Atom lithography with 1D and 2D optical masks

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Atom lithography aims at producing smaller structures than the patterns obtained with conventional (optical) lithography. The structures are created in a gold film on a glass or silicon substrate via a two-step process. First, helium atoms in a metastable state locally damage a hydrofobic organic resist layer (a Self-Assembled Monolayer) through a mask. Next, the pattern is transferred to the underlying gold film by means of a wet etching process [1].

The optical mask is made by the interference pattern of a standing light wave. The atoms can be attracted to the high or low intensity regions of the optical mask, depending on the sign of the detuning of the light from an atomic transition. By using various mirror configurations, both 1D and 2D interference patterns can be made, guiding the atoms into lines or dots respectively.

In the experiment, the atoms are guided into the dark regions of the (1D or 2D) standing wave, using far-blue-detuned light with respect to the $2\ ^3S_1 \rightarrow 2\ ^3P_2$ optical transition of the metastable helium atom. This light is provided by a CW fiber laser operating at $\lambda = 1083$ nm and delivering a power of 1.0 W.

Extensive calculations with several theoretical models have been performed to simulate the trajectories of the atoms, subject to the dipole force in the light field. A model that includes the velocity dependence of the dipole force [2] has been used to obtain a better insight in the atomic movement. The simulations have shown that structures on the order of 50 nm should be attainable. The first experimental results obtained with both the 1D and 2D optical masks agree with the calculated feature size.

[1] S. Nowak, T. Pfau and J. Mlynek, *Appl. Phys. B* **63**, 203 (1996).
[2] V.G. Minogin and O.T. Serimaa, *Opt. Comm.* **3**, 373 (1979).