Sydor Technologies

Developments in imaging, via advanced electronics and detection methodologies
Sydor Technologies

Experts at solving diagnostics and imaging problems
- Personally Committed in partnership with our customers
- Sensitivity ranging from high energy x-ray to IR to ballistics
History of Sydor Technologies

• Started in 2004 with Tech Transfer of ROSS Streak Cameras from LLE. Now over 60 streak cameras installed
• Continued SBIR/grants and other developmental and funding channels
• Wide ranging novel applications (cameras/detectors/imaging/ballistic sciences)
• Core R&D with USA/EU labs
• Now over 35 people, <$10M revenue
Sydor Technologies DNA

- **Sydor Instruments**: Rochester, New York USA
  - Manufacturing of streak cameras and detectors
  - System integration, tech-transfers, and application support
- **SABRE Ballistics**: Caterham, United Kingdom
  - Ballistic testing systems
- North American partner for:
  - **Photek**
  - **Kentech Instruments, Ltd.**
Experts at solving diagnostics and imaging problems
Our Core: ROSS Streak Cameras

- Maintains accuracy
- Capable of in-situ, remote pre-shot calibrations

- Several different streak tube options available
  - Exclusive designs
- Modular and upgradable

- Laser diagnostics
  - optical streak cameras (IR, visible, and UV range)
- Target diagnostics
  - x-ray streak cameras (30 eV to 10 keV)
Source Diagnostics

Laser IR & UV performance – ROSS 5100

Sample UV ROSS image with three beams active

(Acts as 12 channel recorder)

Laser timing and power balance ROSS–8200

X-Ray timing, spectral, imaging

TARGET POSITION

Ablated blow-off plasma creates “rocket effect”
Main pulse drives implosion and final shock
Core “hot spot” disassembles

Picket pulses launch the initial shocks
X-ray burst from the imploded “hot spot”

Laser pulse

Time →
Target Diagnostics

Optical Thompson Scattering – Dual ROSS 5100's

Line VISAR Results – Dual ROSS 5100's

Neutron Burn History ROSS 5100

Optical Pyrometer – ROSS 5100
Sydor understands the pros & cons of multiple systems & tubes

**Sydor is a valuable consultant to solve specific application issues**

Sydor welcomes customized configurations
<table>
<thead>
<tr>
<th>Camera</th>
<th>ROSS 8600</th>
<th>ROSS 8200</th>
<th>ROSS 6000</th>
<th>ROSS 5800</th>
<th>ROSS 5100</th>
<th>ROSS 2000</th>
<th>ROSS 1000</th>
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<tbody>
<tr>
<td>Streak Tube</td>
<td>P860X</td>
<td>P820</td>
<td>Kentech Low Mag</td>
<td>ST-D5</td>
<td>PS10</td>
<td>ST-X</td>
<td>Photochron 5</td>
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<td>Tube Manufacturer</td>
<td>Photonis</td>
<td>Photonis</td>
<td>Kentech</td>
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<td>X-ray or Optical</td>
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<td>Optical</td>
<td>X-ray</td>
<td>Optical</td>
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<td>Photocathode Size</td>
<td>10 mm</td>
<td>10 mm</td>
<td>25 mm</td>
<td>35 mm</td>
<td>20 mm</td>
<td>8 mm</td>
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<tr>
<td>MCP</td>
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<td>No</td>
<td>Optional (40 mm)</td>
<td>No</td>
<td>No</td>
<td>Yes (25 mm)</td>
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<td>Standard Camera</td>
<td>2048 x 2048 chilled scientific grade CCD 16-bit</td>
<td>2048 x 2048 chilled scientific grade CCD 16-bit</td>
<td>4096 x 4096 chilled scientific grade CCD 16-bit</td>
<td>2048 x 2048 chilled scientific grade CCD 16-bit</td>
<td>2048 x 2048 chilled scientific grade CCD 16-bit</td>
<td>1040 x 1392 interline CCD 12-bit</td>
<td>1040 x 1392 interline CCD 12-bit</td>
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<td>Camera Coupling</td>
<td>1:1 Fiber</td>
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<td>Lens</td>
<td>Lens</td>
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<td>Spatial Resolution</td>
<td>20 lp/mm @ 50% contrast</td>
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<td>10 lp/mm</td>
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<td>10 lp/mm @ 50% contrast</td>
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<td>Limiting Temporal Resolution</td>
<td>1 ps</td>
<td>1 ps</td>
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<td>&lt; 36 ps</td>
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<td>No</td>
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<td>Maximum Sweep Speeds</td>
<td>2 speeds</td>
<td>4 speeds</td>
<td>12 speeds</td>
<td>6 speeds</td>
<td>6 speeds</td>
<td>12 Speeds</td>
<td>16 Speeds</td>
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<td>Gateable Photocathode</td>
<td>No (Blanking Available)</td>
<td>No (Blanking Available)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Mu-metal Shielding</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Integrated Fiber Input</td>
<td>No</td>
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<td>2 Standard</td>
<td>2 standard</td>
<td>1 optional</td>
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<td>Mounting Configurations</td>
<td>TIM/DIM</td>
<td>Bench (Multiple Slit Configurations)</td>
<td>Flange, TIM/DIM</td>
<td>Bench (Multiple Slit Configurations)</td>
<td>Bench (Multiple Slit Configurations)</td>
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<td>Bench</td>
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<td>DynaCal DCM Support</td>
<td>No</td>
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<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
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What’s New?

- ROSS 5800
- ROSS 6000
- ROSS 2000 speed ramps
- psGOI gated optical imager
- PD-PMT Pulse dilation
  Photomultiplier tube
- Direct X Ray detection cameras
  – SBIRs and P2 funding
- Torch PMT (square)
- Multi-anode
- Space rated IPD’s
What’s New: ROSS 5800

- Optimizes temporal and spatial tradeoff. Target accuracy much improved over full photocathode. Best when paired with DynaCal.
- Integrates tube and dual slots with electronics, software, and controls for optimum performance.
- Tube exclusive to Sydor Instruments.

Lower magnification
This provides 3.5mm more usable (optimized) cathode area

Image plane focused on a curved output screen for uniform focus over the entire field.

Adds dual slots to eliminate Space-Ti focus astigmatism.

Offner input optics via DynaCal or bench configuration
ROSS 5800 improvement

Above: Whole image and 4X zoom of upper left corner of corrected slow swept image of ROSS 5800 & 5100 Streak Camera System with GeoCal reticle pattern

New ROSS 5800

Industry standard
ROSS 5100
What’s New: ROSS 6000

- A more comprehensive x-ray streak camera
- Re-entrant, TIM or DIM design
- High rep-rate system
- Integrates ROSS_App with X-Ray system

Specifications:
- 25 mm interchangeable photocathode.
- <5ps time resolution and a spatial resolution of 10 lp/mm
- Fiber coupled 1:1 cooled scientific readout system
- Capable of both single shot and high rep rate applications up to 1kHz.
- Can be supplied with a 40 mm single stage image intensifier
- A UV fiber optic timing fiducial system is available for use with the ROSS 6000
What’s New: DynaCal

DynaCal adds calibration during a sweep function, thus providing in-situ testing of static and dynamic verification.

Lowers COO via remote calibration and reducing the need to remove a unit from service or have expensive labor spend time calibrating pre shot.

COMPACT motorized assembly containing Offner input optics, 35mm shutter & variable slit, comb generator, data head, flat-field head, illumination head, reticle, flat field generator, grid pattern reticles. ROSS_App Wizard software controls actions and geometric distortion calibration and other parameters.
psGOI (gated optical imager)

- 2D 18mm MCP based 80-100ps imaging – clean, in focus images
- Heads use axial magnetic field linked to high performance MCP and unique pulser driver to achieve performance
- Flexible multichannel (1,4,8) configurations
- Excellent trigger configuration for serial or concurrent channel triggering
psGOI (gated optical imager)

4 channel bench configuration, courtesy of A. Meadowcroft, AWE

4 channel, 80ps showing data 15 & 18ns after laser shot with shock. Viewing window of target resolved is in green. courtesy of A. Meadowcroft, AWE
Interferometry traces of preplasma captured at 80ps with interframe times of 500ps and 1ns. Preplasma blowoff is still evident 3ns after long pulse laser shot. Courtesy of A. Meadowcroft, AWE
Background:
Multi kV sub ns risetime pulser with very low jitter and proven repeatability have been the enabling technology for several fast diagnostic instruments including:

- GXD (Gated X-ray Detector) (LANL/LLNL)
- DISC DIM cart X-ray streak camera
- Sub 100ps GOI (Gated Optical Imager)
- DIXI ultra-fast X-ray gating

Plus projects in progress such as

- ✓ SLOS (Single Line of Sight) X-ray framing camera
- ✓ PD-PMT (Pulsed Dilation Photo-Multiplier Tube)

Enabling capability – pulse drive

- Linear Ramp: DIXI - Dilation Xray Imager, 10ps X-ray gating
- Shaped Ramp: SLOS - Single Line Of Sight Xray imager, 10ps X-ray framing
- Shaped Ramp with Blanking: PD-PMT - Pulsed Dilation PhotoMultiplier Tube, 10ps PMT

Photo-cathode drive pulses need to be shaped, need to have multi kV amplitude and have rise times down to 100psecs

Support systems such as MCP bias, local delay control and high current solenoid drive are also required, usually constrained by the need for a limited volume
Pulse Dilation – what is it?

- Photo-electrons (pe) are launched and the ramp pulser reduces the drift velocity via $\Delta v$
- PE’s are guided through the drift section via magnetic field and the electron signal spreads out in time.
- Net effect is a short exposure at the cathode is dilated into a long exposure at the readout device.
PD with PMT and Oscilloscope

10ps with 1ns record length (requires about 150ps rise time scope)

Magnification ~15x

Expensive/fast scope not required

Allows use of less expensive scope (maybe 150ps/2GHz)
Tube Basics

- 10mm active area
- High Speed, stainless tube
- Mesh Drift (entry delta v)
- Ramp generator jitter 3ps RMS
- Modest magnetic field
  - Not imaging
  - DC solenoid for repetition
- Environmentally stable and can handle much more severe environment than a streak camera.

- MCP Photo-cathode and mesh entry to drift region
- stainless steel drift region
- low inductance feed to PC for application of fast ramp
- Drift length is 35cm

the axial B field will be ~100 gauss, enabling a DC field and repetitive operation.
Blanking and Recording

Blanking uses a slow pulsing of the cathode bias voltage.

Eases timing setup
Allows recording of a short, fast event together with a slower signal

Photocathode at a constant voltage, traditional PMT operation with unity temporal magnification (pre and post dilation)

Time Dilation limited ~ drift time divided by the magnification (5-20ns)

Expanded Region of Interest
Sydor Instruments - Detectors

- X-Ray Detectors
- Diamond Beam Monitors
- Tech Transfers
- Developing Technology

Original 1947 GE Synchrotron
X-Ray Detector Family and DBPM’s

**Direct Detectors**
- Fast CCD – soft X-ray
- SpectroCCD – soft, fine pixel
- KeckPAD – tender X-ray, irreversible event
- MMPAD – Tender, HDR
- X-Ray Strip – 1D, unique pixel

**Indirect/other:**
- X-Ray framing cameras
- psGOI - Gated Optical Imagers
- PD-PMT
- Streak Cameras
- X-Ray Streak Cameras

**DBPM’s**
- DBPM’s – position and flux
FastCCD X-ray Detector

- Direct detection of EUV to soft x-rays to 20keV
- Photon counting @ high efficiency
- Readout speeds up to 120 fps plus burst modes (compared to commercial x-ray CCD options with 1 fps readout)
- In-vacuum camera head, multiple mounting configurations, incl. mounting on swing arm w/ vacuum ports

<table>
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<tr>
<th>Property</th>
<th>Specification</th>
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<tbody>
<tr>
<td>eV Range</td>
<td>0.5 keV-9 keV (100% eff), 100eV to 20keV</td>
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<tr>
<td>Pixel Size</td>
<td>30 µm × 30 µm</td>
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<tr>
<td>Sensor Size</td>
<td>1920 × 960</td>
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<tr>
<td>Speed</td>
<td>5 ms/frame (120fps)</td>
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</table>

Commercialization partner for LBNL
FastCCD X-ray Detector cont’d

- As installed at NSLSII
  - Swing arm
FastCCD Roadmap

FastCCD is in production, available commercially from Sydor
- SBIR is submitted for further commercialization, key focus on read out optimization and simplicity in computer operations
- Sensor and components undergo incremental improvements
**SpectroCCD**

- Direct detection of EUV to soft x-rays to 20keV
- Improved detector position resolution and ∴ improved energy resolution (5-10x better)
- No need to use centroiding
- Slow readout and long integration times. Low noise 4e⁻ capable.
- Pixel-level resolution
- Reduces spectrometer length

<table>
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<tr>
<th>Specification</th>
<th>Details</th>
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<tr>
<td>eV Range</td>
<td>0.5 keV-9 keV (100% eff), 100eV to 20keV</td>
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<tr>
<td>Pixel Size</td>
<td>45 µm × 5 µm</td>
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<tr>
<td>Sensor Size</td>
<td>620 × 2,496</td>
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<tr>
<td>Speed</td>
<td>6 s/ frame</td>
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SpectroCCD applications

- Current SBIR Phase II furthers development
  - ALS test very good
- Same basic sensor structure as the FastCCD
- Electronics/readout differ and ultra low noise capable
SpectroCCD Roadmap

SpectroCCD: X-ray Camera for Energy Dispersive Spectrometers — Sydor/LBNL collaboration

- Direct detection 0.5–10 keV
- 5 µm x 45 µm pixels
- Larger arrays

- SpectroCCD is in prototype, commercialization underway by Sydor
- Successful tests at ALS complete
- P2A SBIR submitted for larger array sensor
- Looking for partners for initial installations with some time horizon
KeckPAD

- Energy Range: 8 keV - 20+ keV
- Pixel Size: 150 µm × 150 µm
- Sensor Size: 128*128 n*n sensors
- Speed: 150 ns/ frame, 8 frames independently controllable

- Well depth ~5k photons at 8keV, read noise 1.1 photons
- Currently 8 frames, individually controllable, of storage @150 ns
- Can be synchronized to x-ray pulse trains
- Allows measurements of dynamic compressions via very high dynamic range (10^3 x-rays/pixel/frame) capability
- Single photon sensitivity
- Cost effective versus other pending developments
KeckPAD Roadmap

Keck-PAD: Fast-Framing Hybrid Pixel Array Detector — Sydor/Cornell collaboration

- KeckPAD initial design is available. Tiled array soon ready for orders or beta installs.
- SBIR for High Energy (HE Keck) materials for hard X-Ray
- Looking for partners for initial installations with flexible time horizon
MM-PAD - HDR

- Mixes analog and digital (Mixed Mode):
- At 8keV HDR of 10e8 photons/sec/pixel with read noise of 0.16 photons. Single photon counting ability remains.
- Uses PAD technology from KeckPAD
- Sample application: APS ran entire profile of Bragg peaks, captured at a rate of ~1 kHz at each angle of incidence for every field pulse
- Phase I STTR underway between Cornell and Sydor

<table>
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<tr>
<th>Energy Range</th>
<th>8 keV-20+ keV</th>
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<tr>
<td>Pixel Size</td>
<td>150 µm × 150 µm</td>
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<tr>
<td>Sensor Size</td>
<td>128<em>128 n</em>n sensors</td>
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<tr>
<td>Dynamic Range</td>
<td>10e8 @ 8keV at 1kHz.</td>
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X-ray Strip Detector

- **1-D array Si detector**

- Simultaneous, threshold of 3 acquisition buckets, all with different energy ranges, with resolution down to ~350 eV. 24bit and high DR than competitor

- Used at BNL-XPD, CHESS-GISAXS, CHESS-XRR APS-MERIX & CHESS-RIXS

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<th>eV Range</th>
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<tr>
<td>Pixel Size</td>
<td>125 µm × 4 mm</td>
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<td>Sensor Size</td>
<td>1 × 640</td>
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<td>Speed</td>
<td>1 ms/frame</td>
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X-Ray Strip Detector: One-Dimensional Linear Array — Sydor/BNL collaboration

- Commercial Engineering
- Reduced Cost of Ownership
- Installation & Support

640 pixels, 3–30 keV detection, excellent dynamic range

In production, demo unit available
X-Ray Framing Camera (XRFC)

- 2D spatially time-resolved frames or 1D spectrally resolved images of target features
- Allows 4 independent strips/pulser
- Can resolve spectral info on strip
- Nanosecond time regime, ps resolutions
- Designed for use in vacuum

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<th>Specification</th>
<th>Value</th>
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<td>Energy Range</td>
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<td>Pixel Size</td>
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<td>Sensor Size</td>
<td>4096 × 4096</td>
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<td>Speed</td>
<td>40-1,000 ps/frame</td>
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Figure 1. OMEGA gated XRFC output on a pointing shot with a spherical target. Here the individual strip lines (S1–S4) are staggered in increments of 200 ps.
Diamond based BPM’s (DBPM’s)

- Position resolution 0.1% of beam diameter
- Flux linearity tested to over to 11 orders of magnitude
- Less dispersion than ion chambers (some testing in progress)
- Thickness selectable. Sydor producing @ <50 µm to >100µm
- Evolving metallization, optimum electronics grade CVD diamond
- Sydor in-house X-Ray source for manufacturing assurance

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<th>Energy Range</th>
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<td>Aperture</td>
<td>3mm circular</td>
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<tr>
<td>Environment</td>
<td>Air (He), HV, UHV</td>
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<tr>
<td>Speed</td>
<td>Compatible with modern synchrotron sources (&gt;1Mhz)</td>
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</table>
DBPM’s

Transmission options

Single Crystal Diamond Flux Calibration

Transmission spectrum

Linearity

Ion chamber Calibration
Calorimetric Calibration

Fit, $w = 12.8 \pm 0.6$ eV

Complex Measurements—Critical Results
Matching DBPM smart electrometer

- Smart unit with 4 DAC outputs for feedback, 6 SFP ports and Ethernet based communications
- Software included – Linux and EPICS

<table>
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<tr>
<th>Data Rate</th>
<th>378k samples/sec [customizable to 1.1M samples/sec]</th>
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<tr>
<td>Resolution</td>
<td>18 bit</td>
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<tr>
<td>Gain</td>
<td>Five, programmable 20 pA to 35 mA</td>
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DBPM’s Roadmap

Diamond X-ray Beam Monitors — Sydor/BNL/Stony Brook collaboration

- Currently shipping, many packaging designs available, optimized thicknesses.
- Matching electrometers, smart A3P ready to integrate detector, calibration, motion control etc.
- SBIR for pixelated imaging detector for future applications that include beam profiling and more
North American Partners For:

- Photek Ltd.
- Kentech Instruments Ltd.
Photek Products

Image Intensifiers
Photomultiplier tubes & Photodiodes
Photon Counting Cameras
Space Detectors and Electronics
Image Intensifiers

- Custom configurations
- 18 mm, 25 mm, 40 mm, 75 mm, and 150 mm options
- Single, chevron, or z-stacked
- Wide range of spectral responses
- Photek offers high voltage power supplies and gating units
- Optional environmental stress screening, space qualified systems
Photomultiplier Tubes & Photodiodes

- Fastest responding PMTs and PDs in the world
- Custom configurations
- 10 mm, 25 mm, and 40 mm options
- Space rated, tube and electronics
- Electronics available, custom pulsers available via Photek and Kentech
Intensifier/PMT review

- Scintillator (much work for fastest from LLNL, LANL and more)
- Analog signal
- Rise times:
  - As fast as 50 ps
  - FWHM 80 ps
Intensifier/PMT review

II Units
-18, 25, 40, 75, 150mm ++

PMT Units
-18, 25, 40mm ++

Multi-Anode "Cameras"
-25mm@ 8*8
-40mm@ 32*32

VID Units
-25, 40, 75mm ++

IPD (Image Photon)Units
-25, CDL40, 75mm ++

Multi anode
TORCH: square PMT

output window

CCD sensor

fiber optic taper
or 1:1 Fiber optics
or glass

Phosphor
P43, P46, P47....
Photon Counting Cameras

3rd Gen. Image Photon Detector (IPD3)
- Single photon counting system
- Serial readout
- 10 ns time tag resolution

4th Gen. High Resolution Photon Counting System (HRPCS4)
- Single photon counting system
- Parallel readout device
- 10 ms time tag resolution
- X-ray input, VID, and cooled housing options

Applications: Bio/chem luminescence; Measurement of Aequorin, Luciferase & ATP; Multiλ imaging; Missile warning; Astronomy
Sydor Instruments - Photek

- Vacuum Imaging systems

- VID 225/240/275, cooled housing
Kentech PBG1 and Lasermetrics 1111 Pockels Cell
Kentech Instruments Ltd.

- UK based high-speed electronics company
- Pulse generator systems
  - High-voltage (<50 kV)
  - Fast rise-time (~90 ps)
  - High rep-rate (<500 MHz, single shot)
- Custom designs for unique applications
- Supplier of x-ray streak camera components
Kentech Instruments Ltd.

Kentech Engineered Products:

• Pulse generators
• Gated optical imagers
• Gated x-ray imagers
• Delay generators
• Pockels cell drivers
• Arbitrary waveform generators
• Laser electronics
Kentech Instruments Ltd. Products

**PBG Series**
- 5 models:
  - Amplitudes 6.5kV-45kV
  - Rep. rates 10 Hz-100Hz
- <100 ps rise, 3 ns exponential fall time

**CPS Series**
- 3 models:
  - Amplitudes 2kV-6kV
  - Rep. rates 10Hz-1000Hz
- <150 ps rise, 2 ns fall time

**SPS/V Pulser**
- Amplitudes >1kV-6 kV
- Rep. rates 1K Hz
- 0.7ns rise
- 1,2,4,8,10 and 12ns pulses
Kentech Instruments Ltd.

**Programmable Sub-ns Pockels Cell (PSP1) Driver**
- Single channel
- 2.5kV-3.5kV
- <300ps to 10ns pulse width in 25ps steps
- ≥150ps rise time
- ≥100Hz rep rate

**High Voltage Pockels Cell Driver**
- Adjustable to ~9kV
- 12ns to 60ns single pulse; 20ns to 60ns double pulse
- Various delay modes up to 400ns
- ~4ns rise time
- 20Hz rep rate single pulse, 10Hz rep rate double pulse
Kentech Instruments Ltd. Products

Arbitrary Waveform Generator
- Used as a fiber optic modulation driver and for RF testing
- 5V output
- <100ps rise and fall times
- 100ns duration
- 100kHz rep rate

Reverse Terminated Voltage 30 (RTV30) Sub-ns Pulser
- <30V amplitude, with 25% to 100% adjustment
- Adjustable <300ps to 20ns pulse width
- <300ps rise time
- <100kHz rep rate

Unterminated Voltage 50 (UTV50) Pulse Generator
- 0-50V amplitude, adjustable
- 1-100ns pulse width, adjustable
- <200ps rise time, <500ps fall time
- 200kHz rep rate
Thank You!