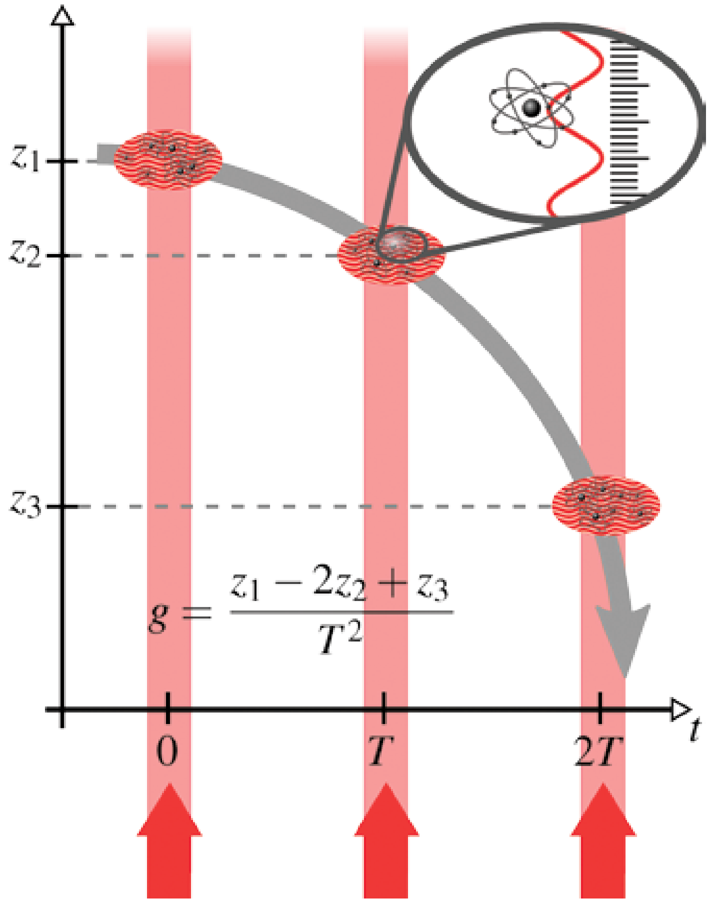
Quantum leaps

GG-TOP's development of quantum technologies for oil and gas



NEW gravity gradient technologies are having a major impact in the geodesy field and are emerging as a powerful geophysical mapping tool for oil and mineral exploration. (See: "Gravity of the situation," InnovOil Issue 3, October 2012, page 9)

Gravity gradient sensing looks at how gravity changes with height. It is attractive to operators in that it is a passive technology. It reacts directly to density contrast in the ground, with the signal being unperturbed as it penetrates material at long ranges.

This characteristic lends itself to a wide range of applications, including airborne reservoir mapping, monitoring of CO2 sequestration sites and enhanced reservoir recovery. However, although very successful in airborne geomapping, the technology that is currently available is not achieving the full potential of gravity gradient opportunities.

It is too large, heavy, relatively difficult to operate and can run foul of US export controls on a number of countries. Atom interferometry – a technology based on the quantum interpretation of atoms as matter waves – has some exciting features that promise to overcome current limitations.

Atom interferometric sensors are essentially drift-free, promise ten to one hundred times higher sensitivity than current technology at less cost and have the potential to be shrunk to borehole size in the future.

GG-TOP

It is at this juncture that the Engineering and Physical Sciences Research Council (EPSRC)-funded project GG-TOP emerges as an important innovator in the field.

GG-TOP has been set up to develop new atom interferometric technology in collaboration with physicists and engineers at the Universities of Birmingham and Aberdeen.

The basic idea of atom interferometric gravity gradient sensors is simple: they measure the trajectories of two vertically separated ensembles of atoms under the influence of gravity using a laser ruler. The gravity gradient will show up in tiny differences in how the two ensembles drop: a density anomaly in the ground will attract the lower ensemble more than the higher one, leading to the lower ensemble to drop faster.

The key to high sensitivity lies in the exploitation of quantum features of the atomic probe particles. In quantum mechanics these are described by matter waves that can interfere similar to the interference of the waves created by dropping two stones in a pool of water. During the measurement two nearly resting atomic ensembles are first prepared in a small vacuum chamber using the laser cooling technology that led to the Nobel Prize in Physics in 1997. These ensembles are then dropped and during their free fall in the gravity field are subjected to three consecutive laser pulses, spaced equally in time. These pulses are tailored to encode the position of the atom at the time of the pulse into the phase of its matter wave function. This is done in such a way as to generate a small quantum calculation that yields the second derivative of the trajectory, which is directly proportional to gravity. The difference between the results for the two vertically separated ensembles results in the gravity gradient output of the sensor.

Special features

The special features of this quantum technology are threefold.

First, using atoms, the probe particles are made always the same by Nature without any manufacturing tolerances.

Secondly, using the same laser ruler for both ensembles ensures an ideal cancellation of common-mode accelerations, one of the key issues in alternative technologies. This greatly eases the use on moving platforms.

Thirdly, the measurement can be linked to the frequency defined by atomic transitions, making the technology drift-free. This could enable comparative long-term measurements, for example to assess reservoir recovery or traceable monitoring of CO2 sequestration sites.

The innovative nature of atom interferometric quantum technology opens new opportunities for the oil and gas industry. The unique selling point lies in the flexibility to adapt this technology to the needs of diverse applications.

Although current research pursues backpack sized sensors with a weight of 20 kg and a power consumption of 50 Watts, the use of the same laser technology as in CD-ROM drives in combination with integrated optics, electronics and vacuum solutions opens a straightforward development route to smaller and fully customised sensors.

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