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SUCCESS STORY

Inner workings of a photon scanner from Siemens Healthineers
Source: German Future Prize/Ansgar Pudenz

Photon Scanners: Taking CT to the Next Level

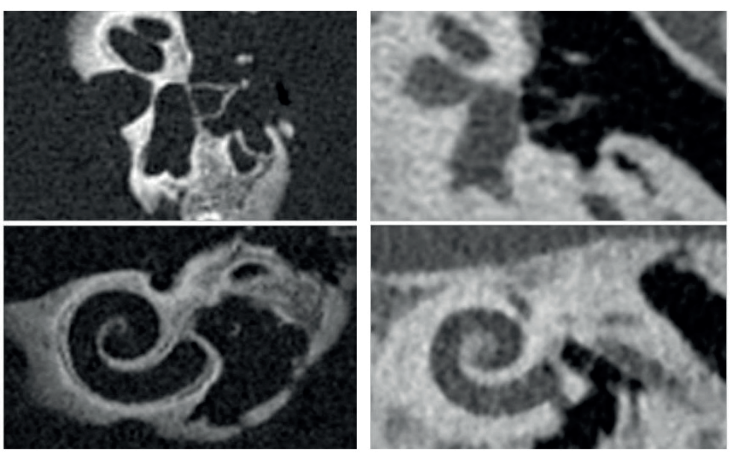
Medical technology is in the midst of a revolution - and the classic CT scanner is increasingly being replaced as the generator of clinical images. Photon-counting detectors in CT scanners make it possible to produce much sharper images in much less time. This means that patients can receive a more accurate diagnosis more quickly. The NAEOTOM Alpha was the first clinical photon-counting CT system to be launched in 2021. The system was developed by Siemens Healthineers in Forchheim, Germany. Cross-company teams also worked with software developers from ISO Software Systeme to develop the necessary software.

Revolution in clinical imaging

Computed tomography (CT) has been the reliable workhorse of clinical imaging for decades. Thanks to its robustness, coupled with high spatial and temporal resolution, this imaging modality quickly established itself in clinical diagnostics in the 20th century and has since become irreplaceable in everyday clinical practice. Since its invention, clinical CT imaging has undergone considerable development. However, the last few decades have been characterized by gradual improvements in CT technology.

Photon Counting Detector (PCD) technology represents a major leap forward in this area, providing significantly better images than previous CT imaging.

Research institutions such as CERN, the European Organization for Nuclear Research, have been working for some time to use this technology for medical purposes.



Photon-counting detectors provide a much clearer image...

...than conventional CT scanners. (Pictured: middle and inner ear)

Source: Dr. A. Persson, Linköping University, Sweden

Sharper images with less radiation

With the NAEOTOM Alpha, Siemens Healthineers has developed the world's first photon-counting scanner, which has been in routine clinical use since 2021. The system delivers significantly better images with less radiation exposure than the technologies previously used in these devices. Siemens Healthineers is committed to improving diagnostic capabilities for the benefit of people.

Software also plays an important role in these scanners, controlling the PCD scanners and collecting the necessary data from the X-rays to create detailed images. The software can also help analyze the data to provide information about the structure and composition of materials. Overall, the software in photon-counting CT scanners helps improve the accuracy and effectiveness of materials analysis.

To ensure smooth operation, a powerful IT infrastructure is also required, since the amount of data generated by the highly detailed images is much larger than in the past. This is where the software experts from ISO Software Systeme come into play: for many years, more than 50 software developers from the Nuremberg-based IT specialist have been working in several teams for Siemens Healthineers in Forchheim.

C++ and Python are mainly used for concept creation and pre-development programming. C# is used for product development. Software development includes programming the user interface, controlling the hardware components, recording and analyzing the data, and integrating algorithms for signal processing and noise reduction. The software must also be able to process and display data in real time to provide rapid feedback to the user.

In addition, it is important for software development to calibrate and maintain the photon-counting CTs so that the instruments function properly and provide accurate measurement results.

How it works: Conventional CT scanner vs. photon-counting CT scanner

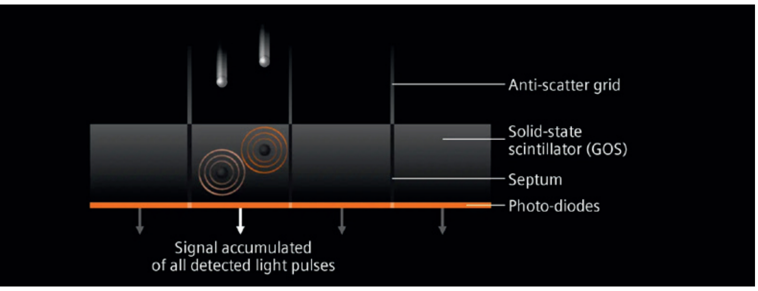
Basically, the two main components of a conventional CT scanner are the X-ray tube and the detector, which rotate around the patient up to four times per second.

The tube generates X-rays. The associated photons pass through the patient and then hit the detector, which converts the signals into brightness values. This happens about a thousand times per revolution, with about 30,000 photons hitting each detector element. This means that the detector is hit by a photon about every eight nanoseconds. Until now, no detector has been able to react to and measure the photons that quickly, so all 30,000 photons are combined and measured at once.

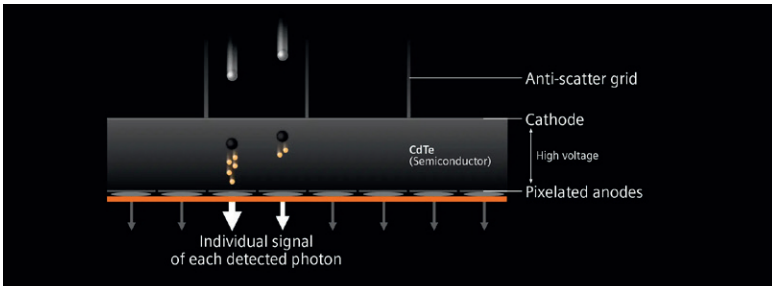
But how exactly are photons converted into analyzable data? So far, all available detectors are made of a special ceramic that lights up when hit by a photon. This light is then measured by photodiodes and converted into voltages. These voltages can then be converted into brightness values, i.e. a CT image.

However, the process has drawbacks: Because it uses light, the individual detector elements must be surrounded by a reflective layer to direct all the light rays onto the diode. This creates areas on the detector that cannot use the incoming photons, so the radiation dose must be increased to still obtain a good image. In addition, the size of the individual detector elements cannot be reduced arbitrarily, because this reduction results in significantly more areas that do not produce any data which in turn leads to an increased radiation dose.

With the new detectors of the photon-counting CTs, Siemens Healthineers has succeeded in eliminating the conversion into light. As a result, a reflective layer is no longer required. Instead, a crystalline semiconductor is used that converts the photons directly into an electrical signal. This allows much faster measurements to be made at a distance of just a few nanoseconds. This makes it possible to measure each photon individually. It also significantly reduces radiation exposure.



Energy-integrating detector
Source: Siemens Healthineers

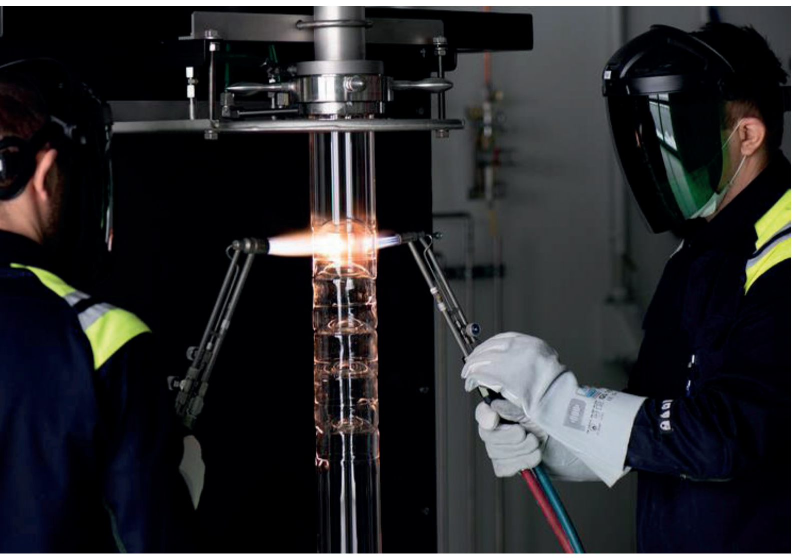


Photon-counting detector
Source: Siemens Healthineers

The result is high-resolution, high-contrast images that enable faster and more comprehensive diagnoses of diseases. As a result, the right therapies and their effectiveness can be determined much faster than with conventional CT scanners.

The key: cadmium telluride crystals

All this is made possible by cadmium telluride crystals grown by Siemens Healthineers. The project began in 2003 with simulations designed to show the advantages of this new technology. At the time, many competitors rejected the theory and abandoned their projects. Siemens Healthineers persevered and continued its research, beating the competition by years. The first prototype, and thus the first scan on a real patient, was realized in 2014.



The crystals required for the photon counters are grown in ampoules which technicians elaborately seal at 3,000°C.
Source: Siemens Healthineers

The research had to be continued for several more years until the market launch in 2021. Since mid-2023, Siemens Healthineers has been building a dedicated factory in Forchheim, Germany, to grow these crystals for semiconductor production on an industrial scale. The crystal factory, which will cover an area of more than 9,000 square meters, is scheduled to go into operation in 2026. The new building will significantly increase crystal production capacity, eliminate supply bottlenecks and shorten construction times. Research and development for the highly complex production of these crystals will also be expanded in Forchheim.

The effort is well worth it, because absolute purity is crucial in the production of cadmium telluride crystals. The crystal structure must be absolutely perfect so that the electrical properties of the material are not affected. To ensure this, the crystals must be produced in clean rooms. The slightest impurity will render the grown crystal unusable. In fact, even the material of the hammer used to crush the raw materials has to be specially selected.

Once the crystals have been grown for ten to twelve weeks, they are sliced along the crystalline structure into thin wafers that can be further processed into detector elements.

Siemens Healthineers has been nominated for the German Future Prize 2021 for this technology and the resulting CT scanners. A great success in which the software developers of ISO Software Systeme also played a part.

„Being able to serve the benefit of mankind is a great incentive for our daily work. In addition to the innovative environment in which we at Siemens Healthineers work on future-oriented technologies, we always focus on people and their health,“ explains Klaus Hettrich, Head of Medical Technology Products & Innovation (PI), ISO Software Systeme GmbH.

Key Data

Siemens Healthineers AG

www.siemens-healthineers.com

Sector

Medical Technology

Geography

Forchheim, Upper Franconia, Germany

Fields of application

- Computed Tomography
- Magnetic Resonance Imaging
- Angiography
- etc.

Used technologies and methods

- Image Analysis
- Data Science
- Radiomics
- Virtual and Augmented Reality
- GPU based 2D/3D rendering (GLSL, CUDA)
- C++, Python, C#, R, MevisLab, Keras,
- Tensorflow, SQL, OpenGL etc.

Key benefits for the customer

- High resolution images with less radiation
- More accurate diagnosis

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