First theoretical proof: Measurement of a single nuclear spin in biological samples

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Physicists of the University of Basel and the Swiss Nanoscience Institute were able to show for the first time that the nuclear spins of single molecules can be detected with the help of magnetic particles at room temperature. In *Nature Nanotechnology*, the researchers describe a novel experimental setup with which the tiny magnetic fields of the nuclear spins of single biomolecules - undetectable so far - could be registered for the first time. The proposed concept would improve medical diagnostics as well as analyses of biological and chemical samples in a decisive step forward.

The measurement of nuclear spins is routine by now in medical diagnostics (MRI). However, the currently existing devices need billions of atoms for the analysis and thus are not useful for many small-scale applications. Over many decades, scientists worldwide have thus engaged in an intense search for alternative methods, which would improve the sensitivity of the measurement techniques.

With the help of various types of sensors (SQUID- and Hall-sensors) and with magnetic resonance force microscopes, it has become possible to detect spins of single electrons and achieve structural resolution at the nanoscale. However, the detection of single nuclear spins of complex biological samples - the holy grail in the field - has not been possible so far.

Diamond crystals with tiny defects

The researchers from Basel now investigate the application of sensors made out of diamonds that host tiny defects in their crystal structure. In the crystal lattice of the diamond a Carbon atom is replaced by a Nitrogen atom, with a vacant site next to it. These so-called Nitrogen-Vacancy (NV) centers generate spins, which are ideally suited for detection of magnetic fields. At room temperature, researchers have shown experimentally in many labs before that with such NV centers resolution of single molecules is possible. However, this requires atomistically close distances between sensor and sample, which is not possible for biological material.

A tiny ferromagnetic particle, placed between sample and NV center, can solve this problem. Indeed, if the nuclear spin of the sample is driven at a specific resonance frequency, the resonance of the ferromagnetic particle changes. With the help of an NV center that is in close proximity of the magnetic particle, the scientists can then detect this modified resonance.

Measuring technology breakthrough?

The theoretical analysis and experimental techniques of the researchers in the teams of Prof. Daniel Loss and Prof. Patrick Maletinsky have shown that the use of such ferromagnetic particles can lead to a ten-thousand-fold amplification of the magnetic field of nuclear spins. "I am confident that our concept will soon be implemented in real systems and will lead to a breakthrough in metrology," comments Daniel Loss the recent publication, where the first author Dr. Luka Trifunovic, postdoc in the Loss team, made essential contributions and which was performed in collaboration with colleagues from the JARA Institute for Quantum Information (Aachen, Germany) and the Harvard University (Cambridge).

More information: Luka Trifunovic, Fabio L. Pedrocchi, Silas Hoffman, Patrick Maletinsky, Amir Yacoby, and Daniel Loss , High-efficiency resonant amplification of weak magnetic fields for single spin magnetometry at room temperature , *Nature Nanotechnology* (2015), DOI: 10.1038/nnano.2015.74

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