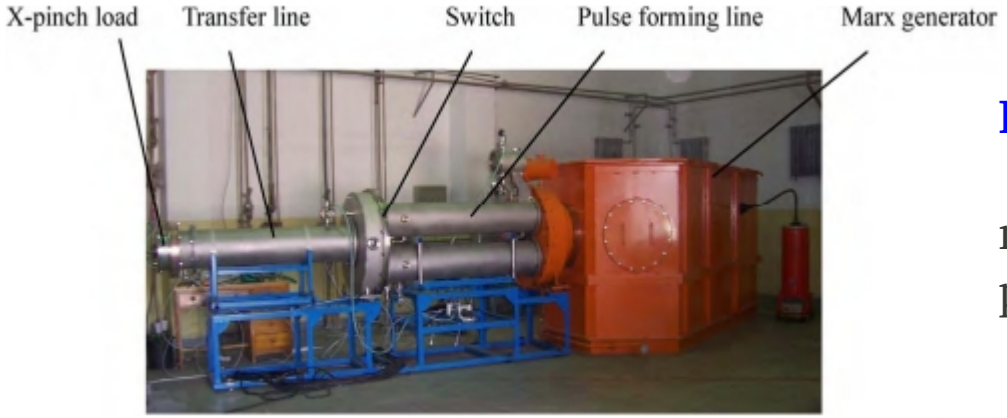

Fig. 1. View of the PPG-I.

Pulsed Power Generator PPG-1

max output current: 400 kA
pulse width: 100 ns

X-Pinch Performance:

output current: ~200 kA
X-pinch: two 25 um (or 13 um) Mo wires
distance between anode and cathode: 10 mm

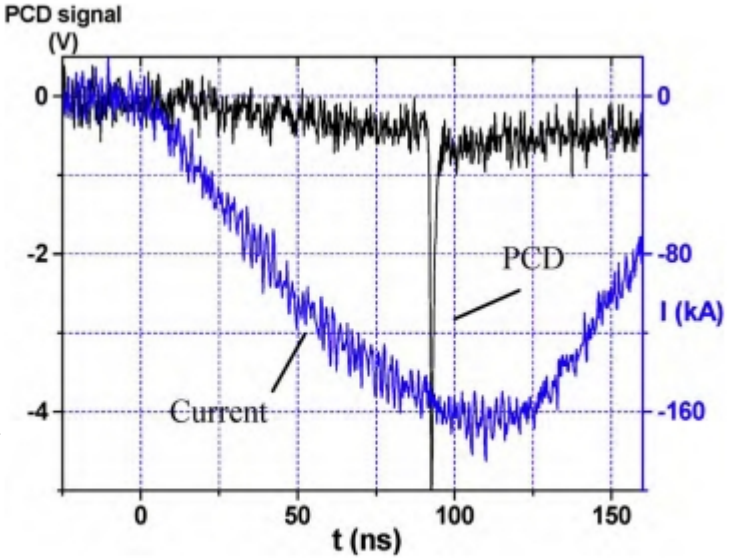

Fig.2. Typical X-ray burst measured with a PCD detector and the load current measured with a Rogowski coil.

Ran Zhang et al. "X-pinch applications in X-ray radiography and design of compact table-top X-pinch device" 2010 IEEE

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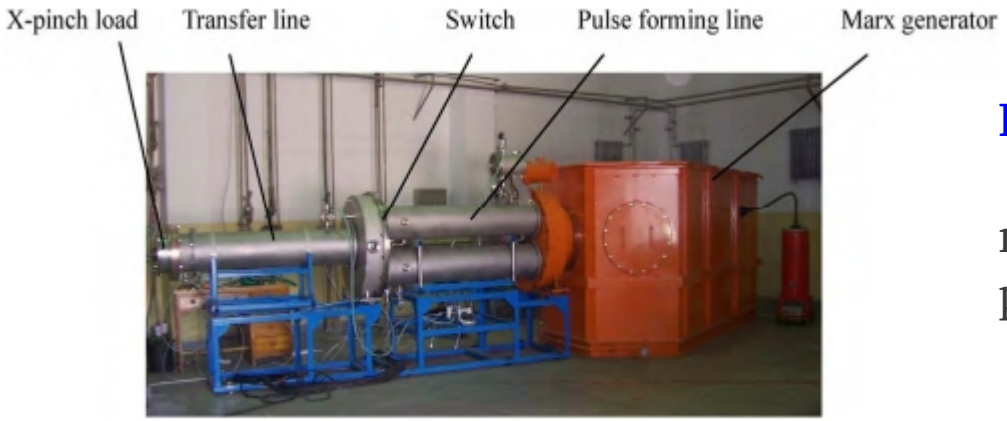

Fig. 1. View of the PPG-I.

Pulsed Power Generator PPG-1

max output current: 400 kA
pulse width: 100 ns

Backlighting Experiment

X-pinch current: ~100 kA
X-pinch: two 13 um Mo wires
Z-pinch: two 50 um Mo wires
anode/cathode distance: 10 mm

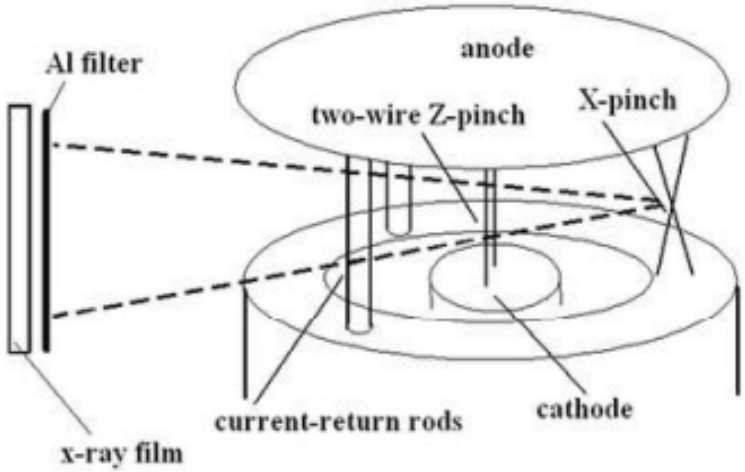

Fig. 3. Experimental arrangements for backlighting of Z-pinch using X-pinch as x-ray source.

Ran Zhang et al. "X-pinch applications in X-ray radiography and design of compact table-top X-pinch device" 2010 IEEE

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Compact Table-Top X-Pinch Device

output current: 100 kA
pulse width: 60 ns
Load: X-pinch with a few um

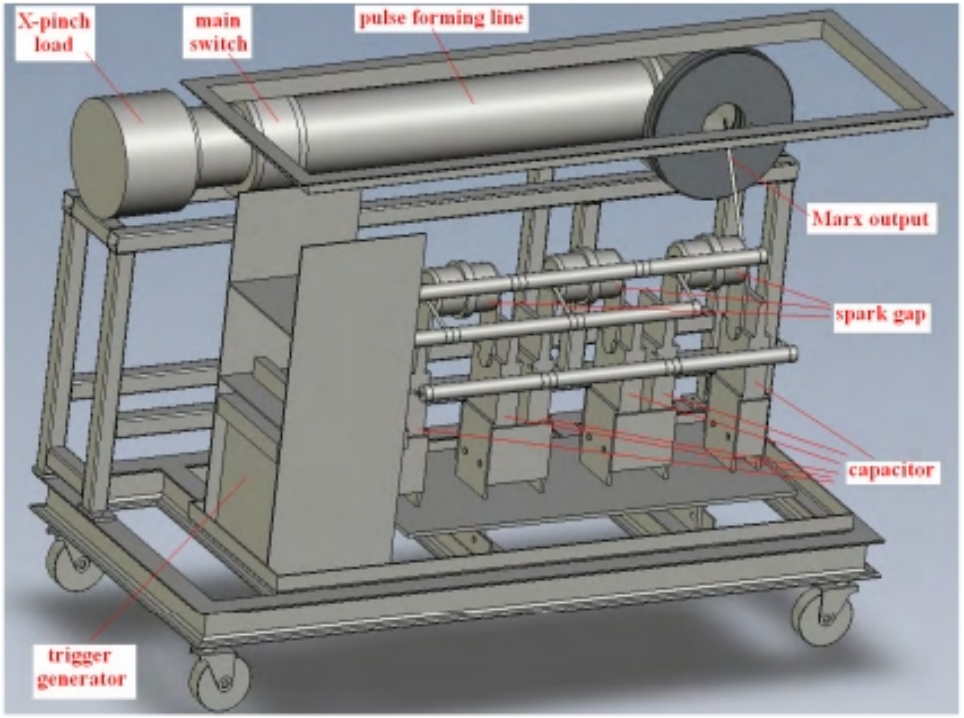


Fig.8. Design drawing of the compact table-top X-pinch device.

Ran Zhang et al. "X-pinch applications in X-ray radiography and design of compact table-top X-pinch device" 2010 IEEE

Overview: Laboratory of Plasma Studies, Cornell University

XP facility

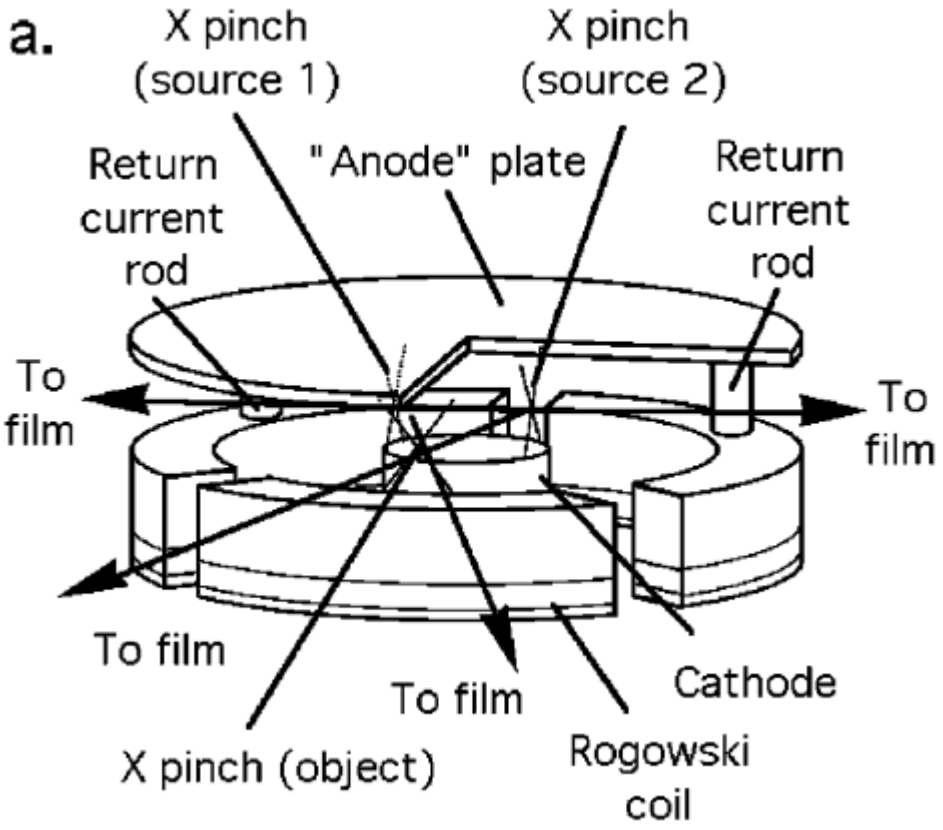
* 470 kA peak current
* 100 ns pulse duration

X-Pinch 1 and 2 (backlighter)

* 235 kA peak current
* Two 17-30 um Mo wires
* 1.5 cm long

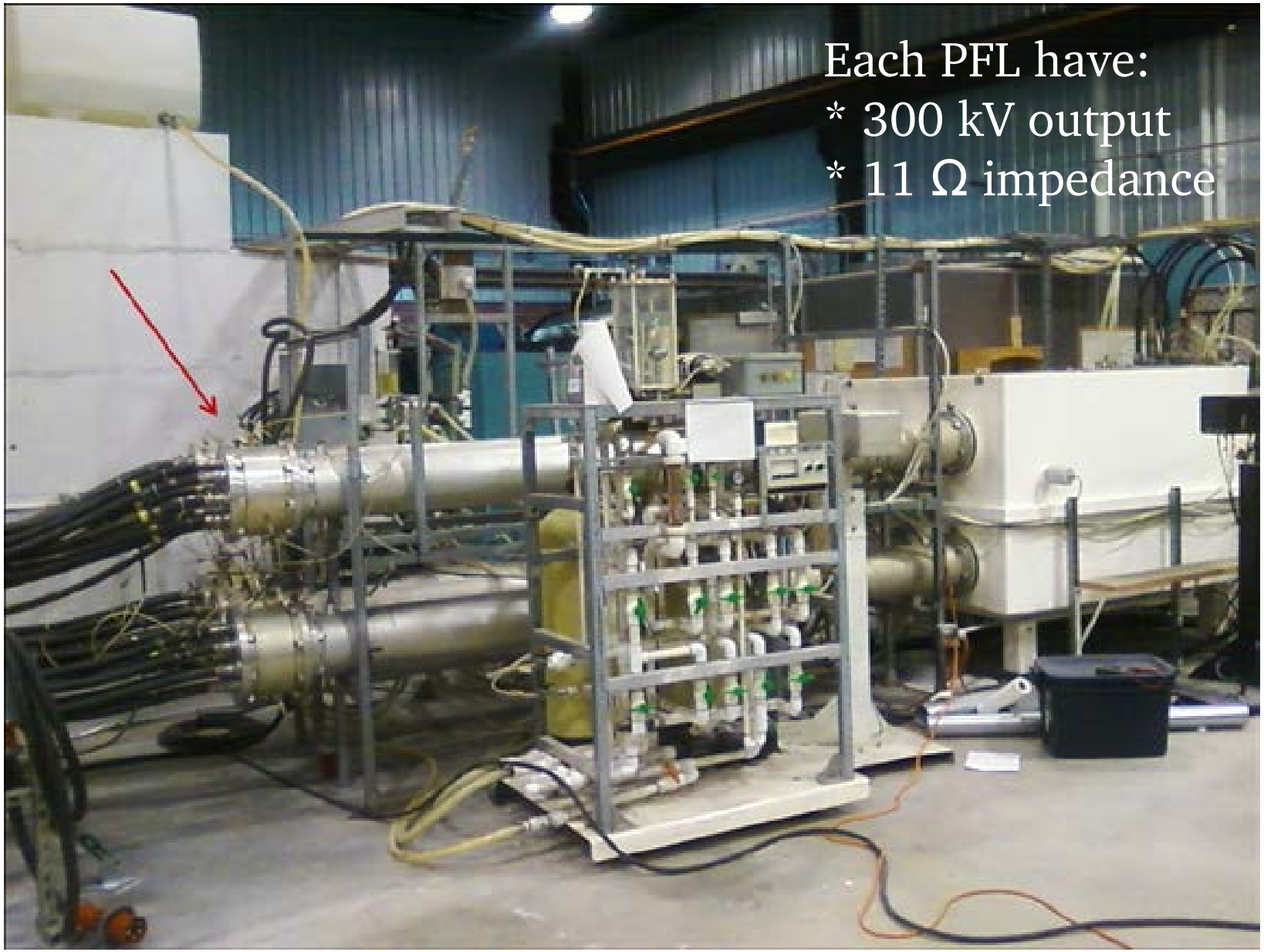
Object X-Pinch

* 90-120 kA peak current
* W, Mo, Au, or Al wires
* 1.5 cm long

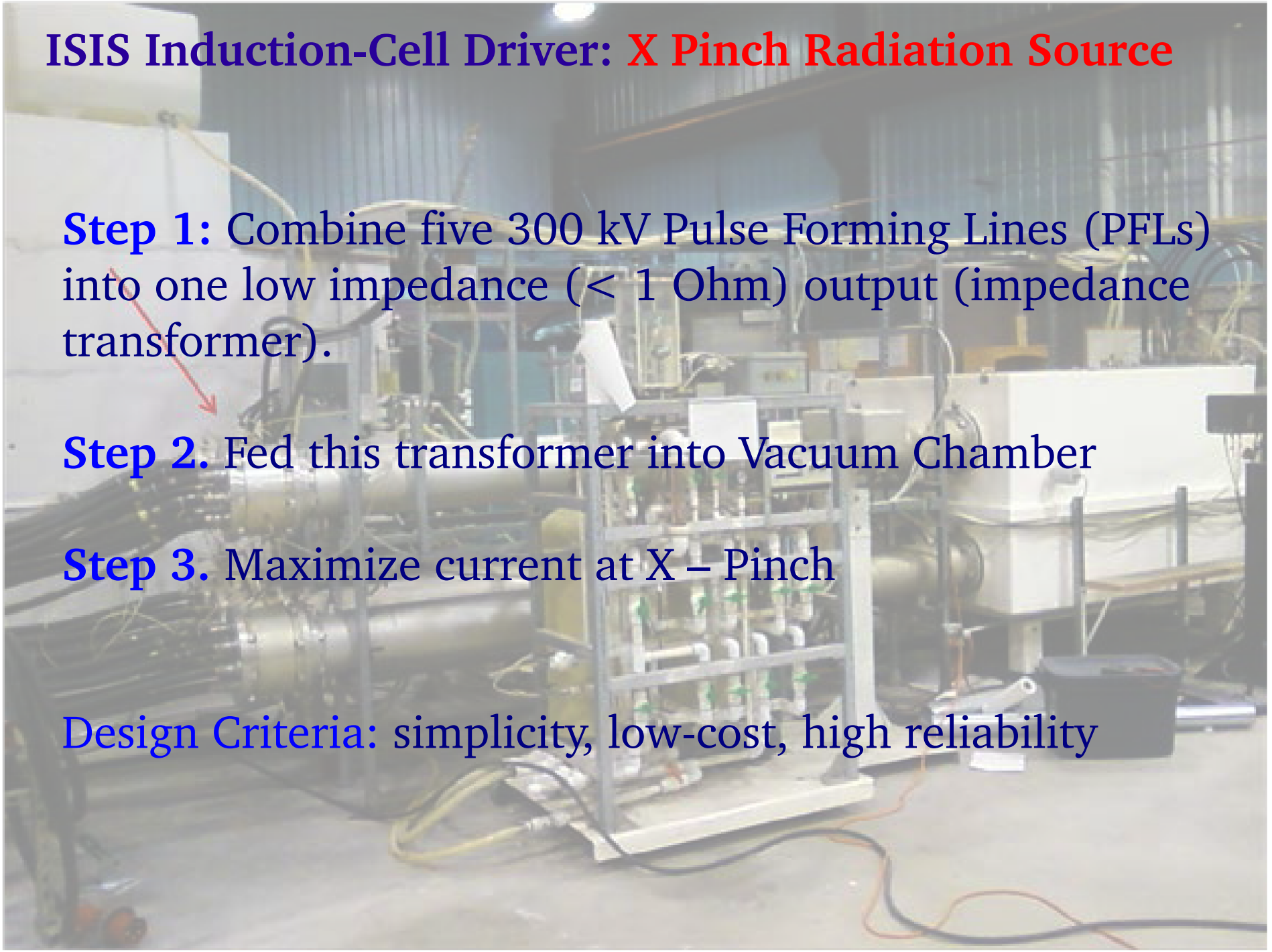


T. A. Shelkovenko et. al. "Radiographic and spectroscopic studies of X-pinch plasma implosion dynamics and x-ray burst emission characteristics" 2001 AIP

ISIS Induction-Cell Driver: 5 Pulse Forming Lines



ISIS Induction-Cell Driver: X Pinch Radiation Source



Step 1: Combine five 300 kV Pulse Forming Lines (PFLs) into one low impedance (< 1 Ohm) output (impedance transformer).

Step 2. Fed this transformer into Vacuum Chamber

Step 3. Maximize current at X – Pinch

Design Criteria: simplicity, low-cost, high reliability

ISIS Induction-Cell Driver: 5 Pulse Forming Lines

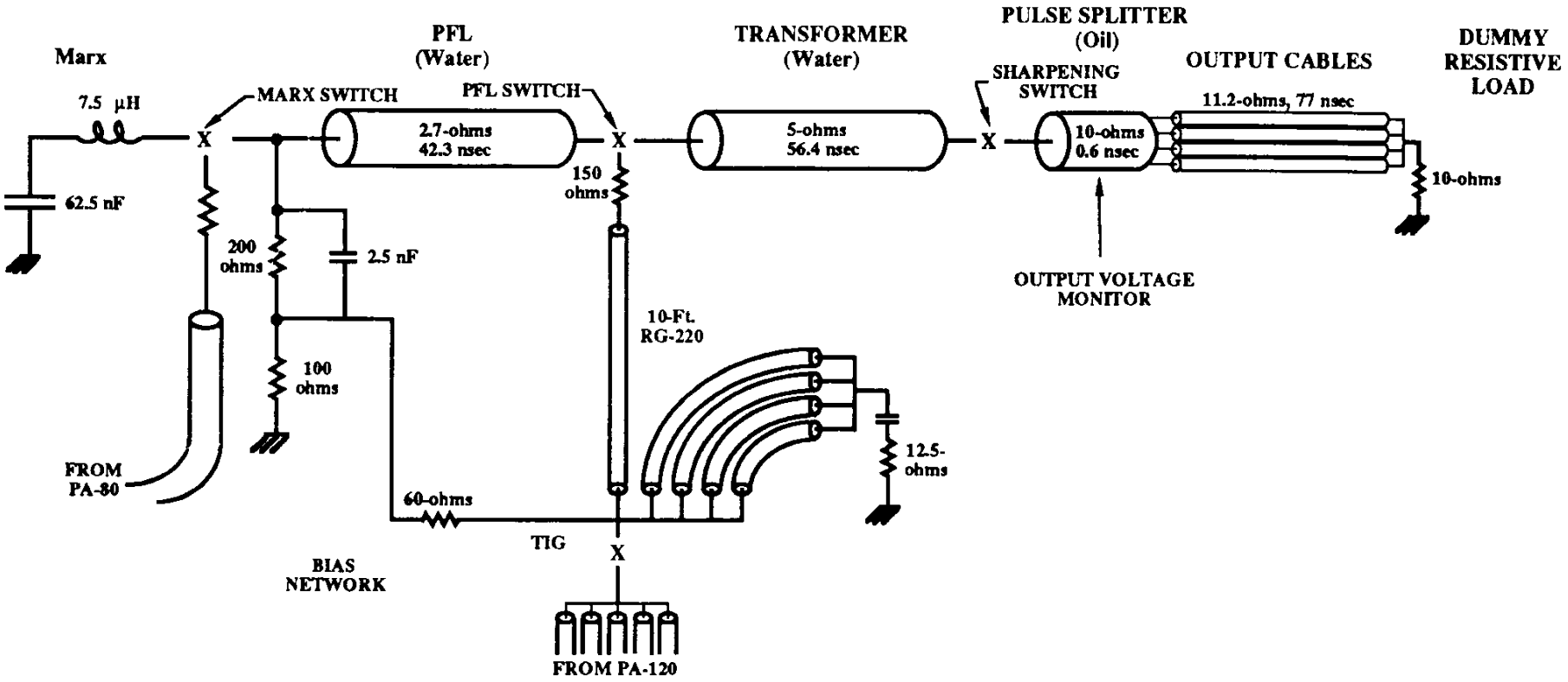
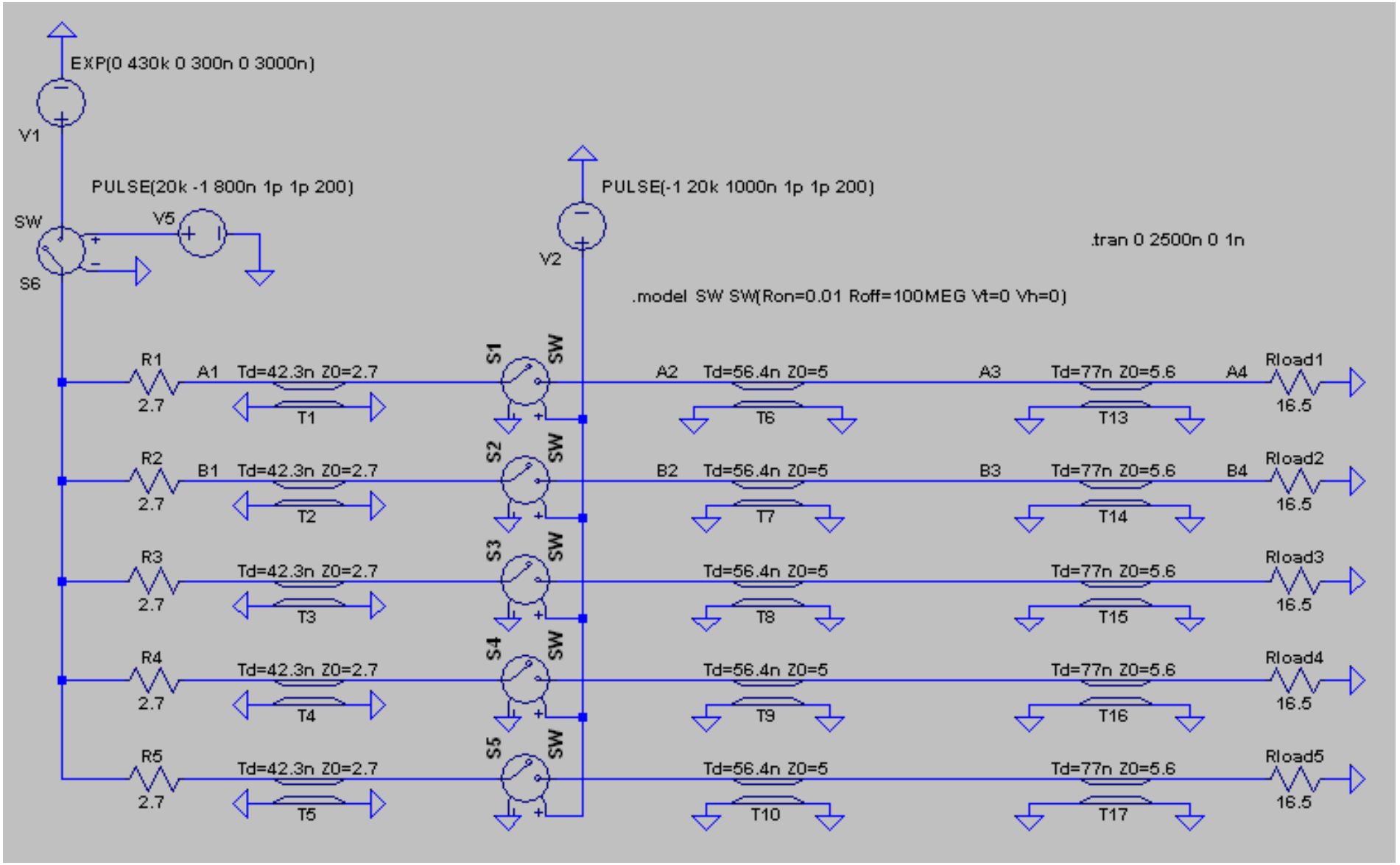


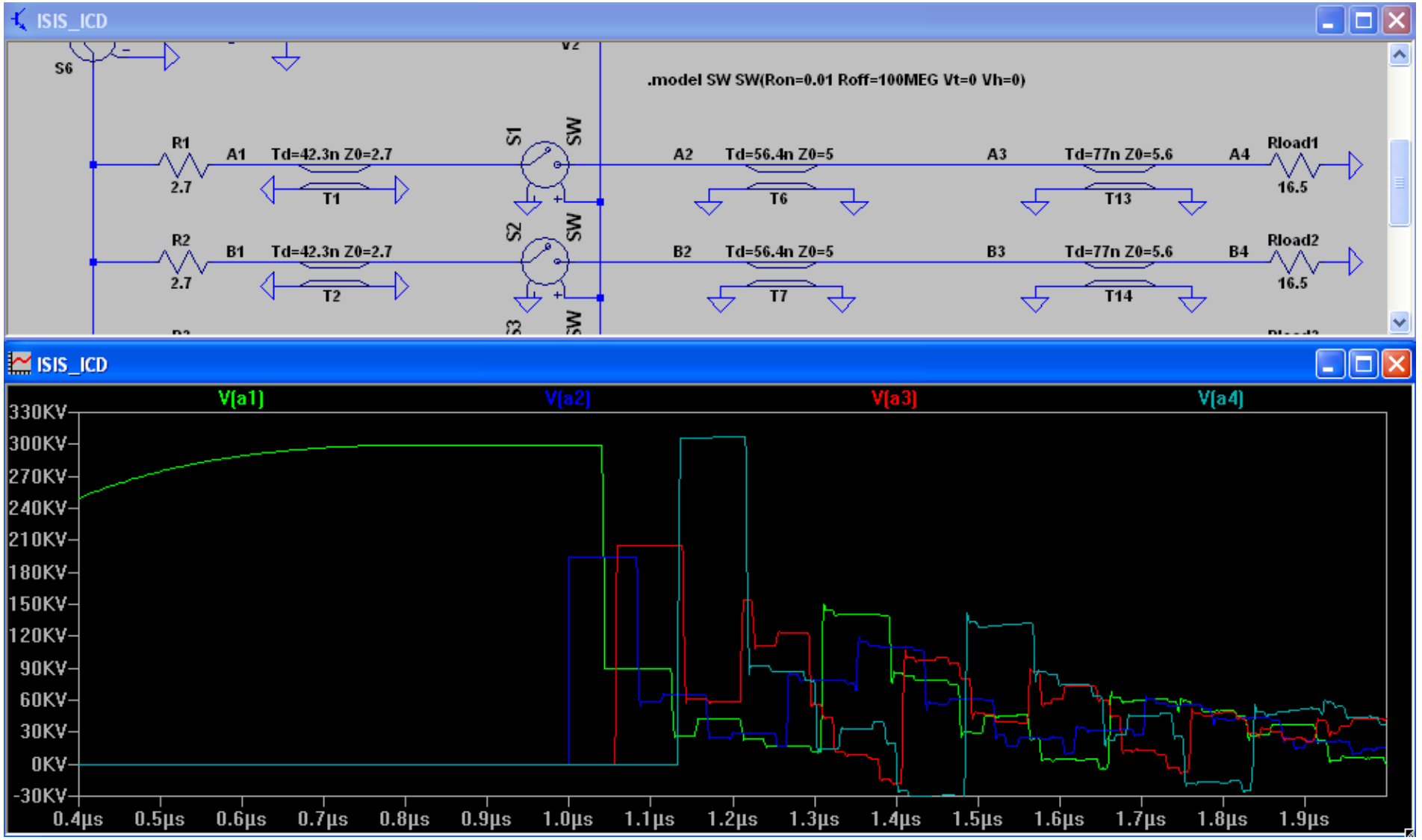
Figure 1. Prototype power supply circuit.

P. Corcoran et al. "Experimental Tests of the Power Supply and Prototype Cell for 1.5 MeV SLIA Acceleratot Unit", Particle Accelerator Conference, 1991 IEEE

ISIS Induction-Cell Driver: LTspice schematics



ISIS Induction-Cell Driver: LTspice simulation



ISIS Induction-Cell Driver: 5 Pulse Forming Lines

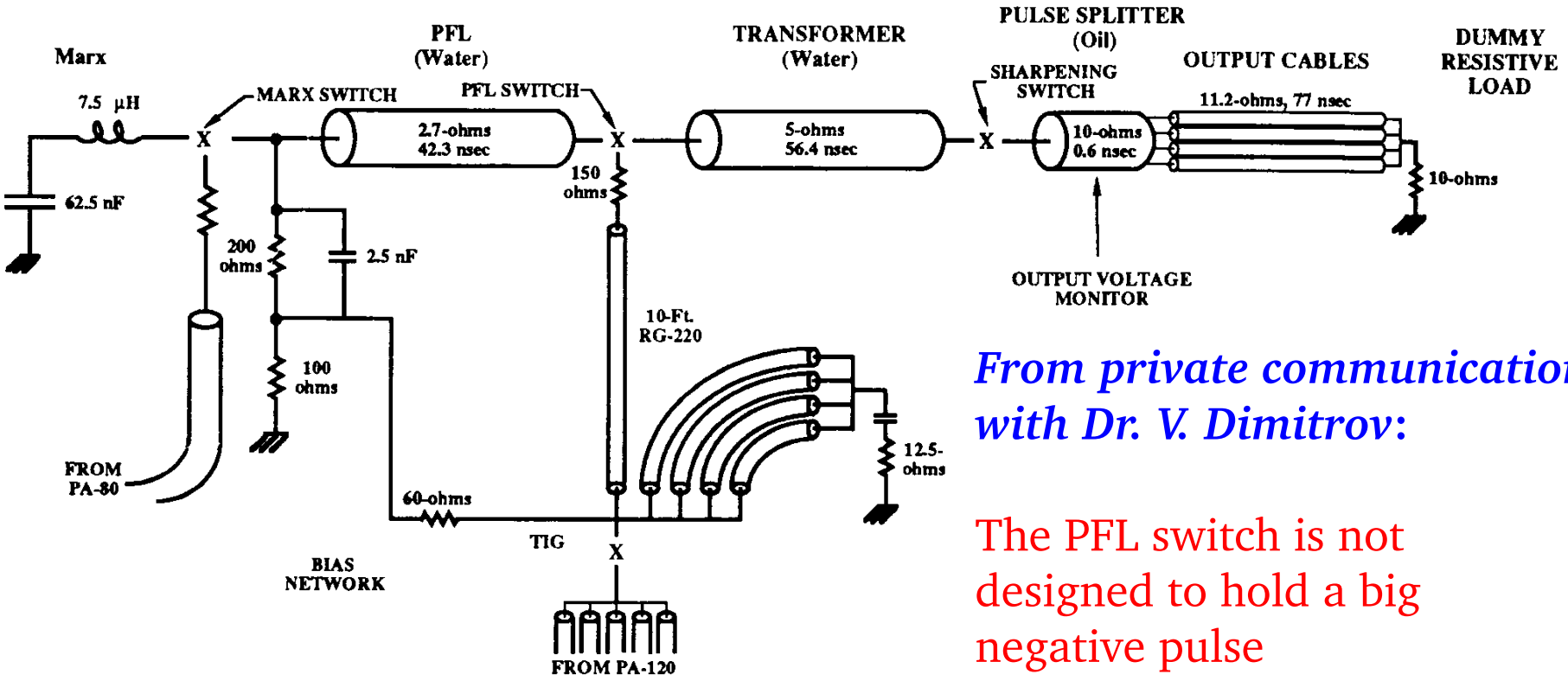


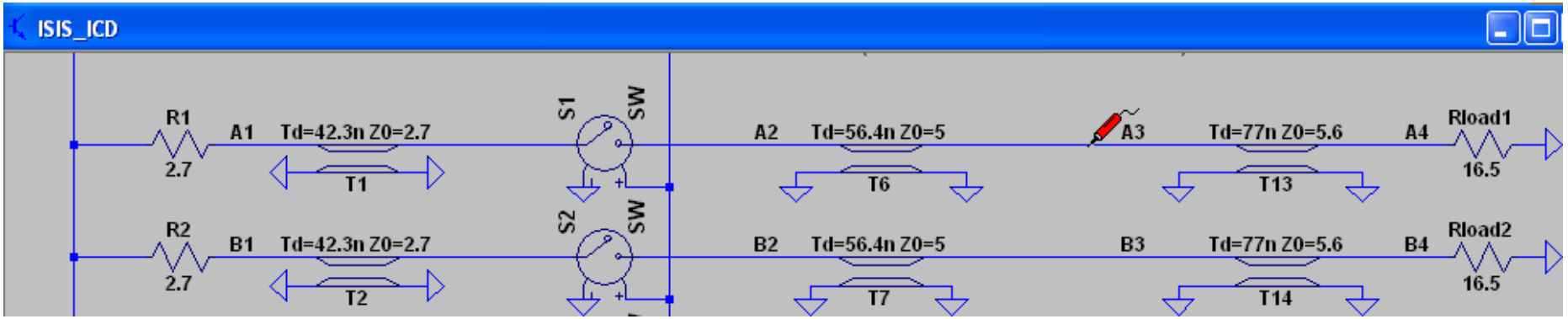
Figure 1. Prototype power supply circuit.

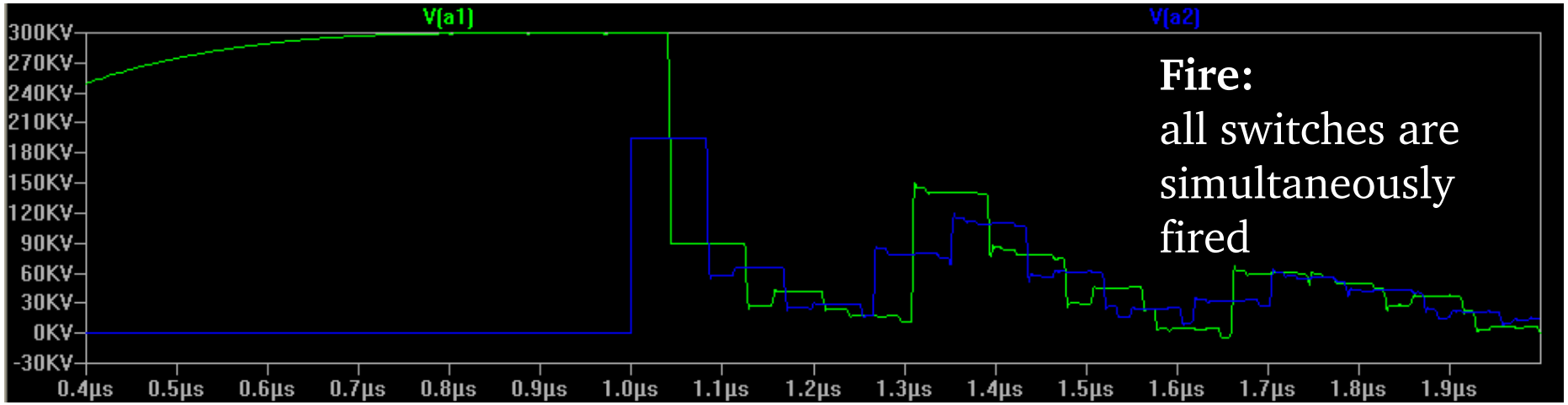
From private communication with Dr. V. Dimitrov:

The PFL switch is not designed to hold a big negative pulse

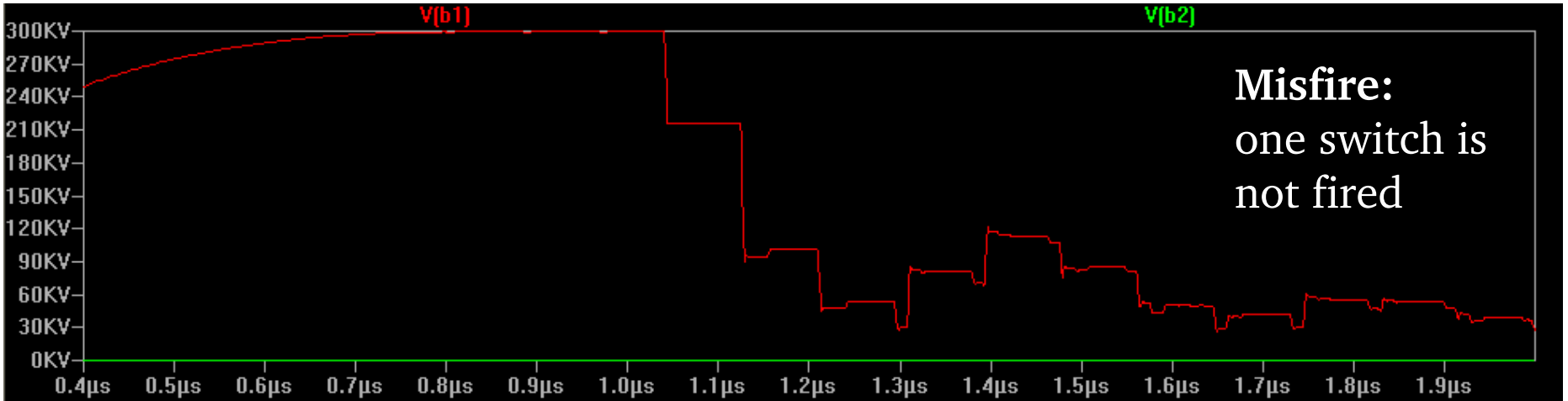
P. Corcoran et al. "Experimental Tests of the Power Supply and Prototype Cell for 1.5 MeV SLIA Acceleratot Unit", Particle Accelerator Conference, 1991 IEEE

ISIS Induction-Cell Driver: fire and misfire





Fire:
all switches are simultaneously fired



Misfire:
one switch is not fired

ISIS Induction-Cell Driver: facts

***From private communication with Dr. V. Dimitrov*:**

The PFL switch is not designed to hold
a big negative pulse

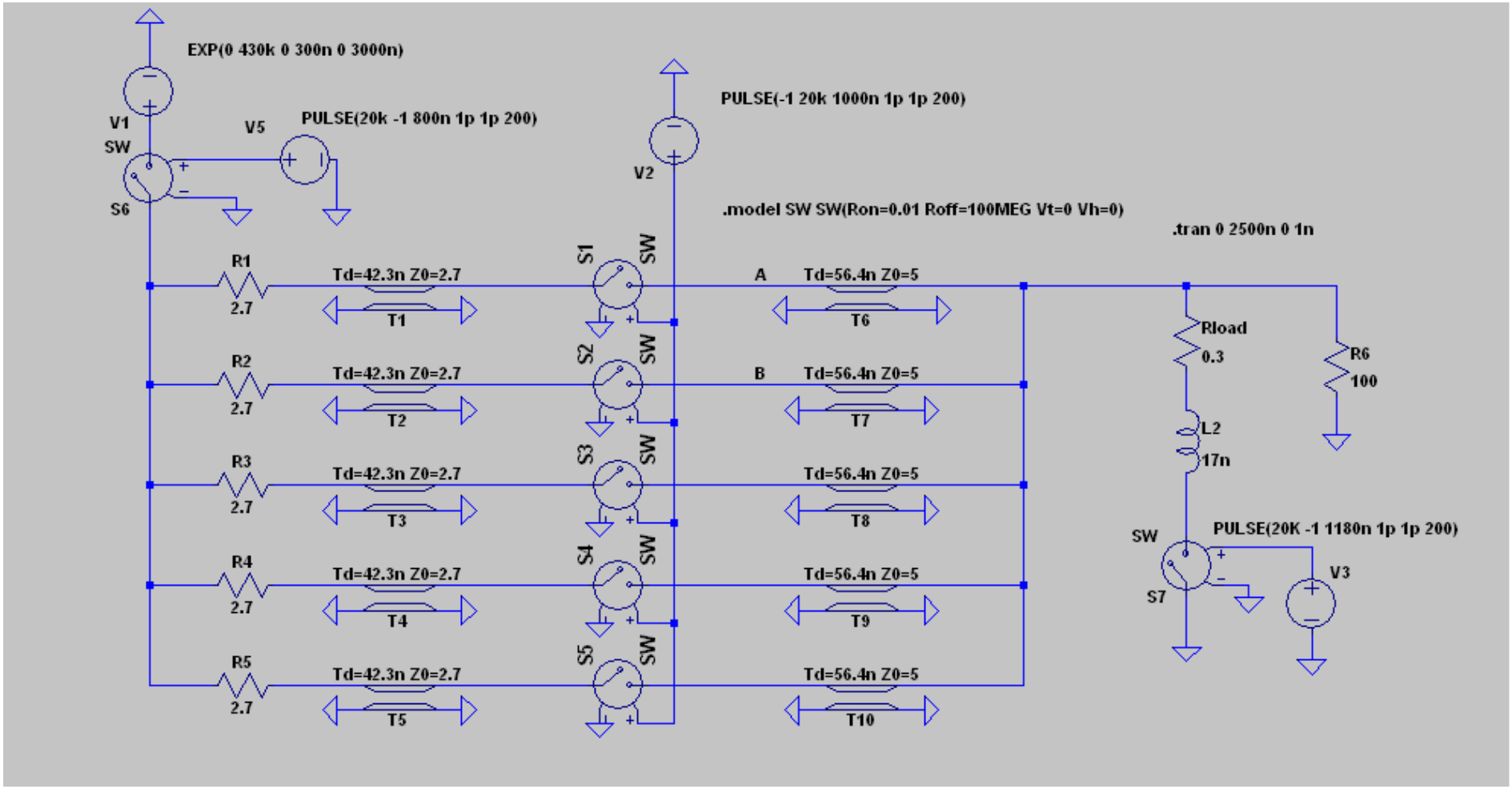
***From LTspice simulation*:**

There are always positive pulse at PFL switch
during fire and possible misfire

Wire resistance and inductance

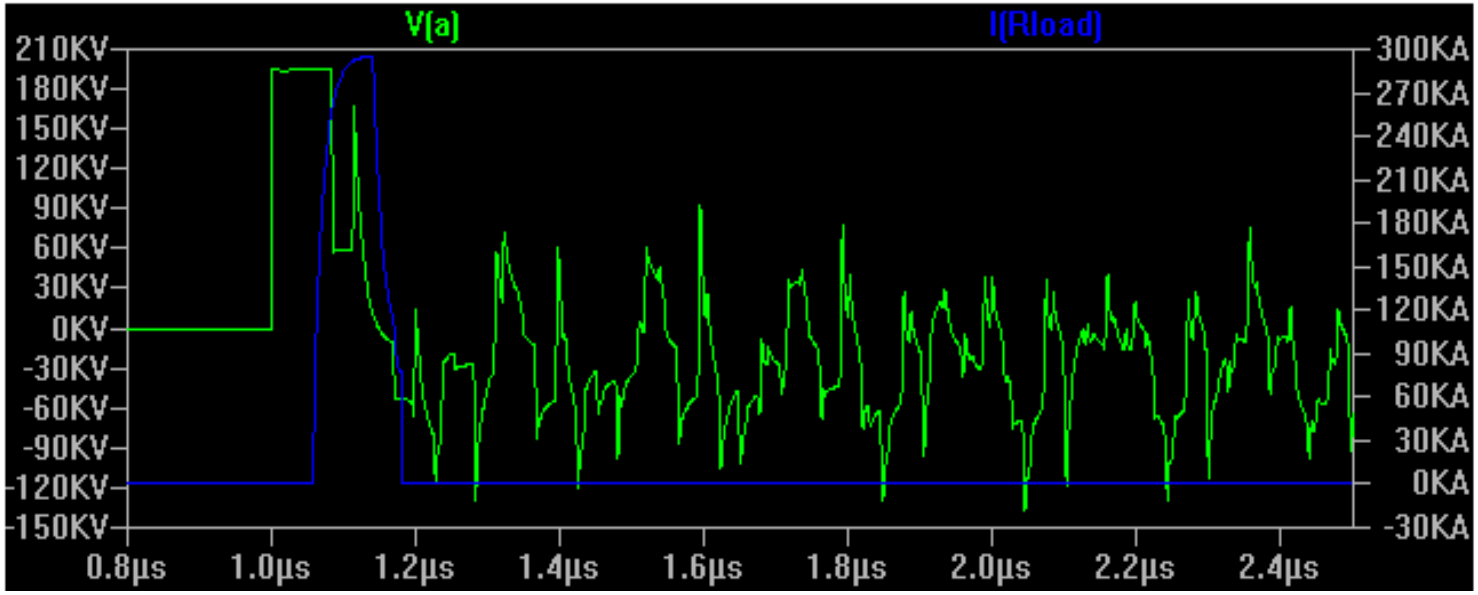
material	rho, 10^{-8} Ω*m	L, mm	d, um	R, Ω	L, nH
Aluminium	2.82	25.00	5	35.92	45.8
Gold	2.44	25.00	5	31.08	45.8
Molybdenum	5.20	25.00	5	66.24	45.8
Tungsten	5.60	25.00	5	71.34	45.8
Aluminium	2.82	25.00	10	8.98	42.3
Gold	2.44	25.00	10	7.77	42.3
Molybdenum	5.20	25.00	10	16.56	42.3
Tungsten	5.60	25.00	10	17.83	42.3
Aluminium	2.82	25.00	30	1.00	36.8
Gold	2.44	25.00	30	0.86	36.8
Molybdenum	5.20	25.00	30	1.84	36.8
Tungsten	5.60	25.00	30	1.98	36.8
Aluminium	2.82	25.00	50	0.36	34.3
Gold	2.44	25.00	50	0.31	34.3
Molybdenum	5.20	25.00	50	0.66	34.3
Tungsten	5.60	25.00	50	0.71	34.3

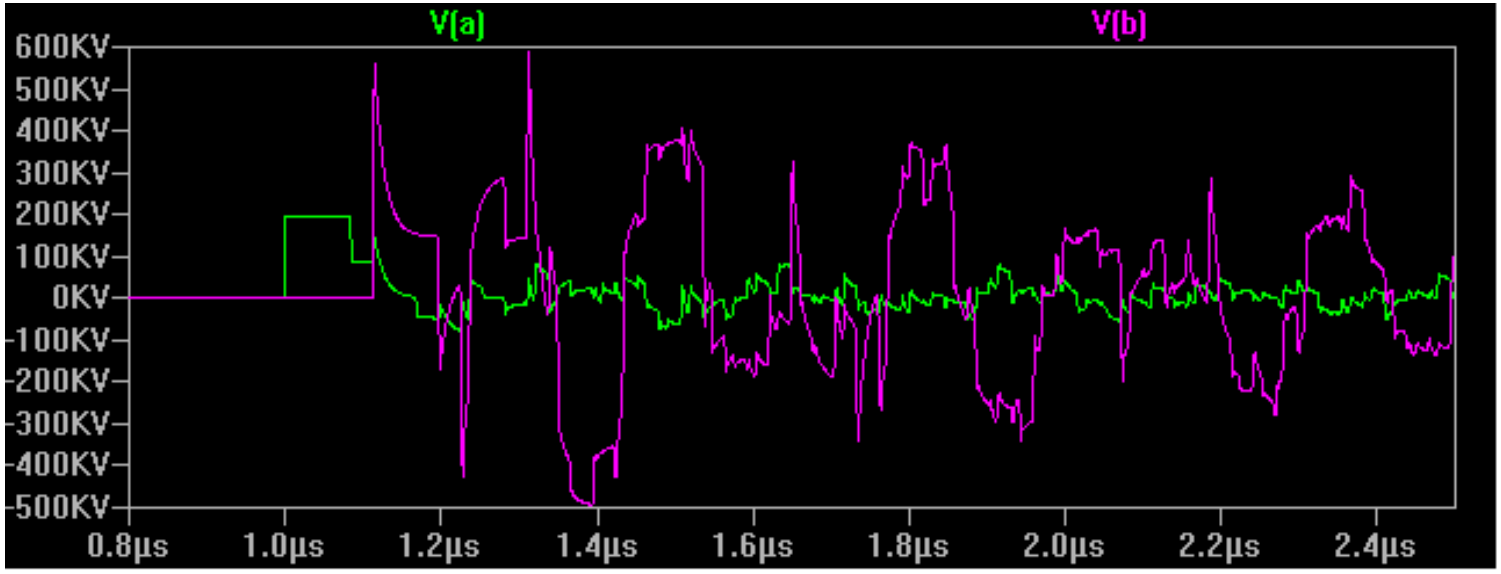
Modified ISIS Induction-Cell Driver



Modified ISIS Induction-Cell Driver: fire and misfire

Fire:
300 kA current
-120 kV at S1-S6





Misfire:

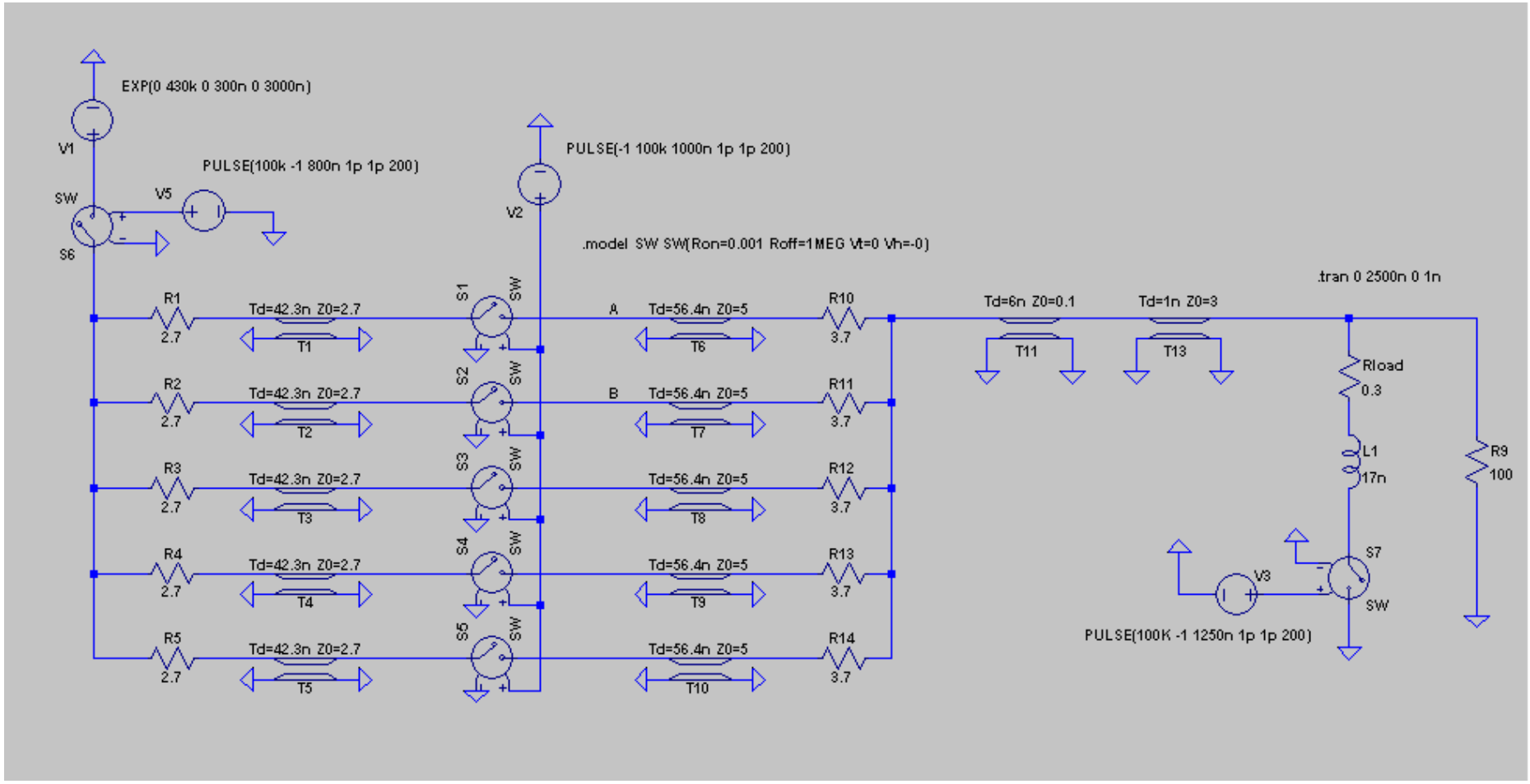
-400 kV
at switch SW2

Modified ISIS Induction-Cell Driver

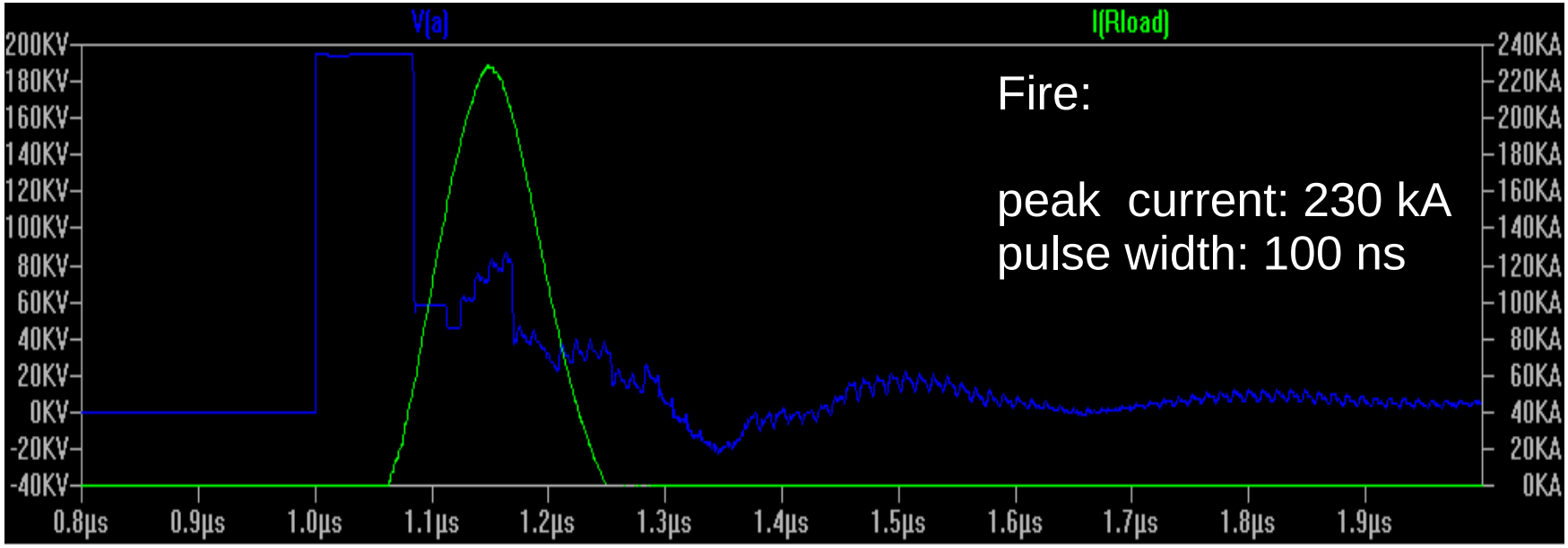
Danger:
The negative pulse at PFL switch will probably destroy the Induction Cell Driver

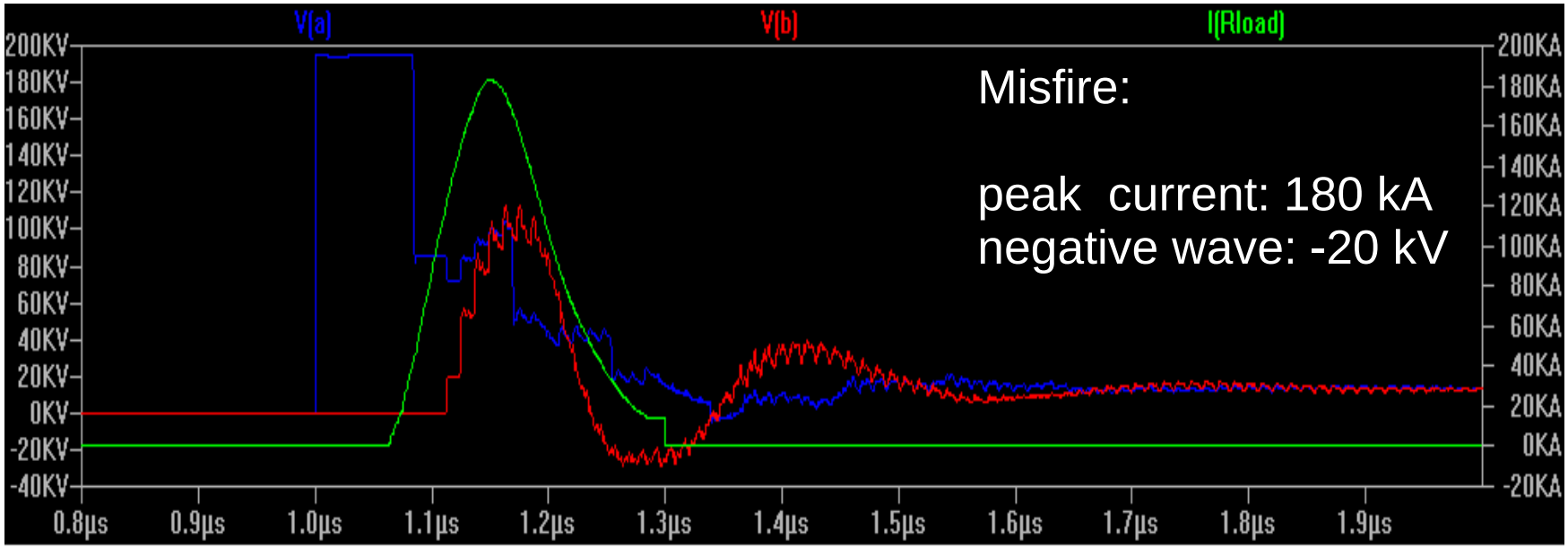
Solution:
Minimize the possible dangerous negative wave at PFL switch

Modified ISIS Induction-Cell Driver: 0.3 Ω load

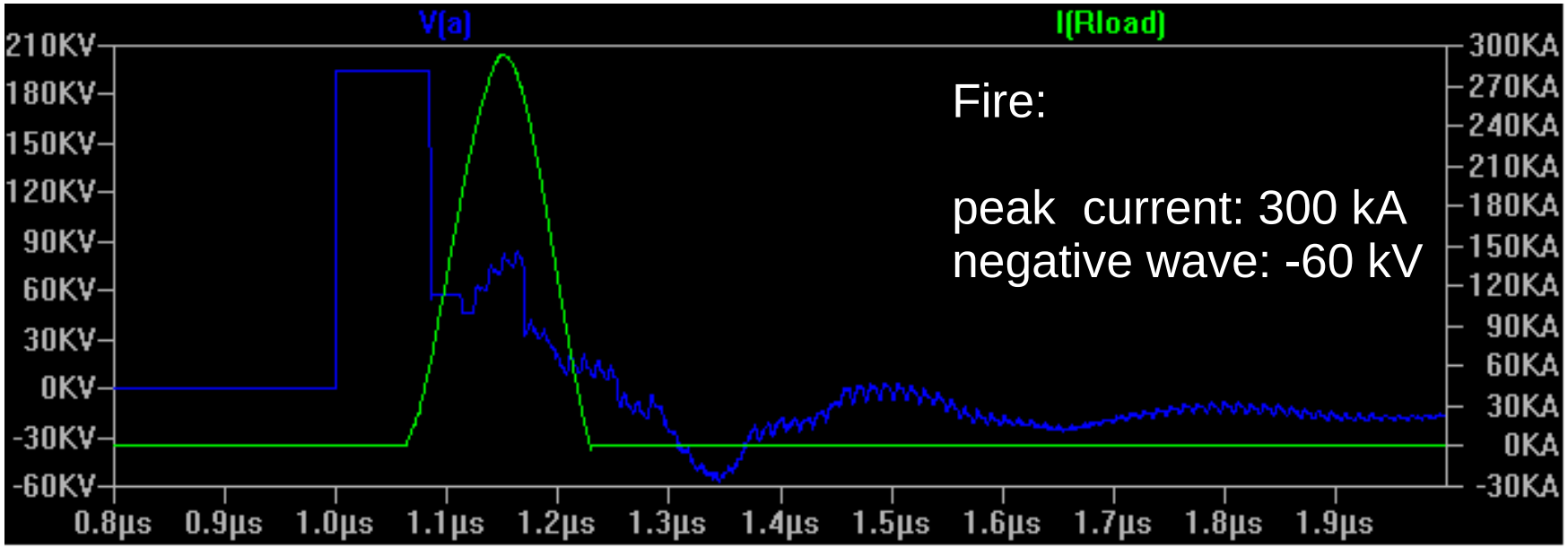


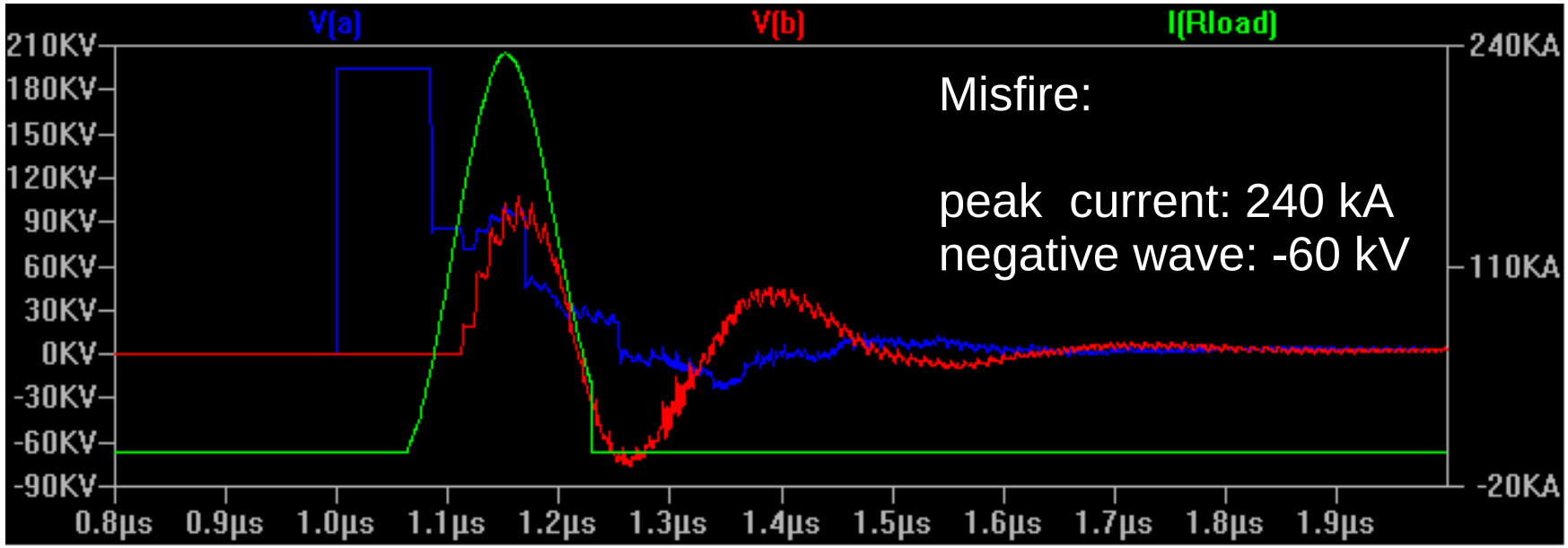
Modified ISIS Induction-Cell Driver: 0.3 Ω load



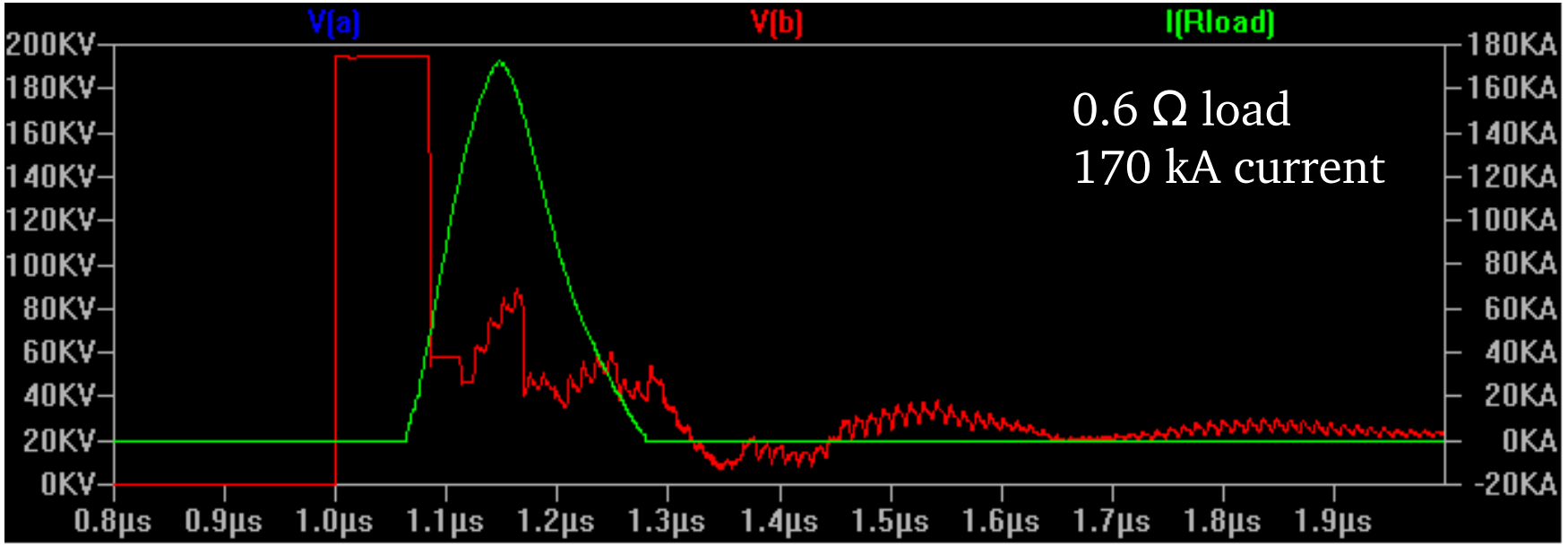


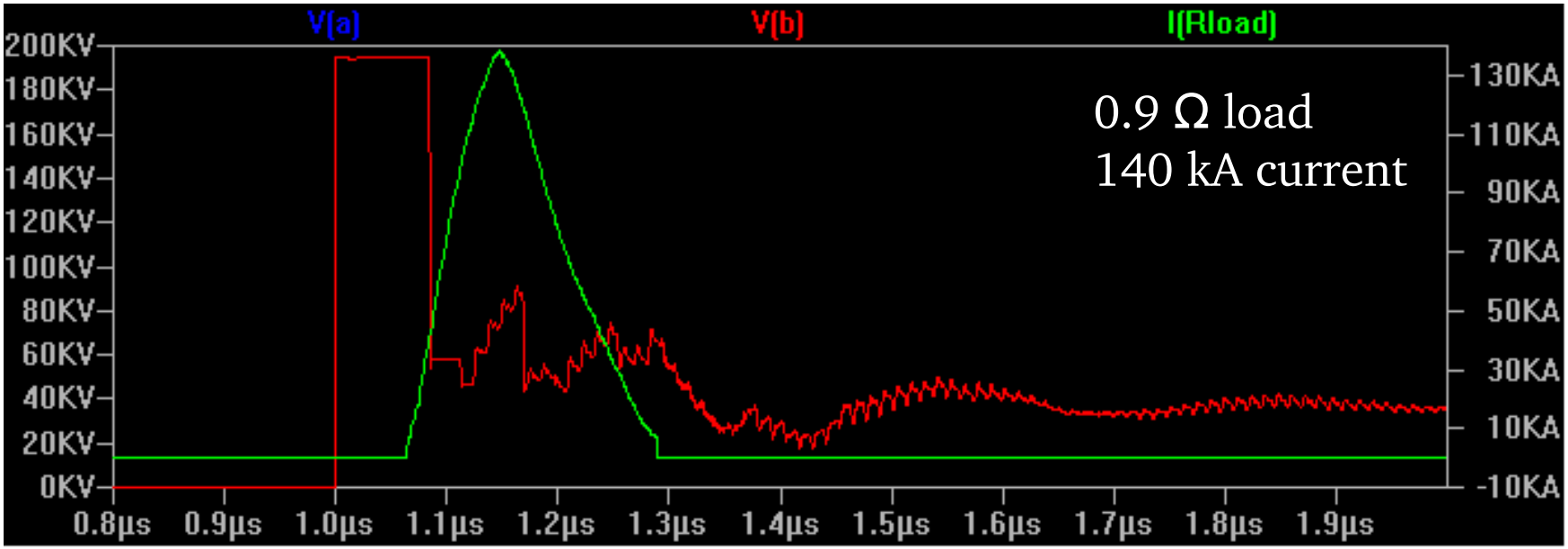
Modified ISIS Induction-Cell Driver: 0.1 Ω load



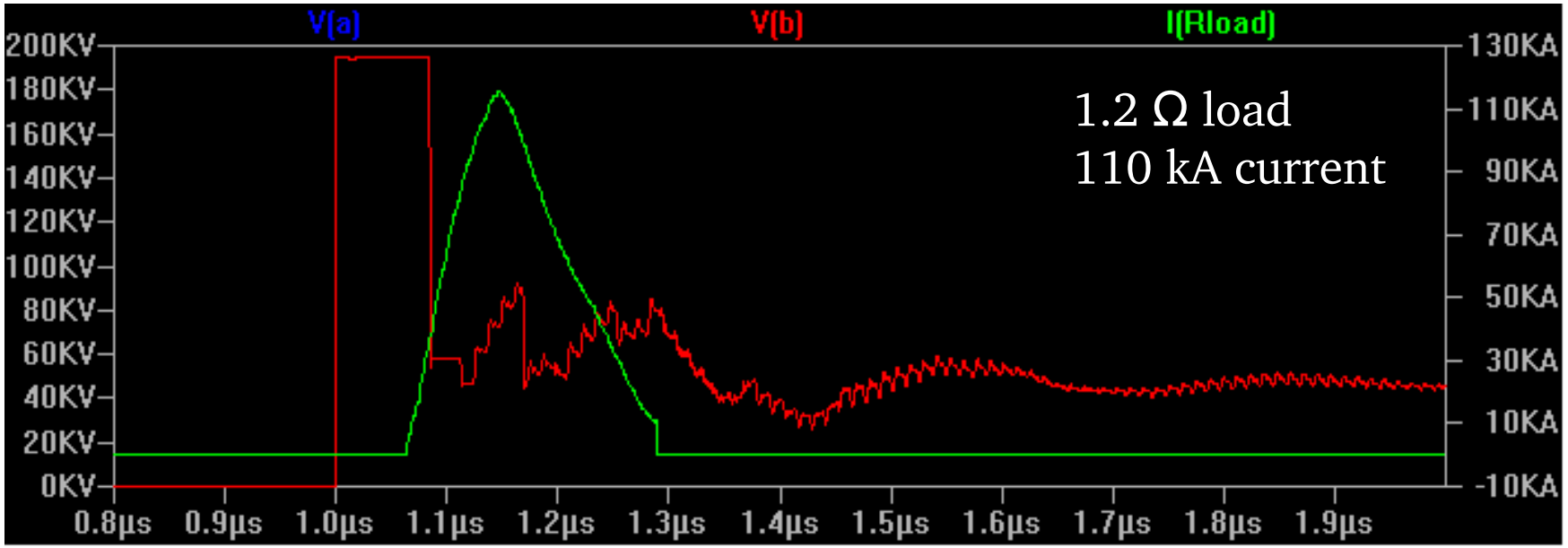


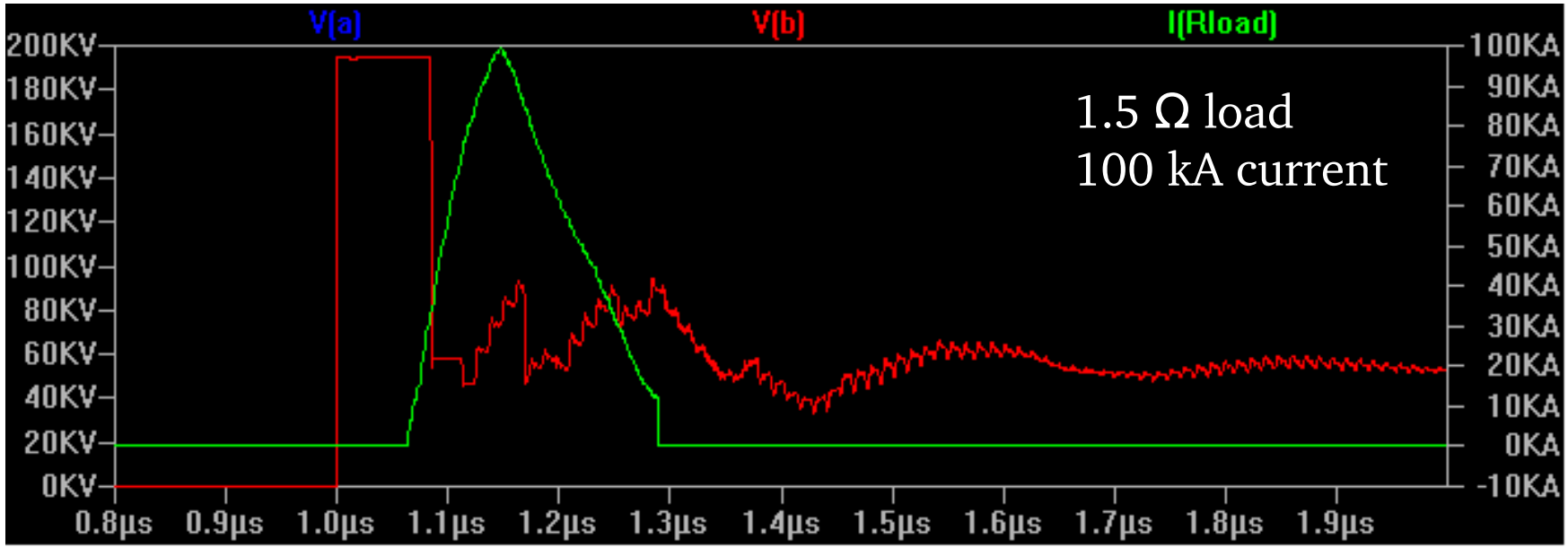
Modified ISIS Induction-Cell Driver: 0.3, 0.9 Ω loads





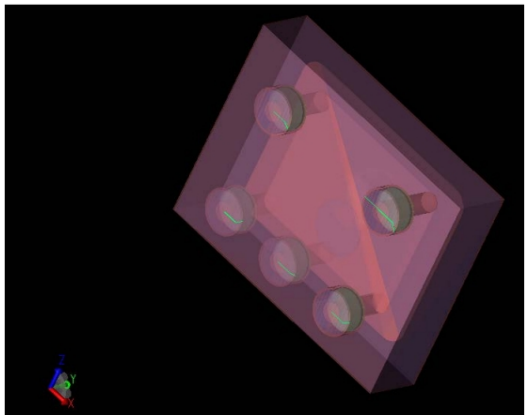
Modified ISIS Induction-Cell Driver: 1.2, 1.5 Ω loads





Modified ISIS Induction-Cell Driver: What We Need

1. Five high power resistors: 3.7 Ω each



2. Transformer/combiner:

T=6 ns
Z_0=0.1 Ω

3. Vacuum Camber:

T=1 ns
Z_0=3 Ω

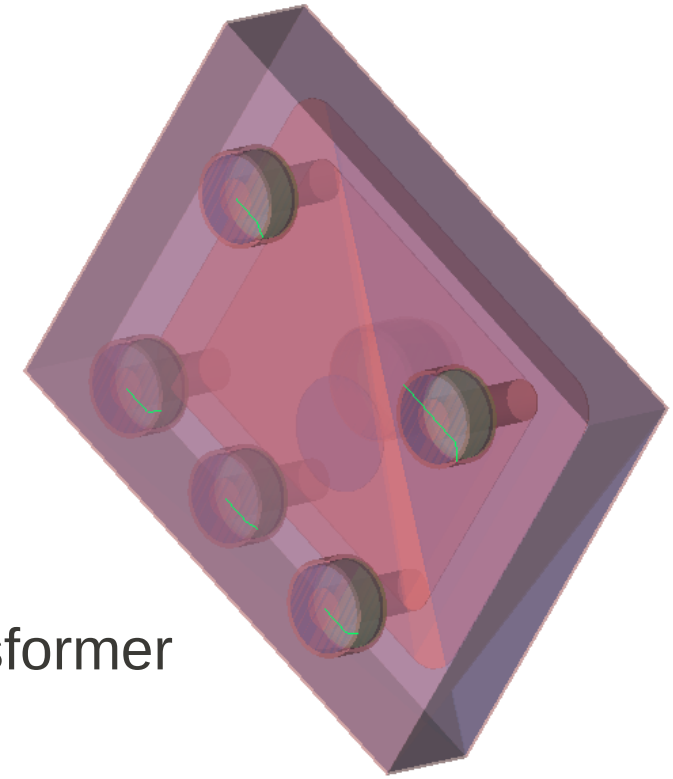
4. X-Pinch wires (Load):

R = 0.3 Ω and more
L = 17 nH and more
l = 25 mm long

Modified ISIS Induction-Cell Driver: Transformer

$T = 6$ 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

Challenge to design, but can be done with XFdtd