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Floating femtodroplets

6 September 2004

Physicists have built a magnetic-levitation device that can control the forces on tiny particles and droplets of liquid with much greater precision than existing methods. Igor Lyuksyutov and colleagues at Texas A&M University in the US say their technique could be used for both basic research and a range of applications (*Appl. Phys. Lett.* to be published).

Magnetic levitation occurs when the force on a diamagnetic object -- an object that is slightly repelled by a magnet -- is strong enough to balance the weight of the object. In the past, physicists have levitated a wide range of diamagnetic objects, including frogs, with powerful magnets. Lyuksyutov and colleagues have now extended this approach to much smaller objects by developing micron-sized magnetic traps.

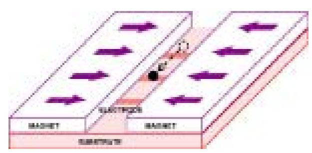

Figure 1

The new device consists of two permanent magnets, 250 microns high and 10 millimetres across, separated from each other by about 80 microns and mounted on a steel plate (figure 1). The device creates a region of low magnetic field (the trap) surrounded by a region of high magnetic field. Since the energy of a diamagnetic object is proportional to the magnetic field energy density, it is energetically more favourable for the object to stay in the low field region. The force on the object is proportional to the gradient of the energy density, which is high because the energy density changes over very short distances.

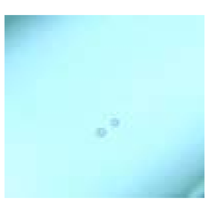

Figure 2

Liquid droplets are injected into the device from an atomiser and observed with an optical microscope. The Texas physicists found they could move, rotate or even merge droplets by applying electric or magnetic fields, and that they were able to control the potential energy of a droplet on the sub-zeptojoule (10^{-21} J) scale. Moreover, the force could be controlled with sub-femtonewton (10^{-15} N) resolution, which is about two orders of magnitude better than can be achieved with optical tweezers. The floating particles can also be positioned to within an accuracy of 300 nanometres (figure 2).

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The apparatus could be used to levitate droplets of almost any non-paramagnetic substance and provides a completely new path to making labs-on-a-chip, says Lyuksyutov. "Femtolitre-sized droplets could be used as 'beakers' located on a magnetic 'bench' in the potential energy minimum," he told *PhysicsWeb*. "These beakers could be moved by pulses of magnetic or electric fields."

The team has already incorporated its chip into a levitation-based microfluidic processor that is capable of manipulating droplets up to a billion times smaller than in conventional microfluidic devices. The processor could be used to analyse droplets containing a variety of fluids, including biological cells, bacteria and viruses. Other applications include new types of micro- and nano-electromechanical systems, and experiments with aerosols and colloids.

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