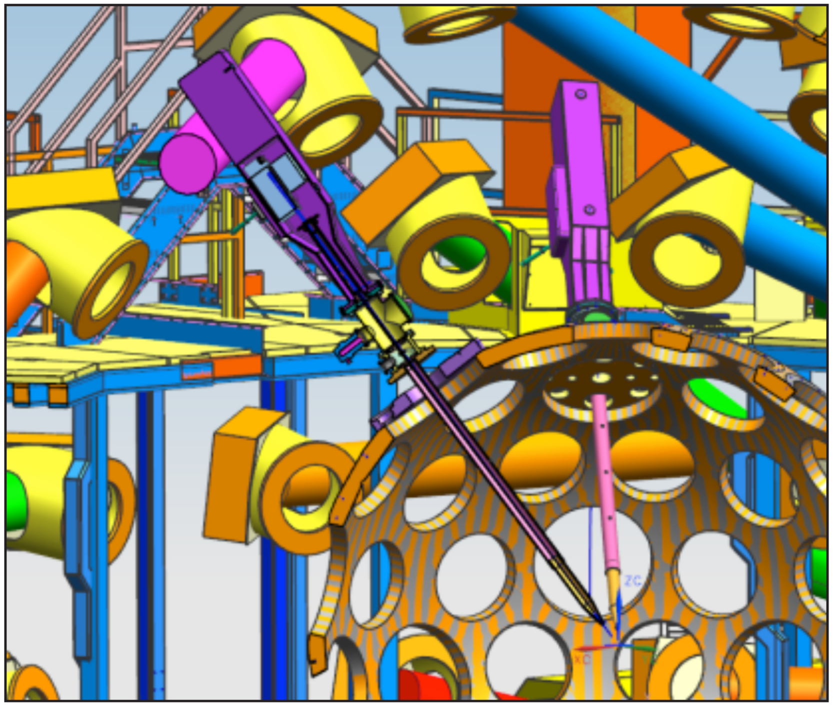
Conceptual Design of a Single-Line-of-Sight, Time-Resolved X-Ray Imager on OMEGA



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CEA–NNSA Joint Diagnostic Meeting
Rochester, NY
29–30 June 2016

An x-ray imager is combined with the pulse-dilation technique and the hybrid complementary metal–oxide–semiconductor (hCMOS) technology to create a true multiframe, ultrafast framing camera

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- The single-line-of-sight, time-resolved x-ray imager (SLOS-TRXI) on OMEGA will record images of the hot-spot self-emission from cryogenic target implosions and will provide critical information for inferring the hot-spot pressure
- Phase I will utilize a pinhole array as the x-ray optic
- Phase II will use an advanced x-ray optic (Kirkpatrick–Baez or Wolter)
- The conceptual design of phase I has been presented with planned installation on OMEGA in FY17Q1 and the first use in FY17Q2

The goal is to record gated images of the hot spot along three orthogonal views.

E25204

Collaborators

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Sandia National Laboratories

Time-resolved x-ray imaging of self-emission from the hot spot provides critical information for achieving the 100-Gbar goal*

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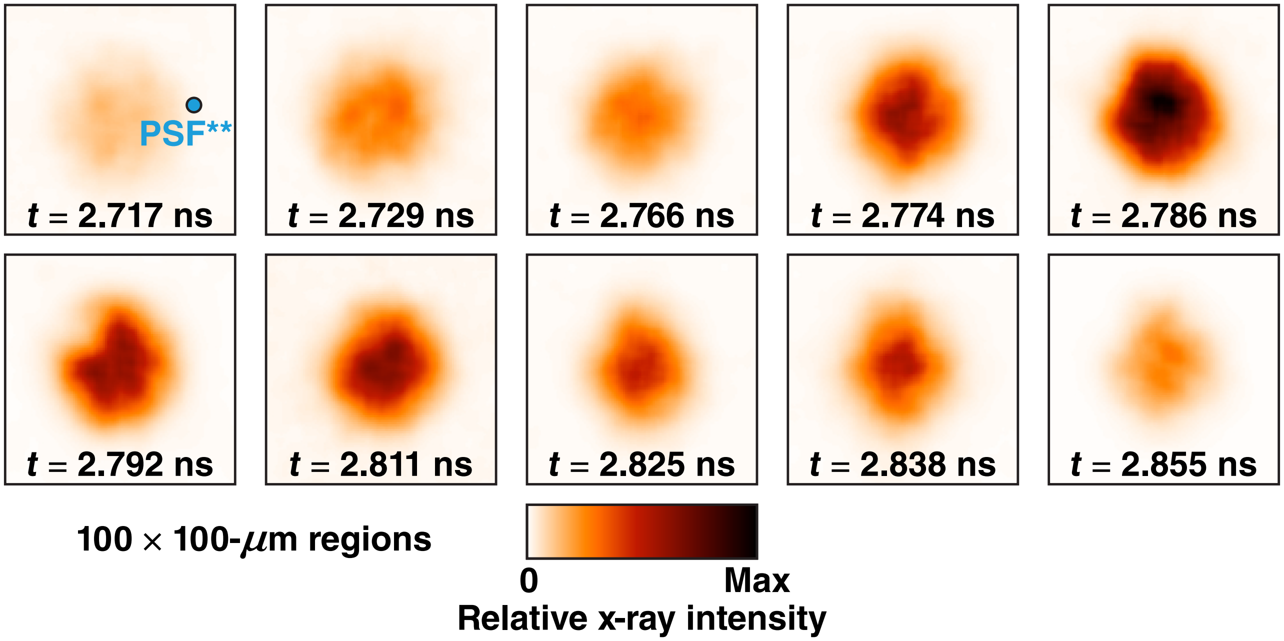
OMEGA cryogenic DT target implosion, shot 76828



KBframed has 30-ps temporal resolution and 6-μm spatial resolution, and records an image every 15 ps in the 4- to 8-keV photon-energy range.

F. J. Marshall, Rev. Sci. Instrum. 83, 10E518 (2012).

*S. P. Regan *et al*., "Demonstration of Fuel Hot-Spot Pressure in Excess of 50 Gbar for Direct-Drive Layered Deuterium-Tritium Implosions on OMEGA," submitted to Physical Review Letters.

**PSF: point-spread function

E24014f

The parameters for inferring the hot-spot pressure are neutron yield, ion temperature, hot-spot size, and burn duration

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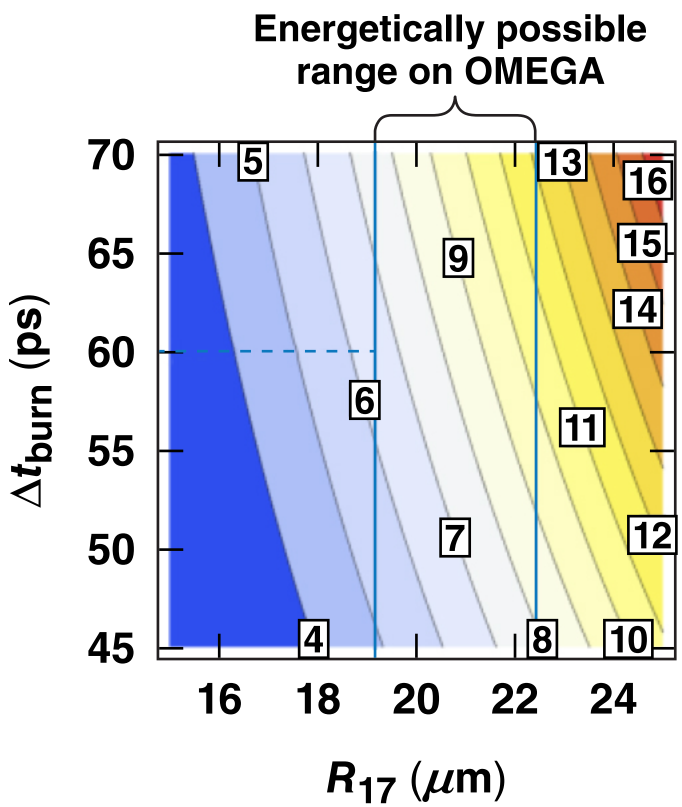
T_i = 3.5 keV, 4.5% increase/decrease in required *Y* per 100 eV increase/decrease in T_i

Map of the required neutron yield ($\times 10^{13}$) to achieve intermediate goal of 80 Gbar



Example:

- Hot-spot size: R_{17} = 19 μm
- Burn duration: Δt_{burn} = 60 ps
- Neutron yield: $Y = 6.5 \times 10^{13}$
- Ion temperature: T_i = 3.5 keV

Current:

- $R_{17} = 21.5 \pm 0.4$ μm
- $\Delta t_{burn} = 67 \pm 5$ ps
- $Y = 4.1 \times 10^{13}$
- $T_i = 3.2 \pm 0.25$ keV

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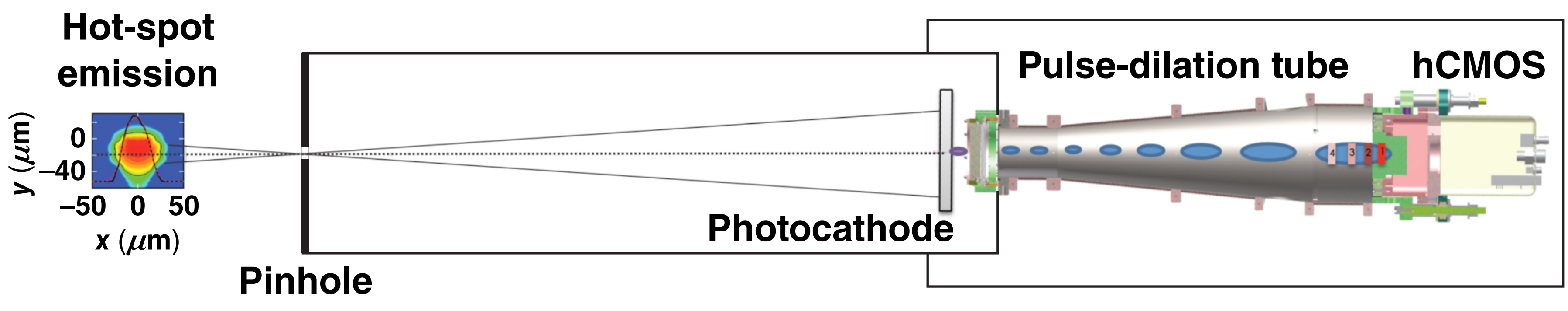
Phase I of the diagnostic on OMEGA comprises a pinhole imager, a pulse-dilation tube, and an hCMOS detector



- Hot-spot image in the ~4- to 8-keV photon-energy range
- Temporal resolution ~30 ps
- Three frames to sample ~90-ps neutron burnwidths from cryogenic DT implosions
- Pinhole provides ~8-μm spatial resolution for an ~20-μm hot-spot radius

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Photometric calculations were performed for the pinhole imager in three different port locations

- Integration time: 20 ps
- Filtration: 165-μm Be + 12-μm Al or 890-μm Be
- Photocathode: CsI
- Pinhole size: 10 μm
- Calculations are based on KB3 measurements of cryo shot 73586

Port	TCC*-pinhole (mm)	Solid angle (sr)	Magnification	hCMOS signal (counts/pixel)	Signal to noise
H12	80	1.2×10^{-8}	26.3	480	32
H4	163	3.0×10^{-9}	12.8	495	16
H5	191	2.2×10^{-9}	10.7	505	14

hCMOS saturation limit: ~1000 counts/pixel

*TCC: target chamber center

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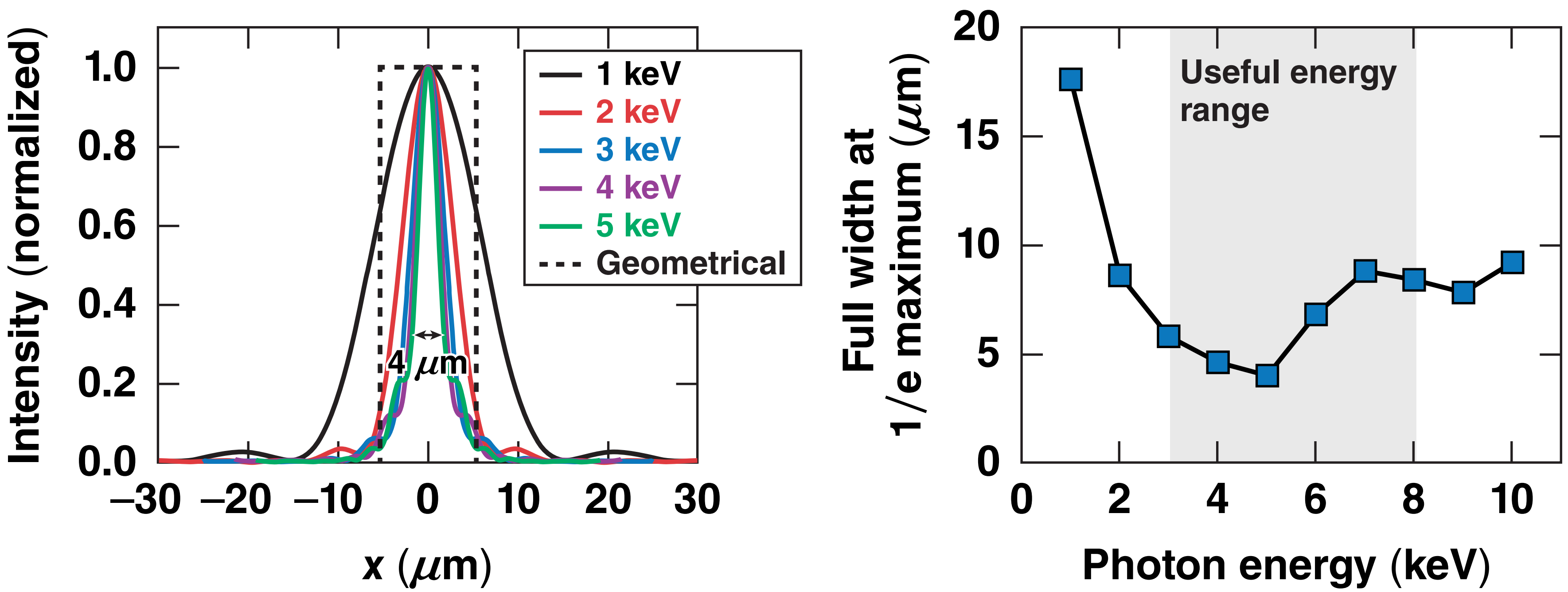
The point-spread function of the pinhole imager was calculated for different photon energies using the Fresnel approximation



Pulse-dilation electron imaging* is combined with the hCMOS technology of Sandia's UXI to create a true multiframe, ultrafast framing camera

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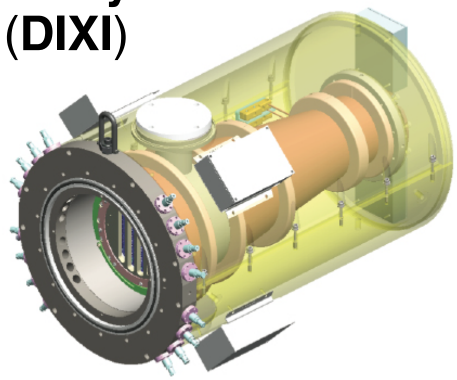
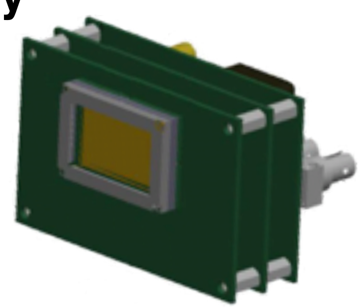
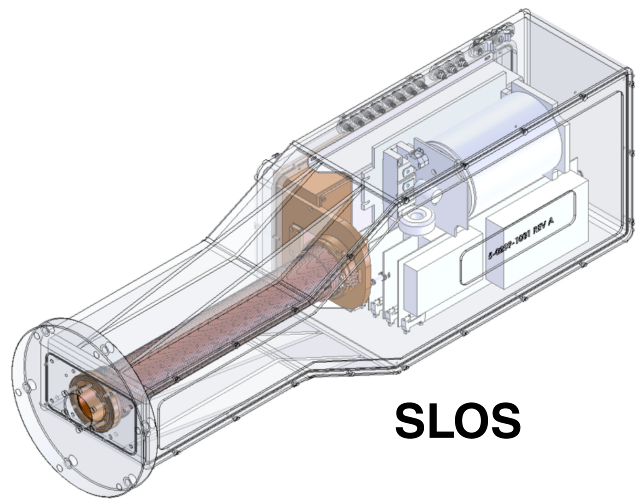
Dilation x-ray imager (DIXI)



Ultrafast x-ray imager (UXI)



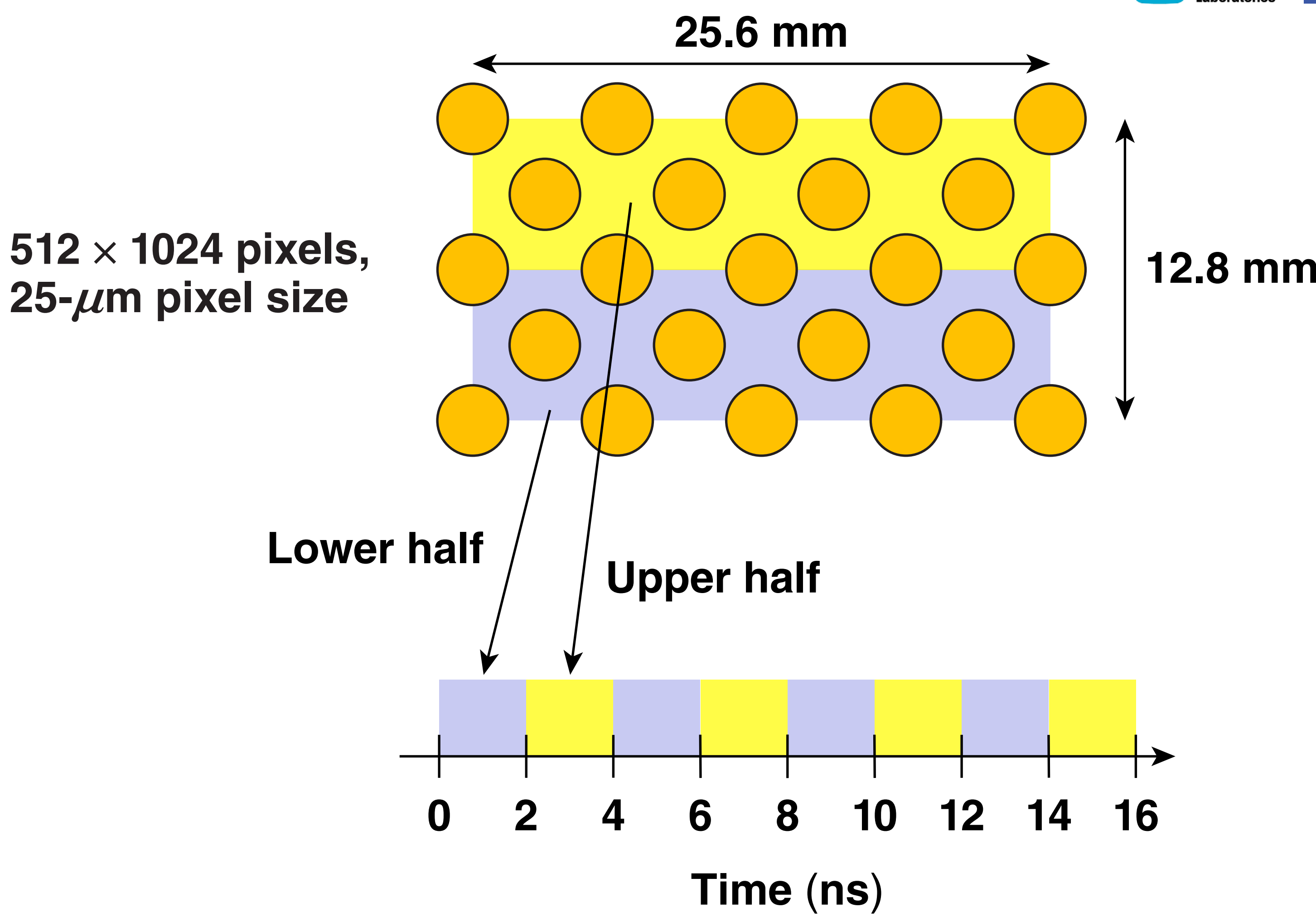


SLOS

SLOS camera is a joint technology development between General Atomics, Kentech, and Sandia.

*T. J. Hilsabeck *et al*., Rev. Sci. Instrum. 81, 10E317 (2010).

A pinhole array produces multiple images on the Icarus hCMOS detector



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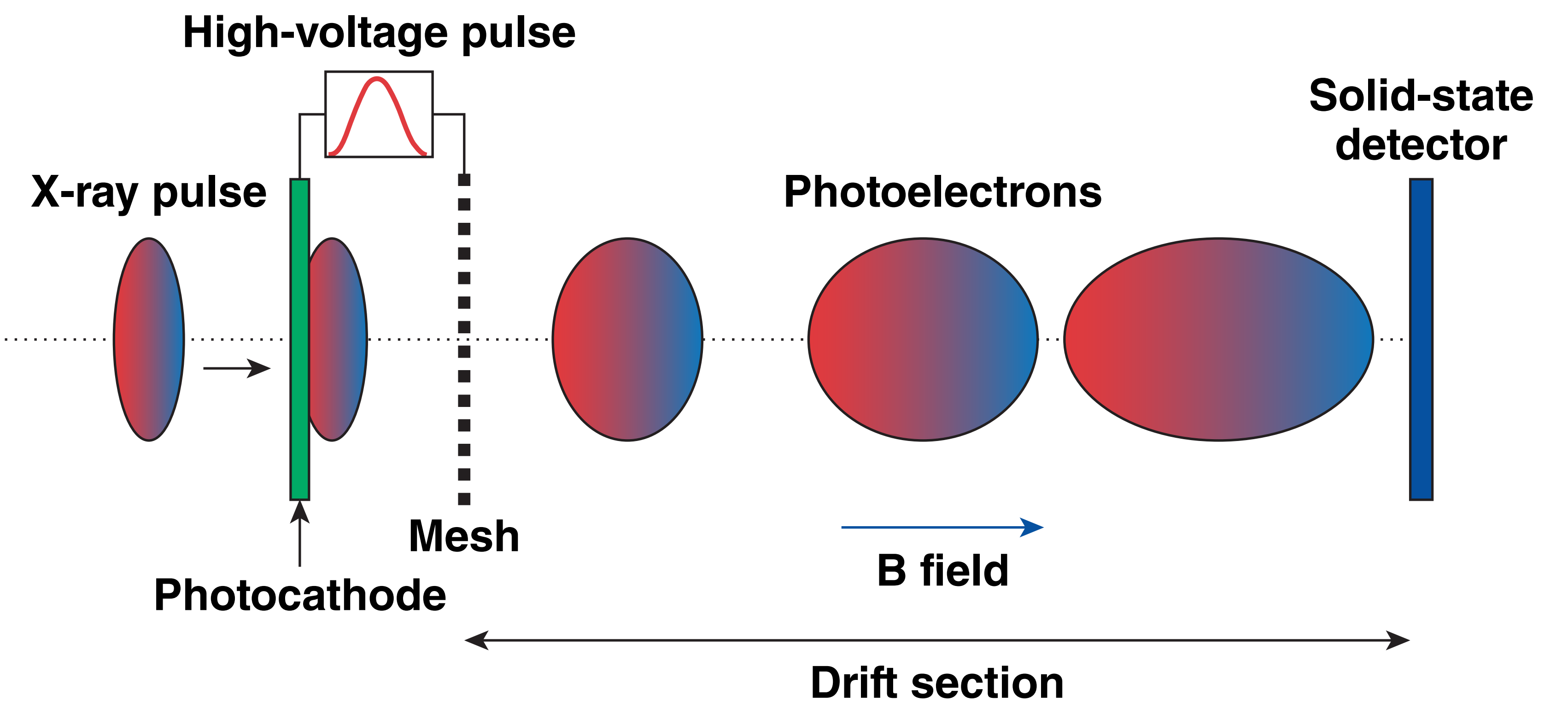
The pulse-dilation technique* transforms a fast transient signal into a linearly dispersed electronic signal that can be measured with a time-resolved detector



*R. D. Prosser, J. Phys. E: Sci. Instrum. 9, 57 (1976);
T. J. Hilsabeck *et al*., Rev. Sci. Instrum. 81, 10E317 (2010).

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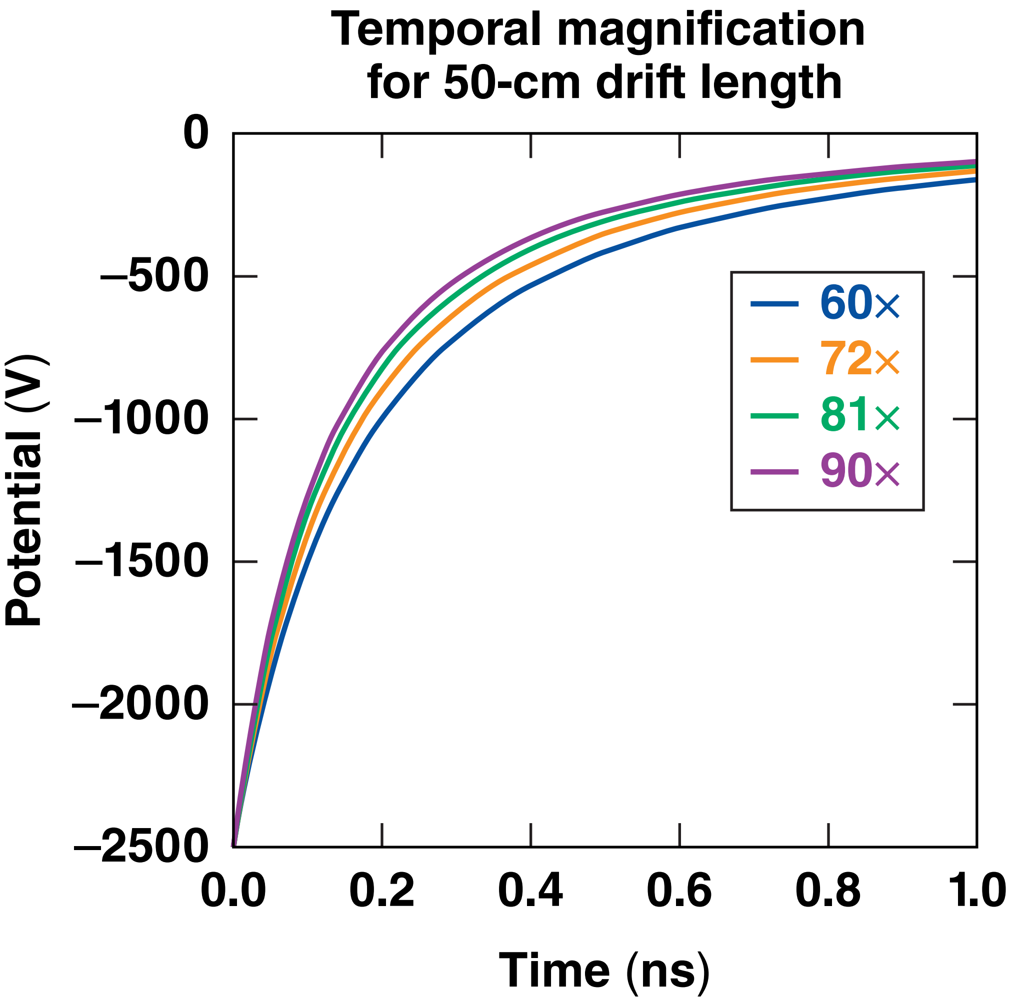
The photocathode ramp voltage determines the temporal magnification



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A 6-kG pulsed uniform magnetic field provides 1:1 electron imaging and results in 40-μm spatial resolution

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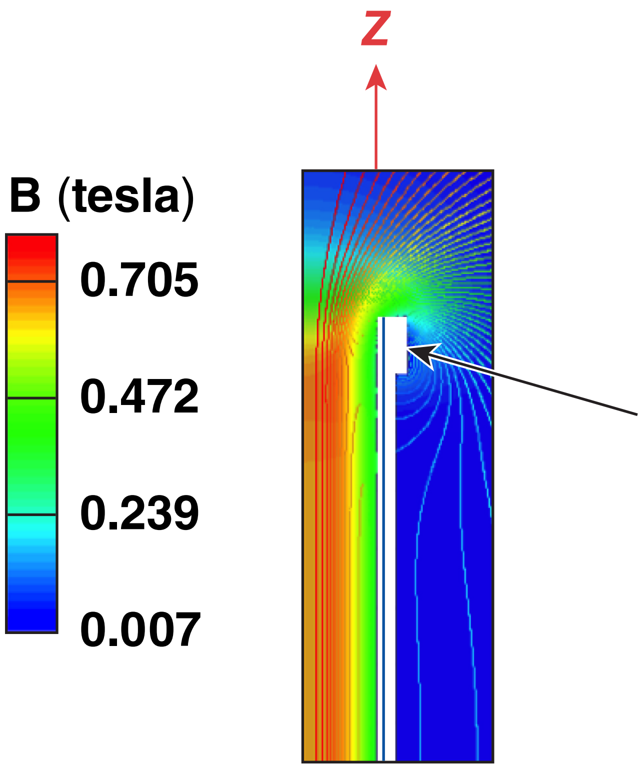
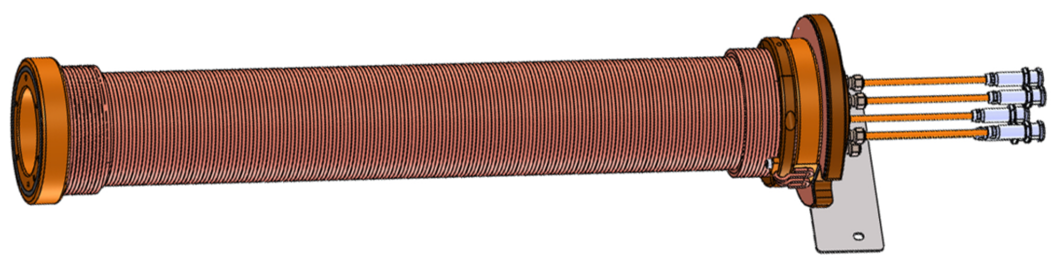


- A 1-kJ magnetic field is stored in a 295-μF, 2-kV electrolytic capacitor
- The coil is wound onto a vessel with a single winding
- Turns are doubled near the end for field shaping

$$\delta = \sqrt{(4r_L)^2 + \delta^2_{CMOS}} = 39\ \mu\text{m at 6 kG}$$

The single-solenoid-pulser design precludes "zooming" the electron image.



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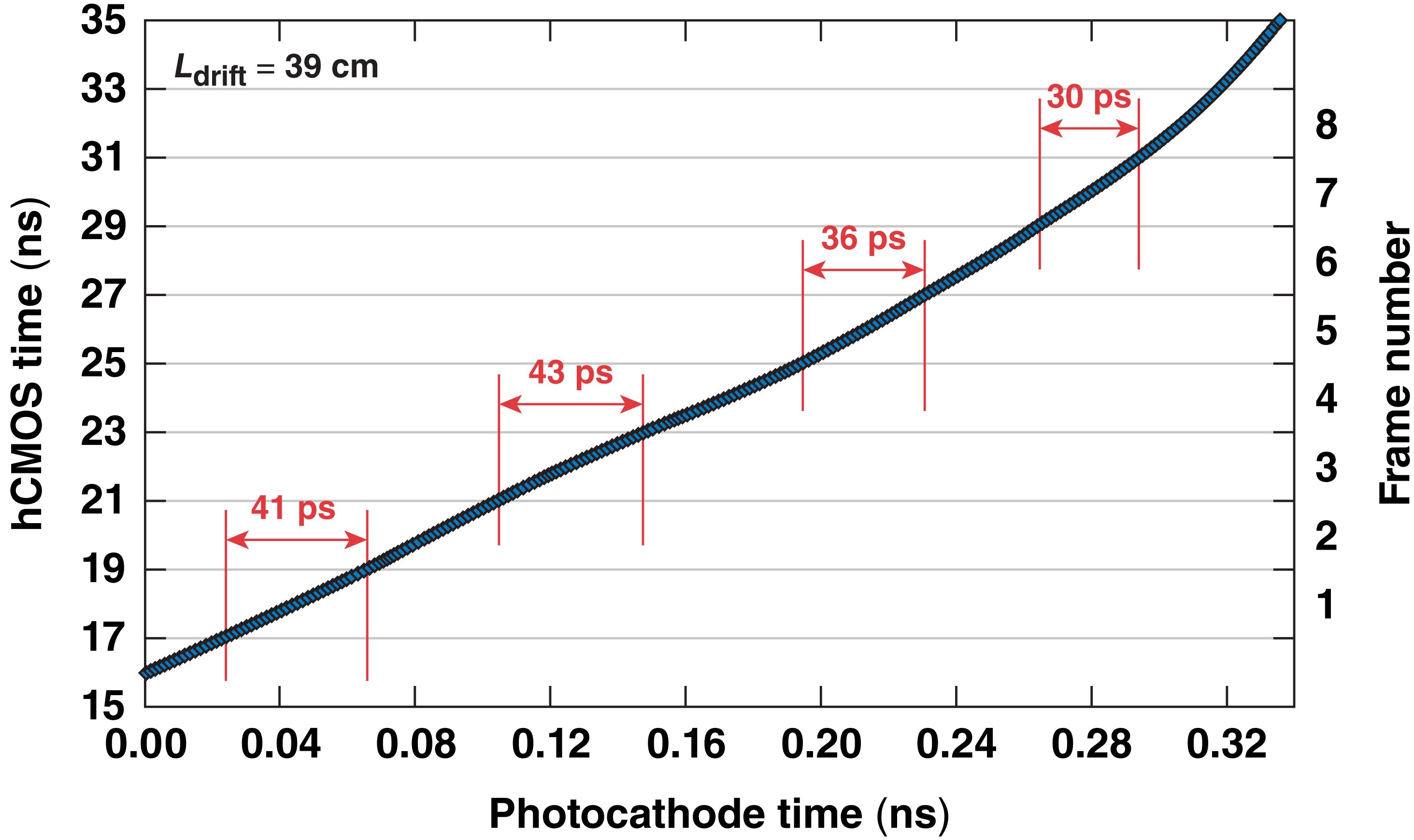
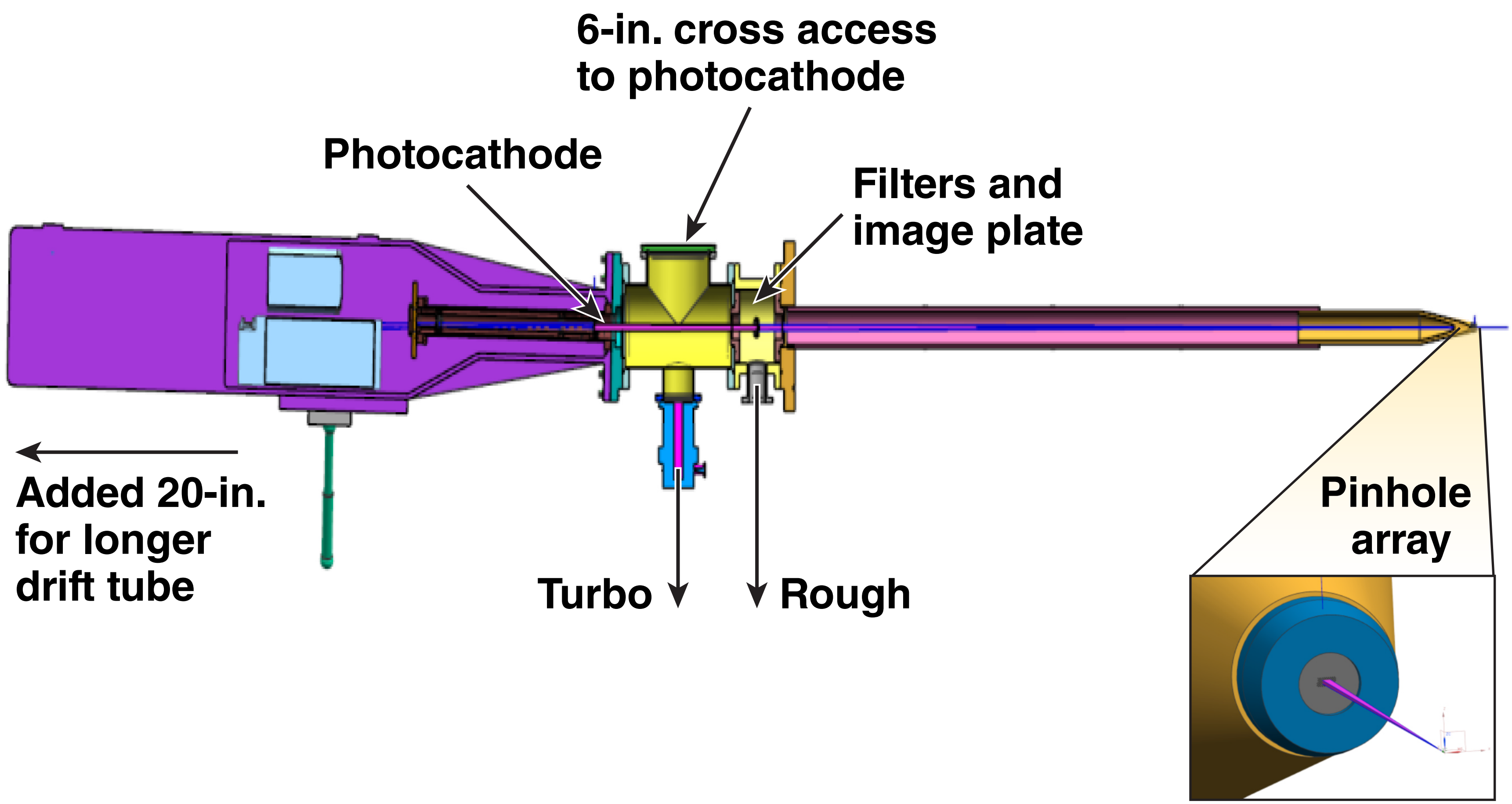
The pulse-dilation transfer function for a 39-cm drift tube demonstrates ~40-ps time resolution



A 50-cm drift tube will be developed that will provide ~30-ps time resolution.

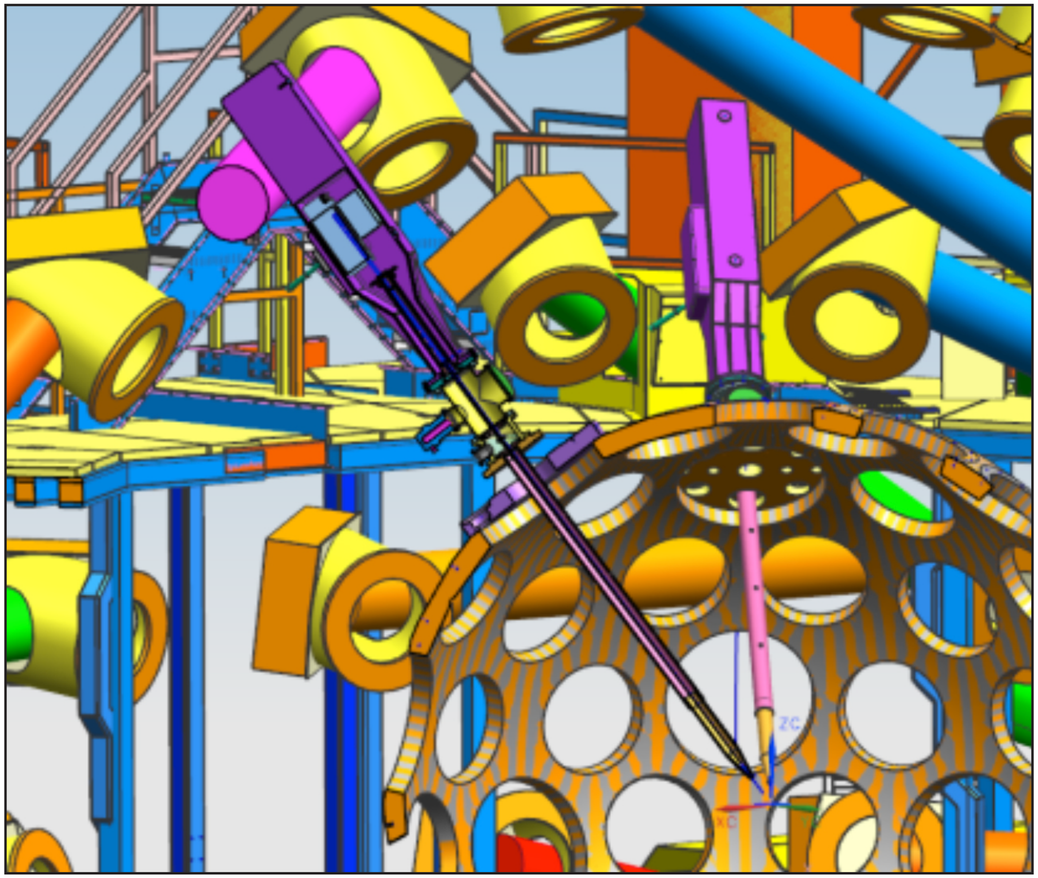
E25214

The conceptual design of the SLOS-TRXI has been completed



E25215

The installation on OMEGA is planned in Q1FY17 and the first use in Q2FY17



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An x-ray imager is combined with the pulse-dilation technique and the hybrid complementary metal–oxide–semiconductor (hCMOS) technology to create a true multiframe, ultrafast framing camera

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The goal is to record gated images of the hot spot along three orthogonal views.

E25204

The photocathode high-voltage ramp is created with a programmable pulser designed and built by Kentech Instruments

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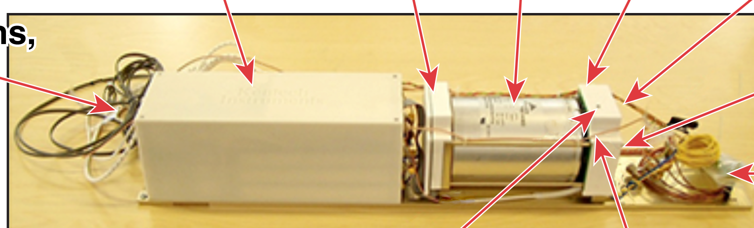
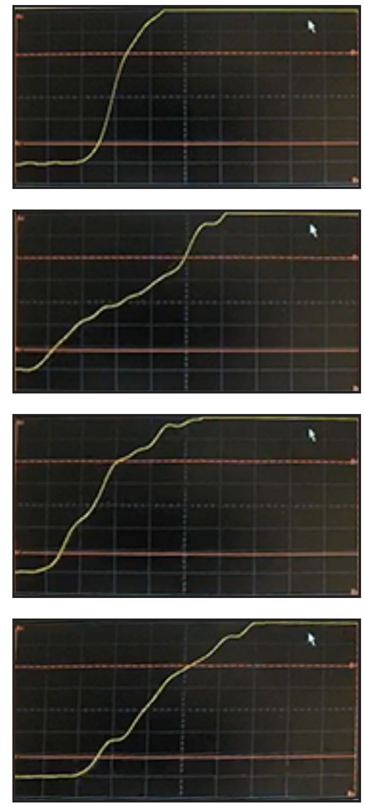
- The fast-ramp pulser is comprised of eight avalanche step generators that are added together to create the main pulse
- Each step generator can be independently timed via programmable delays, thereby controlling the ramp shape





E25213