Manipulations of neutral atoms in magnetic micro-traps

J. Estève, C. Aussibal , D. Stevens , I. Bouchoule , C. Westbrook and A. Aspect

Laboratoire Charles Fabry de l'Institut d'Optique, UMR CNRS 8501
Centre Scientifique de l'Université Paris Sud
Bât. 503, 91403, Orsay, France
Tel +33-(0)1-69-35-88-32, Fax +33-(0)1-69-35-87-00
E-mail: christine.aussibal@iota.u-psud.fr, Website: http://atomoptic.iota.u-psud.fr

In most of laser trapping and cooling experiments, magnetic trapping potentials are created by macroscopic structures as coils, permanent magnets, or electromagnets. However, miniaturization allows one to achieve larger trap gradients than with traditional macroscopic structures. We propose manipulations of Rb atoms using the magnetic field of micro-fabricated current carrying conductors, deposited on a surface, sometimes known as an atom-chip.

The trapping field results from high currents circulating in metallic wires with micro-metric dimensions. The wires need to be thick, with low resistance, and well thermally coupled with the substrate. Our micro-fabrication procedure is similar to the one used by the Australian group of P. Hannaford [1]. We use gold wires deposited onto a surface of silicon by optical lithography and electro-deposition. A picture of the section of a wire obtained for typical parameters of fabrication is shown in Fig. 1.

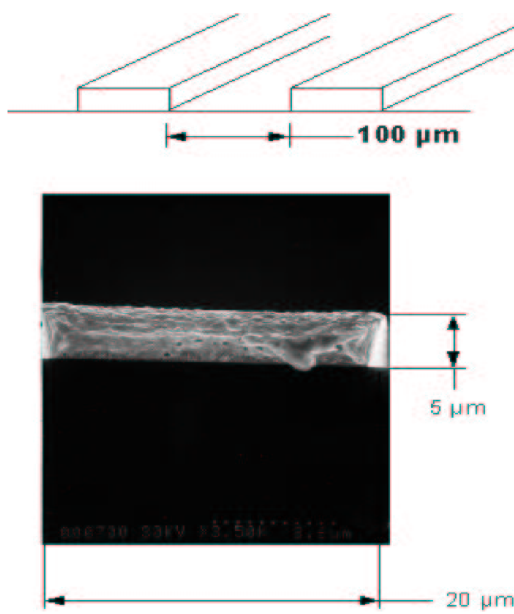

Figure 1: Section of a metallic wire fabricated by optical lithography and electro-deposition

Once fabricated, an insulating layer is first deposited on the circuit pattern and recovered by a layer of gold, which will be used as a reflecting surface. Experimentally, the current density sent through the wires can be up to 10^7A.cm^{-2}, without damaging the wires. Typically, the gradient obtained with 1μm^2 section wires spaced by 10 μm and a current density of 10^7A.cm^{-2} is about 2 10^5G.cm^{-1}.

The trapping field results from superposing the field of a U-shape or Z-shape wire and an external bias field. In the U configuration, a quadrupole trap is formed. With the Z configuration, the trap is of the Ioffe-Pritchard type. A picture of the chip is shown in Fig. 2.

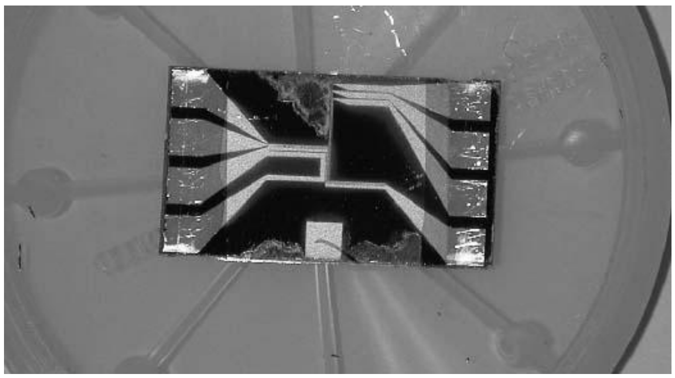

Figure 2: Picture of the atom chip. U-shape wire and Z-shape wires are visible in the center of the chip.

A resistively heated alkali-metal dispenser, mounted close to the trapping region, serves as a compact, pulsed source for Rb atoms. Trapping atoms on the surface of the chip requires three main steps. Atoms are first collected from the background vapor and trapped in a mirror-MOT. The mirror-MOT is a variant of the standard Magneto-Optical-Trap which cools and traps atoms a few millimeters above a surface. During the loading of the MOT, the chip is simply used as a reflecting surface and the trapping potential is created by external quadrupole coils, positioned as shown in Fig. 3.

Then, atoms are shifted close to the surface by unbalancing the currents in the quadrupole coils. The quadrupole field of the MOT coils is switched off and replaced by the quadrupole field of the micro-trap, whose axes coincide with those of the external quadrupole.

The last step consists in loading the Ioffe-Pritchard trap by switching on the current in the Z-shape wire, and switching off the current of the quadrupole micro-trap.

At this stage, the atom cloud is stored onto the surface of the chip and can be manipulated. As the gradient and the position of the trap depend on the currents in the wires and the bias field, the cloud can be subsequently compressed and shifted. Because of the micrometric dimensions of the system, we can achieve much higher gradients than with traditional macroscopic structures. Recently, in a similar experiment, the realization of a Bose-Einstein condensate in miniaturized surface trap was achieved [2][3].

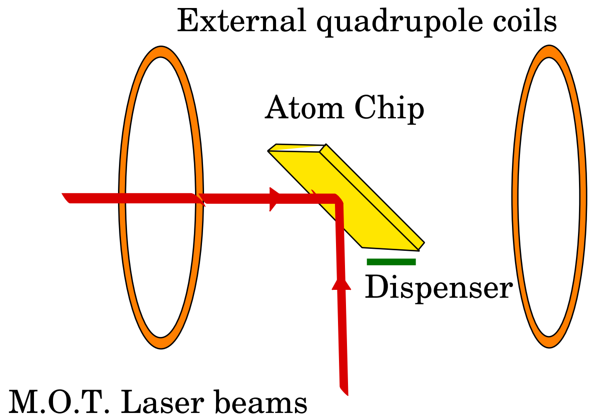

Figure 3: Schematic of the mirror-MOT. The chip is orientated at 45° with respect to gravity. Atoms are trapped below the surface to allow time-of-flight measurement.

Starting from the basic potential configurations described above, more complex configurations can be constructed. We can create a double-well potential and control the height of the potential barrier between the wells. Then, we could split a BEC by increasing adiabatically the potential barrier and observe the behavior of the system with respect to the height of the potential barrier.

Acknowledgments. We thank D. Mailly and G.C. Fainy from L2M for their collaboration and advices in the fabrication of the chips.

[1] D.C. Lau, A.I. Sidorov,G.I. Opat,R.J. McLean, W.J. Rowlands & P. Hannaford,*Eur. Phys. J. D* **5** 193 (1999).

[2] W. Hansël, P. Hommelhoff, T.W. Hänsch & J. Reichel, *Nature* **413** 498 (2001).

[3] H. Ott, J. Fortagh, G. schlotterbeck, A. Grossmann & C. Zimmermann, *Phys. Rev. Lett.* **87** 230401 (2001).