Quantum technology: iSensing the underworld

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Professor Kai Bongs

“While understanding the rules of the abstract part of physics called ‘quantum mechanics’ occupied the 20th century, harnessing its power for applications will be a dominant theme of the 21st century. Making the earth beneath our feet transparent is the latest example of utilising the strange properties of the microscopic quantum world to provide such a ‘Quantum Technology’.

The most down-to-earth application concerns the 4 million holes dug in UK roads every year. Only around 30 per cent of the buried infrastructure is known beforehand, making the task much slower (due to the care needed) with consequent delays to traffic. Quantum ‘gravimeters’ will revolutionise this business, especially with the moist soil conditions typical of the UK.

In general, a Quantum Technology makes use of the counterintuitive consequences of quantum mechanics – the principal theory explaining our world on a microscopic scale. One of these consequences is that a single object can be in several different places (or in several different ‘states’) at the same time. In the quantum world, a person could pass a tree simultaneously on the right and the left side, or be wearing business clothes and beach attire simultaneously.

For example, in our everyday experience the force we feel due to gravity appears to be the same anywhere on Earth. A precision quantum gravity sensor picks up variations, by letting single atoms explore different paths in the gravitational field of the Earth. From those differences one can infer what lies beneath the Earth’s surface.

So far there are only two commercially viable quantum technologies: quantum cryptography and quantum sensors. Quantum cryptography systems are well established in the market, eg, for secure communications between banks, while quantum sensors are just becoming commercially available.

Gravity sensors will be the first in this new industrial revolution, with remarkably diverse applications. The University of Birmingham led EU iSENSE and EPSRC GG-TOP projects are leading the way in providing the means to enhance oil and mineral exploration, find water resources, drive climate research and to map urban infrastructure and archaeology. These collaborations encompass all the European work in this area, with pioneering involvement of engineers and archeologists (both of these last groups are at the University of Birmingham).

There are many more applications of the quantum gravity sensors. Helping determine the spatial extent of aquifers that have run dry – by the change in gravity due to the water being pumped out, or the equivalent processes in oil and gas recovery (where unrecovered pockets of oil and gas can represent considerable residual value) are other big applications.

More academically, climate change science (snow cover of mountains and magnitude of ocean currents) and archeology (‘seeing’ without digging) will benefit greatly.

This panorama of applications has been hailed by Neelie Kroes (Vice-President of the EU, with responsibility for the Digital Agenda) as the ‘coolest thing’ at the 2013 EU Information and Communication Technologies meeting this week in Vilnius. This area, which brings together the oldest part of physics, gravity, with one of the most recent, ultracold quantum atomic gases, shows the capacity of scientific research driven by curiosity to have large and unexpected dividends."