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TOSHIBA MEDICAL SYSTEMS CORPORATION

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TOSHIBA

Leading Innovation

Toshiba's PUREViSION Detector

Safer Imaging — Clearer Outcomes

CT Detector Technology Redefined

Introduction

Radiologists 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 centers across the world. With the introduction of PURE ViSION technology, Toshiba's new CT detector meets these expectations right now.

Breakthrough innovations in manufacturing processes and data acquisition system (DAS) design have resulted in a detector with a **40% increase in light output** and minimal electronic noise, making PURE ViSION one of the most efficient detectors commercially available and still the only detector featuring true 0.5 mm resolution for high-quality imaging.

PURE ViSION delivers 4D dynamic capabilities at high resolution with dose levels approaching those in routine diagnostic studies, an important development in the evolution of dynamic volume CT. For routine diagnostic and therapeutic CT procedures PURE ViSION offers improved patient safety through a lower radiation dose.

And since patient safety should never be an option, Toshiba's commitment is to deliver PURE ViSION technology across the entire Aquilion™ CT product range (**Figure 1**).

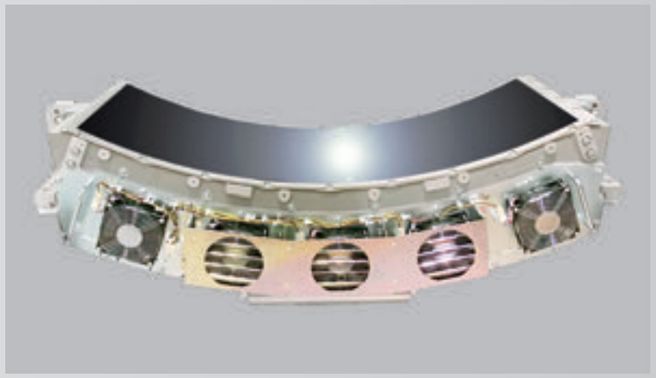


Figure 1: The PURE ViSION detector for the Aquilion ONE™ and Aquilion ONE /VISION Edition features 16 cm of anatomical coverage in a single gantry rotation.

Breakthrough Manufacturing Process

Leveraging Toshiba Corporation's expertise in state-of-the-art mechatronics and semiconductor technologies, Toshiba Medical has revolutionized CT detector manufacturing and production techniques to improve the purity of the detector scintillator to new levels of precision, **increasing light output by 40%** (Figure 2)**.**

During production of the PURE ViSION detector, the entire scintillator array of 0.5 mm elements is forged from a solid ceramic ingot, dramatically reducing imperfections and ensuring superior luminescent properties. This is a major step forward compared to historical cutting methods, which results in unwanted imperfections and ultimately reducing X-ray conversion efficiency (**Figure 3**).

Each individual PURE ViSION detector element is created using precision micro-blade technology, resulting in separations with an accuracy of just a few microns and the maximum surface area for X-ray absorption. These elements are optically isolated with a special material that has a very high reflection coefficient to ensure excellent light transmission through the scintillator to the photodiode while minimizing crosstalk.

This revolution in detector manufacturing results in an extremely pure scintillator with a 40% increase of information-carrying photons transmitted to the photodiode (**Figure 4**).

Praseodymium Activated Scintillator

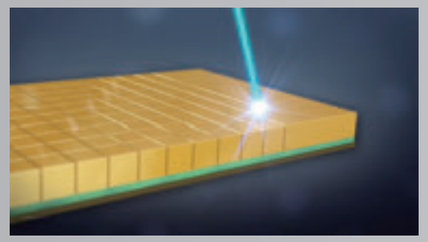
The PURE ViSION detector is composed of a highly efficient Toshiba scintillator incorporating praseodymium (pray-se-o-dim-e-um) as the key activator to ensure fast, uniform, and consistent imaging. Praseodymium is a rare earth material valued for its optical, magnetic, and electrical properties, all of which contribute to fast decay times and short scintillator afterglow for routine high-resolution imaging with high view rates at scan speeds as fast as 0.275 s.[1]
The Praseodymium Activated Scintillator converts almost 100% of incident X-ray photons for maximum dose efficiency.

Miniaturized Electronics

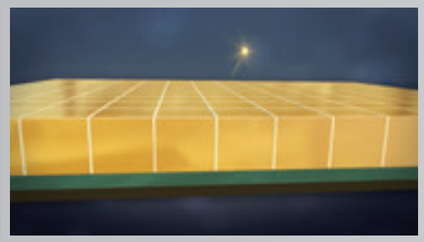
The fundamental design concept of integrated DAS circuits has been utilized in Toshiba CT systems since 2010. This design reduces electronic noise and minimizes power consumption.

Considerable investment in research and development has resulted in breakthroughs in DAS circuitry design. Leveraging know-how in the miniaturization of electronics, the integrated DAS board has been reduced to almost half the size, resulting in a reduction in electronic noise by 28% as quantified by the system's data collection and analysis software.

This reduction means that fewer photons are needed to maintain the signal-to-noise ratio in CT images. Therefore, with the PURE ViSION DAS (**Figure 5**), less radiation exposure is needed to achieve equivalent image quality.



Microblade cutting of a single Ingot



Optical isolation

Figure 2: Breakthrough manufacturing process of the PURE ViSION scintillator.

Figure 3: Micro-blade cutting technology (left) compared with a traditional saw-cut detector (right). The detector cut with the ultra-fine micro-blade has superior reflective properties with reduced imperfections. As a result, for each incident X-ray photon, more light is channeled to the photodiode.

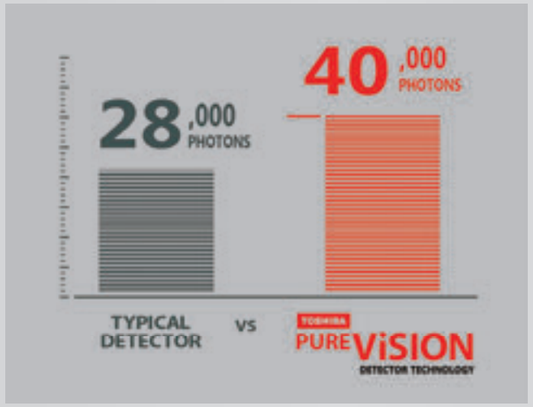


Figure 4: Direct comparison of the photon output of the PURE ViSION scintillator and a conventionally manufactured scintillator demonstrating a 40% increase in light output.

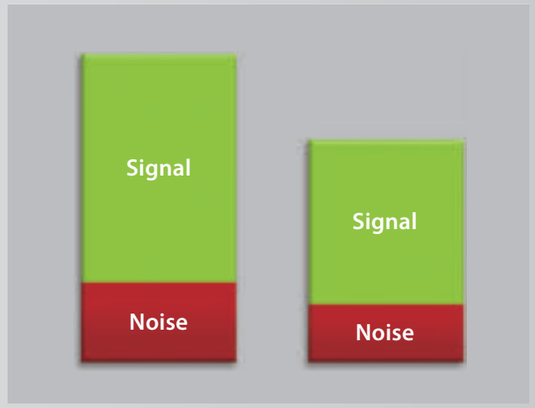


Figure 5: Diagrammatic representation of images with an equivalent signal-to-noise ratio. Less electronic noise translates to less signal and ultimately lower radiation exposure.

Low-noise electronics are critical for low-dose fast scanning. With scan times as fast as 0.275 s for one rotation and with the introduction of AIDR 3D iterative reconstruction, the imaging system is being pushed to ultra-low photon counts and extremely fast response times. Thus, for the fastest and lowest dose scans, the ratio of electronic noise must be minimized to maintain high image quality. The PURE ViSION detector has been designed for minimal electronic noise with today's low-dose imaging in mind (**Figure 6**).

Intelligent Scatter Removal

During the development of Aquilion ONE with 16 cm of anatomical coverage, Toshiba's reconstruction engineers faced a number of new challenges in basic physics. In particular, the increased amount of scattered radiation was a primary challenge that needed to be overcome in order to ensure high-quality volumetric acquisition. There were two possible approaches to solving the problem of scattered radiation: one smart and the other easy.

The easy solution was to simply employ a three-dimensional scatter grid overlaying the detector to absorb the scattered photons. While this technique is effective, the scatter grid also absorbs primary incident photons, necessitating an increase in radiation exposure to ensure acceptable image quality.[2]

The smart solution was to refine computer-generated scatter projection models and then utilize these iteratively in the reconstruction process to "virtually" remove the effects of scattered radiation, without sacrificing primary photons in the process.

Toshiba has developed a reconstruction technique based on these principles incorporating both Compton and Rayleigh forward-based scatter modeling and correction processes. The resultant image quality means excellent HU uniformity along the Z-axis with improved low-contrast and spatial resolution[3] (**Figure 7**).

Figure 6: Ultra-low-dose chest CT identifies a small lung nodule in the left lung. The CTDIvol for this scan was 0.3 mGy and the effective dose was just 0.15 mSv.

Figure 7: Images demonstrating the effectiveness of algorithm-based scatter removal.

Toshiba's innovative solution to scattered radiation is applied in Volume and Ultra-Helical scan modes, ensuring high overall efficiency of the entire imaging chain.

Optimizing Patient Dose

PURE ViSION has been designed with patient safety as the top priority. Minimizing radiation dose is a key consideration when imaging patients with CT. Signal-to-noise optimization through increased light output and minimized electronic noise translates to lower radiation dose in CT examinations for the majority of patients. By combining this advanced detector design with integrated iterative reconstruction, Toshiba has optimized every step of the imaging chain to reduce radiation dose and improve image quality.

These new standards in low-dose imaging dramatically reduce the required generator power, which means low-kVp imaging is available for a wider range of patients. Imaging at lower kVp permits a reduction in the volume of contrast medium needed to achieve diagnostic-quality opacification due to the increased photoelectric absorption of iodine near the K-edge.[4]

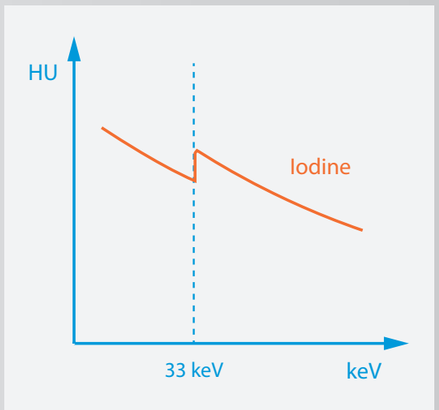


Figure 8: This graph shows the sudden increase in the HU density of iodine at (and above) 33 keV due to the K-edge effect.

The X-ray tube spectrum is polychromatic, and lower kVp X-ray beams contain a higher proportion of photons at an energy level just above the binding energy of the K-shell electrons of iodine at 33.2 keV. Photons at and slightly above this energy are more likely to be absorbed by the photoelectric effect, which results in an increase in the HU density of contrast-enhanced tissues in the resultant images (**Figure 8**).

Through lower radiation doses and low-kVp imaging, PURE ViSION offers peace of mind in the optimization of radiation and contrast dose protocols, permitting physicians to perform safer CT examinations for all patients.

Conclusion

With the introduction of 0.5 mm detector technology in 1999, Toshiba established itself as the industry's leading innovator in detector design and manufacturing, and it remains so to this day. Toshiba has since introduced many groundbreaking innovations in CT, most notably the world's first wide-area 320-row detector in 2007.

PURE ViSION builds on over 15 years of experience to redefine yet again detector design as well as technological and manufacturing excellence.

Toshiba's commitment to ALARA while delivering 4D functional dynamic studies at conventional dose levels was a key driver in the development of PURE ViSION. Having achieved a further 40% increase in light output and a 28% decrease in electronic noise with this development, PURE ViSION provides the latest generation in detector performance for clinical and diagnostic excellence while ensuring patient safety at all times.

Since diagnostic performance and patient safety should never be an option, Toshiba's commitment is to incorporate PURE ViSION detectors across the entire Aquilion CT product range.