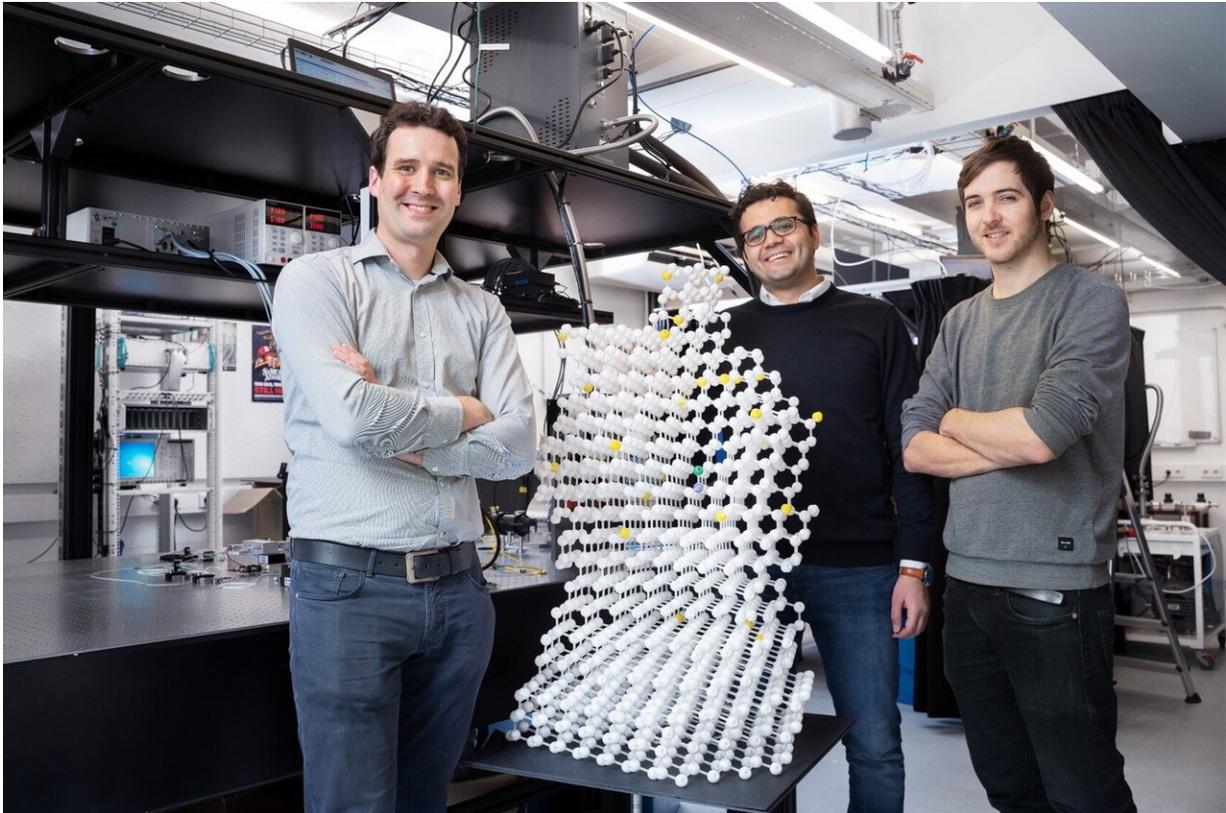


# Researchers report MRI on the atomic scale

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Tim Taminiau (l), Mohamed Abobeih and Joe Randall (r) in the lab with a 3D model of the spins in the diamond structure imaged by the novel method (scale 250.000.000 : 1) Credit: Ernst de Groot for QuTech

Researchers at QuTech, a collaboration of TU Delft and TNO, have developed a new magnetic quantum sensing technology that can image samples with atomic-scale resolution. It opens the door towards imaging

individual molecules, like proteins and other complex systems, atom by atom. The team reports on their results in *Nature* on the 18th of December.

Magnetic resonance imaging (MRI) and [nuclear magnetic resonance](#) (NMR) are powerful and widely-used methods in material science, biology, chemistry and medicine. Many [atomic nuclei](#) have a property called spin. Atomic nuclei behave like little magnets that generate tiny magnetic fields, which can be detected using antennas.

Magnetic imaging is non-invasive, can distinguish different types of [atoms](#), and works under a wide range of conditions, including at room temperature. But current methods are limited to averaging over large volumes with large amounts of atoms, and imaging individual molecules or nanoscale structures is not possible. Researchers at QuTech have now made an important advance towards overcoming that limitation.

## Quantum sensors

"Our work is based on the nitrogen vacancy (NV) center," said first author Mohamed Abobeih. "This NV center occurs naturally in diamond: two carbon atoms are replaced by a single nitrogen atom. The center traps a single electron spin that can function as an atomic-sized sensor. By precisely manipulating this electron we can selectively pick up the tiny magnetic fields created by nuclei in the vicinity."

"At QuTech we generally use these NV centers as quantum bits, the building blocks for future quantum computers and the quantum internet. But the same properties that make NV centers good quantum bits, also make them good quantum sensors," said Tim Taminiau, lead investigator.

## **3-D imaging**

Taminiau explained that his team built on previous research observing well-isolated nuclear spins. "These earlier studies indicated that the NV center is sensitive enough to resolve the tiny signals of individual nuclei. But for imaging complex samples such as molecules, just detecting nuclear spins is not enough," explained Taminiau. "You need to precisely determine the position of each spin in the sample, and that is what we set out to do."

"We developed a method to obtain the 3-D structure of complex spin systems," said co-author Joe Randall. "Each nuclear spin feels the magnetic field from all the other nuclear spins. These interactions depend on the precise positions of the atoms and therefore encode the spatial structure. For example, two atoms that are closer to each other tend to interact more strongly. We developed methods to precisely measure these interactions and to transform them into a complete 3-D image with atomic resolution."

## **Atomic-scale resolution**

To test their method, the researchers applied it to a cluster of 27 carbon-13 atoms in a highly pure diamond. This cluster of spins provides a model system for a molecule. After measuring more than 150 interactions between the nuclei and running an intense numerical reconstruction algorithm, the complete 3-D structure was obtained with a spatial precision much smaller than the size of an atom.

## **Sensing outside the diamond**

The next step is to detect samples outside of the diamond by bringing NV centers close to the surface. The ultimate goal is to be able to image

individual molecules, such as proteins, and single quantum devices with atomic resolution.

The publication in *Nature* is a collaboration of QuTech and Element Six, which grew the ultrapure diamonds used in the research.

**More information:** M. H. Aboeih et al. Atomic-scale imaging of a 27-nuclear-spin cluster using a quantum sensor, *Nature* (2019). [DOI: 10.1038/s41586-019-1834-7](https://doi.org/10.1038/s41586-019-1834-7)

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