kromek
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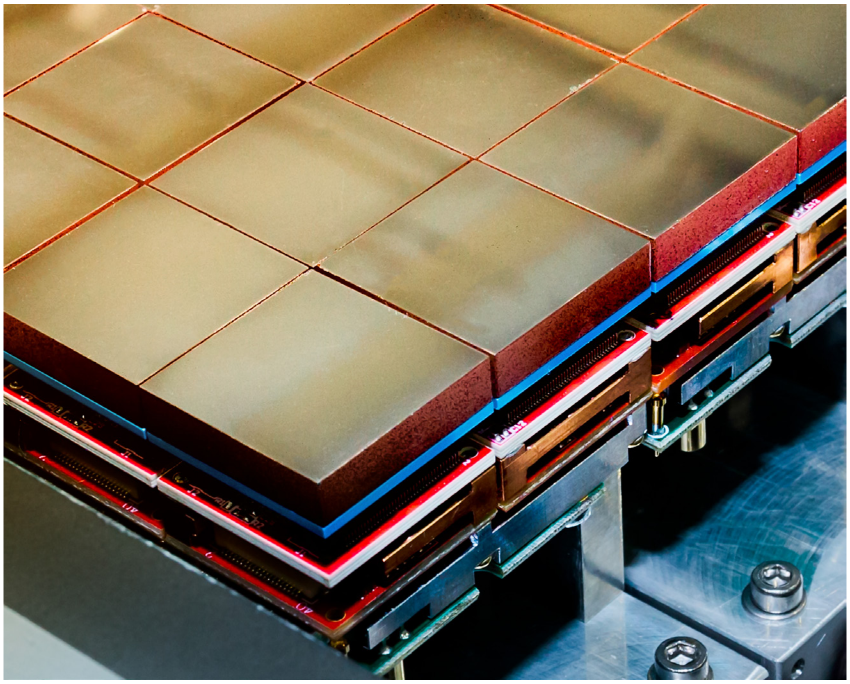


Whole-Body SPECT CZT Detector Solutions

Powered by the D-Matrix Detector Platform

Analog scintillator detection technology is steadily replaced with digital, CZT (Cadmium Zinc Telluride) based gamma ray detectors. This new generation detectors finds a myriad of uses in Single Photon Emission Computed Tomography (SPECT) applications, and provides dramatic advantages in the medical imaging space, including:

- Earlier and more precise diagnoses
- Quantitative treatment monitoring (including theranostics)
- Higher specificity
- Lower patient dosage exposure
- Shorter scan times and greater patient throughput and reduced Cost of Ownership.

New technologies must offer a vast improvement to legacy scintillator technology (for example, better energy resolution, improved spatial resolution, higher count throughput, etc.) AND must provide solutions that integrate and scale appropriately to achieve long-term effectiveness, efficiency, and value.

The D-Matrix SPECT Platform offers a modular and scalable detector design approach, enabling performance differentiation and configuration flexibility to the SPECT OEM system designer. The D-Matrix module is the enabling building block comprised of 4 CZT detector tiles offering 121 pixels per tile at 2mm pitch. The modules are x and y directionally scalable, maintaining pixel pitch across detector arrays. The detector module is enabled by a full-featured ASIC which offers detector optimization functionality including charge-sharing and depth-of interaction corrections.

CZT is a high-impedance (high-Z) room-temperature semiconductor that directly converts x-ray or gamma photons into electrons and holes which produce a signal that can be digitized. Compared with silicon and germanium detectors, CZT detectors operate at room temperature and can count at >1E8 cps/mm^2 while still providing spectral information about each photon. CZT's spectroscopic energy resolution significantly outperforms any commercially available scintillator. The unique combination of spectroscopy and very high count-rate capability at room temperature makes CZT an ideal detector solution for nuclear medicine imaging applications.

Kromek offers a scalable solution for all SPECT applications including gamma detector modules for hand-held surgical cameras used for thyroid, breast, cardiac, veterinary, and general-purpose molecular imaging.

D-MATRIX CZT GAMMA DETECTOR PERFORMANCE COMPARISON

Benefit	Description	Key Points
Better Diagnostic Images	With energy resolution < 4% FWHM for 99mTc (140 keV), the energy window for imaging can be set as narrow as ±3%, resulting in < 10% scatter fraction compared to 30%-50% for analog scintillator detectors. Lesion conspicuity is boosted by the significantly lower tissue background from Compton-scattered photons.	• Better energy resolution means less scatter • Better lesion contrast-to-background ratio (>40%)[2] • Excellent separation between multiple isotopes with little crosstalk • 100% of FOV performance is optimum
Faster Scans and/or Lower Injected Doses	As above, with lower tissue background, quality diagnostic images can be obtained with lower count densities. Either scan time or injected dose, or both, can be reduced substantially. Obviously, patient throughput can be increased: one digital CZT SPECT system may be able to perform the same number of patient studies as two conventional analog SPECT systems, greatly reducing the cost of ownership. Another benefit of a faster scan is less patient discomfort and, thus, less movement that leads to image blurring.	• Up to 80% reduced exam times • High patient throughput • Less patient motion • Lower injected dose[1,2] addressing ^{99m}Tc supply fragility and cost
Earlier Detection of Disease	Digital CZT detector spatial resolution is 2.0 mm square pixels with no overlap between neighboring pixels. Small lesion conspicuity is boosted by reduced partial-volume contrast dilution with the ~2x smaller, non-overlapping pixels. Furthermore, highly efficient collimators can be designed for pixelated digital CZT detectors that can further reduce the scan time and/or injected dose required for superior diagnostic images.	• Detect smaller lesions • Visualize heart right-ventricle • Better quantitation for staging and therapy monitoring • Less partial-volume contrast dilution • 60% reduced nonuniformity for better lesion contrast • 68% reduced shielding frame (CZT vs. NaI) • Molecular breast imaging • Intra-operative cancer imaging
Simultaneous Multiple-Isotope Studies	The superb energy resolution of digital CZT detectors enables the simultaneous imaging of multiple isotopes, each with its own radiotracer for different molecular targets in the body. For example, in cardiac SPECT: ^{99m}Tc-sestamibi (or ^{99m}Tc-tetrofosmin) and ^{123}I-MIBG can be injected simultaneously to perform high quality MPI (myocardial perfusion imaging) and imaging of autonomic innervation, critical in cardiac arrythmias and heart failure. Other applications have been clinically demonstrated, including brain (e.g., Parkinson's disease, refractory epilepsy, dementias), lung, cancer, and infection imaging. Two or more pathophysiological 3D-SPECT images can be acquired in a single imaging session and they will be in precise alignment.	• Excellent separation between multiple isotopes with little crosstalk
Quantitative SPECT	Digital semiconductor CZT detectors are perfect for quantitation due to their long-term stability and superior performance. This quantitative capability, long available in PET imaging, enables better diagnosis (e.g., triple-vessel heart disease, myocardial flow reserve), staging and prognosis from longitudinal studies, and therapeutic response monitoring.	• 1st-pass cardiac and pharmacokinetic studies • 3X – 5X higher output count rates vs. NaI and PMTs • Better quantitation for staging and therapy monitoring

[1] – *Efficiency gains are due to 1) less count density required due to better contrast-to-background ratio due to a) better scatter rejection due to better CZT energy resolution and b) reduced partial-volume contrast dilution due to smaller CZT intrinsic detector pixels; 2) recovery of spectral tail events using neighboring pixel signals; and 3) optimized efficiency collimator designs. The actual time/dose reduction depends on the clinical task, patient size, anatomical location and clinical practice.*

[2] – *Demonstrated in quantitative phantom studies.*

[3] – *In a magnetic field, the Lorentz force due to a magnetic field with direction parallel to the plane of the CZT detector for 140 keV gamma photons shifts the electron cloud on average ~0.5 mm/Tesla or 1 pixel (2 mm) at 4T. This shift is easily compensated in image reconstruction. In the fringe field of a magnet, the effect is negligible.*

D-MATRIX CZT GAMMA DETECTOR PERFORMANCE COMPARISON

Metric (NEMA NU-1:2012)	Typical NaI-PMT Detectors	D-Matrix CZT Detectors
Detector crystal thickness	0.95 cm NaI scintillator with 59 to 96 PMTs	0.5 – 1.0 cm CZT Direct-conversion, room-temperature semiconductor
Useful Field of View (general-purpose SPECT)	40.6 cm x 54.0 cm	39.6 cm x 52.8 cm
Intrinsic spatial resolution (FWHM, FWTM)	3.3 mm, 6.3 mm (gaussian)	2.0 mm, 2.0 mm (square)
Pixels per detector	20,132 (gaussian)	52,272 (square)
Intrinsic energy resolution (FWHM, 140 keV)	9.6%	< 4.0%
System spatial resolution (LEHR @ 10 cm) • FWHM, FWTM no scatter and with scatter	7.4 mm, 14.0 mm 7.8 mm, 16.5 mm	6.7 mm, 12.2 mm 7.3 mm, 13.2 mm
System sensitivity (LEGP, LEHR, hexagonal) ± 7%	280 cpm/µCi, 170 cpm/µCi	300 cpm/µCi, 170 cpm/µCi
Intrinsic flood field uniformity (UFOV, CFOV) • Integral and differential	± 2.5%, ± 2.2% ± 2.0%, ± 1.5%	± 2.0%, ± 2.0% ± 1.4%, ± 1.4%
Intrinsic spatial linearity (UFOV, CFOV) • Absolute and differential	0.50 mm, 0.35 mm 0.10 mm, 0.09 mm	< 0.10 mm, < 0.10 mm < 0.05 mm, < 0.05 mm
Multiple window spatial registration (UFOV)	0.6 mm	< 0.6 mm
Intrinsic detector count rate performance: • Output max and at 20% loss	Entire detector paralyzable: 350k cps 300k cps	Non-paralyzable: < 3.5% loss at 1.7M cps (maximum observed)
Energy range	56-920 keV	30-3,000 keV
Shielding	364 keV	364 keV
Non-active frame	75 mm (shielding + edge PMTs)	25 mm (shielding)
High performance area	56% central FOV (CFOV)	100% of FOV
Calibration frequency	Monthly - weekly	Yearly
Magnetic susceptibility	Even with mu-metal shielding, PMTs are still susceptible	Immune[1]

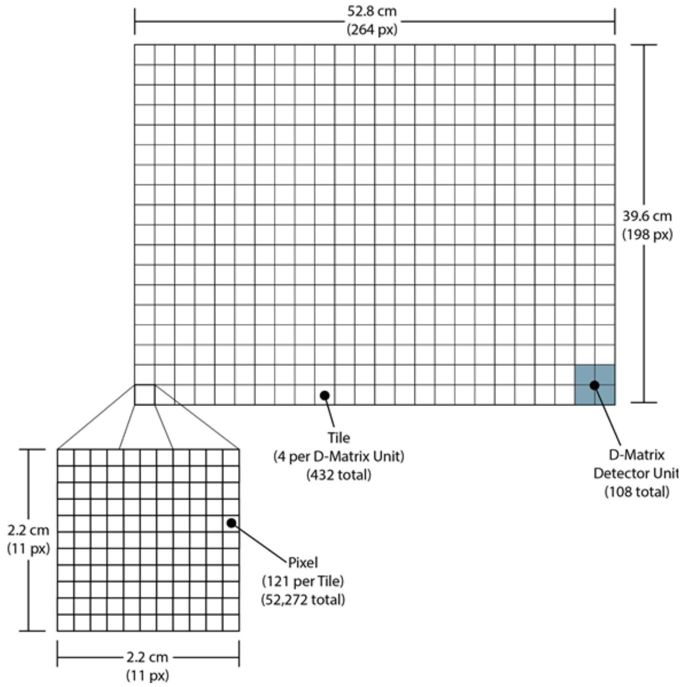
[1] – In a magnetic field, the Lorentz force due to a magnetic field with direction parallel to the plane of the CZT detector for 140 keV gamma photons shifts the electron cloud on average ~0.5 mm/Tesla or 1 pixel (2 mm) at 4T. This shift is easily compensated in image reconstruction. In the fringe field of a magnet, the effect is negligible.

The Physics of CZT

As an incident photon interacts with the CZT crystal, electrons detach from some of the atoms making up the crystal. The vacancies where the electrons were previously located are called "holes". The number of electron-hole pairs created is proportional to the energy of the incident photon.

- An electric field is established in the crystal bulk by application of an externally applied bias voltage to metalized contacts placed on opposite sides of the crystal.
- Once dislodged, the negatively charged electrons and positively charged "holes" migrate through the crystal toward the contacts where they induce a charge.
- A charge-sensitive preamplifier transforms the induced charge into a voltage signal which is subsequently shaped – resulting in a voltage pulse whose height is proportional to the incident photon's energy.
- These pulses are digitized to generate the characteristic energy spectrum for the incoming photons.
- The above signal processing steps are often embedded in an Application Specific Integrated Circuit (ASIC) to reduce the size, cost, and power consumption of the readout electronics.
- Kromek's CZT gamma detector arrays, Application Programming Interface (API) software receives event list-mode data from the CZT detector array, applies energy and uniformity corrections, and formats the events for the image display and SPECT reconstruction engine.

D-MATRIX MODULE & DETECTOR ARRAY DETAILS



Kromek has been at the forefront of CZT semiconductor detector development for three decades. We have acquired the deep scientific knowledge and product manufacturing experience to accelerate and de-risk OEM entry into modern digital SPECT.

Kromek uses a proprietary optimization process to grow CZT ingots. Ingots are sliced, diced and polished and fabricated into detectors with very thin metalized electrodes deposited on the detector surfaces. The metals used for electrodes are chosen to match the detector application. The detector electrodes are electrically biased creating an electric field within the detector volume. When ionizing radiation interacts with the CZT crystal, many pairs of electrons and holes are created, with the number of pairs proportional to the energy of the incident photon.

Kromek's expertise extends beyond crystal growth to fabricating detectors that can help transform imaging and detection solutions. Kromek makes a range of monolithic spectroscopic photon-counting CZT detectors, ranging in size from 0.5 x 2.5 x 0.3 cm up to 4.0 x 4.0 x 1.5cm.

Kromek is the only CZT manufacturer that provides complete gamma detector array solutions to OEM medical imaging manufacturers. Our CZT detector systems include:

- Digital read-out electronics (ASICs and FPGAs)
- API software that delivers event data in list mode to your SPECT reconstruction engine.
- Event data that is energy- and uniformity-corrected
- Optional 3D gamma photon event position measurements
- Optional depth-of-interaction and subpixel accuracy.

CZT detector arrays can be assembled in both common and custom configurations to meet your specific application needs. Design, manufacturing, assembly, and after-sale service are performed to ISO 9001/13485 quality standards.

Kromek provides a scalable modular solution for all quantitative SPECT and planar gamma imaging applications. Kromek builds configurable arrays from gamma detector modules for OEM integration into hand-held surgical cameras, thyroid imaging, molecular breast imaging, cardiac SPECT, preclinical or veterinary SPECT, and general-purpose whole-body SPECT.

The modular design and flexibility of Kromek's D Matrix line of imaging components means easy integration with new or existing detection equipment and true long-term scalability. The D-Matrix Demonstrator offers a low-cost entry point to evaluate Kromek technology and materials. Kromek has many options that are flexible, scalable, and work exactly like the D-Matrix Demonstrator.

For more information or to request a quotation for CZT SPECT scanning application, visit www.kromek.com on the web or contact us directly.

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