Sponzorski članek

STELLAR DETECTOR PERFORMANCE IN COMPUTED TOMOGRAPHY

The first fully-integrated detector in the CT industry sets a new reference in image quality with HiDynamics, TrueSignal and Ultra Fast Ceramics

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Siemens has continually evolved its technology for the most critical components in the CT scanner, including the X-ray tube, detector array and efficient image reconstruction algorithms. Back in 2002, Siemens introduced a revolutionary concept for a new X-ray tube. The STRATON® tube's compact design led to the development of fast rotation speeds and Dual Source Technology. STRATON X-ray tubes have a high power output, small focal spot sizes and virtually no cooling delays, thanks to unique technology that cools the anode directly. Siemens has also improved its image reconstruction methods continuously. While other vendors still use single-slice techniques which require compromises between image quality and speed, Siemens has developed SureViewTM for the first generation of multi-slice detectors, offering optimal dose utilization and excellent image quality at arbitrary pitch values. Such extensive research and development has fueled the latest generation of iterative reconstruction approaches, which include IRIS, and SAFIRE – Siemens´ raw-data-based iterative reconstruction application available commercially.

HIGH ABSORPTION, FAST DECAY AND LOW AFTERGLOW

CT scanner detectors convert the attenuated X-ray beam into a digital signal that can be processed by computers. To achieve very high dose efficiency, the detector's capacity for X-ray absorption must be as high as possible. After decades of using Xenon gas detectors in CT, Siemens introduced the first solid-state detector in 1999 (Fig. 1). Based on the proprietary scintillator material, Ultra Fast Ceramics (UFC™), the detector offered high X-ray absorption, short decay times, and extremely low after-glow. The UFC layer used in Siemens CT scanners converts almost 100% of the X-rays into visible light, whereas Xenon detectors can only convert between 60% and 90% of the X-ray into a usable signal. A direct comparison of Xenon detectors and UFC-based detectors indicated an increase of 23% in dose efficiency (Fuchs et al., 2000). Decay time and afterglow are two other important properties of scintillator materials that characterize the light out-put of the scintillator after the X-rays are switched off. Decay refers to the short-term behavior of the signal directly after the X-ray is switched off and afterglow is the longer-term composition of the signal output due to luminescence. UFC has set an industry standard with a consistent decay time of 2.5 microseconds, and an afterglow below 10-4 after 1 millisecond and 10-5 after 10 milliseconds. Until recently, other vendors still had to use afterglow correction mechanisms (Hsieh et al., 2000) since long decay time and high after-glow can completely ruin spatial resolution. Siemens has continued this trend of innovation by developing the first fully-integrated detector, which is designed to dramatically reduce electronic noise, extend the dynamic range and increase spatial resolution in combination with new reconstruction methods.

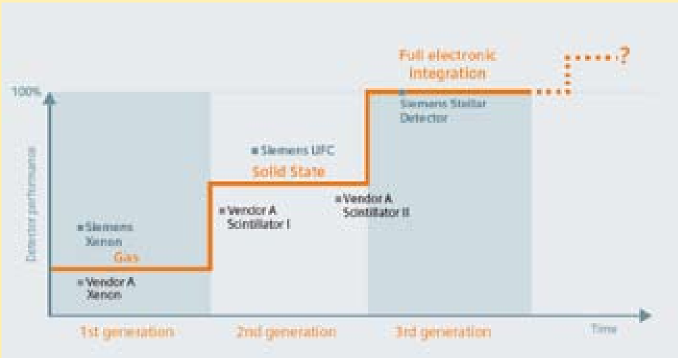

***Figure 1:** First generation detectors still used Xenon gas under high pressure to convert the incoming X-rays into electric current. Second-generation detectors use solid-state ceramic scintillators to convert X-rays into light, photodiodes to convert the light into current, and analog-to-digital converters (ADC) to digitize the signal. The Stellar Detector is the first third-generation detector that combines the photodiode and the ADC in one Application-Specific Integrated Circuit (ASIC), dramatically reducing electronic noise, power consumption, and heat dissipation.*

REVOLUTIONARY NEW DETECTOR DESIGN

Detector performance is not only measured by fast and high X-ray absorption, short decay times, and low afterglow; low electronic noise levels and a high dynamic range are also key to designing effective detectors. With the new Stellar Detector, Siemens is pioneering the first fully-integrated CT detector. Conventional solid-state detectors consist of a scintillator layer that converts the incoming X-rays into visible light, a photodiode array that converts the visible light into an electric current and an analog-to-digital converter (ADC) which digitizes the signal on a separate electronic board (Fig. 2).

Figure 2: Prototype configuration of a second-generation detector module includes anti-scatter collimator, scintillator layer, photodiode array and a separate electronic board with ADCs

The number of electronic components and relatively long conducting paths increase power consumption, and add to the electronic noise produced by the detector. In the Stellar Detector, Siemens has combined the photodiode and the ADC in one application-specific integrated circuit (ASIC) for the first time in the history of CT, reducing the path of the signal. Fig. 3A shows a schematic of the new Stellar Detector configuration. The light from the UFC scintillator reaches the back-illuminated photodiode on top of the CMOS wafer, which houses the ADC. A digital signal is then produced on the other side of the wafer. This geometry consists of a 3D package of electronic circuits in a through-silicon via (TSV); a high performance technique for creating vertical connections that pass completely through the silicon wafer. Fig. 3B shows the complete configuration of the compact Stellar Detector array with the ADC positioned entirely underneath the photodiode array. This small module replaces all the boards and electronic components shown in Fig. 2. Stellar Detectors transfer the digitized signal without any losses and the electronic noise produced by the detector is reduced by a factor of two (TrueSignal Technology).

Figure 3: Schematic drawing shows the configuration of the new Stellar Detector. The light from the UFC scintillator reaches the back-illuminated photodiode on top of the CMOS wafer that contains the ADC. The digital signal is then produced on the other side of the wafer (Fig. 3A). A picture of the compact Stellar Detector array with the ADC positioned entirely underneath the photodiode array (Fig. 3B).

The new ASIC consumes 85% less power and dissipates less heat, further reducing electronic noise. Fig. 4 shows the reduced noise produced by the new Stellar Detector compared to a conventional second-generation detector.

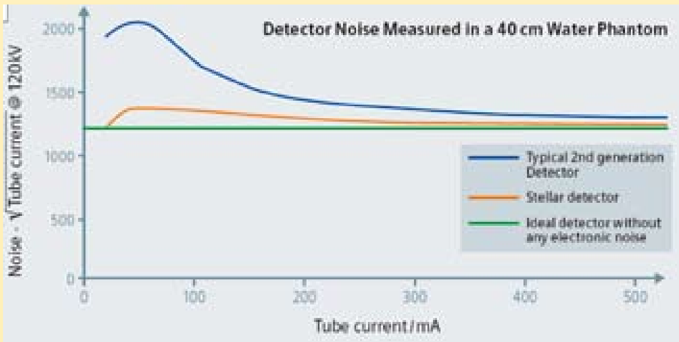

Figure 4: Reduced noise of the new Stellar Detector measured with a 40 cm water phantom and compared to a conventional second-generation detector. Stellar produces almost no electronic noise (green line), benefiting low dose applications and large patient scans where signals are very low.

LOW ELECTRONIC NOISE AND HIGH DYNAMICS

In clinical CT, the attenuation of the measured object varies dramatically and so do the signal levels at the detector. The dynamic range describes the range of the input signal levels that can be reliably measured simultaneously without saturation. HiDynamics has an exceptionally high dynamic range of 120 dB, 15% more than conventional detector systems, eliminating the need to modify amplification and avoiding detector saturation. Combined with the noise reduction provided by TrueSignal, Stellar Detectors can measure smaller signals over a wider dynamic range which directly enhances CT image quality (Fig. 5). Applications with extremely low signal levels at the detector benefit especially from HiDynamics and TrueSignal, such as scanning large patients and low-dose scans, as well as the low-kV datasets of Dual Energy examinations.

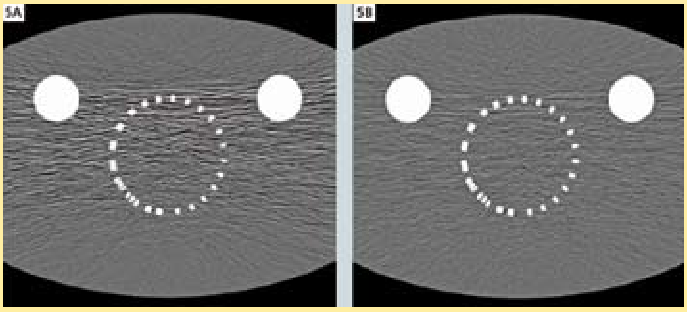

Figure 5: Simulation of a hip phantom with resolution insert, conventional detector technology and the new Stellar Detector. Using conventional technology, low signal levels in projections with high attenuation cause streak noise patterns in clinical images (left). With the Stellar Detector and TrueSignal Technology these unwanted noise patterns are eliminated (right).

MODEL-BASED AND DETECTOR-OPTIMIZED RECONSTRUCTION

With SAFIRE (Sinogram Affirmed Iterative Reconstruction), Siemens introduced the first model-based and raw data-based iterative reconstruction application capable of reducing noise and artifacts, suited for a broad range of applications in clinical routine. SAFIRE can thus model the Stellar Detector precisely, including the cross talk between detector elements, detector aperture, detector grid, and the focal spot of the STRATON X-ray tube, reconstructing true 0.5 mm slices and unmatched spatial resolution in routine clinical protocols with excellent dose efficiency (Fig. 6).

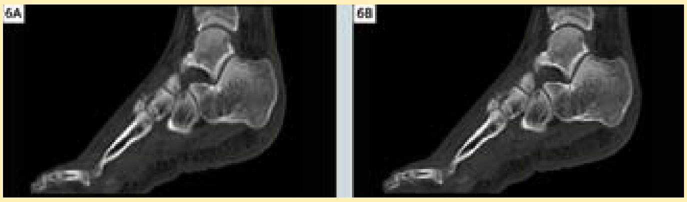

Figure 6: A foot has been scanned and reconstructed with conventional technology (Fig. 6A) and Stellar technology with optimized SAFIRE model-based reconstruction (Fig. 6B).

SOMATOM DEFINITION EDGE AND SOMATOM DEFINITION FLASH NOW EQUIPPED WITH NEXT-GENERATION DETECTOR TECHNOLOGY

Siemens high-end scanners are now equipped with the latest Stellar Detector1 in Single Source and Dual Source configurations.

References

Fuchs TOJ et al. (2000). Direct comparison of a xenon and a solidstate CT detector system: easurements under working conditions. IEEE Trans Med Imaging, 19 (9): 941-8.
Hsieh J, Gurmen OE, King KF (2000). Investigation of a solid-statedetector for advanced computed omography. IEEE Trans Med Imaging, 19 (9): 930-40.