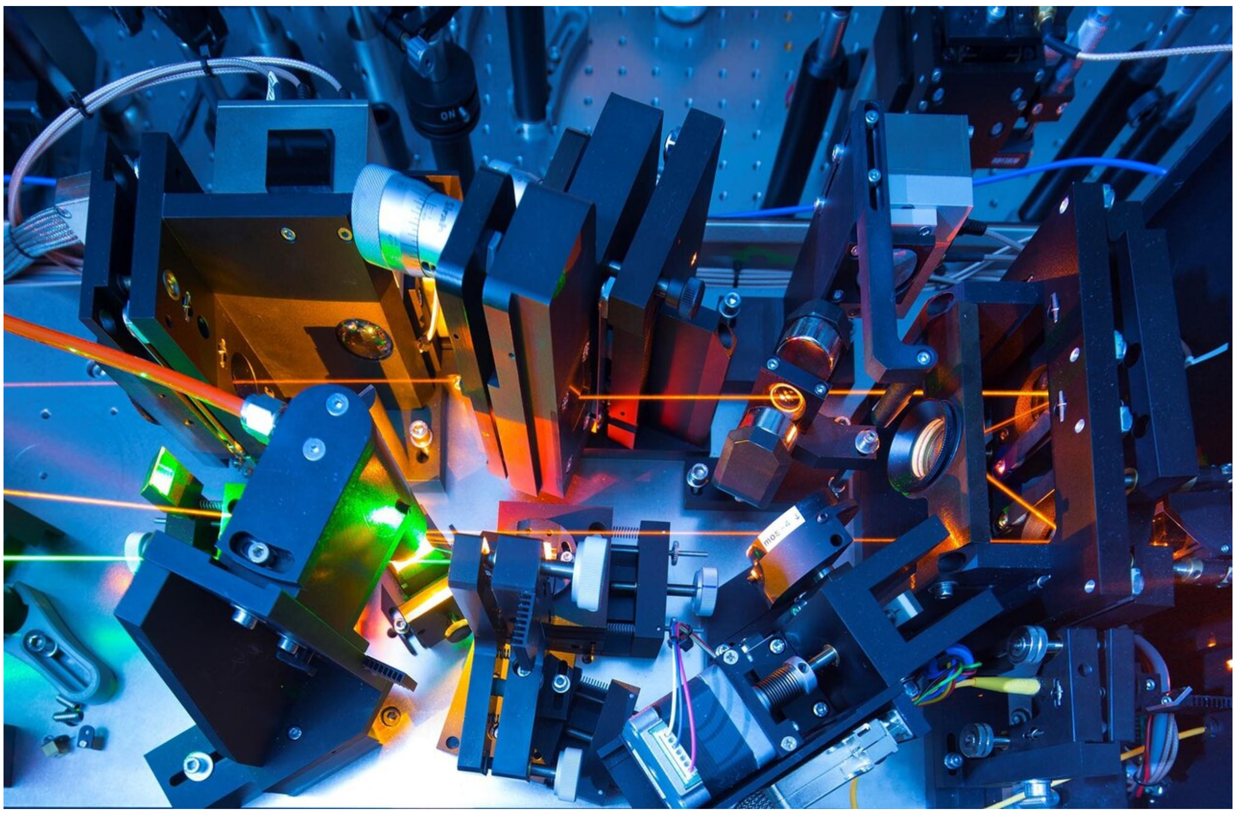
How quantum technology could revolutionise the detection and treatment of diseases

June 24 2019, by Jonathan O'callaghan, From Horizon Magazine



Quantum sensors could transform a range of areas from atomic clocks and the way we measure electromagnetic radiation. Image credit - Heiko Grandel for the institute of quantum optics from Ulm. Credit: Universität Ulm / Heiko Grandel

When you hear the word 'quantum," you may imagine physicists working on a new ground breaking theory. Or perhaps you've read about quantum computers and how they might change the world. But one lesser-known field is also starting to reap the benefits of the quantum realm—medicine.

As part of the EU's Quantum Technologies Flagship program, a number of quantum technologies are being developed in Europe to transform a variety of fields. Medicine in particular looks set to gain, with several projects now underway to see how we could improve medical imaging or detect certain diseases more easily.

One of those projects is macQsimal, which is using small devices known as quantum sensors to revolutionise several areas—quantum-enabled atomic clocks, gyroscopes, magnetometers, and more precise electromagnetic radiation and gas concentration measurements. The project, which began in October 2018, hopes to bring their ideas to market as some of the first quantum-enabled technologies.

"The goal is to put products as prototypes on the market," said Dr. Jacques Haesler from the Swiss Centre for Electronics and Microtechnology (CSEM), the project coordinator for macQsimal. "At the end, (we want to) be able to take further steps then commercialise these devices. But we also have to think about the next generation of quantum sensors, which will use more fancy quantum effects like entanglement or the superposition of states."

Quantum sensors

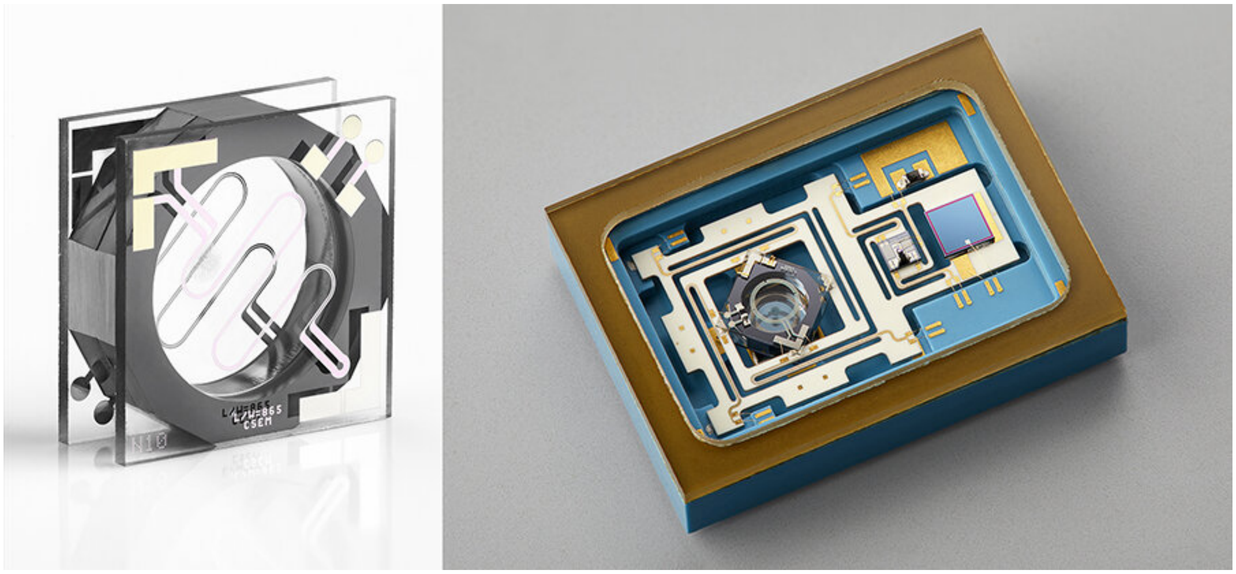
A quantum sensor is essentially a very small device, perhaps the size of a sugar cube, that can make very precise measurements using the known strangeness of the quantum world. Here, particles are linked as one over great distances, known as entanglement, or even appear in two places at once, known as superposition.

This could be particularly useful in things like brain imaging. Currently, Magnetoencephalography (MEG) scanners rely on bulky equipment that must be cooled by liquid nitrogen or liquid helium. As a result, the machines are not only large, but they cannot go near a person's skull to measure brain activity—instead measuring from afar with the help of sensors.

"The goal is to replace these instruments with a kind of helmet on which you could put all the sensors, which you can put on the skull, so you can improve the accuracy of the measurement," said Dr. Haesler. "You can then make a helmet with hundreds of sensors. So then you can measure at hundreds of different points on the skull where the magnetic field is coming from."

The macQsimal project hopes to prove this can work using the magnetometers it is developing. By drastically shrinking the size of the equipment, it could be possible to much more easily detect diseases in a person's brain. The hope is that within five years, the technology they are developing could be used commercially.

There may be other benefits as well, such as cardiac imaging—taking images of the heart to check for diseases—which could benefit greatly from these smaller and more accurate sensors, and drug discovery too—finding new drugs to address certain diseases. "Most probably there are much more applications in the medical field," added Dr. Haesler.



New quantum sensors will use more sophisticated quantum effects like entanglement. Credit: Fraunhofer Institute for Applied Solid State Physics

Hyperpolarisation

By investigating a quantum technique called hyperpolarisation, other researchers want to see if MRI scanners can be made to be much more sensitive and accurate than they are now. This is the aim of a project called MetaboliQS project, also started in October 2018.

"We are basically trying to make MRI maybe a factor of 10,000 more sensitive," said Dr. Christoph Nebel from the Fraunhofer Institute for Applied Solid State Physics in Germany, the project coordinator. "Using the hyperpolarisation of biomolecules, which are injected, these molecules are tuned to accumulate in certain tissue. And if they accumulate, the MRI can easier detect what's going on."

Hyperpolarised MRI involves taking images by looking at the minute physics of cells and molecules to see what's going on inside our body. This is done by using selective biomarker molecules, which at the moment need to be cooled to -270°C and then warmed up to body temperature. This process not only takes a long time—at least 30 minutes—it is also extremely costly.

But using quantum sensors made with diamonds, the MetaboliQS team think they can conduct the whole process with mild cooling or at room temperature with no cooling at all. This could allow MRI machines to more easily observe time-sensitive effects in the body such as cancerous tissue, and also take more detailed images.

"When you improve the images you see more details, you can distinguish between early stage illness or later stage, or dead tissue," said Dr. Nebel. "To have better images means you make your medical understanding much better."

This could open up new avenues for MRI scanners too, such as research into implants or understanding how illnesses develop in the human body. And if successful, MRI imaging could be one of the first health areas to benefit from quantum techniques as early as 2020. "Hyperpolarisation is definitely something which may be the first real (medical) application of quantum technology," said Dr. Nebel.

Health conditions

If these projects are successful, the range of conditions they could address are vast. Dr. Haesler notes that dementia and Alzheimer's could both be diagnosed more easily with the help of more accurate MRI scanners. And heart and brain imaging would benefit, allowing for other issues to be seen with finer detail.

"With these quantum sensors we are currently developing, you can detect new neuron activity quite nicely," said Dr. Nebel. "We can basically investigate very small molecules, biosystems. This is basically MRI on a nanoscale."

The next steps now will be bringing these products to market, and proving they can be commercialised. And with the help of the EU's quantum flagship program, it's hoped that technologies like these could be the start of an exciting new quantum era that has a direct impact on our lives.

And that's not just within the realms of medicine. The program is also looking at ways to develop better atomic clocks and other devices that could improve, for example, how we use our mobile phone networks. But it is the medical applications that will likely arrive first, with vital implications for our health.

"In five years, we think that the atomic clock and the magnetometer should enter the market," said Dr. Haesler. "We are also working on the second generation of sensors, which are more sensitive, and may enter the market in 15 to 20 years."

Provided by Horizon: The EU Research & Innovation Magazine