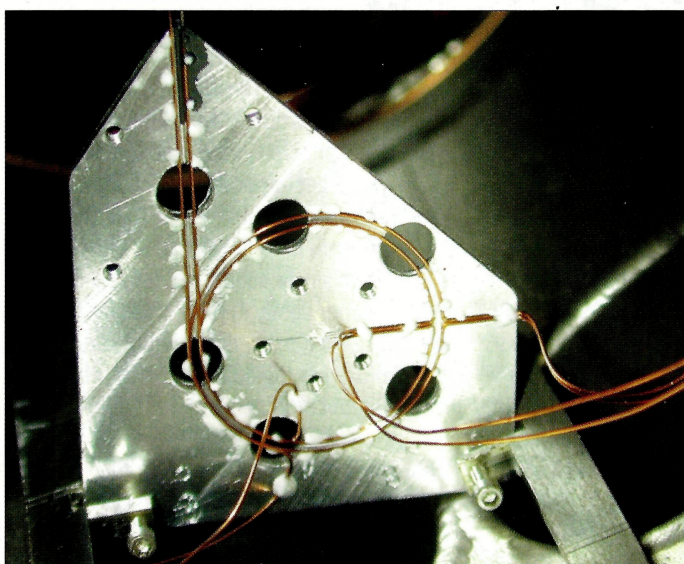


Edited by Archana Sharma

Georgia Tech builds the world's smallest neutral-atom storage ring

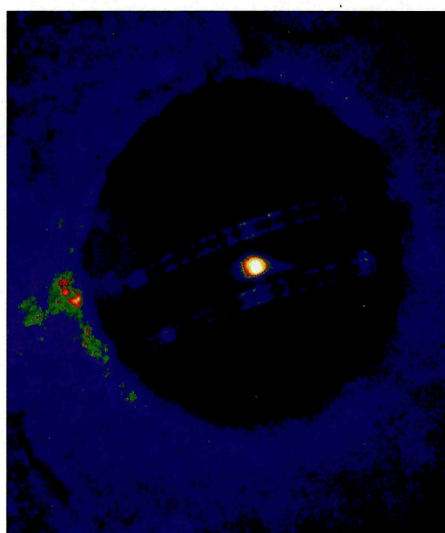


Familiar geometry, different scale: Georgia Tech's Nevatron (left) measures just 2 cm across. Fermilab's Tevatron (right, back), which is more familiar to CERN Courier readers, has a circumference of nearly 6.5 km. (Georgia Institute of Technology; Fermilab Visual Media Services.)

Researchers at the Georgia Institute of Technology have demonstrated the first storage ring that is able to confine and guide the flow of ultracold neutral atoms in a circular path. Called the nano-electron-volt neutral-atom storage ring (Nevatron) the ring measures just 2 cm across.

In general, storage rings not only store particles but also serve to define an energy and trajectory in so far as the particles are guided round a prescribed track by some kind of magnet system. Particles with the wrong energy would fly away. Normally the ring's magnets exert themselves by acting on the particles' electric charge. Neutral atoms do not have a net charge but they can possess a net dipole moment that, if the atom is moving slowly enough, is sufficient for guidance. The Nevatron is a circular waveguide that uses magnetic fields from tiny electrical wires to direct low-energy atoms.

In contrast with high-energy particle storage rings, in which the goal is to increase the energy of the confined particles up to and beyond the tera-electron-volt scale, the researchers at Georgia Tech are interested in the opposite – using ultracold atoms with



Cold storage: the bright spot in the centre of this false-colour image shows rubidium atoms between the Nevatron's guide wires 840 μm apart.

nano-electron-volt energies. Their experiment takes place within a vacuum chamber. First, a standard magneto-optical trap uses a combination of magnetic fields and intense laser beams to confine a few million atoms of

rubidium while reducing their speed to a crawl – less than 10 cm/s.

When the atoms in the trap reach the appropriate temperature – about 3 μK – the magnetic fields and laser beams confining them are switched off. That allows the cold atoms to flow by gravity into a “funnel” made up of two current-carrying wires about 1 mm apart. The funnel guides the atoms into the storage ring where they are confined by magnetic fields created by parallel wires, each of which carries a few amps of electric current.

So far, swarms of 1 million rubidium atoms have made as many as seven circuits around the ring, moving at speeds of 1 m/s. It is early days yet, but the ultimate goal of the Georgia Tech team is to do for uncharged atoms what optical fibre has done for light. In one potential application, the 2 cm storage ring could serve as the foundation for a miniaturized atom interferometer that would improve the accuracy of inertial guidance systems used in commercial aircraft.

Reference

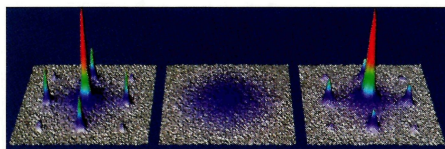
J A Sauer *et al.* 2001 *Phys. Rev. Letts.* **87** 270401.

Phase transition behaves as quantum switch

German researchers have created a new type of matter by trapping globules of Bose-Einstein condensate in a regular array of indentations. Bose-Einstein condensates are quantum liquids that exist only at very low temperatures where the thermal motion of atoms is small enough to reveal their wave-like properties. By varying the size of the indentations, the team induced a phase transition.

The researchers started with a vapour of Bose-Einstein condensate consisting of about 100 000 rubidium atoms confined to a small volume by a magnetic field and cooled to a few billionths of a degree above absolute zero. All of the atoms in a Bose-Einstein condensate are coherent, acting like a single giant particle. Consequently, the vapour becomes a superfluid. If it moves, it does so en masse. Superfluids have no viscosity because one atom cannot be slowed down without slowing down all of them.

The superfluid was then placed in an opti-



Quantum switch: a phase transition induced in a Bose-Einstein condensate. (Max Planck Institute for Quantum Optics.)

cal lattice made up of the interference pattern between several laser beams. The atoms moved easily around the lattice's 150 000 valleys. However, as the lattice was made more intense – with deeper valleys and higher peaks – there came a point at which the fluid became stuck – it ceased to be a superfluid and the localized blobs of rubidium vapour were no longer coherent with one another. This trapped state is called a Mott insulator after the British physicist Neville Mott who first observed a similar effect in semiconductors in the 1960s. Reducing the strength of the

optical lattice led to the reappearance of the Bose-Einstein condensate, demonstrating that the transition is reversible.

The sharp change between a coherent condensate and a non-coherent Mott insulator state is loosely analogous to the way a magnet can become non-magnetic when heated, but heat plays no part in the change in the quantum fluid. That is driven by Heisenberg's uncertainty principle, which stipulates that when atoms get trapped in particular valleys, they must lose their coherence. Their wave-like quantum state is no longer like the rippling surface of a single ocean. Instead it is like many independently rippling little lakes. The ability to switch between quantum states in this way is a key ingredient of many proposals for quantum computers.

Reference

M Greiner, O Mandel, T Esslinger, T W Hansch and I Bloch 2002 *Nature* **415** 39–44.

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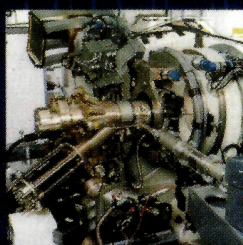
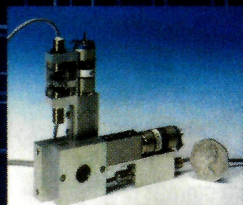
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