Website address:
https://www.gesundheitsindustrie-bw.de/en/article/press-release/mit-diamant-sensoren-neurale-exoskelette-praeziser-steuern

Controlling neural exoskeletons more precisely with diamond sensors

Brain-computer interfaces are able to restore some mobility to paralyzed people by controlling exoskeletons. However, more complex control signals cannot yet be read from the head surface because conventional sensors are not sensitive enough. A collaboration of Fraunhofer IAF, Charité – Universitätsmedizin Berlin, University of Stuttgart and other industrial partners has taken up this challenge: In the recently launched NeuroQ lighthouse project, the project partners develop highly sensitive diamond-based quantum sensors that will enable paralyzed people to control neural exoskeletons more precisely.

For people who cannot move their hands or legs due to, for example, a spinal cord injury, a stroke or other diseases, so-called brain-computer interfaces (BCIs) offer great hope: They allow a device to be controlled by brain activity alone — for example, an exoskeleton can be operated solely by imagining a motion. Thus, BCIs offer paralyzed people the chance to regain control over some of their movement.

BCIs, which measure brain activity from the surface of the head, have the advantage of sparing patients a complicated and risky brain surgery. "We have already developed a non-invasive BCI system that enables people with high paraplegia to grasp everyday objects by means of arbitrary changes in their brain waves," reports Prof. Dr. Surjo Soekadar, Professor for Clinical Neurotechnology at the Charité, adding: "However, despite the considerable progress made, it has not yet been possible to control complex hand movements with such a non-invasive system." Thus, although the intention to move can be detected, it is not possible to determine exactly which movement is to be executed. To achieve this, the sensitivity of the sensors would have to be increased considerably.

Quantum sensors measure brain waves

Nine partners from research and industry have now taken on this task and launched the project "Laser Threshold Magnetometer for Neural Communication Interfaces", or NeuroQ for short. In this project, which is funded by the German Federal Ministry of Education and Research (BMBF), the project partners develop quantum sensors that are so sensitive that they can measure the smallest magnetic fields generated by brain waves. These quantum magnetometers will be integrated into a BCI system, enabling paralyzed people to control a hand exoskeleton much more precisely than it is currently the case.

Magnetic fields provide more distinct signals

In non-invasive BCIs, the measurement of neuronal activity has so far mainly been performed via electric fields. However, the measurement of magnetic fields offers considerable advantages: "Magnetic fields penetrate the skin and skull undistorted and thus provide much more distinct signals than electric fields, since these are strongly attenuated on the way from the source to the sensor. Hence, magnetoencephalography (MEG) has significant advantages over electroencephalography (EEG), but is rarely used due to technical obstacles," explains Dr. Jan Jeske, project leader of NeuroQ and researcher at Fraunhofer IAF.

The technical obstacles of MEGs are related to the used sensor technologies: SQUID sensors (superconducting quantum interference devices) are highly accurate, but require cryogenic cooling, which makes their use extremely expensive and complex. Optically pumped magnetometers (OPMs) based on vapor cells even surpass the sensitivity of SQUIDs, but work only in the a zero-field environment — this means that any background magnetic field (including the earth's magnetic field) must be completely shielded for their operation, and comes along with an enormous amount of construction effort.

"So far, no magnetometers have been realized that achieve a sensitivity under environmental conditions — i.e., in unshielded environments — that would be suitable for the detection of neuromagnetic fields. The aim of NeuroQ significantly exceeds the state of the art," summarizes Prof. Dr. Jörg Wrachtrup, Head of the 3rd Physics Institute at the University of Stuttgart.

Diamond-based sensor allows use in everyday environment

The outstanding feature of the quantum magnetometers developed in the NeuroQ project is their starting material. They are based on NV (nitrogen-vacancy) centers in diamond and thus have unique properties: Diamond quantum magnetometers are the only highly sensitive magnetometers that operate at room or body temperature. They can also be operated in the presence of a background magnetic field and enable the determination of the exact direction of a magnetic field (i.e., all three components of the vector). In addition, they are biocompatible and can be brought close to the signal source, which in turn leads to stronger signals.
All this leads to the fact that, diamond quantum magnetometers could be used in clinics, medical practices, rehabilitation environments, but also at home and in everyday life to significantly improve the quality of life of paralyzed people and to make an important contribution to their social inclusion.

Multidisciplinary collaborative project

Since the diamond magnetometers developed so far do not yet achieve the required sensitivity, new highly sensitive quantum magnetometers based on a novel NV diamond laser will first be realized within the framework of NeuroQ. With the required communication interface, the measurement system will be further developed into a BCI system and used for demonstration, evaluation and further development in the clinical environment at the Charité in Berlin.

The start-ups and small and medium-sized enterprises (SME) involved contribute significantly not only to the development but also to the subsequent exploitation of the technology, thus promoting the transfer of the results into marketable products and applications.

The BMBF is funding the five-year collaborative project as part of the measure "Lighthouse projects in quantum-based metrology to address societal challenges" with a total of almost 9 million euros.

The project partners at a glance:

- Fraunhofer Institute for Applied Solid State Physics IAF
- Charité – Universitätsmedizin Berlin
- University of Stuttgart
- Twenty-One Semiconductors
- Sacher Lasertechnik GmbH
- Advanced Quantum GmbH
- W+R Schirmungstechnik GmbH
- neuroConn GmbH
- NIRx Medizintechnik GmbH

Press release

24-Jan-2023
Source: Fraunhofer Institute for Applied Solid State Physics IAF

Further information

Jennifer Funk
Editor
Tullastraße 72
79108 Freiburg
Tel.: +49 (0)761 5159 418

- Fraunhofer Institute for Applied Solid State Physics IAF