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

Roman Shapovalov
IAC
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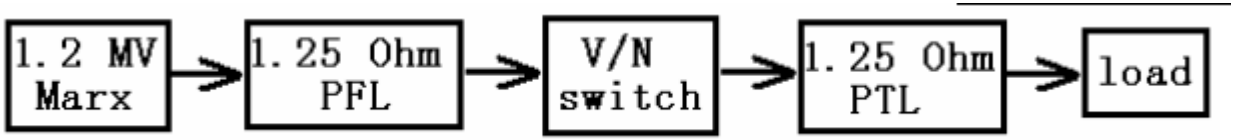
Overview: Pulsed Power Generator (PPG-1), Beijing



(b) A photograph of PPG-I

max current: **400 kA**

pulse width: **100 ns**

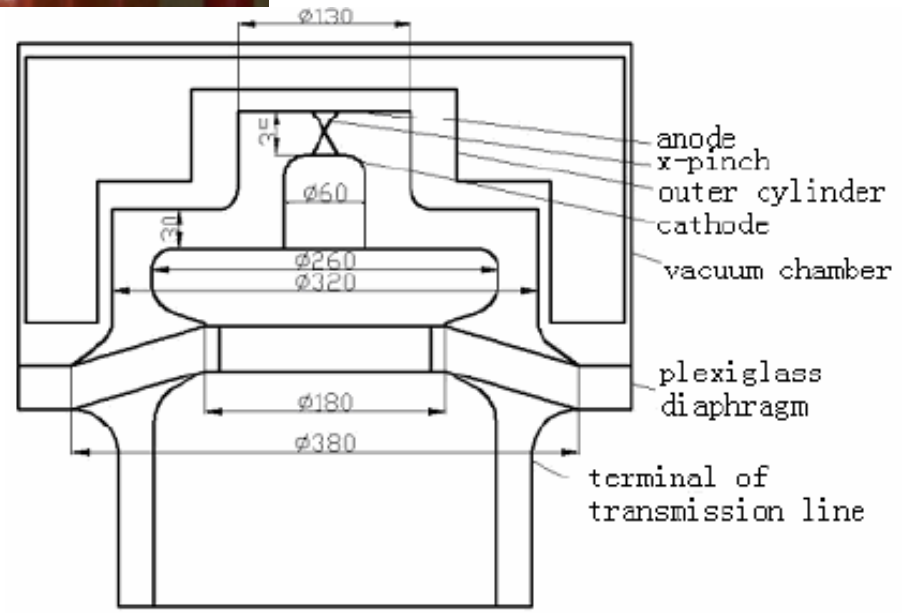


Figure 3. The sketch of the load section.

X-Pinch

two 25 um (or 13 um) Mo wires
anode/cathode distance: 10 mm

Ran Zhang et al. "X-pinch applications in X-ray radiography ..." 2010 IEEE

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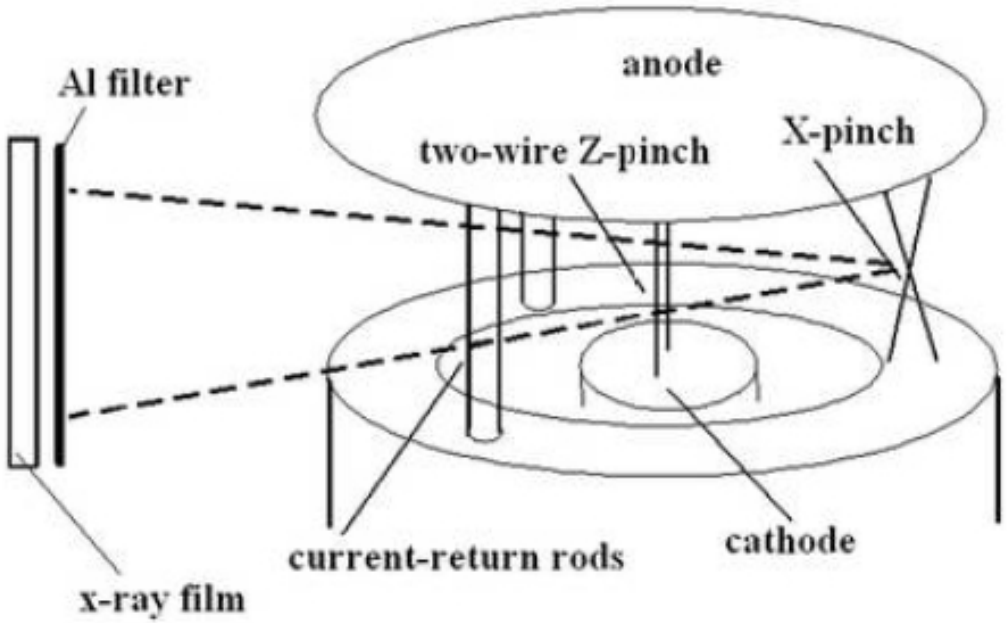
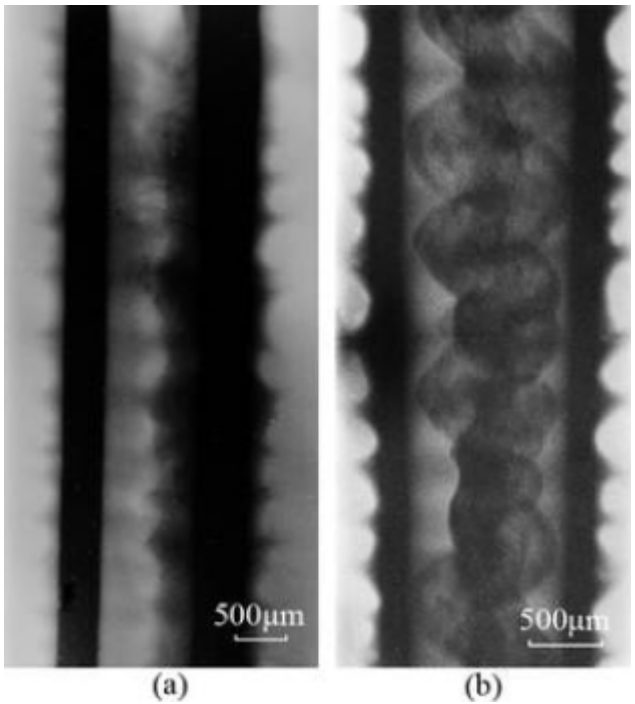


Experimental arrangements for backlighting of Z-pinch using X-pinch as x-ray source

X-ray backlighting images of two-wire z-pinch

X-pinch: two 13 um Mo wires
Z-pinch: two 50 um Mo wires

a) 61 ns and 155 kA, shot No.2009042216
b) 86 ns and 215 kA, shot No.2009060417



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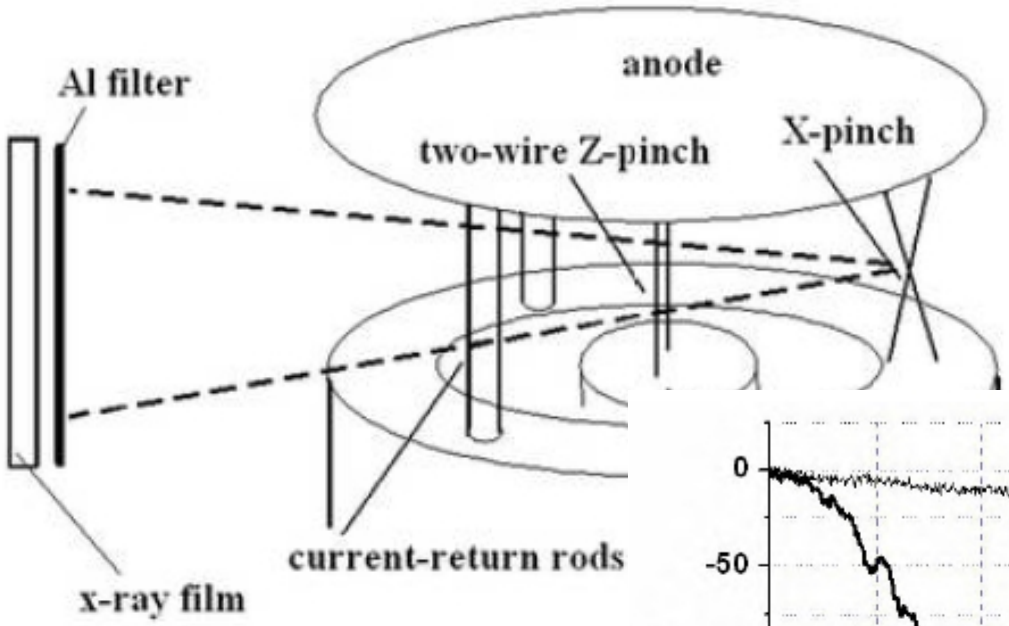
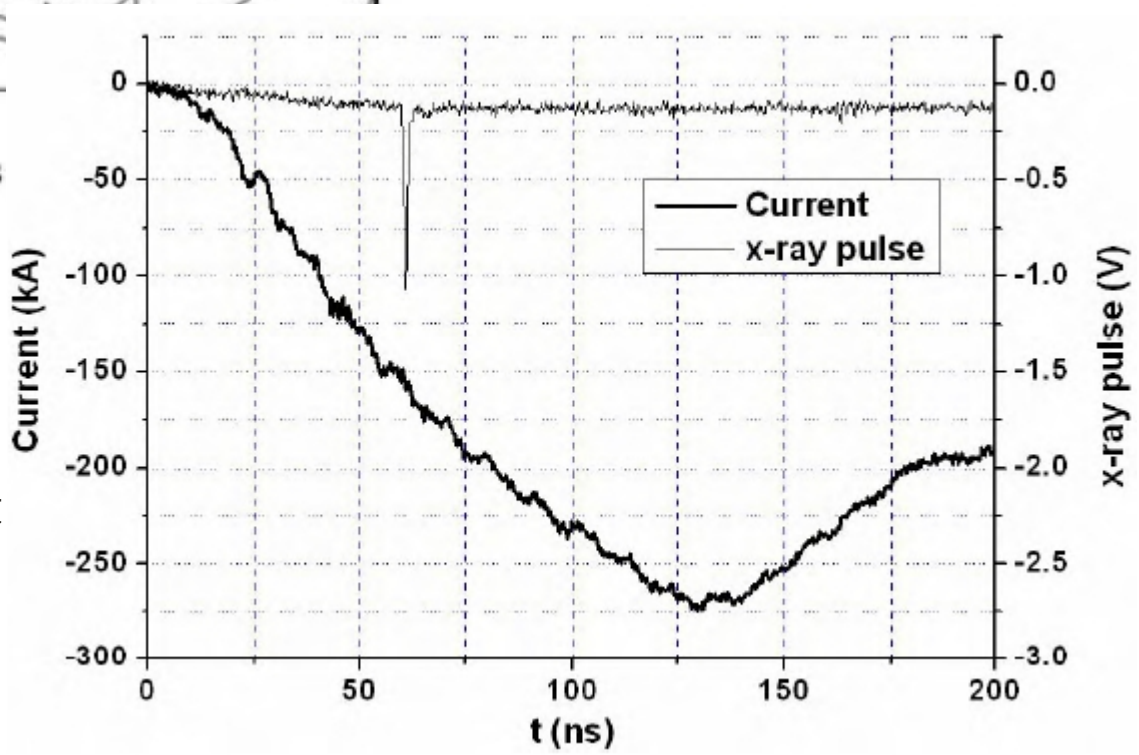


Experimental arrangements for backlighting of Z-pinch using X-pinch as x-ray source

Waveforms of the x-ray pulse and the Z-pinch current for shot NO. 2009042216.



Ran Zhang et al. "X-pinch applications in X-ray radiography ..." 2010 IEEE

Overview: Compact Table-Top X-Pinch Device, Beijing

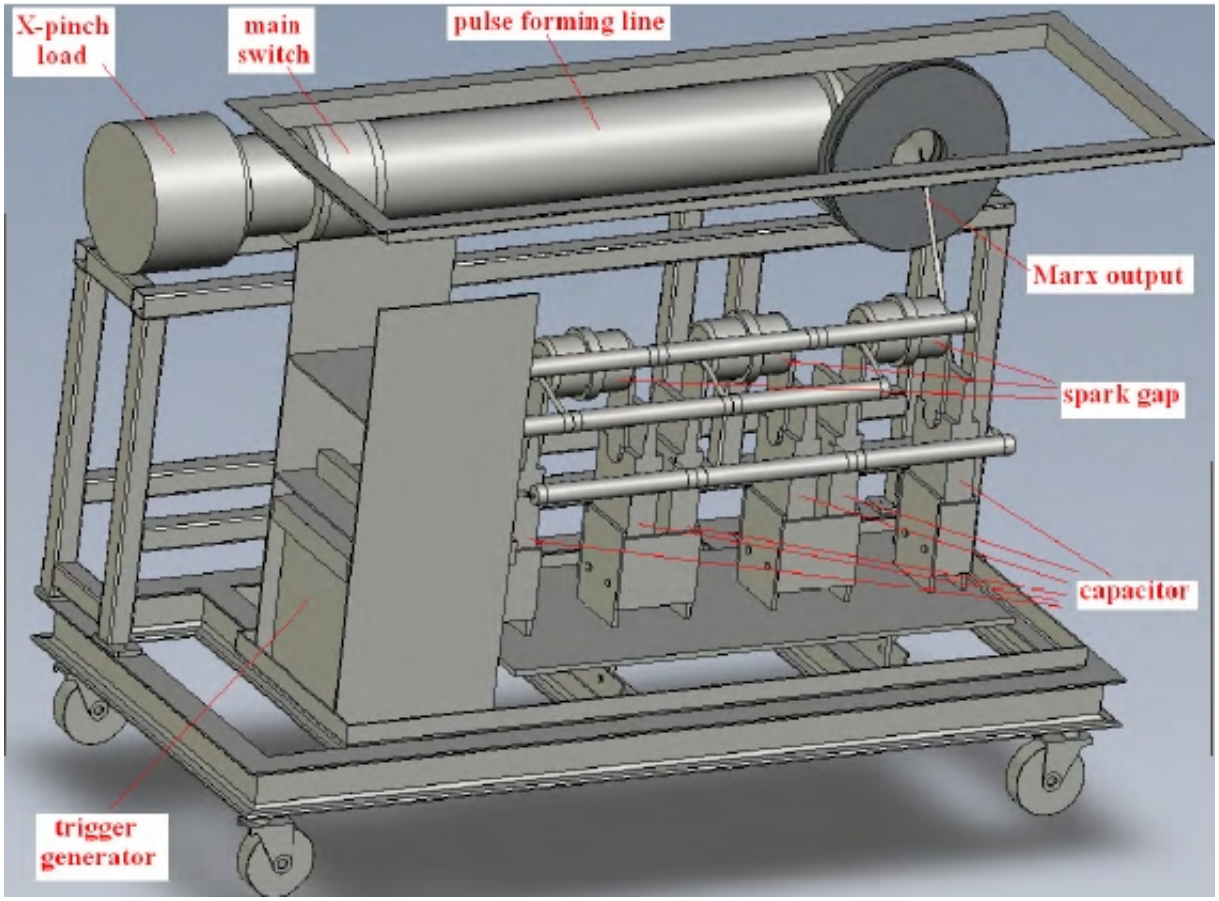


Fig.8. Design drawing of the compact table-top X-pinch device

The size of the device:

2m in length,

1.1m in width,

1.2m in height

current: 100 kA

pulse width: 60 ns

impedance: 1.2 Ω

Ran Zhang et al. "X-pinch applications in X-ray radiography ..." 2010 IEEE

Overview: Laboratory of Plasma Studies, Cornell University

XP facility

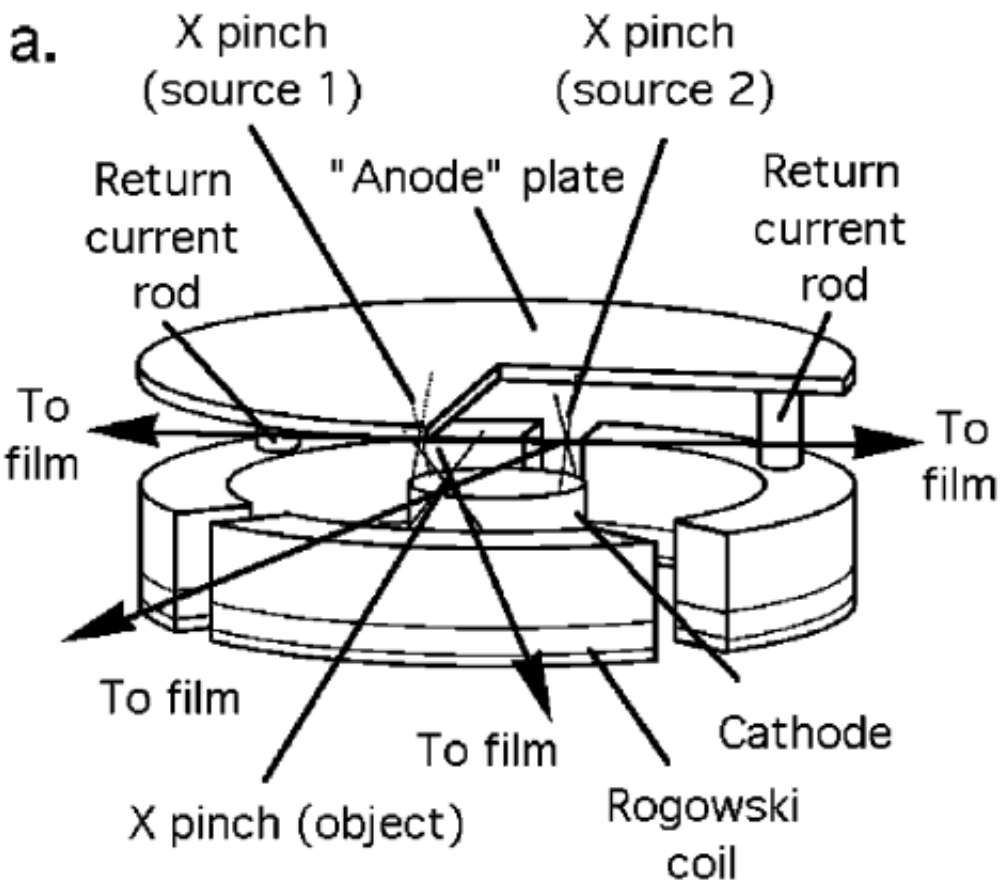
* 470 kA peak current
* 100 ns pulse duration

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 ..." 2001 AIP

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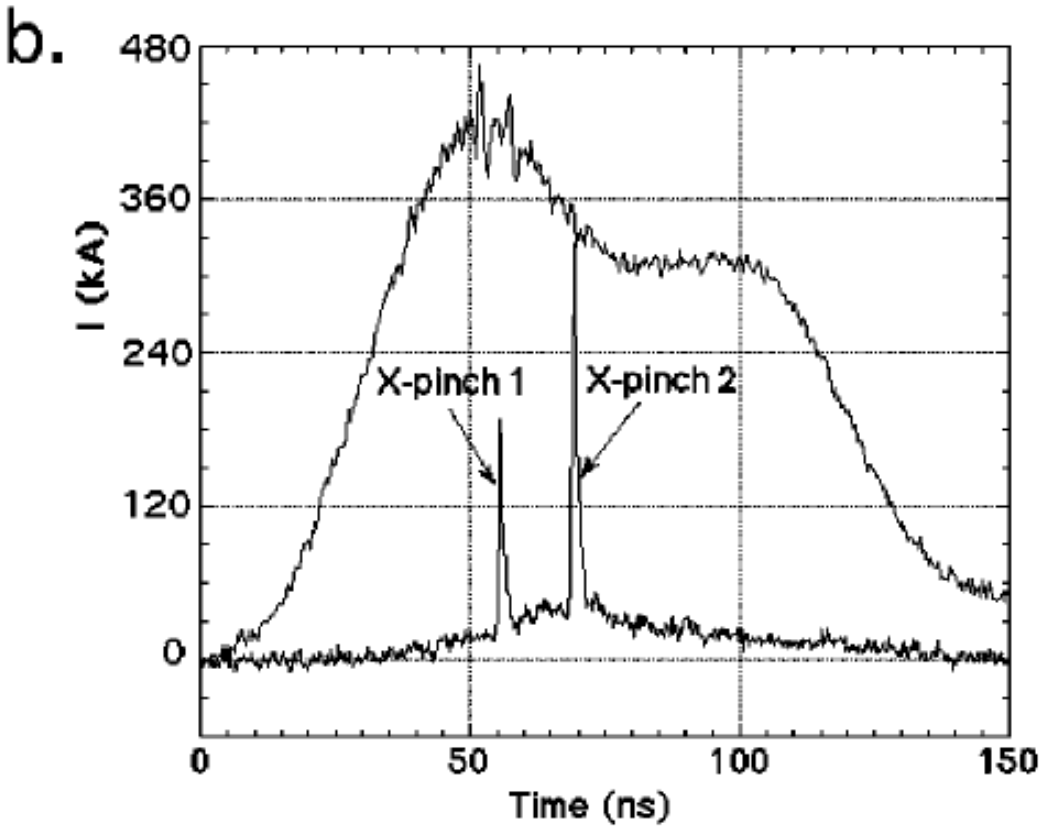
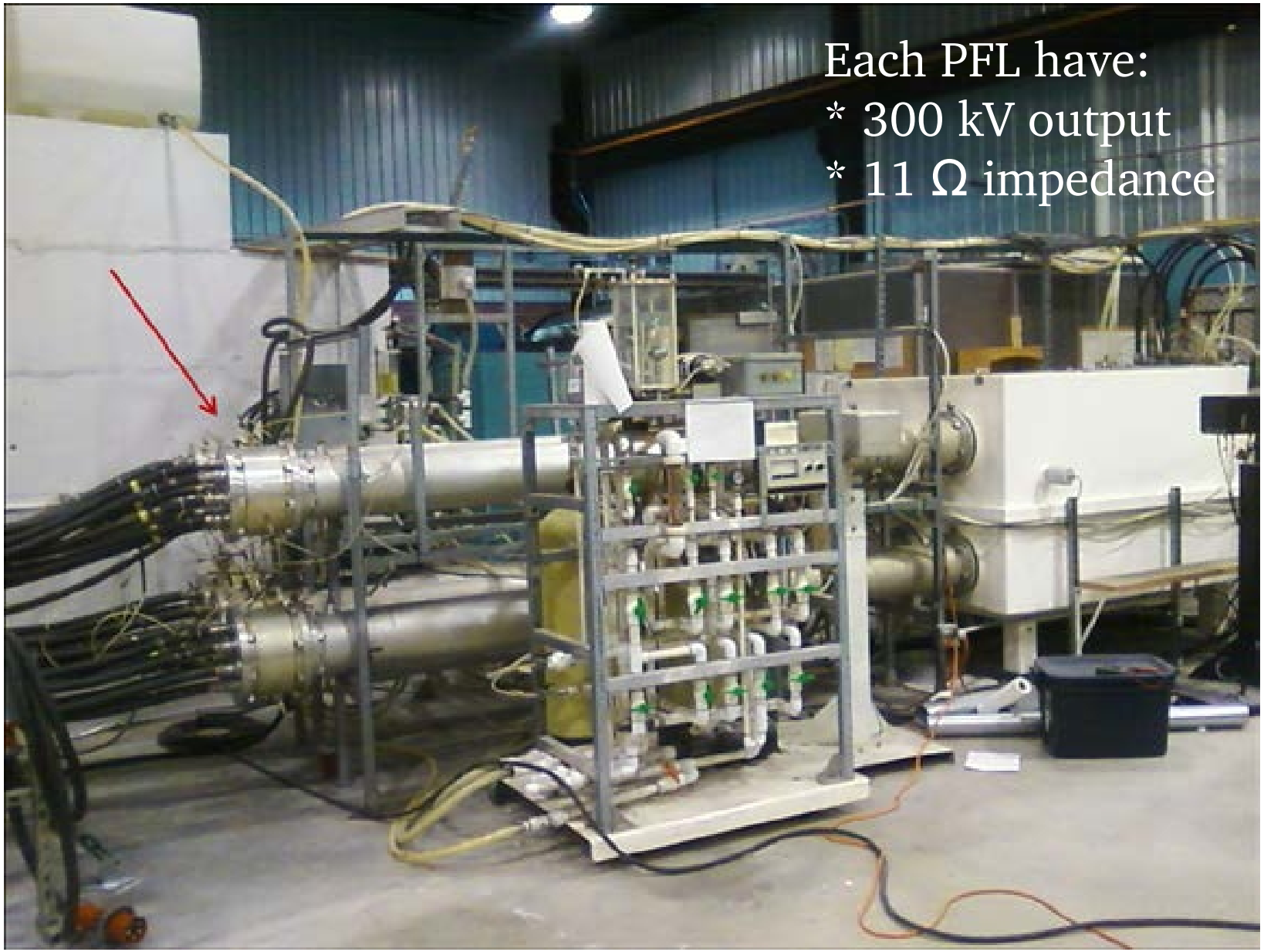
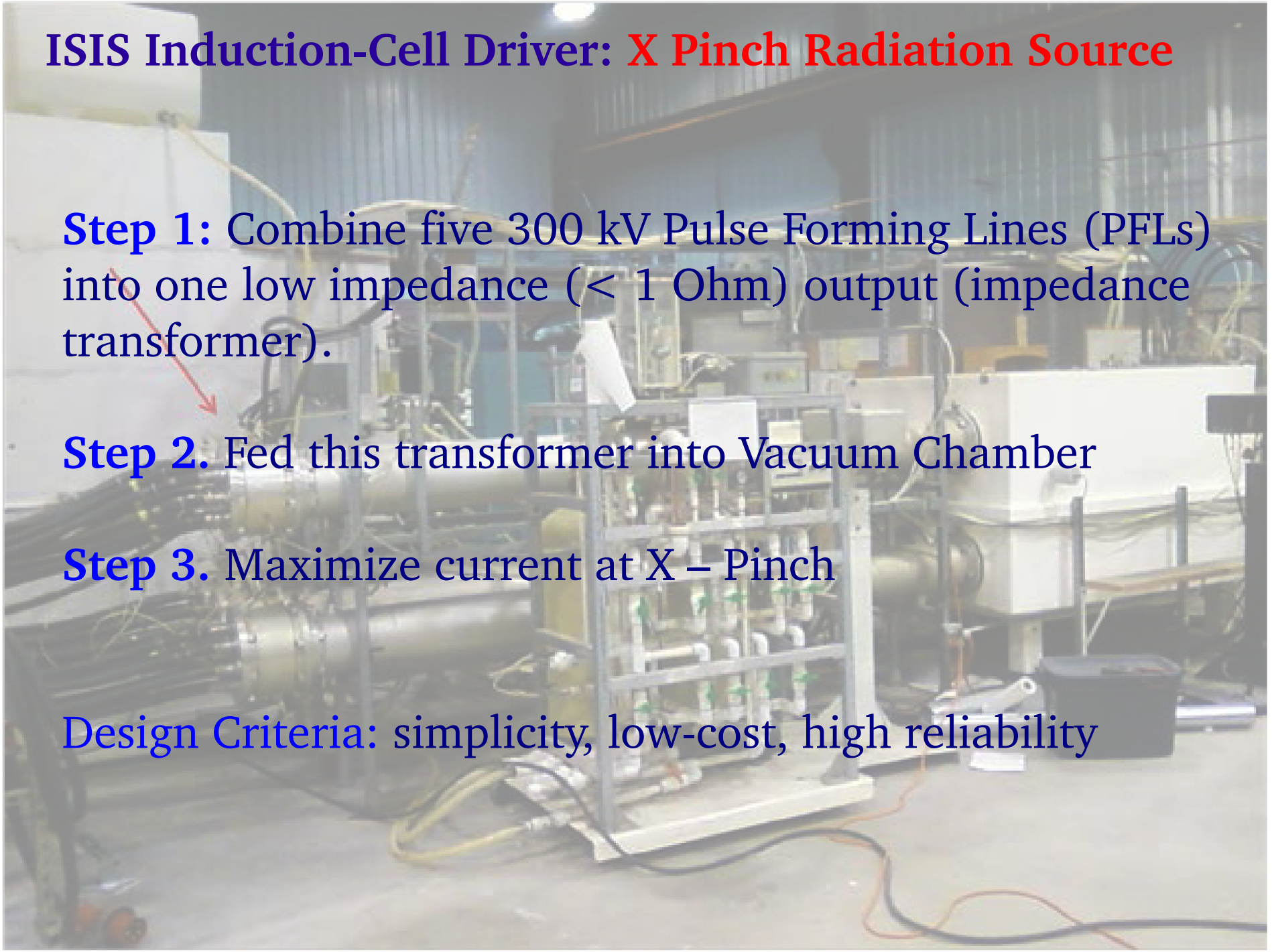


T. A. Shelkovenko et. al. "Radiographic and spectroscopic studies of X-pinch plasma ..." 2001 AIP

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

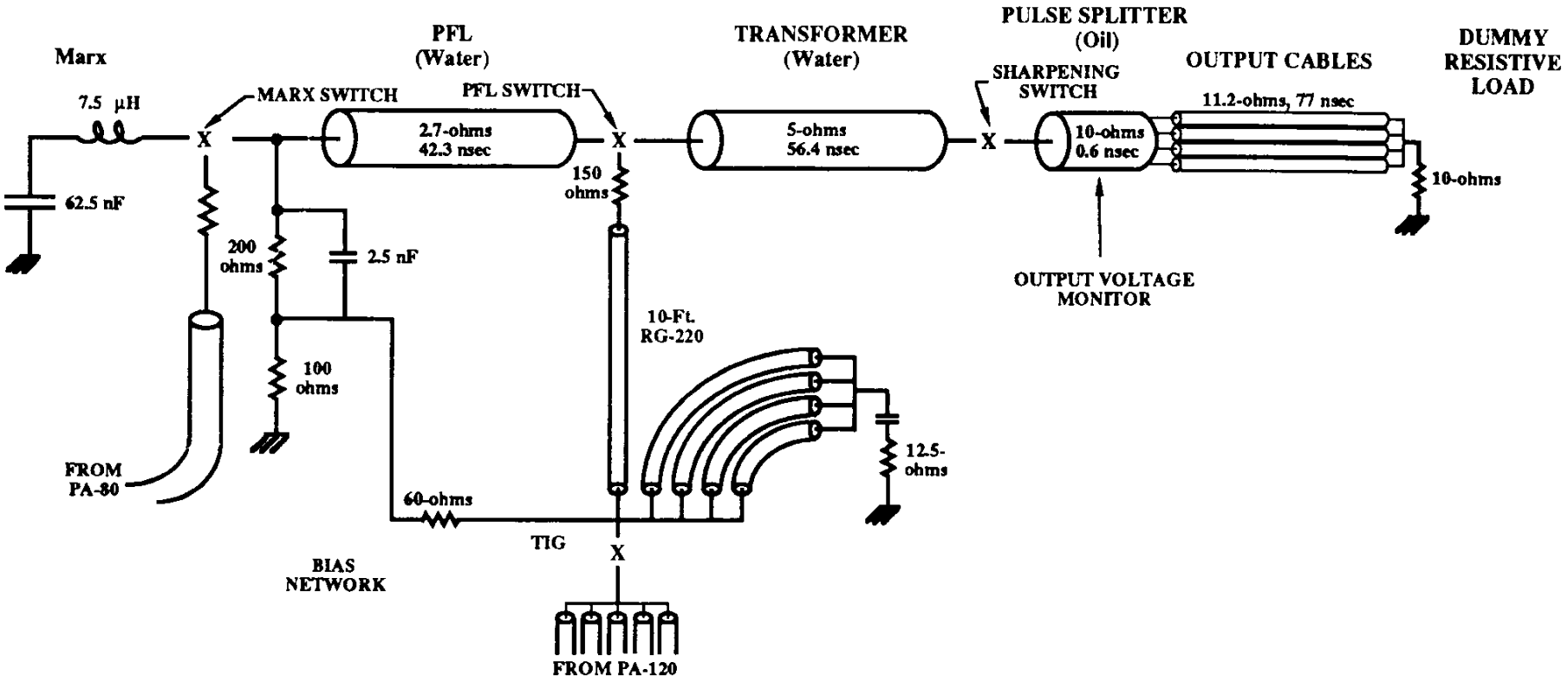


Figure 1. Prototype power supply circuit.

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: 5 Pulse Forming Lines

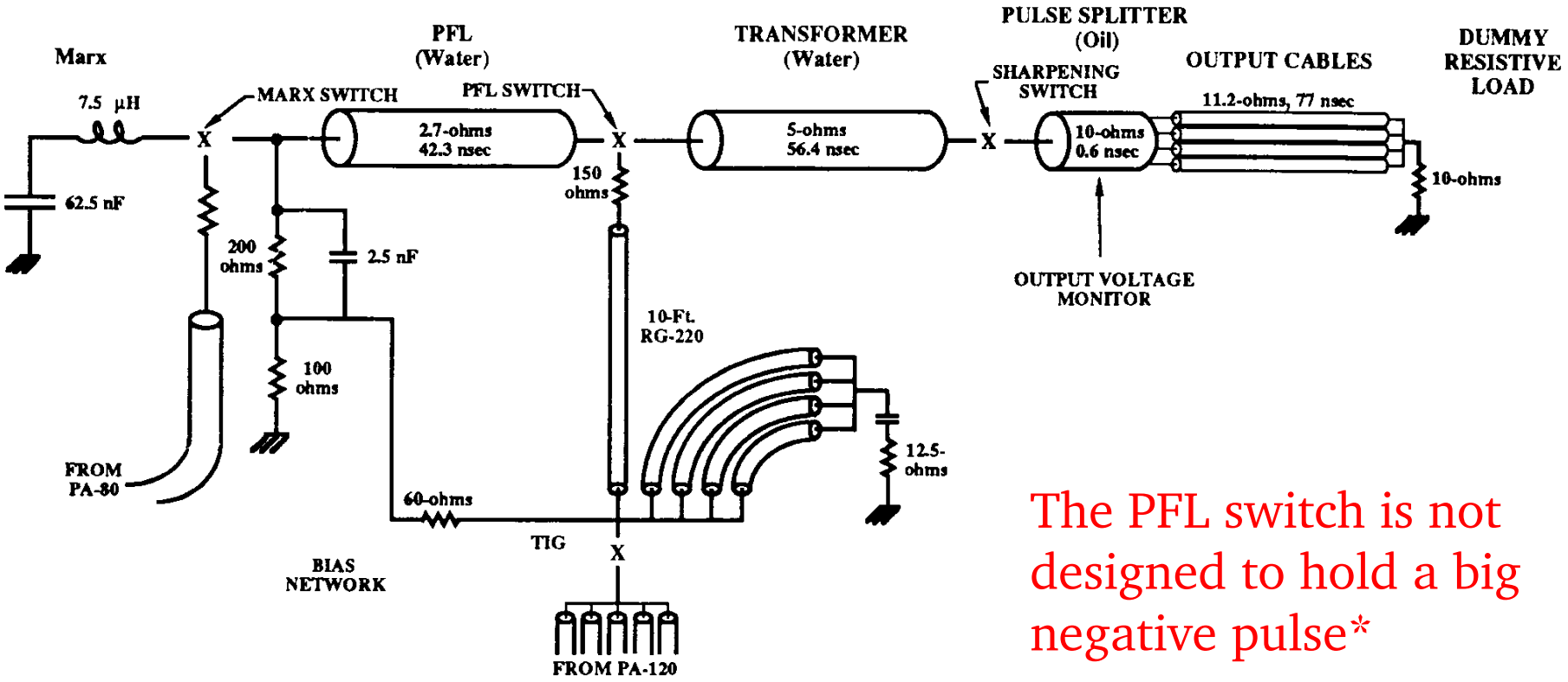
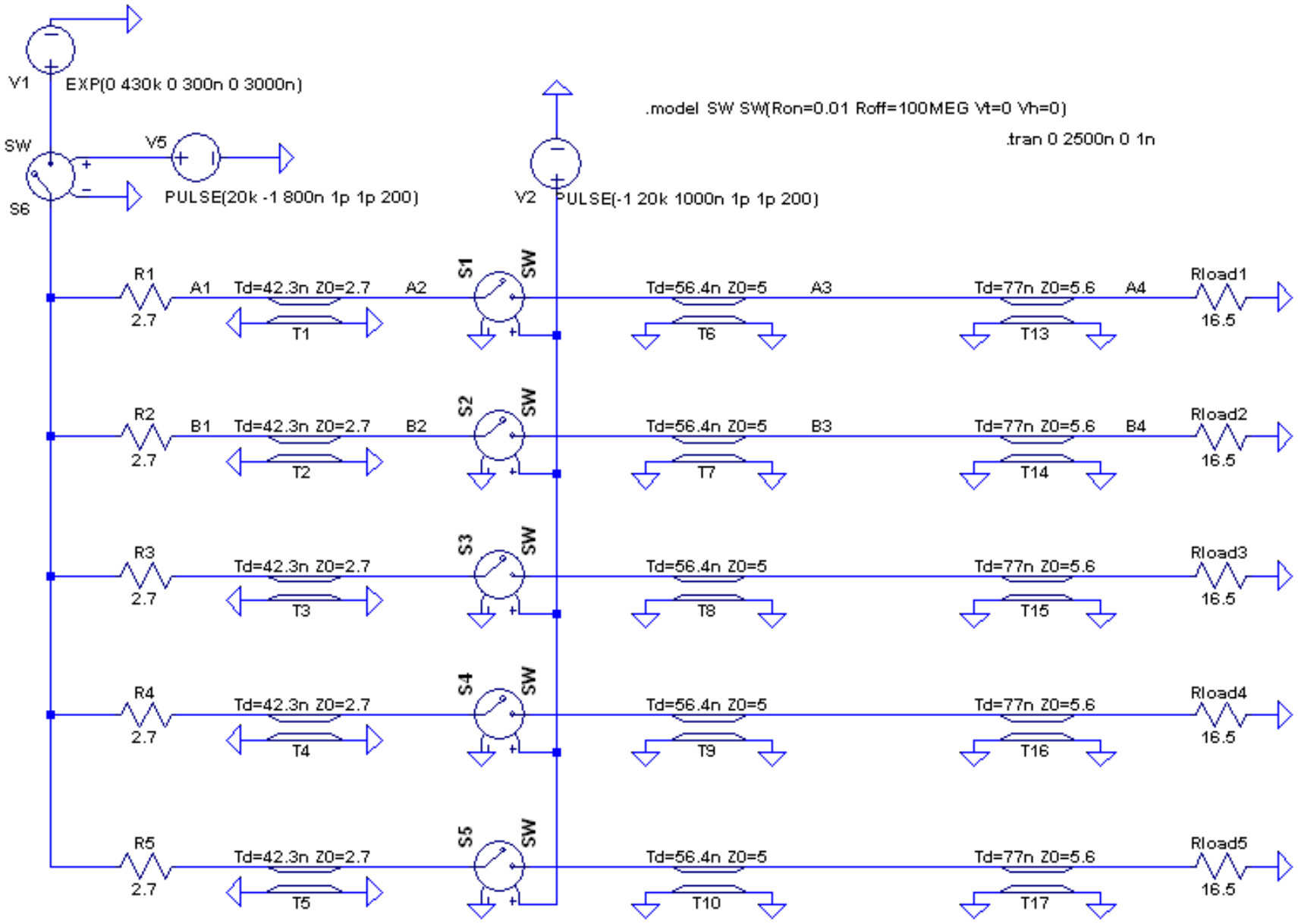


Figure 1. Prototype power supply circuit.

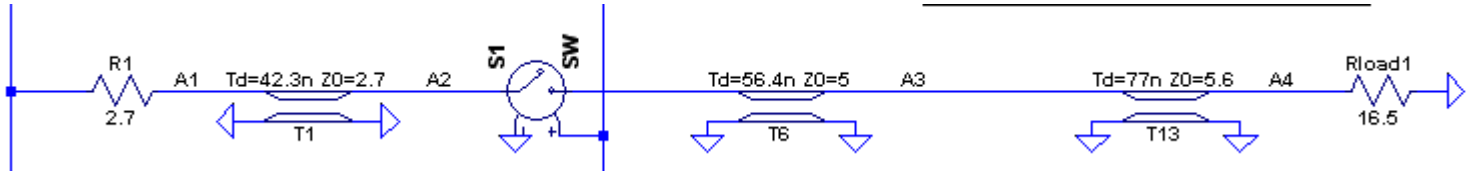
The PFL switch is not designed to hold a big negative pulse*

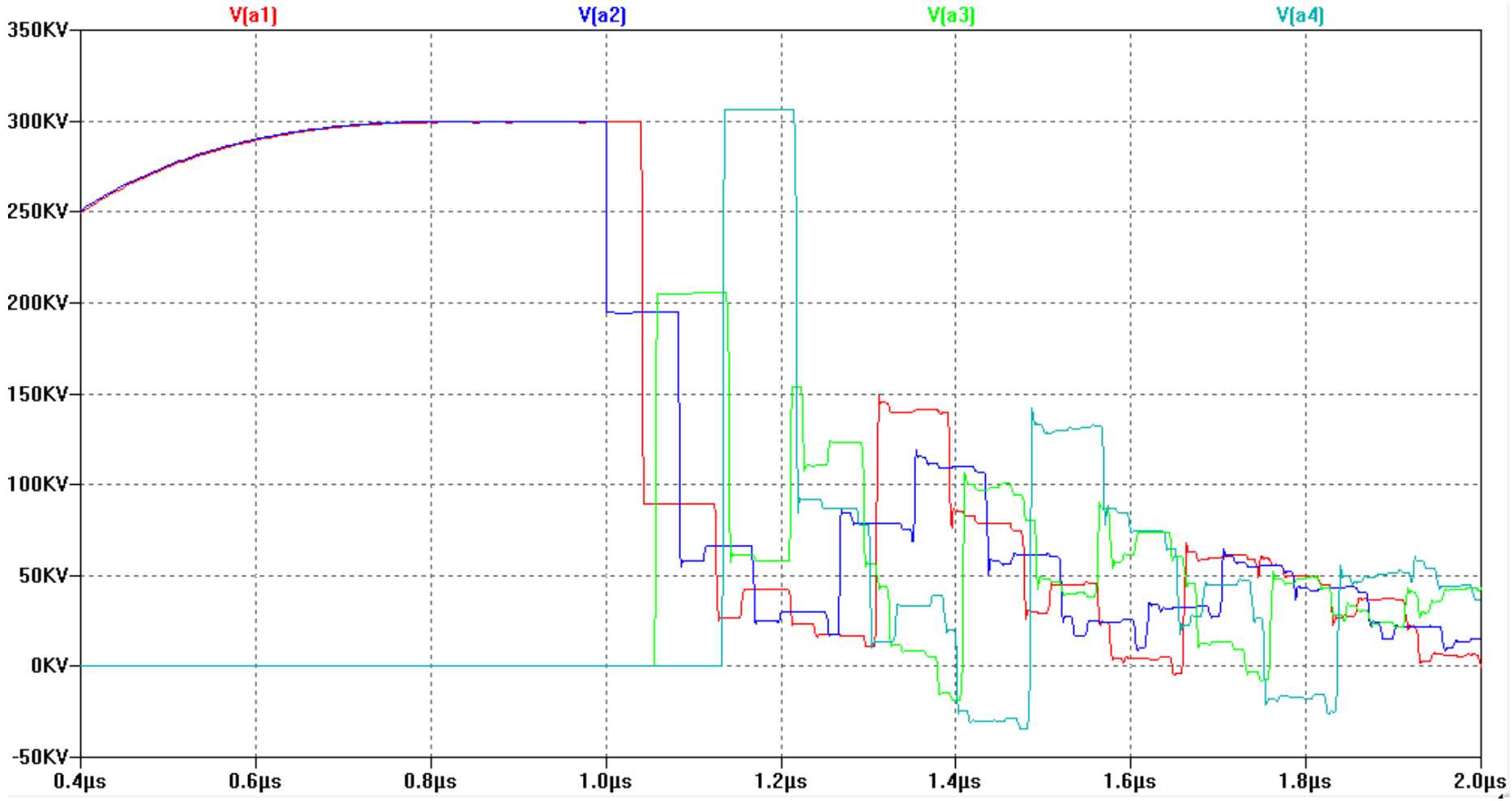
*From private talk with Dr. V. Dimitrov

ISIS Induction-Cell Driver: LTspice schematics



ISIS Induction-Cell Driver: LTspice simulation

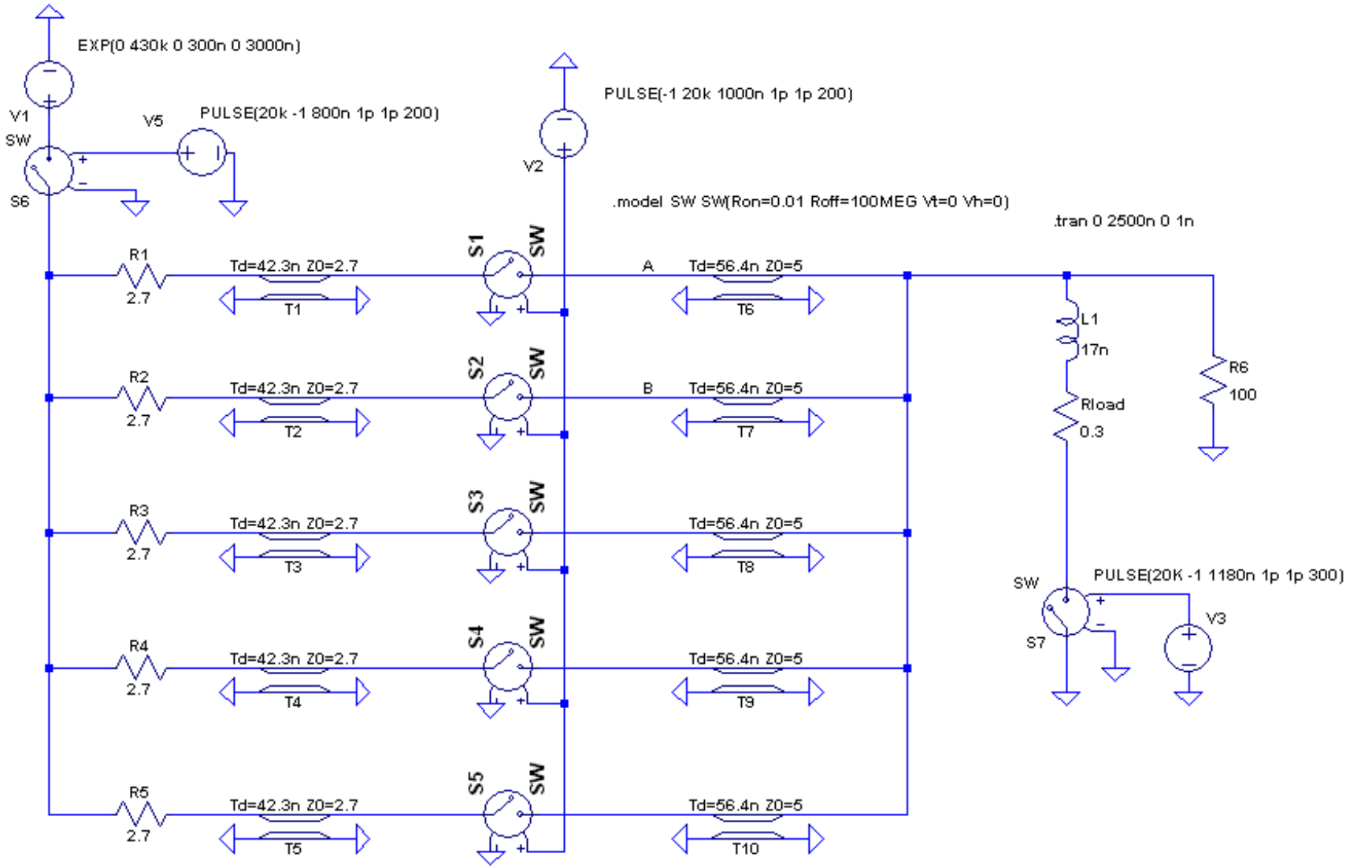




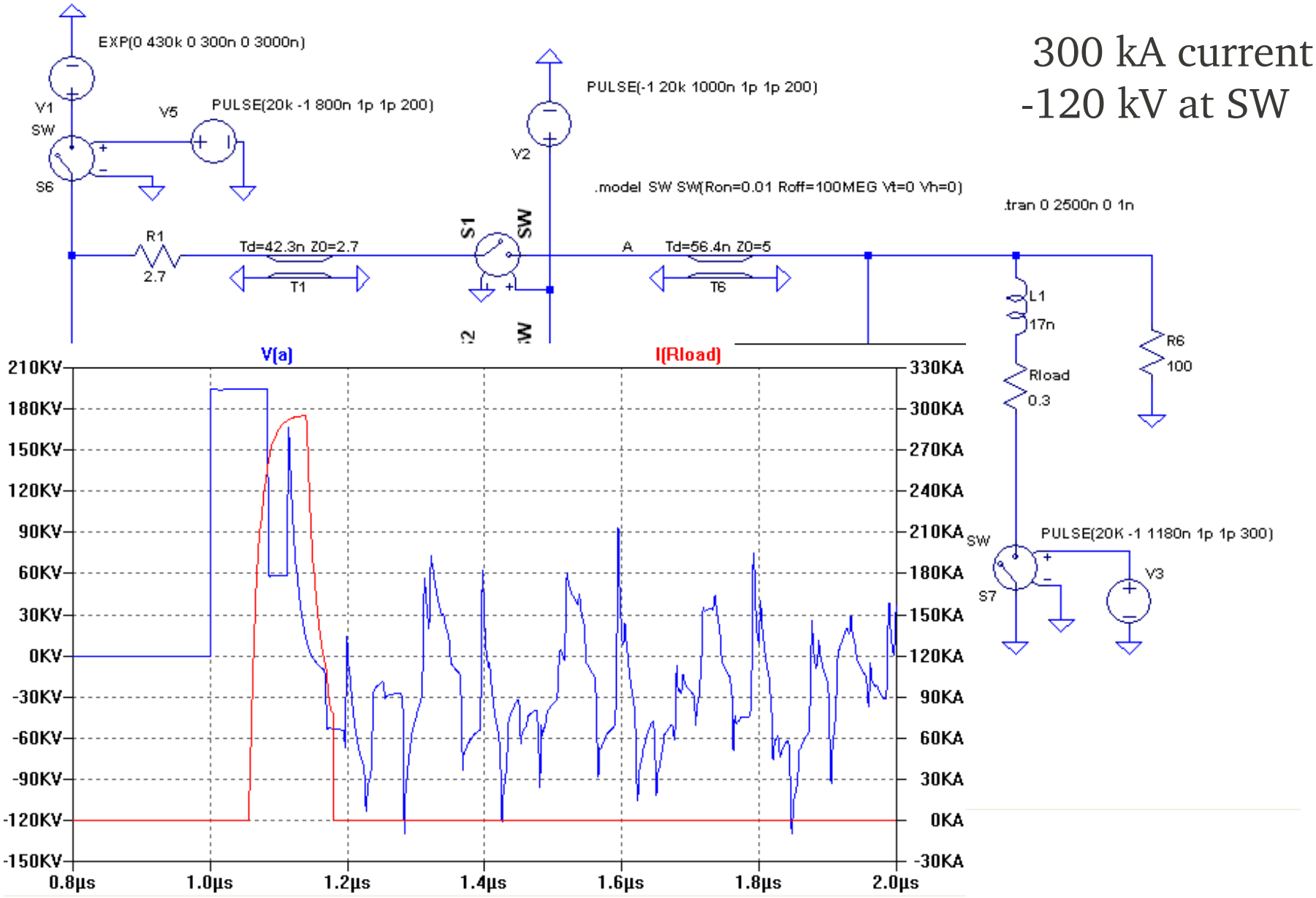
Wire resistance and inductance

material	ρ, 10^{-8} Ω*m	L, mm	d, um	R, Ω	L, nH	L, nH
Au	2.44	15	30	0.52	20.6	18.5
Al	2.82	15	30	0.60	20.6	18.5
Mo	5.20	15	30	1.10	20.6	18.5
W	5.60	15	30	1.19	20.6	18.5
Au	2.44	15	40	0.29	19.7	17.6
Al	2.82	15	40	0.34	19.7	17.6
Mo	5.20	10	40	0.41	12.3	10.9
W	5.60	10	40	0.45	12.3	10.9
Au	2.44	15	50	0.19	19.0	16.9
Al	2.82	15	50	0.22	19.0	16.9
Mo	5.20	15	50	0.40	19.0	16.9
W	5.60	15	50	0.43	19.0	16.9
Au	2.44	15	75	0.08	17.8	15.7
Al	2.82	15	75	0.10	17.8	15.7
Mo	5.20	15	75	0.18	17.8	15.7
W	5.60	15	75	0.19	17.8	15.7
Au	2.44	15	100	0.05	16.9	14.9
Al	2.82	15	100	0.05	16.9	14.9
Mo	5.20	15	100	0.10	16.9	14.9
W	5.60	15	100	0.11	16.9	14.9

ISIS Induction-Cell Driver + X-Pinch



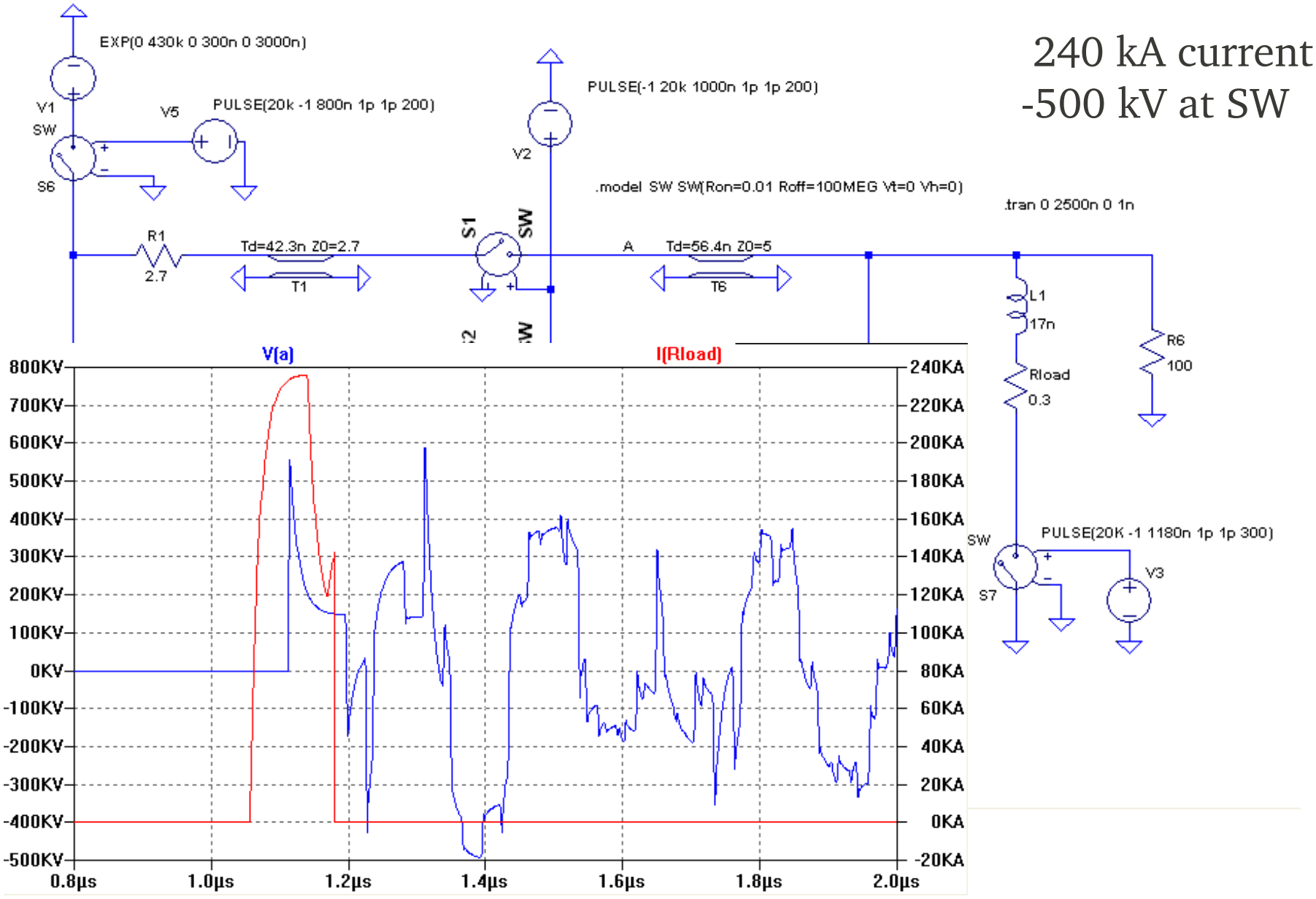
ISIS Induction-Cell Driver + X-Pinch: fire



300 kA current
-120 kV at SW

ISIS Induction-Cell Driver + X-Pinch: misfire

240 kA current
-500 kV at SW

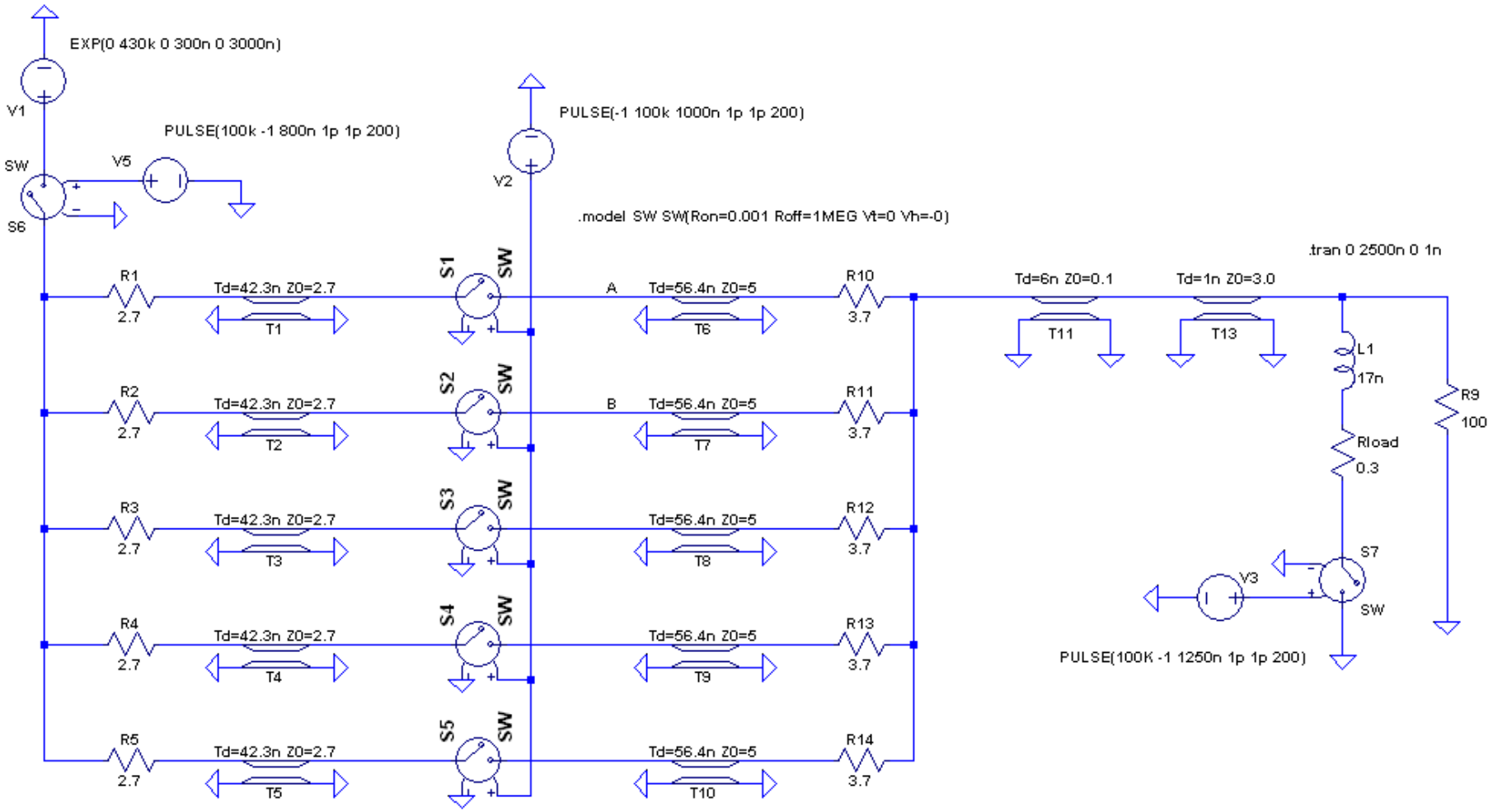


ISIS Induction-Cell Driver + X-Pinch: danger

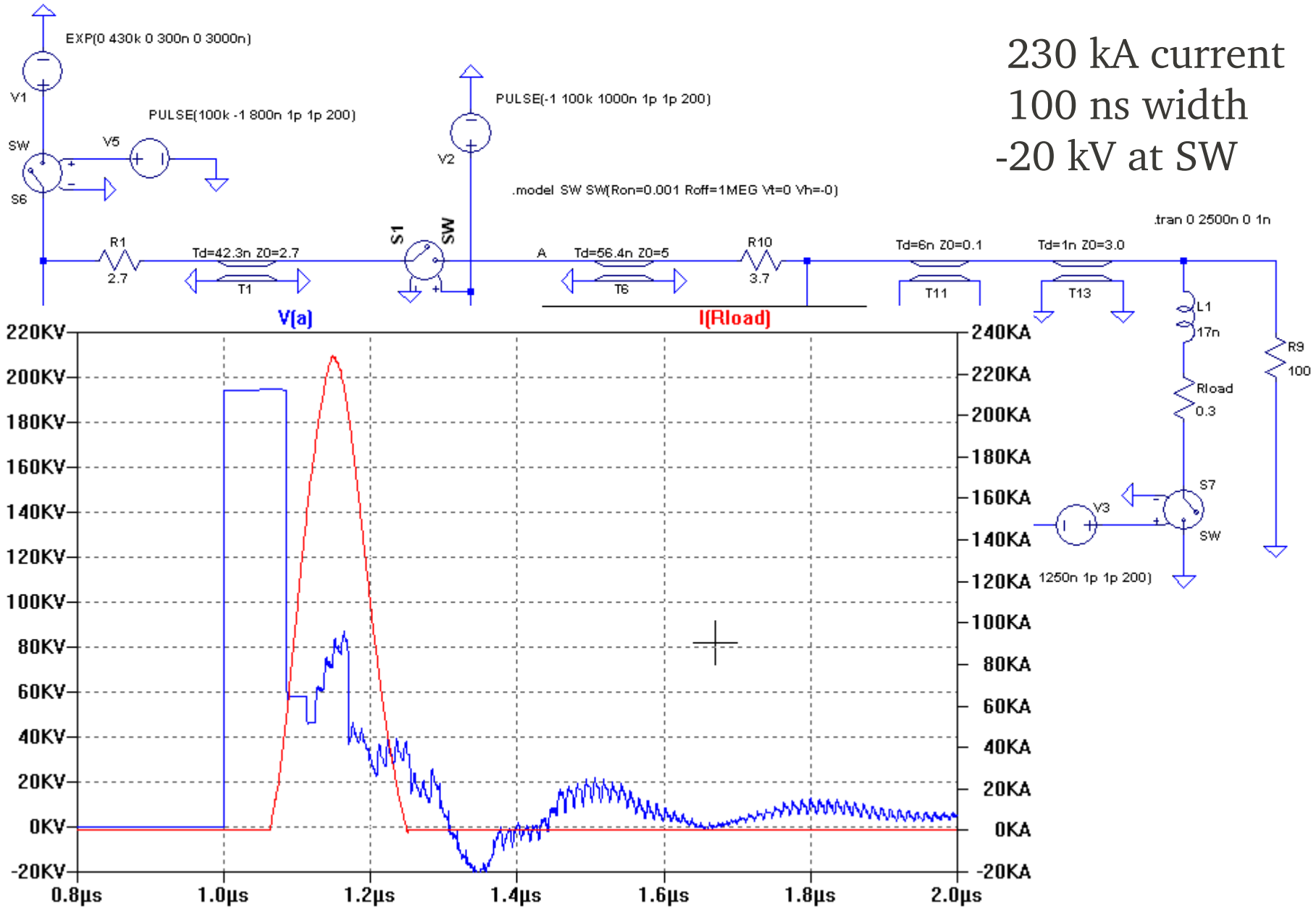
Danger:
The negative pulse at PFL switch will probably destroy the Induction Cell Driver

Solution:
Minimize the possible dangerous negative wave at PFL switch

ISIS Induction-Cell Driver + Transformer: 0.3 Ω load

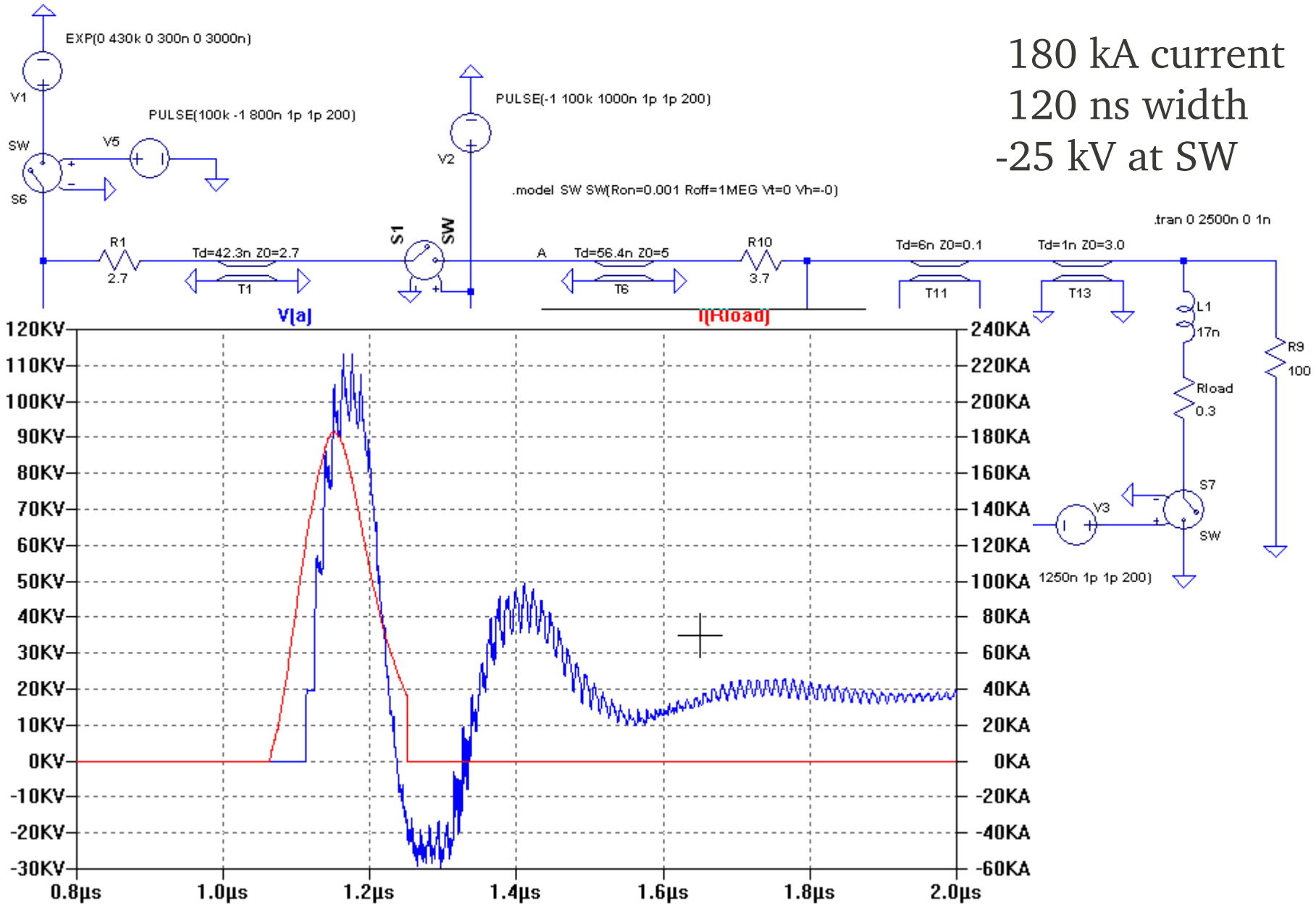


ISIS ICD + Transformer: 0.3 Ω load, fire



230 kA current
100 ns width
-20 kV at SW

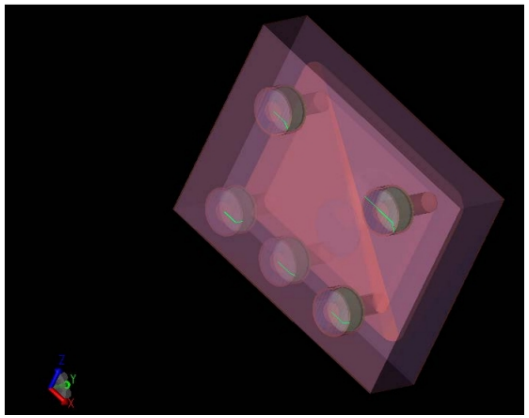
ISIS ICD + Transformer: 0.3 Ω load, misfire



180 kA current
120 ns width
-25 kV at SW

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

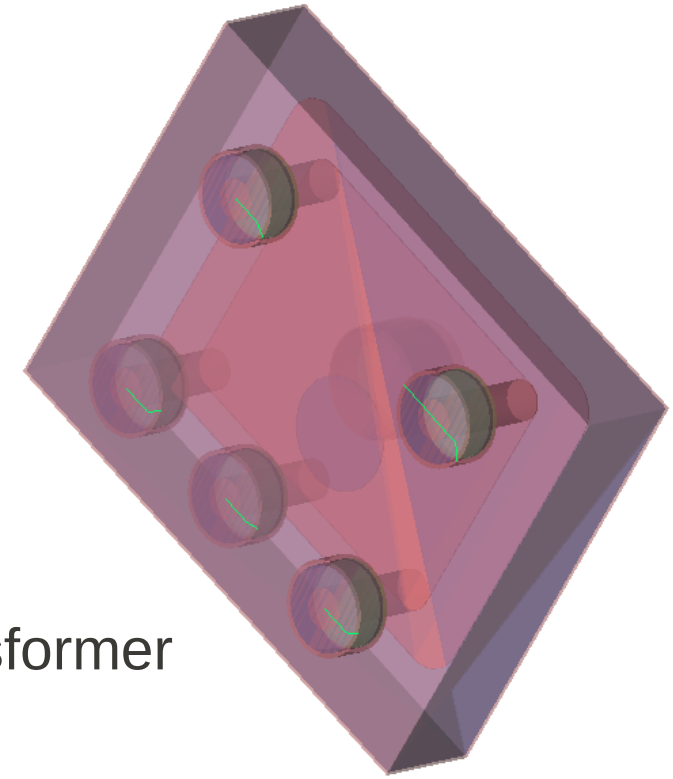
4. X-Pinch wires (Load):

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