Transport of Cold Atoms Near a Surface in a Magnetic Microtrap

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In recent years, there has been spectacular progress in the preparation of degenerate atomic ensembles [1]. To employ these ensembles in applications, there is now a need for devices that can manipulate the atomic de Broglie waves in quantized states of external potentials in a controlled manner. Magnetic microtraps [2, 3] are particularly well suited for such applications. In such a microtrap, the magnetic field gradients are generated by microfabricated wires on a planar substrate. This approach leads to an unprecedented freedom in the design of magnetic potentials. For example, matter waveguides [4], beam splitters or storage rings can easily be constructed with this technique and can be integrated on a single substrate measuring only a few square centimeters. Moreover, extremely large field gradients and curvatures are easily realized with moderate currents on the order of one Ampere.

In our initial experiments [3], we have demonstrated the first magnetic trap of this kind, using a U-shaped microfabricated wire of $300\,\mu$m width to create an elongated quadrupole potential with transverse gradients exceeding 2000 G/cm. One crucial point in these experiments was the loading technique, which involved a modified magneto-optical trap, the "mirror-MOT". More recently, we have also demonstrated integrated Ioffe traps with very high transverse curvatures and a variety of novel trapping potentials.

Here we present some of these recent experimental results, and in particular, the controlled transport of cold atoms parallel to the surface with the "atomic conveyer belt". The magnetic potetial for this device and the wire layout used to create it are shown in figure 1 (a) and (b). The spatial period of the undulating wires is $l = 800\,\mu$m. When time-dependent currents are applied as specified in the figure caption, the minima move to the right with the average speed l/T.

Figure 1 (c) shows a sequence of absorption images which experimentally demonstrates the atomic transport in the pontential of fig. 1 (b). (As the imaging is destructive, the whole sequence of magneto-optic trapping, transfer to the magnetic trap, and magnetic transport is repeated for each picture.) Initially, the two leftmost minima have been populated with atoms from the MOT. During the transport, the two trapped clouds move to the right in accord with the calculated potential.

This device may prove its usefulness in applications such as controlled coupling of trapped atoms to the quantized light field of a high-finesse resonator (e. g., a Fabry-Perot cavity [5] or a silica microsphere [6]). For these and other applications, it is desirable to prepare the atoms in a well-defined vibrational state of the potential. Therefore, we consider evaporative cooling a logical next step for microtrap experiments.

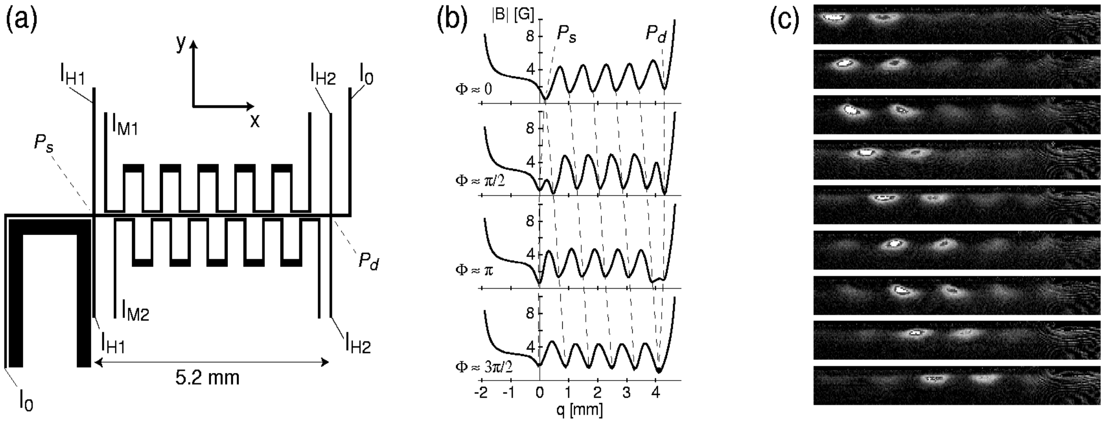

Figure 1: (a) Wire layout for the "atomic conveyer belt". (b) Magnetic potential produced by this layout with a constant field $\vec{B}_0 = 3\,\mathrm{G}\,\vec{e}_\mathrm{x} + 16\,\mathrm{G}\,\vec{e}_\mathrm{y}$ and the following currents: $I_0 = 1.5\,\mathrm{A}$, $I_{\mathrm{M1}} = 0.8\,\mathrm{A}\cos\phi$, $I_{\mathrm{M2}} = 0.8\,\mathrm{A}\sin\phi$, $I_{\mathrm{H1}} = -0.17\,\mathrm{A} + 0.15\,\mathrm{A}\cos\phi$, $I_{\mathrm{H2}} = -0.25\,\mathrm{A} + 0.18\,\mathrm{A}\sin\phi$. (In the experiment the phase is time dependent, $\phi = 2\pi t/T$, with period T). The coordinate q follows the path of transverse (yz plane) minimum for each value of the longitudinal x coordinate. (c) Sequence of absorption images showing the transport of cold trapped atoms in this potential. The probe beam is directed along the y axis (hence, parallel to the substrate surface). The period is $T = 100\,\mathrm{ms}$; for each image, the transport phase is 25 ms longer than for the preceding one.

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