TOSHIBA MEDICAL

PUREViSION Detector

Increased Signal and Decreased Noise for Low Dose Imaging

Erin Angel, Ph.D.
Senior Manager, Clinical Collaborations
Toshiba America Medical Systems, Inc.

Michael Lacey
Senior Specialist, National Support
Toshiba America Medical Systems, Inc.

Introduction

Physicians today are pushing CT scanners to perform more advanced procedures in less time while ensuring superior patient care and increased patient safety. In particular, driving down both radiation and contrast dose levels is a primary motivator at imaging facilities across the world. We leveraged the widely respected expertise of our companies in the industrial and material sciences to develop a new detector. We are proud to present the result of this collaboration: PUREViSION (Figure 1). The PUREViSION detector technology has been designed specifically to meet the rapidly advancing needs of medical imaging today and in the future.

PUREViSION was designed with three imaging goals in mind: (1) lower image noise for low dose acquisitions, (2) faster scan times, and (3) improved image quality. The team of engineers faced with this challenge had to address each of these goals while maintaining the smallest effective detector aperture in the industry (0.5 mm). The result of their efforts is a detector technology designed to accommodate all imaging needs from the ultra-low dose chest CT to advanced dynamic 4D imaging.

Breakthrough innovations in manufacturing processes and DAS (Data Acquisition System) design have resulted in a detector with a 40 percent increase in output and reduced electronic noise, making PUREViSION one of the most efficient detectors commercially available and still the only detector featuring true 0.5 mm effective detector aperture for high-quality imaging.

In CT imaging, X-rays are the “information carriers.” When X-rays are projected through patient anatomy, dense tissues attenuate X-rays more than less dense tissues. The difference in this absorption based on the patient’s anatomy is the “information” content used to make an image. When the X-rays leave the patient and enter the detector, they carry this important patient “information.”

Each detector element is made-up of three main components: scintillator, photodiode, and the DAS. The X-rays interact with the scintillating material which converts X-rays to visible light. The photodiode converts light into electrical current and the DAS converts the electrical waveform to a digital signal for processing (Figure 2).

Innovation in Manufacturing

Leveraging our expertise in state-of-the art mechatronics and semiconductor technologies, we have revolutionized CT detector manufacturing and production techniques to elevate the detector scintillator to new levels of precision.

During production of the PUREViSION detector, the entire scintillator array of elements is forged from a solid ceramic ingot, dramatically reducing imperfections and ensuring superior luminescent properties. This is a major step forward compared to typical manufacturing methods that require re-assembling detector rows into a matrix array which can result in unwanted imperfections, inherently reducing X-ray conversion efficiency (Figure 3).

Each individual PUREViSION detector element is delineated using precision micro-blade technology. The resulting septa (the space between detector elements) is extremely narrow, ensuring maximum X-ray absorption surface area. Micro-blade cutting technology is specifically designed to cut the scintillator while maintaining straight, smooth edges. The clean edges and near microscopic septa of the detector material gives more X-rays the opportunity to interact with the scintillator, increasing the number of photons detected, and increasing the detection efficiency of the detectors. More scintillation means more light output and more output means more signal. In other words, rather than increasing radiation dose to increase signal, the detectors themselves avoid signal loss, capture more X-rays, and in-turn allow for lower noise image acquisitions (Figure 4).

Each detector element is optically isolated using a special material that has a very high reflection coefficient, enabling optimal transmission of light to the photodiode. The highly reflective material keeps photons in the scintillator to avoid cross-talk and coupling between detector elements and optimizes the percentage of X-rays converted to light. By keeping the X-ray photons in the scintillator, the highly reflective material reduces light scatter between elements to a negligible level. Minimizing cross-talk between detector elements mitigates blurring, an important feature for ultra-high spatial resolution (Figure 5).

Scintillator Materials

The PUREViSION detector is comprised of a highly efficient ceramic doped with a rare activator to ensure fast, uniform, and consistent imaging. This ceramic is ideal due to the material properties and manufacturing process. The ceramic has a large X-ray absorption coefficient making it preferable in terms of reduction in exposure and the short decay time makes it ideal for fast imaging.

The ceramic is characterized by superior physical properties including its mechanical strength and manufacturing uniformity. The mechanical strength of the ceramic allows the scintillator to be cut into smaller crystals as evidenced by the 0.5 mm PUREViSION detectors. The rare earth material used in the detectors is valued for its optical, magnetic and electrical properties all of which enable fast decay times and short scintillator afterglow for routine, high-resolution imaging with high view rates at scan speeds as fast as 0.275 seconds. The PUREViSION scintillator maximizes light output, converting greater than 99 percent of incident X-ray photons for dose efficiency.

Figure 1 PUREViSION detector technology

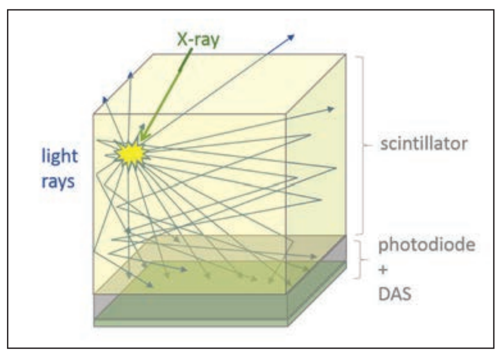

Figure 2 Detector Element: The X-rays interact with the scintillating ceramic to create visible light. The photodiode converts that light to electrical current and the DAS digitizes that signal for processing.

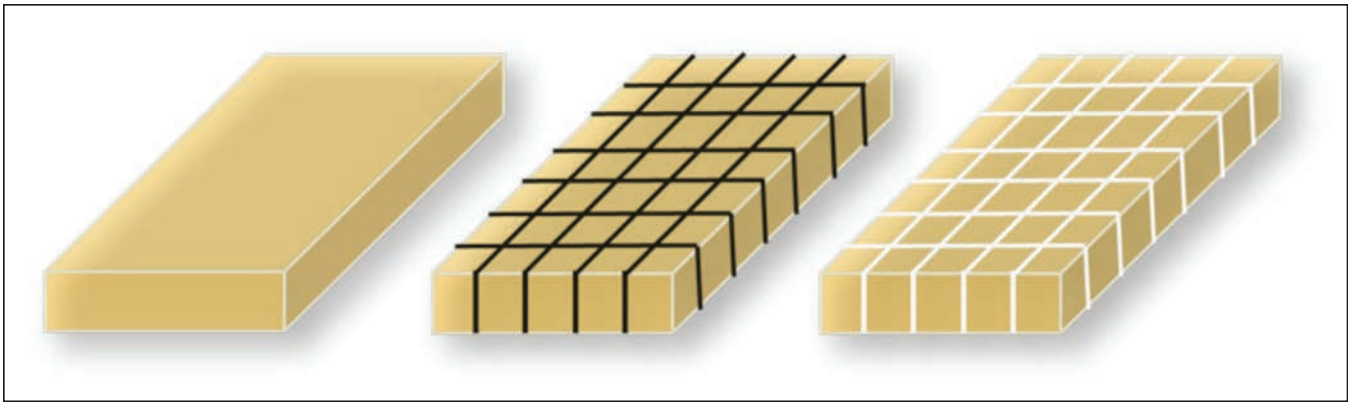

Figure 3 Solid Ingot. Each detector module is cut from a single solid ingot. This produces more uniform ceramic properties, more homogeneous light output, and closely matched geometry. Thus improving detector output and overall image quality.

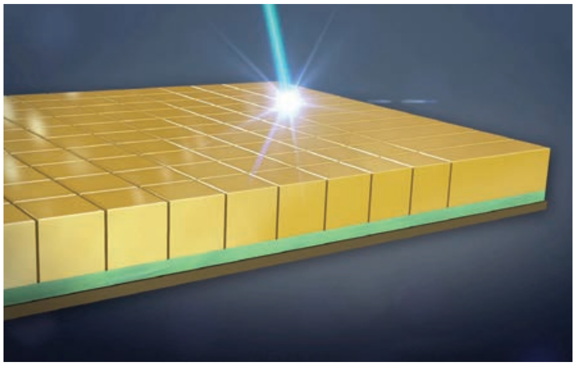

Figure 4 Micro-blade cutting technology optimizes X-ray absorption surface area (detection efficiency) and reduces imperfections compared to traditional cutting methods, and maintains structural integrity throughout the cutting process.

Figure 5 Highly reflecting material between detector elements minimizes detector cross-talk to maintain superior spatial resolution and avoid signal loss.

Environmentally Friendly Manufacturing

The PUREViSION detector is environmentally friendly to manufacture. Unlike some other detector ceramics, the PUREViSION ceramic is non-toxic, eco-friendly and does not contain hazardous materials. It remains stable under environmental conditions and no special waste treatment is necessary.

Miniaturized Electronics

Built upon many years of expertise in integrated DAS circuit design, the PUREViSION DAS system is designed to reduce electronic noise, and minimize power consumption. Considerable investment in research and development has resulted in breakthroughs in DAS circuitry design. Leveraging engineering expertise in miniaturization and multiplexing of electronics, the integrated DAS board has been reduced to almost half the size.

Low noise electronics are critical for low-dose fast scanning. In the past, CT images were considered to be predominantly quantum noise limited. In other words, it was assumed that image noise was quantum limited (limited by the number of photons reaching the detector following Poisson statistics). However, with fast scan times such as a 0.275 second rotation time, and with the introduction of Adaptive Iterative Dose Reduction 3D (AIDR 3D) and Forward projected model-based Iterative Reconstruction SoluTion (FIRST), the imaging system is being pushed to ultra-low photon counts and very fast response times.[1] Thus, for the fastest and lowest dose scans, noise was beginning to be characterized by electronic as well as quantum noise.[2] The PUREViSION detector was designed to address that electronic noise with the goal of ensuring low-dose CT images are primarily quantum limited without concern for electronic noise. See Figure 6 for an example of the noise differences in a 40 cm diameter water phantom.

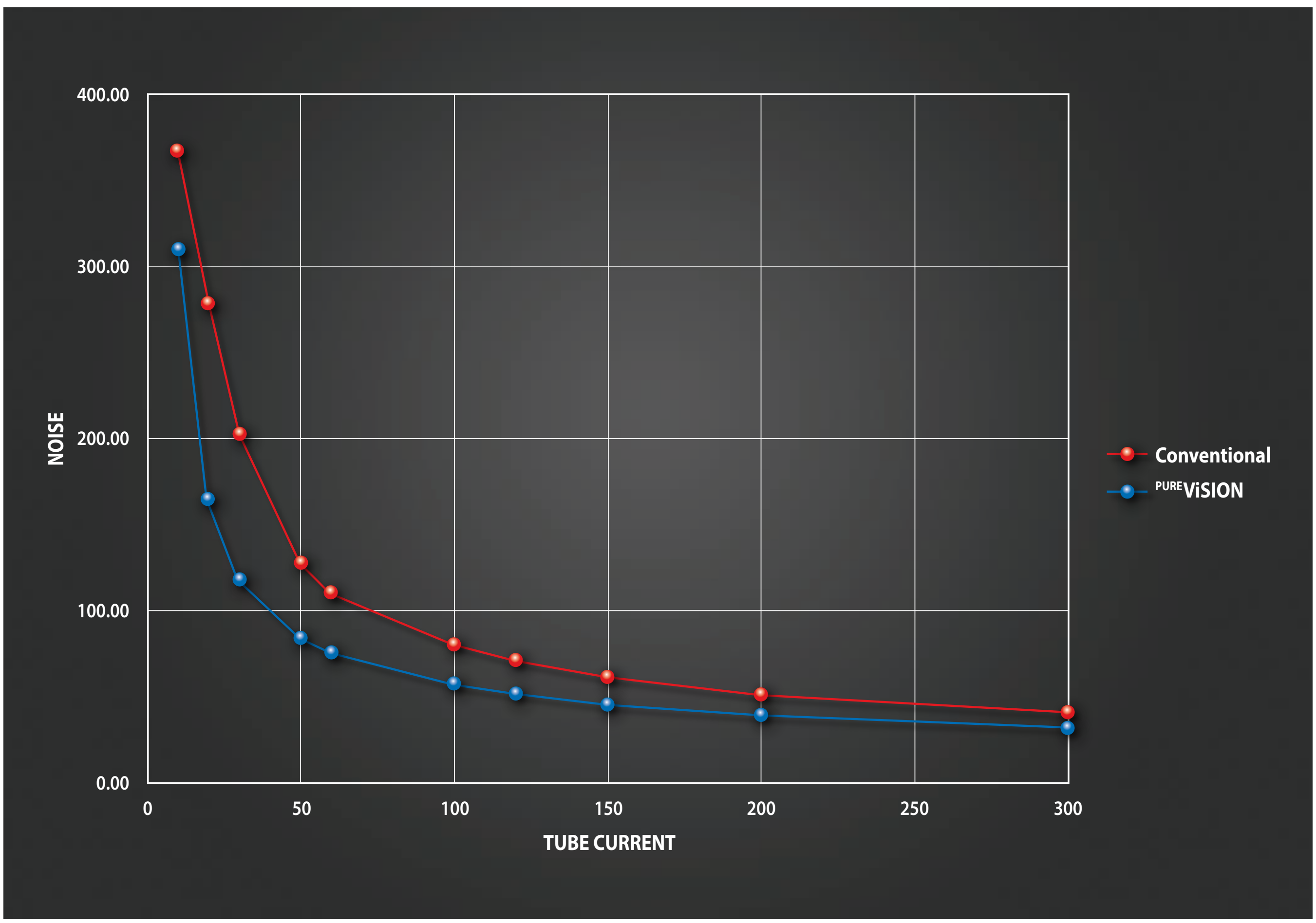

Figure 6 Comparison of image noise for a conventional detector versus the PUREViSION detector. Note that the PUREViSION detector demonstrates lower noise at all dose levels due to improved detector output and increasingly less noise at lower doses due to reduced electronic noise. Lower noise translates to less need for signal.

Reduced electronic noise translates to a reduction in image noise particularly for low dose protocols. By reducing image noise, fewer photons are required to maintain signal to noise ratio in the CT image. Therefore the PUREViSION DAS is designed to accommodate low dose acquisitions. (Figure 7)

Optimizing Patient Dose

PUREViSION is designed with patient safety as a top priority. Minimizing radiation dose is a key consideration when imaging patients with CT. Signal to noise optimization through increased detector output and reduced electronic noise may translate to the potential for lower radiation dose acquisitions (if electronic noise would otherwise have hampered IQ). By combining this advanced detector design with integrated iterative reconstruction solutions such as FIRST, and AIDR 3D, we have optimized every step of the imaging chain to reduce radiation dose and improve image quality.

Detector Performance

The overall detection efficiency of a CT detector is determined by the geometric efficiency and the quantum efficiency. The geometric efficiency represents the X-ray sensitive area of the detector relative to the whole area of the detector. Detectors with greater active surface area and less dead space between detectors (septa) have better geometric efficiencies. The PUREViSION detector maintains the industry's smallest detector elements in the z-direction with greater than 95 percent geometric efficiency. This impressive geometric efficiency is maintained by avoiding an extra collimator between the z-rows of the detector which would hurt geometric efficiency and thus add to patient dose.

Quantum efficiency is the fraction of x-rays that interact with the detector and contribute to the signal. The PUREViSION detector uses a proprietary detector development method to improve light output which improves quantum efficiency and thus overall detection efficiency. In the

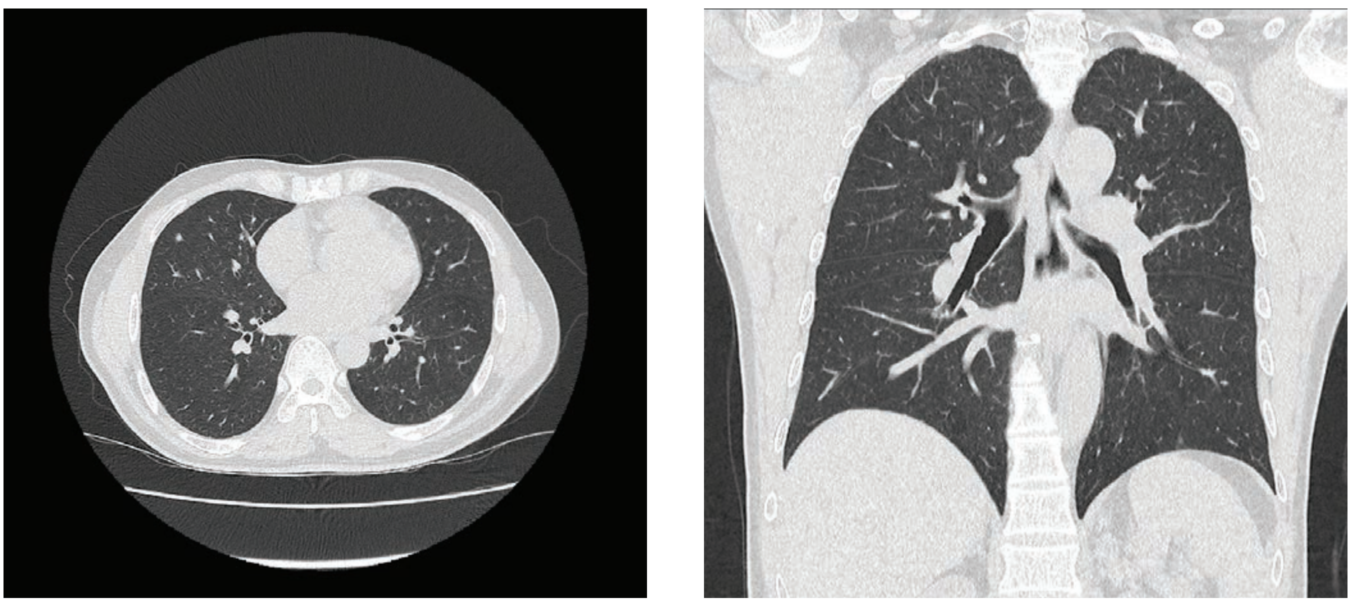

Figure 7 With the introduction of AIDR 3D and FIRST iterative reconstruction, the imaging systems are being pushed to ultra-low photon counts. This acquisition, with a nodule clearly visible in the axial view, was obtained at 2.5 CTDI, 98.9 DLP, or 1.38 mSv. The PUREViSION detector maintains high image quality while electronic noise is reduced.

PUREViSION detector more than 99 percent of the X-rays are converted to light.

The overall detection efficiency of the PUREViSION detector was improved, demonstrating a 40 percent improvement in detector output over the previous model (Figure 8)

Another detector property important to CT imaging is decay time. Decay time affects the speed with which the system can respond to stimulations in the scintillator.

Conclusion

Introducing 0.5 mm detector technology in 1999, we established itself as the industry's leading innovator in detector design and manufacturing, which remains to this day. Since then, we have introduced many industry first innovations in CT, most notably the world's first wide area, 320-row (640-slice*) detector, in 2007.

PUREViSION builds on years of experience to redefine yet again detector design, technology and manufacturing excellence.

Our commitment to ALARA while delivering 4D functional dynamic studies at conventional dose levels was a key driver in developing PUREViSION. Having achieved a further 40 percent increase in output and a decrease in image noise with this development, PUREViSION delivers the latest generation in detector performance, ensuring clinical and diagnostic excellence as well as patient safety at all times.

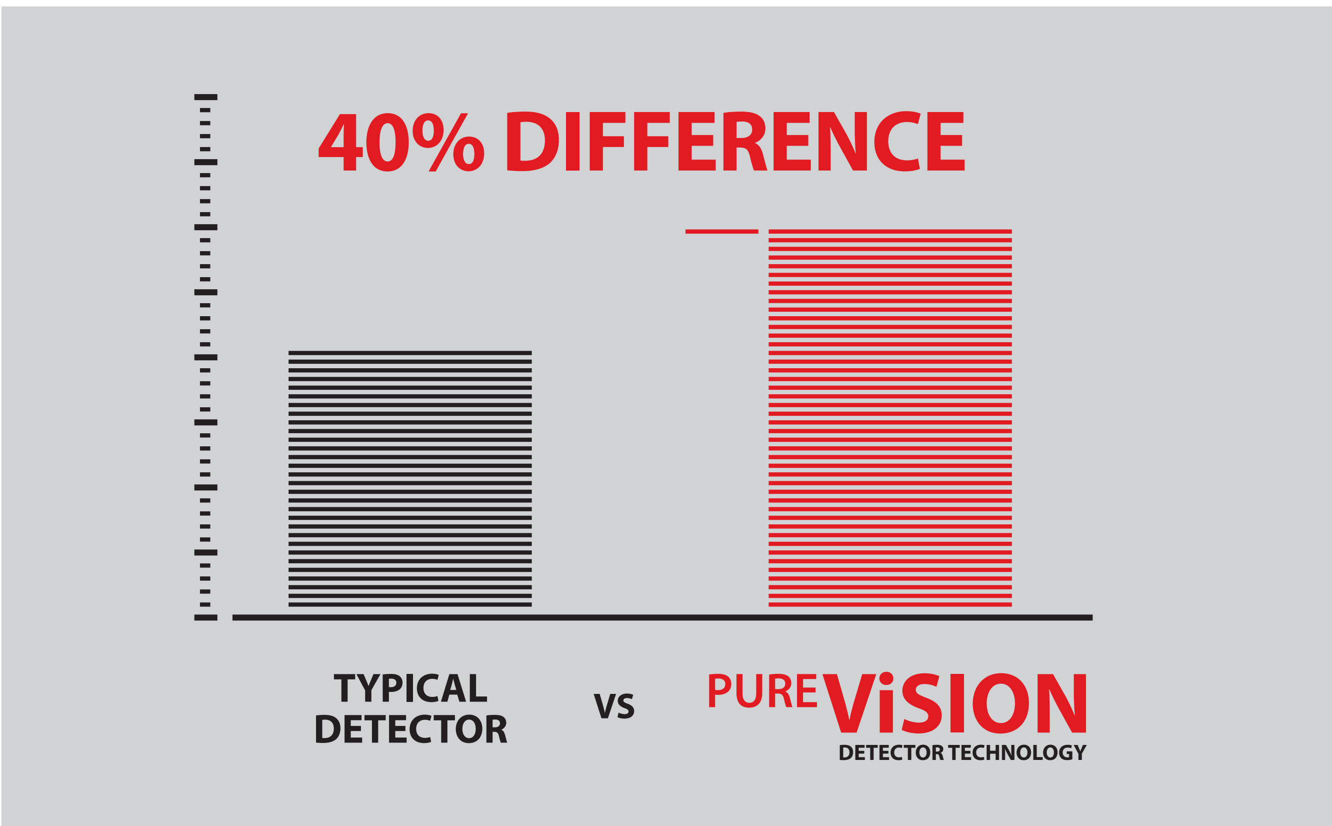

Figure 8 The PUREViSION Detector demonstrates 40 percent improvement in detector output.

**With coneXact™ option.*

References

1. Angel, E (2012). AIDR3D Iterative Reconstruction: Integrated, Automated and Adaptive Dose Reduction. Tustin, CA: Toshiba America Medical Systems.
2. JT Bushberg, JA Seibert, EM Leidholdt and JM Boone, The Essential Physics of Medical Imaging, Third Edition, Lippincott, Williams and Wilkins, Baltimore, MD 2012, ISBN: 9780781780575

Follow us: www.Medical.Toshiba.com @ToshibaMedical +Toshiba Medical Toshiba America Medical Toshiba Medical

TOSHIBA AMERICA MEDICAL SYSTEMS, INC. 2441 Michelle Drive, Tustin CA 92780 | 800.421.1968

CTWP12509US MCACT0318EB

Made For life