R&D at SLAC on Nanosecond Range Multi MW Systems for Advanced FEL Facilities

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U.S. DEPARTMENT OF ENERGY
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SLAC NATIONAL ACCELERATOR LABORATORY

Outline

- Few Examples of Motivation
- LCLS-II Beam Roadmaps for Pump-Probe Experiments
- Pulser Specification
- Potential Engineering Solutions
- Experimental Results
- Project Status and Plans

Motivation

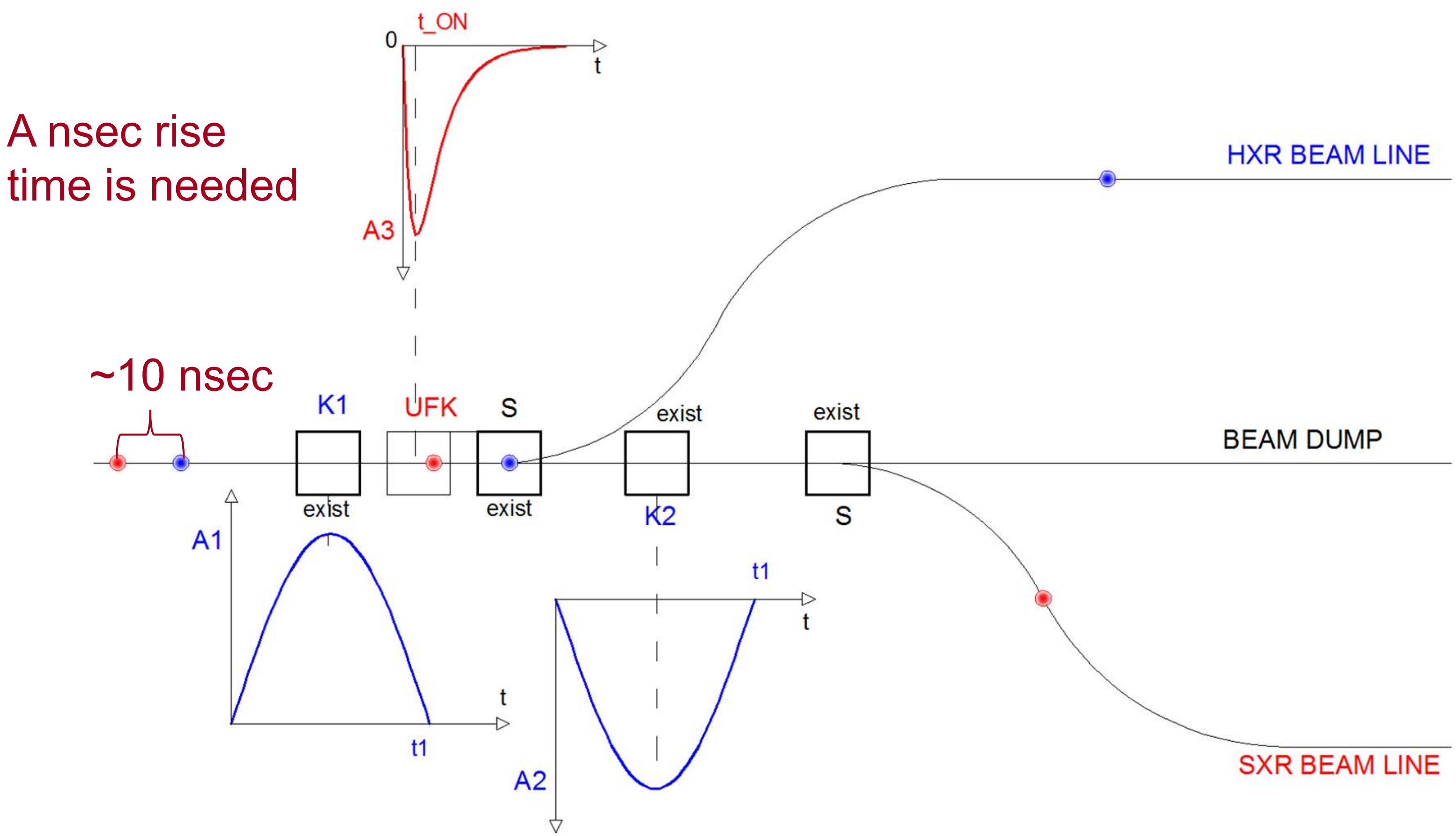
- NGLS, FEL Switch Yards, Spreaders, Two Types (RF and Pulsed)
- US Storage Ring Upgrades, MBA, Injection/Extraction “bad” bunches from the stored circulated train
- ILC DR Injection/extraction kicker (a problem is still alive)
- MaRIE project with pRad, eRad, and Xray linacs and their switchyards

…

More specific motivation is the LCLS-II beamline for pump-probe experiments.

LCLS-II Beam Line With a 13 Bucket Bunch Separation

These experiments deal with two separated bunches. The separating time is approx. 10 nsec (10 ft). One bunch would go to the SXR undulator and the other to the HXR undulator. The resulting x-rays, of different color, would be recombined for pump-probe experiments.



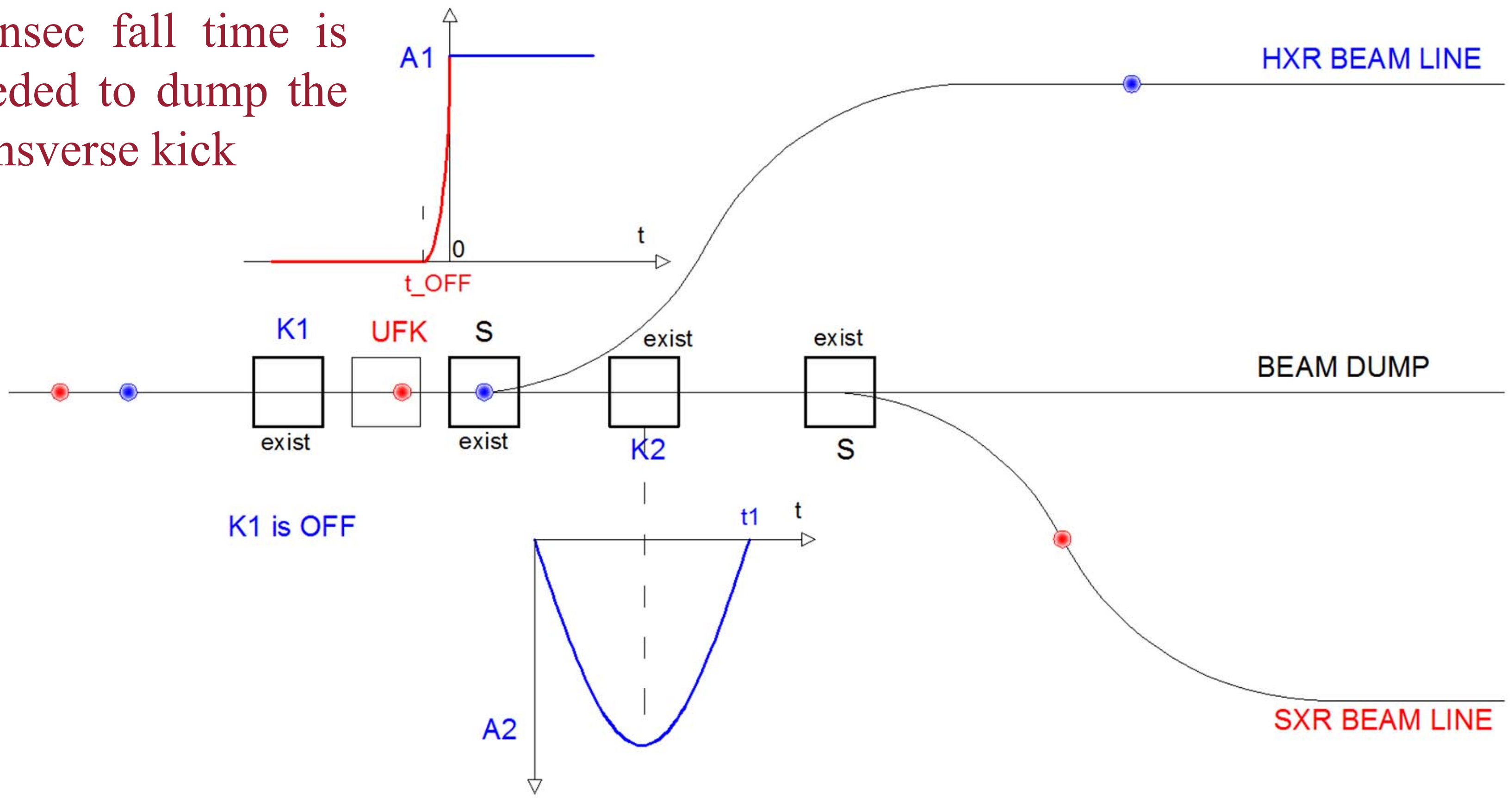
The Physics Required Specifications

Parameter	Requirement	Unit
Deflection	0.75 (3MeV at 4GeV)	mrad
Beam Energy	4.0	GeV
Stay clear	10	mm
Rise Or Fall Time	10.8 is good, 5.4 is better	ns
Pre-pulse/post-pulse	5	% of main pulse
Repeatability	100	ppm rms
Remnant field at next main bunch (1.07μs later)	0.01 good, 0.02 manageable	Gm
Rate	10 (more is better, 1 ok to start)	kHz
Availability	Low	

Alternative Mode Operation with a Fast OFF Pulse

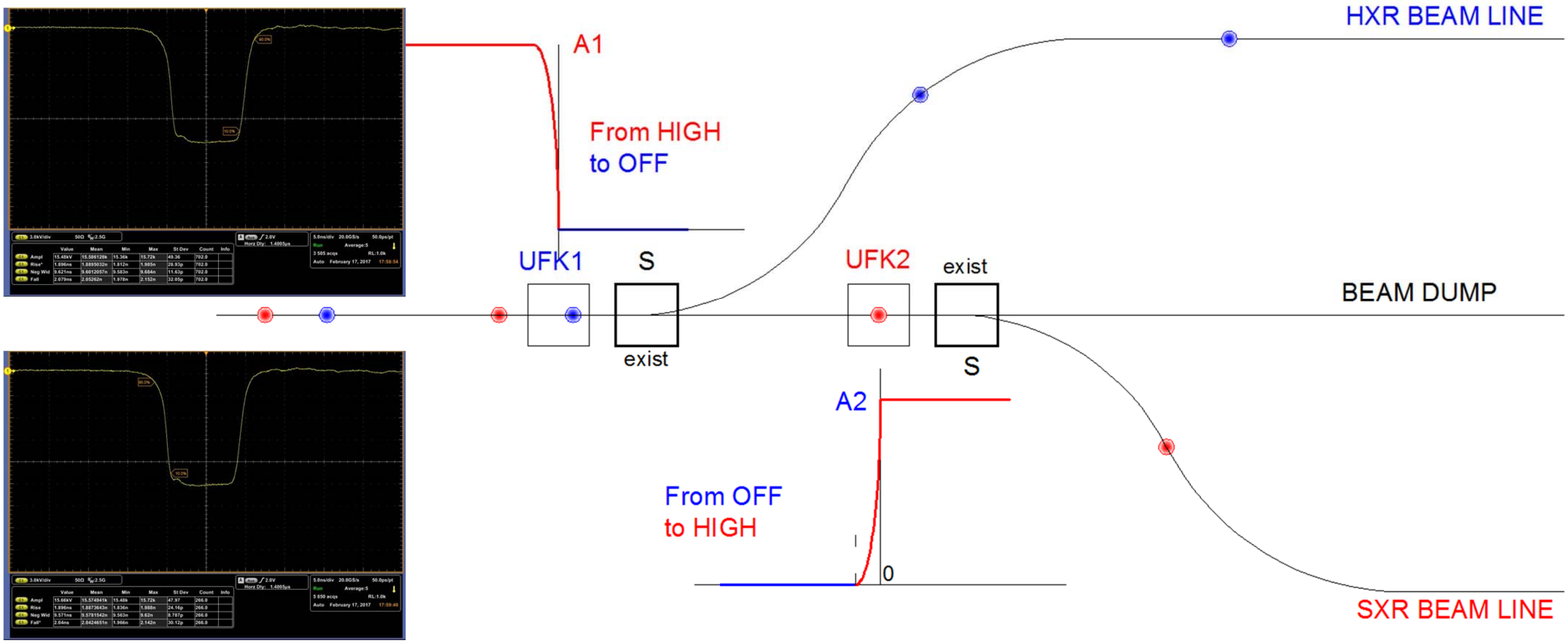
UFK is ON beforehand (a “long” rise front)
UFK is OFF before the HXR bunch enters into it

A nsec fall time is needed to dump the transverse kick



Roadmap with Fast OFF and ON Pulsers*

UFK1 is ON beforehand (a “long” rise front)
UFK1 is fast OFF before the HXR bunch enters into kicker structure
UFK2 is fast ON for HXR

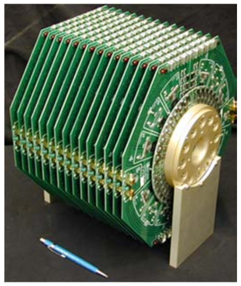


A MW rec shape nsec kick allows to control bunches with arbitrary bunch train pattern. There is a flexibility for the end FEL user.

Potential Engineering Solutions

A switching speed off commercial off shelve devices is limited by time space charge build up
- 1-2 A/nsec for Si-base switches
- 10-20 A/nsec for gas-filled tubes

Array of switches



Courtesy Ed Cook

An Alternative Solutions: Use a non-linear media to assist with switching speed. Magnetic Permeability and Conductance are common material parameters which can be used to "speed up" of a "slow" switch.

Shock wave formation in a ferromagnetic materials

Switching speed:

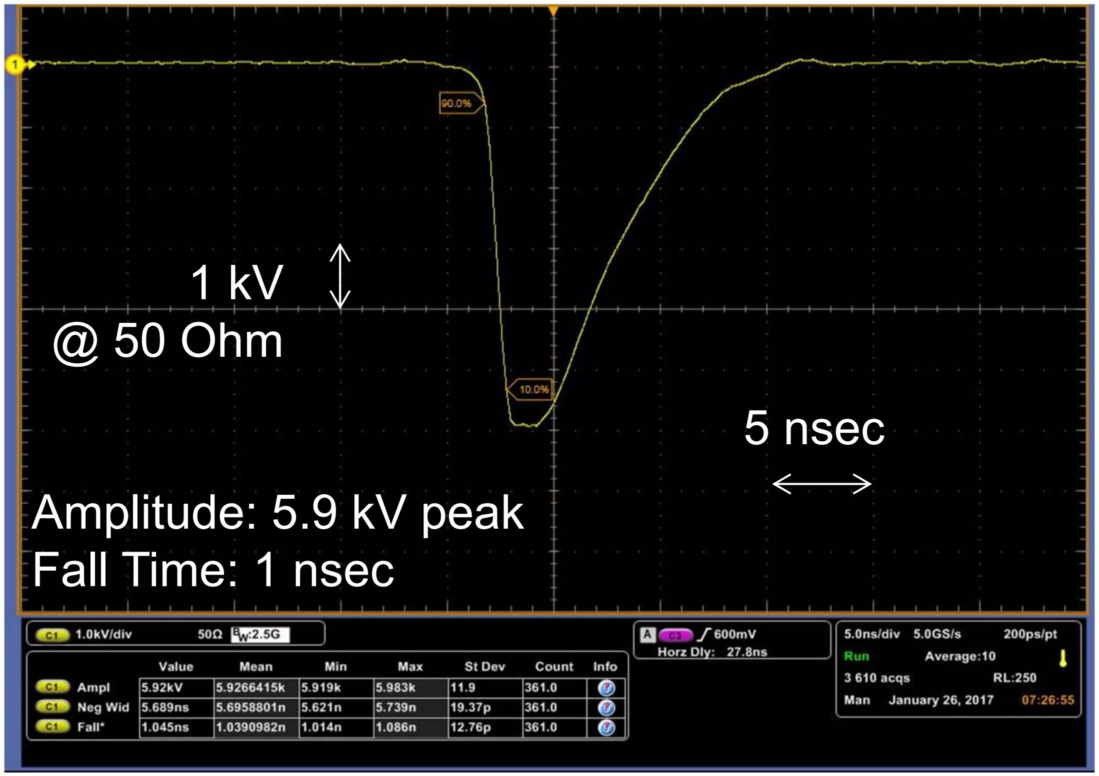
$$t_r \propto \frac{1}{H_{sv}}$$

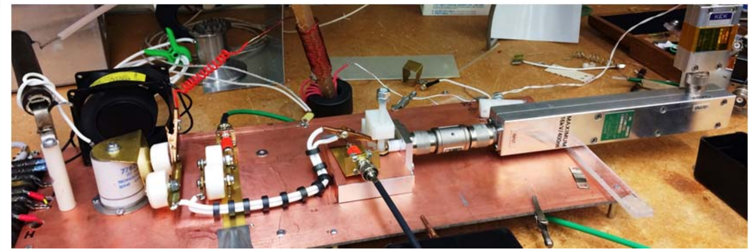
Formation of a solid state plasma and fast ionization processes in Si-base materials

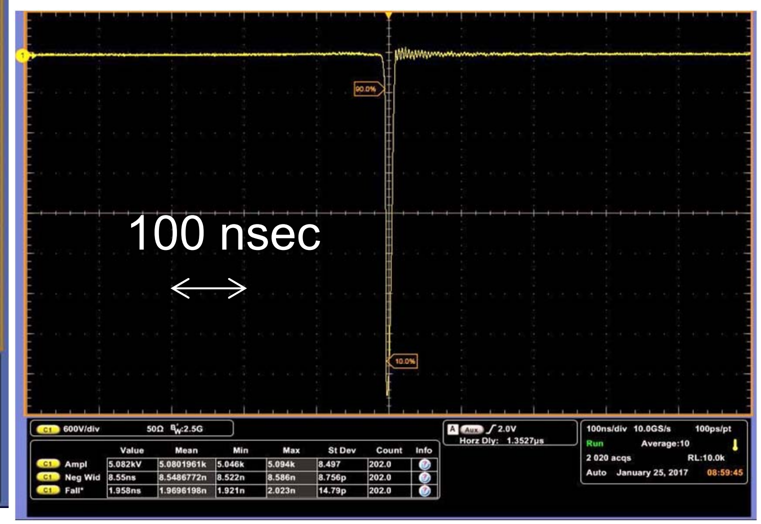
Switching speed:

$$t_r \propto \frac{d_{SCR}}{v_{sat}}$$

Results of Bench Testing on Proof of Principle Circuit @ 60Hz







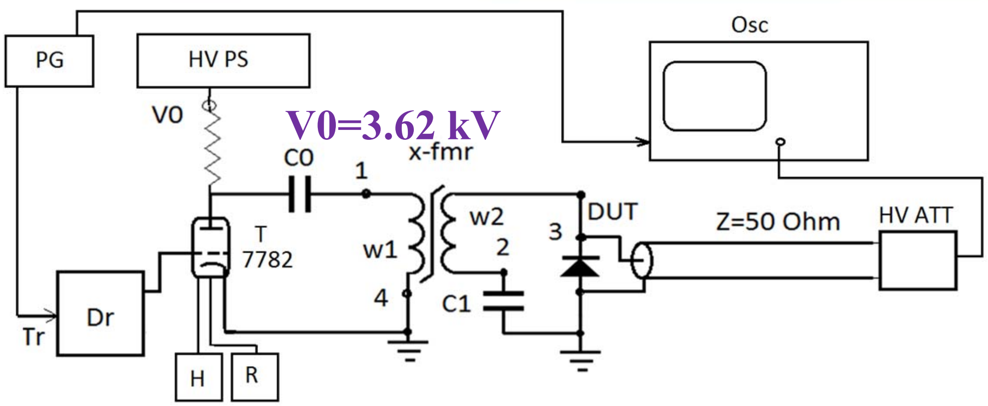
Primary switch is a gas-filled thyratron.

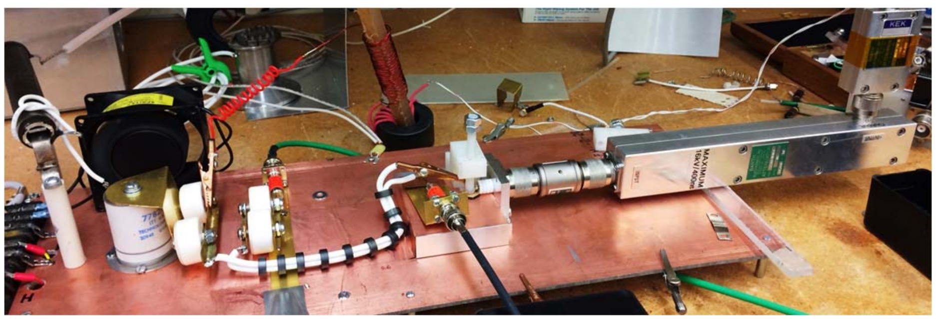
A drift step recovery diode assists the thyratron to obtain the switching di/dt~ 120 A/nsec

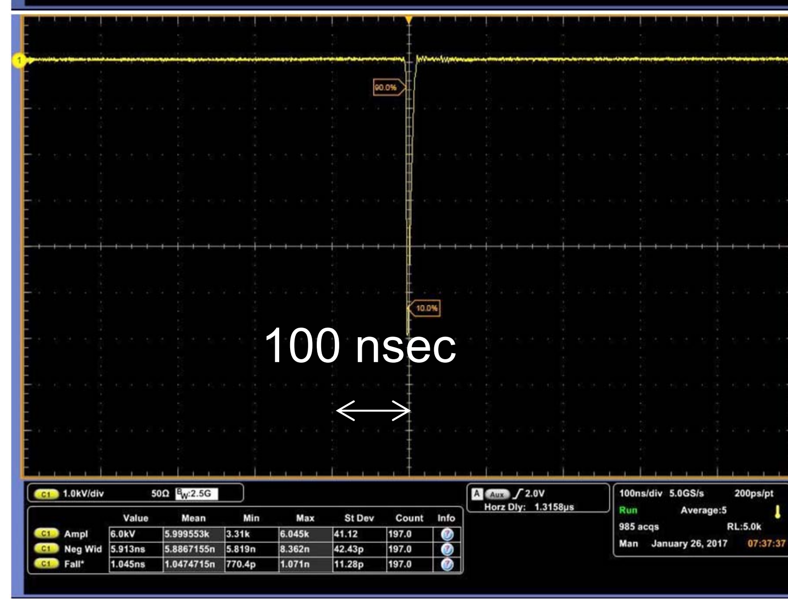
Total number of components is 6. All are available from the US vendors.

Most costly component is a HV broadband attenuator (~$10k).

Demonstrator #1: 6 kV peak, Fall=0.96 nsec

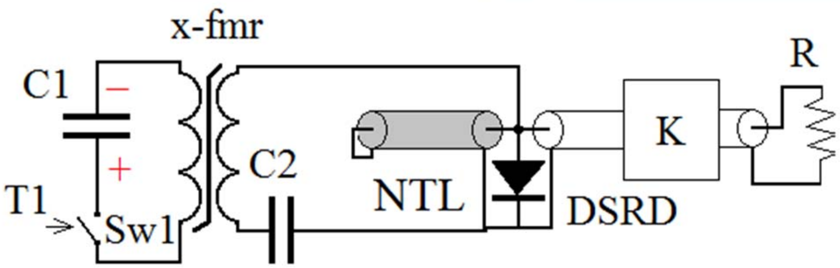


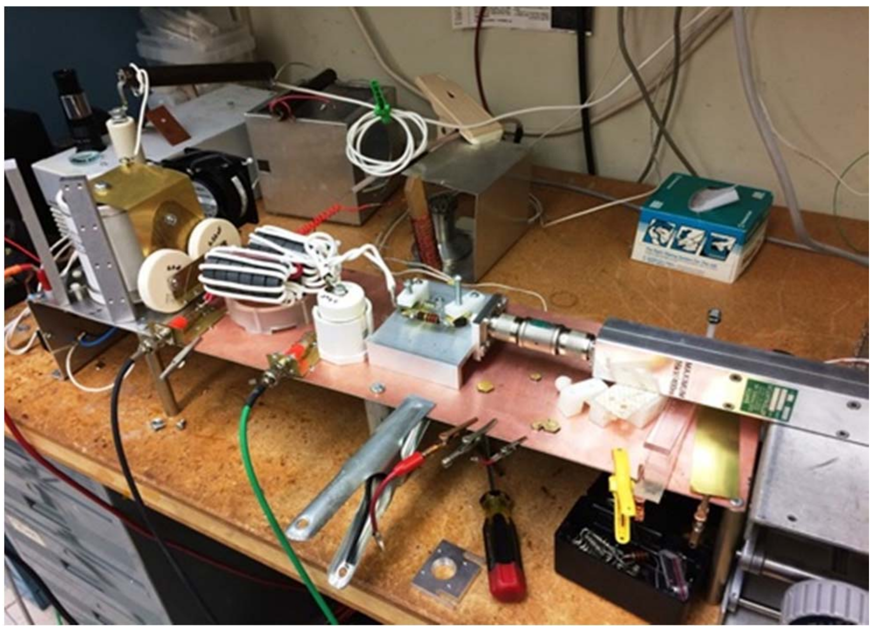


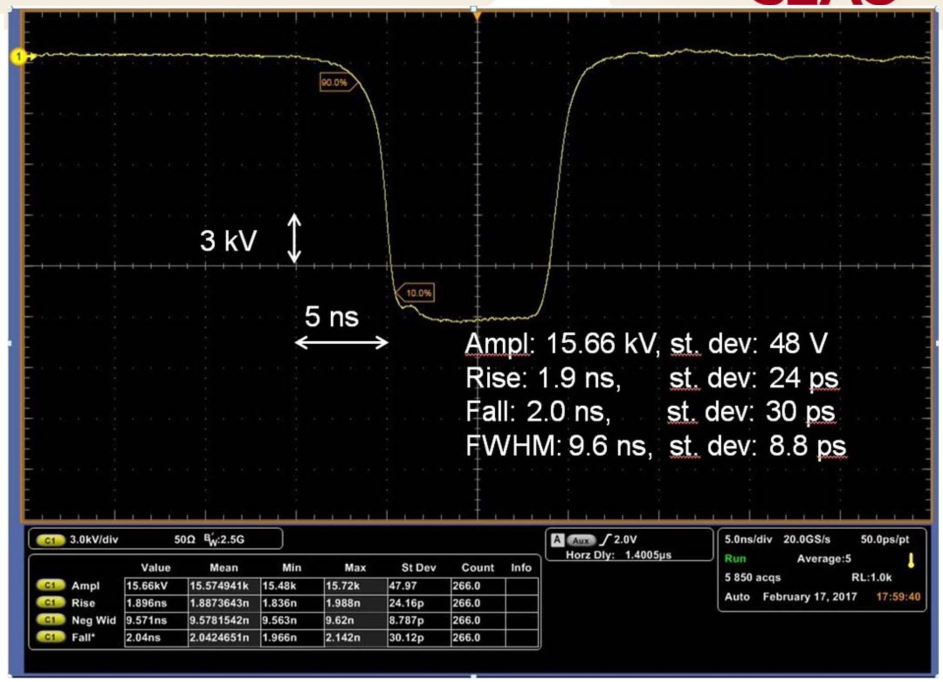


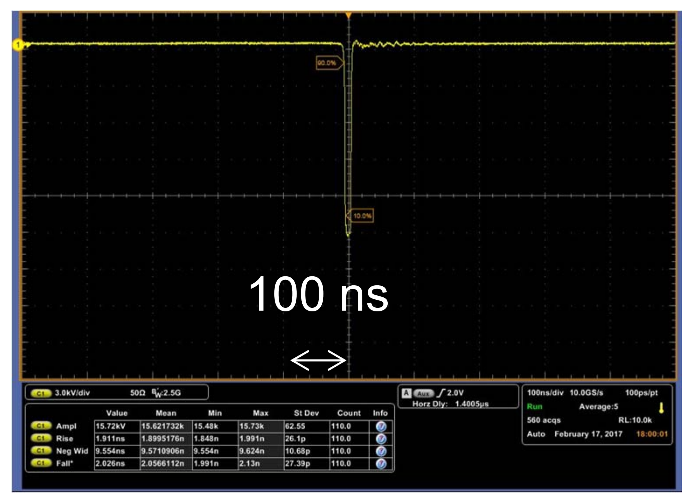
DSRD "pumping" mode: 1:1 x- fmr
FWD = 155 A peak (T/2=~80 nsec)
REV= 293 A peak
Feature: the pulser at Vo=3.6 kVDC produces almost Vout = 6 kV peak with the 1:1 x-fmr and no residuals

Demonstrator #2: 15.7 kV peak, FWHM=9.6nsec



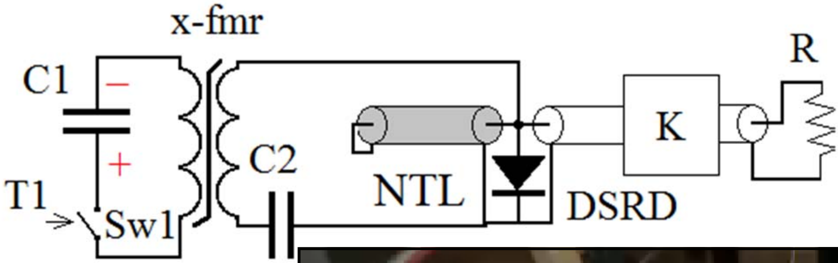


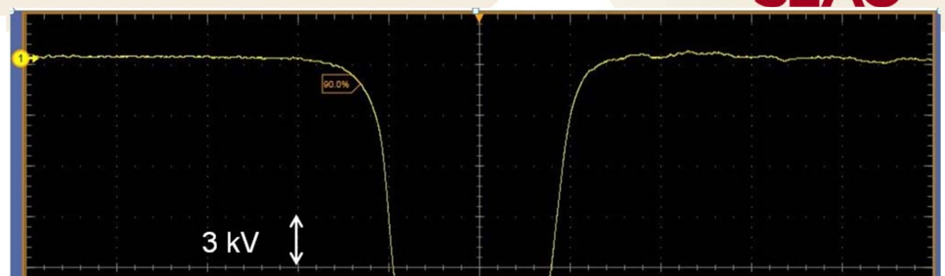


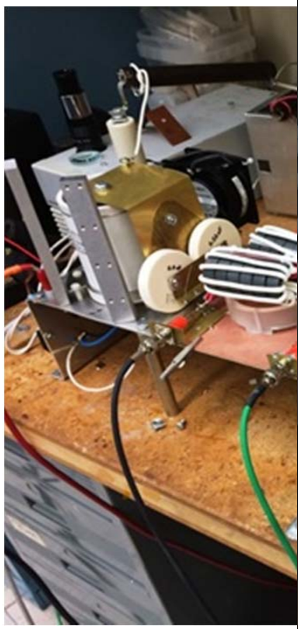


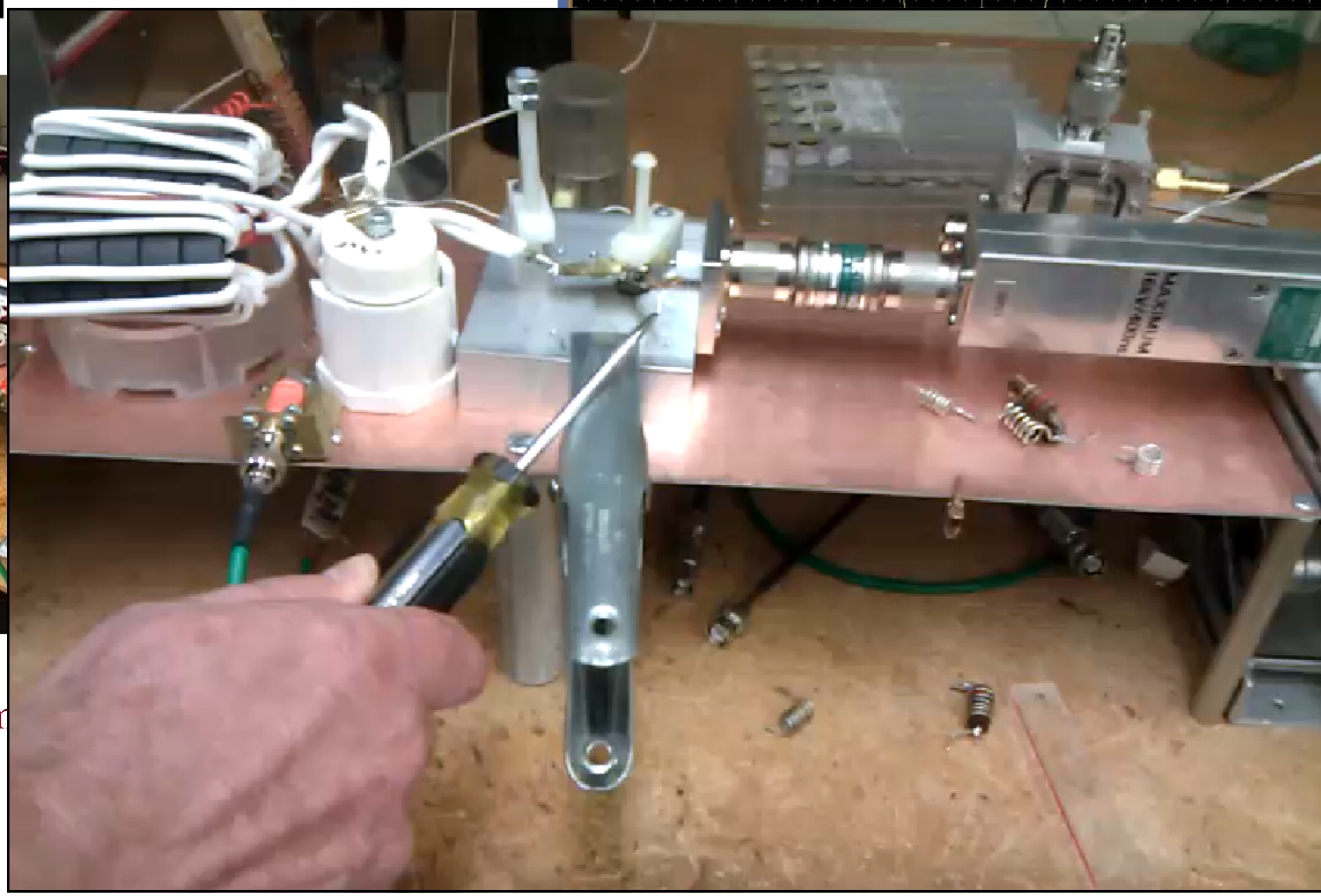
To show the movie of a 20 kV output (120 PPS)

Demonstrator #2: 15.7 kV peak, FWHM=9.6nsec









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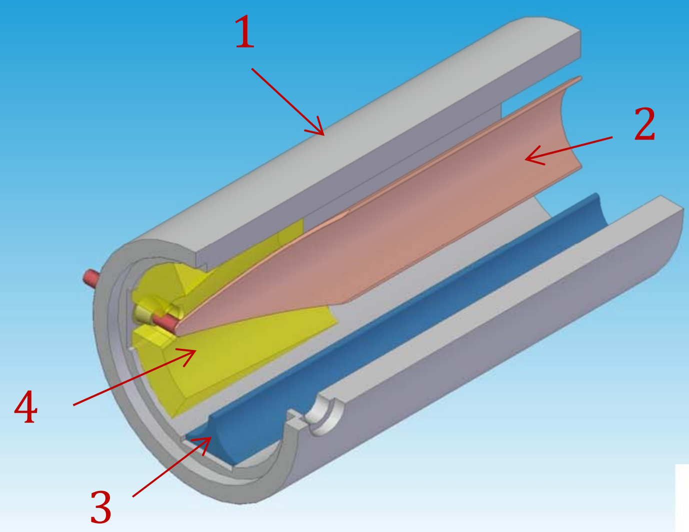
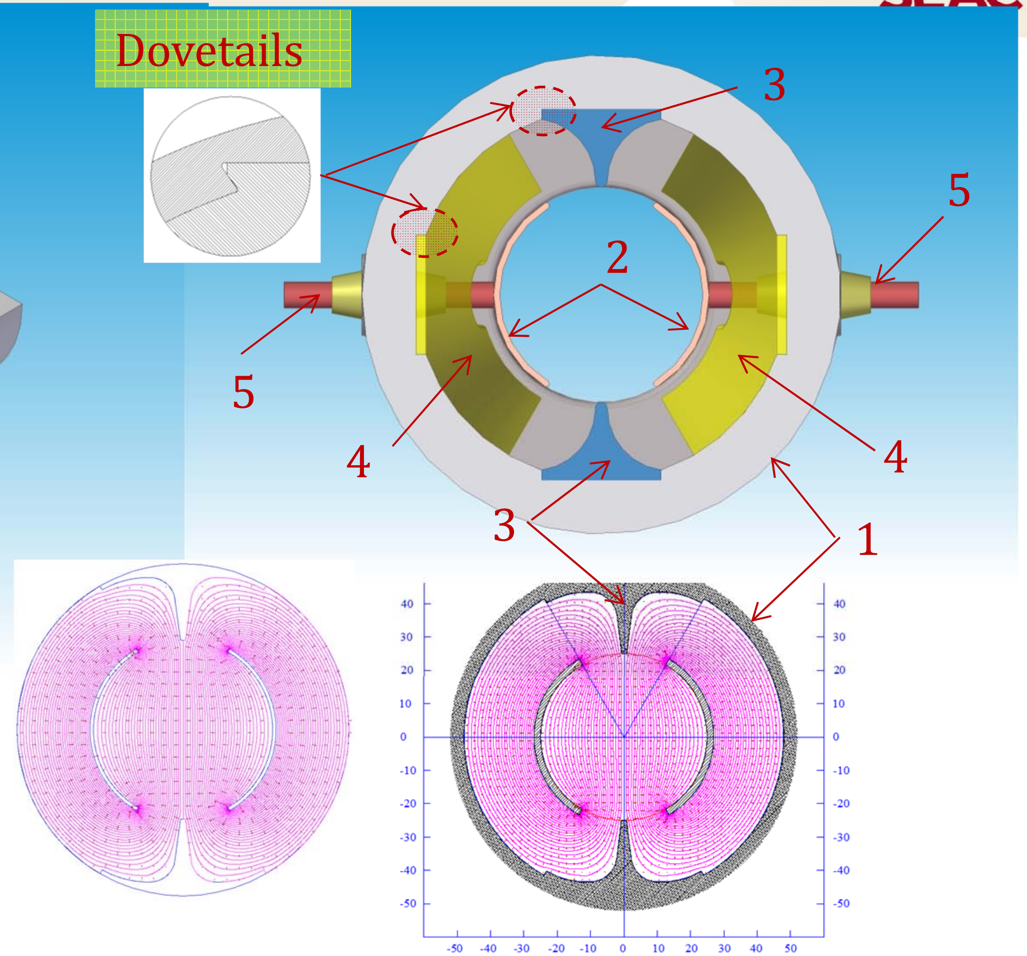
Kicker Concept





1 – Housing
2 – Kicker Plates
3 – Ribs/fenders
4 – HOM dump insertions
5 – Feedthroughs

Proposed in 2002 SLAC's version of the kicker structure for the ILC DR contains three new parts: (1) two matched tapered regions, (2) grounded fenders, and (3) kicker end HOM absorbers (SLAC-PUB-17099) This kicker concept is proposed to study in the LCLS-II beamlines.

R&D Short Range Plan

- High prepetition rate (1kHz, 10 kHz, 100 kHz …modes of operation)
- Stability of operation at high rep. rates
- Experiments show that no a special stabilization need in all used PSs (heater, reservoir, trigger, high voltage, AC etc.). We shall confirm this fact
- Thyratron vs. MOSFET Array as a primary switch. Comparison.
- Concepts of charging circuit vs. the output stability
- HV broadband loads and feedthrough

- Current kicker pulser concept is rather simple and based on the OFF solid state switches. It would be nice to evaluate the fast ionization mode in solid state material. This mode is realized with the ON solid state switches.

- Looking for a collaboration with other institutions who are interesting in this technology and concepts

Related to our SLAC Publications

SLAC Pub ID	Workshop/Conference	When	Where
SLAC-WP-077	ILC DR R&D	2007	Cornell
SLAC-WP-081	European Pulse Power	2009	CERN
SLAC-WP-096	Mini Kicker Workshop	2014	ANL
SLAC-WP-130	IPAC2016	2016	Busan, Korea

See also:

- SLAC-PUB-15098,
- SLAC-PUB-13477,
- SLAC-PUB-16481, and
- SLAC-PUB-17099

Acknowledgement

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