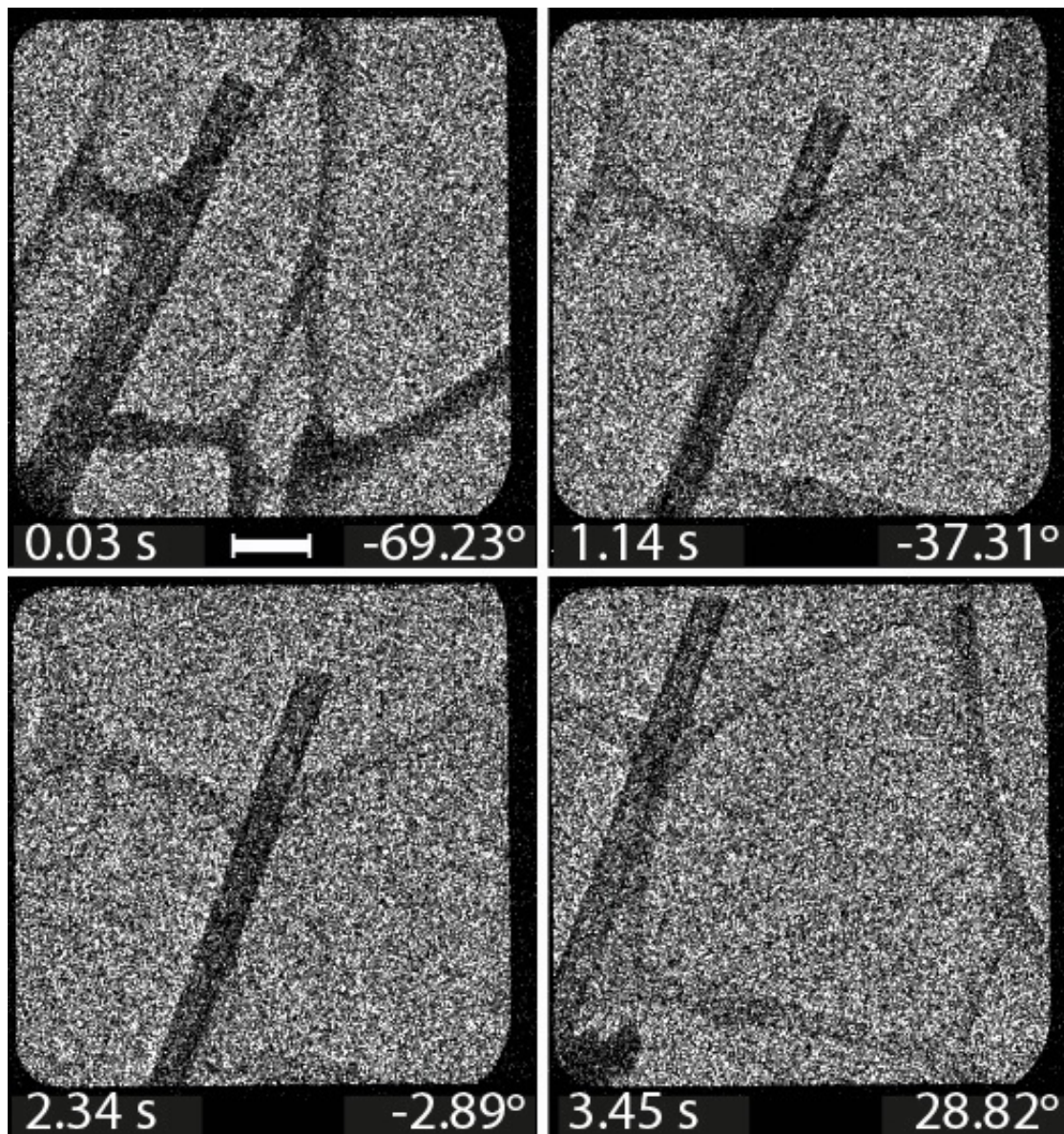


High-speed electron tomography sets new standards for 3-D images of the nanoworld

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The image series serves as a data basis for the reconstruction of the 3D electron tomogram. Credit: Migunov, V. et al. Sci. Rep. 5, 14516, 2015

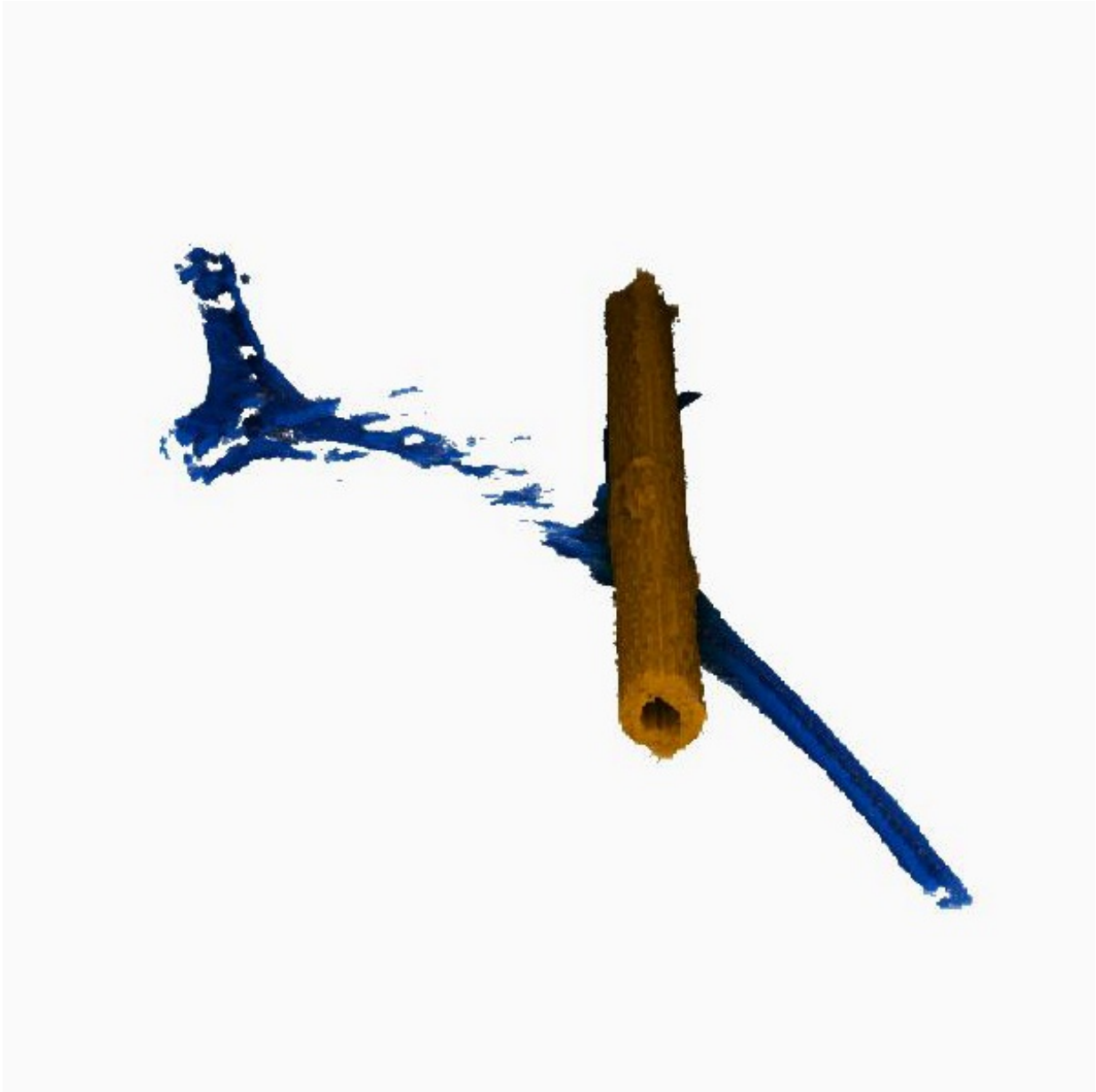
Scientists from the Ernst Ruska-Centre in Forschungszentrum Jülich used a transmission electron microscope to record almost 3500 images in 3.5 seconds for the reconstruction of a 3D electron tomogram. Previously, 10 to 60 minutes and a ten-fold greater electron dose were required to record such image sequences. The new capability is particularly suitable for examining biological cells, bacteria and viruses, whose structure can be damaged by the electron beam. In addition, it enables dynamic processes, such as chemical reactions and electronic switching phenomena, to be visualized in real time in three dimensions with sub-nanometre precision. The findings have been published in the journal *Scientific Reports*.

Electron tomography is related to computed tomography, which has become indispensable in research and clinical studies. Electron tomograms can be obtained from much smaller volumes than with X-ray-based techniques. The three dimensional spatial resolution of [electron tomography](#) is the highest achievable with today's technology. The method is uniquely suited for studying viruses and bacteria to facilitate development of medications, or for imaging the structures of novel nanomaterials for applications that range from nanoelectronics to energy technology.

"The ability to accelerate image acquisition and reduce radiation dose opens up new horizons, particularly in life sciences and soft matter research, by electron tomography," says Prof. Rafal Dunin-Borkowski. In this technique, a [transmission electron microscope](#) is used to record images of a sub-micrometre-sized region from different angles in quick succession.

"The individual images do not show cross-sections of the sample. Instead, the information from different depths inside it is superposed -

similar to an X-ray image - and projected onto a plane," explains the Director of the Ernst Ruska-Centre, who is also Director of the Institute for Microstructure Research (PGI-5) in Jülich's Peter Grünberg Institute. For this reason, algorithms are necessary for a computer to calculate a three-dimensional reconstruction of the object from the series of images.



3D electron tomogram of a nanotube (orange) and the underlying amorphous C

support film (blue). Credit: Migunov, V. et al. Sci. Rep. 5, 14516, 2015 (CC BY 4.0)

The resolution that can be achieved is limited by the destructive effect of the [electron beam](#) on the sample. Soft, biological samples, in particular, tolerate only a limited number of images. Their sensitive structures, for example those of proteins, are rapidly destroyed by high-energy electrons. In order to reduce the electron dose, the researchers in the Ernst Ruska-Centre equipped their electron microscope with a novel detector. This single electron detection camera registers incoming electrons directly, without needing to convert them into photons, i.e. light - the usual practice today.

"The latest generation of detector chips has very high sensitivity, meaning that for the same image quality an electron beam dose that is two to three times lower suffices," explains Dr. Vadim Migunov, from the Ernst Ruska-Centre and Jülich's Peter Grünberg Institute. His colleagues in Jülich's Central Institute of Engineering, Electronics and Analytics (ZEA-2) helped to develop the electronics in the chip, which ensures fast data read-out speed and thus extremely fast recording rates.

First tests with nanotubes and catalysts

In order to test the improved technique, Vadim Migunov, together with his colleagues from the Ernst Ruska-Centre, examined an inorganic lanthanide nanotube using the new sensor. Such structures are currently of interest because they may be suitable for electricity generation from waste heat or as novel light sources and catalysts. With a recording rate of approximately 1000 images per second, electron tomography can now be used for nanoscale observations of fast processes such as chemical reactions involving catalysts, crystal growth processes or phase

transitions," explains Vadim Migunov.

Studies with better temporal and spatial resolution could help to reveal why nanocatalyst functionality is lost over time. Catalyst nanoparticles can be used to produce hydrogen and to separate harmful greenhouse gases. Their efficiency depends predominantly on how atoms are arranged on the surfaces on which the [chemical reactions](#) take place.

The new technique has additional advantages. Only a few seconds of computing time are necessary to record and reconstruct the three-dimensional structure of a specimen on a computer. The time required is thus very short and scientists can observe experiments not only in 3D but also almost "live."

More information: "Rapid low dose electron tomography using direct electron detection camera." *Scientific Reports* (published 5 October 2015), [DOI: 10.1038/srep14516](https://doi.org/10.1038/srep14516)

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