Fabrication of Atom Chips with Femtosecond Laser Ablation

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Abstract: We report on the development of a new microfabrication technique for atom chips which is based on femtosecond laser ablation of thin films and allows the production of arbitrary patterns of microwires. We describe the ablation procedure and present the results of microwire quality analysis, which involves SEM imaging and magnetic field microscopy. We also discuss the designs of magnetic fields above the microwires using particular patterns of wire edges. Simulations of the magnetic fields are compared with the magnetic sensor measurements.

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1 Femtosecond ablation

A femtosecond laser (Spectra Physics, oscillator: Tsunami, regenerative amplifier: Spitfire, pulse duration ca. 150 fs, pulse energy up to 900 nJ, 1 kHz repetition rate) is focused (e^{-2} radius = 0.7 µm) onto a silicon wafer, which is coated with 20 nm SiO_2 and a copper layer with thickness 300 – 500 nm. The copper in the focus is immediately vaporised, with minimal thermal damage to the surrounding copper. The sample is mounted inside a small vacuum chamber to minimise re-deposition of the ablated material. The chamber is attached to a computer controlled 2D translation stage (Newport, 100 nm precision). Femtosecond ablation of metals exhibits a sharp threshold fluence depending on material and thickness [1]. Experimental evidence shows that the threshold for 300 nm thick copper is about 650 mJ/cm^2, corresponding to about 10 nJ pulses in our apparatus.

2 Chip design

Atom chips have recently been used to produce steep magnetic potentials close to surfaces. We have shown that by adiabatically splitting a BEC, the atom number distribution in a double-well potential provides an accurate ($\Delta V/h \approx 1 - 10$ Hz) measure of the potential asymmetry [2]. We have investigated the design of microstructured wire edges to yield an array of symmetric double well potentials that can be used to measure asymmetries induced by gravity, magnetic field gradients or for a new technique to measure the Casimir-Polder Force [3]. Numerical simulations of the magnetic field produced by this design are compared with measurements.

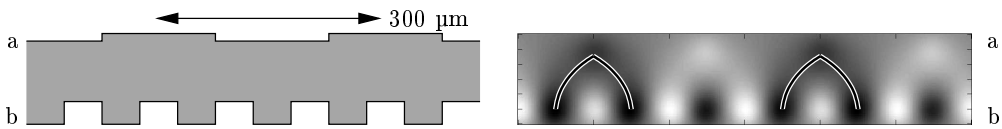

Fig. 1: *Left:* Schematic of a corrugated wire. The steps on the edges are overemphasised; in reality they are 1.4 µm (a) and 5 µm (b) deep. The period on edge (a) is 300 µm, the period on edge (b) 100 µm. The wire has a thickness of 100 µm. *Right:* The corresponding magnetic field component oriented parallel to the wire at a fixed height of 25 µm. Two single wells on side (a) split into a double well each on side (b).

References

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