the CCD; in other words, the image would contain information on the polarization-rotating characteristic of the specimen.

The scanning microscopes described above could be used as building blocks for a multicolor, multipolarization microscope. In the example shown in the figure, six scanning microscopes would be assembled on a single translation stage. The microchannels would be interspersed with light sources that would comprise light-emitting diodes (LEDs) coupled to the beam splitters via prismlike light guides.

This work was done by Yu Wang of Caltech for NASA's Jet Propulsion Laboratory.

Further information is contained in a TSP (see page 1).

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL. Refer to NPO-20821.

Manipulating Neutral Atoms in Chip-Based Magnetic Traps

Magnetic-field gradients are used to accelerate and decelerate atoms.

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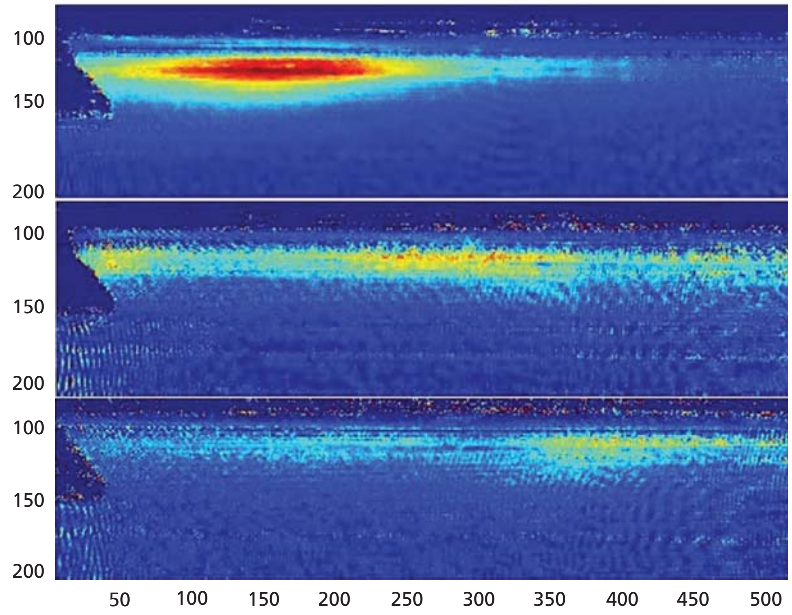
Several techniques for manipulating neutral atoms (more precisely, ultracold clouds of neutral atoms) in chip-based magnetic traps and atomic waveguides have been demonstrated. Such traps and waveguides are promising components of future quantum sensors that would offer sensitivities much greater than those of conventional sensors. Potential applications include gyroscopy and basic research in physical phenomena that involve gravitational and/or electromagnetic fields. The developed techniques make it possible to control atoms with greater versatility and dexterity than were previously possible and, hence, can be expected to contribute to the value of chip-based magnetic traps and atomic waveguides.

The basic principle of these techniques is to control gradient magnetic fields with suitable timing so as to alter a trap to exert position-, velocity-, and/or time-dependent forces on atoms in the trap to obtain desired effects (see figure). The trap magnetic fields are generated by controlled electric currents flowing in both macroscopic off-chip electromagnet coils and microscopic wires on the surface of the chip.



A **Cold Cloud of ^{87}Rb Atoms** is manipulated in an atomic waveguide by use of controlled gradient magnetic fields. This sequence of images shows the cloud moving rightward toward a potential barrier, then splitting into a part that passes through the barrier and a part reflected leftward from the barrier. The numbers on the axes are coordinates in units of 8-μm pixels.

The methods are best explained in terms of examples. Rather than simply allowing atoms to expand freely into an atomic waveguide, one can give them a controllable push by switching on an externally generated or a chip-based gradient magnetic field. This push can increase the speed of the atoms, typically from about 5 to about 20 cm/s. Applying a non-linear magnetic-field gradient exerts different forces on atoms in different positions — a phenomenon that one can exploit by introducing a delay between releasing atoms into the waveguide and turning on the magnetic field.

Before the magnetic field is turned on, the fastest atoms move away from the region where the gradient will be the strongest, while the slower atoms lag behind, remaining in that region for a while. Hence, once the magnetic field is turned on, it can be expected to push the slower atoms harder than it will push the faster atoms. By controlling the amplitude and delay of the gradient, one can tailor the push so as to cause the slower atoms to catch up with the faster ones at a chosen location along the waveguide, thereby effectively focusing the atoms (in other words, greatly increasing the density of the cloud of atoms) at that location. Of course, in addition, the acceleration of the slower atoms effectively raises the temperature of the cloud of atoms. In a proposed variant of this accelerating-and-focusing technique, the gradient would be suitably repositioned along the waveguide and its amplitude and timing suitably altered, so as to preferentially decelerate the faster atoms, thereby effectively cooling the cloud of atoms.

This work was done by David Aveline, Robert Thompson, Nathan Lundblad, Lute Maleki, Nan Yu, and James Kohel of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).
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