Potential modulation by plasmonic sub-micron structures for the manipulation of ultracold atomic gas clouds

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Exciting emerging directions of plasmonic research include hybrid structures, in which plasmonic structures are combined with different physical concepts. Ultracold atomic gases, or Bose Einstein condensates (BEC), are quantum objects that are largely isolated from their environment. This opens up the possibility e.g. of information storage with relatively long decoherence times in quantum circuits. Such atom clouds may be precisely manipulated on a length scale of optical wavelengths using laser traps or optical lattices. However in order to guide objects around surfaces, bring them into interaction, and miniaturize the setup to approach the goal of single atom manipulation, new paths need to be explored.[1]

Here, the highly localized near-field potentials connected with surface plasmon polaritons offer promising possibilities. By patterning suitable plasmonic circuits, variably shaped surface potential landscapes down to the 10 nm scale can be created. The electric near-field extends up to several 100 nm over planar surfaces, while the reach reduces for smaller structures. If atomic clouds are approached to the surface, they begin to interact with these plasmonic potentials. The realization of a first micro-patterned hybrid plasmonic - Rb BEC device was suggested by the group of C. Zimmermann / S. Slama in Tübingen.[2]

Different plasmonic line structures were fabricated by electron beam lithography on an ultra-flat sapphire substrate. Since the position of the structures could not be detected visually in the setup, a marker system for their in-situ detection was developed as a grid of 20 μm high lines of SU-8 resist.

The sample was mounted in a Kretschmann configuration on a prism in a UHV chamber. With this setup, it was possible to demonstrate a plasmon resonance leading to a significantly increased barrier height for approaching cold atoms over the gold structures, with decreasing barrier heights for smaller structures. When an atomic cloud was approached towards a 500 nm half-pitch gold grating, it was matter-wave diffracted by the periodically modulated potential, see Fig. 1. The diffracted cloud was imaged in absorption images, from which the grating period could be reconstructed.

The lithographic fabrication process for the plasmonic structures and marker system will be presented together with results of the interaction between ultracold rubidium atom gas clouds and plasmonic potentials.

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[1] J.P. Shaffer, Nature Photonics **5**, 451 (2011).

[2] C. Stehle, H. Bender, C. Zimmermann, D.P. Kern, M. Fleischer, and S. Slama, Nature Photonics **5**, 494 (2011).

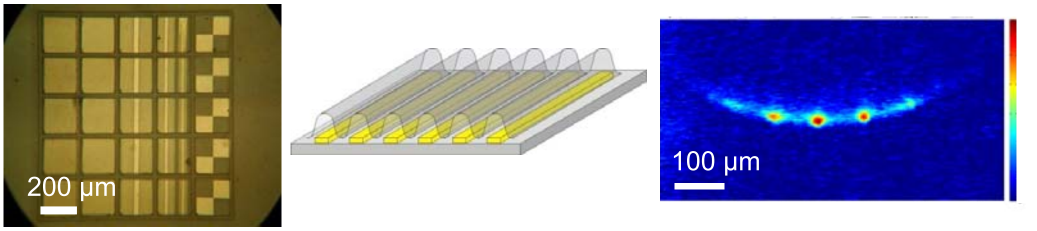

Figure 1: Potential modulation by plasmonic line structures: Left: patterned gold lines and squares in which surface plasmons are launched by a 765 nm laser. Center: Schematic of the potential modulation above the plasmonic line structure (S. Slama). Right: Absorption image of the atomic cloud after matter-wave diffraction by the plasmonic potential landscape.[2]