Integrating light and matter wave optics on Atom Chips

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Scientific and technological progress in the last decades has proven that miniaturization and integration are an important step towards the robust application of fundamental physics. Be it electronics and semiconductor physics in integrated circuits, or optics in micro optical devices and sensors. In this contribution i will describe our effort to achieve the same for miniaturizing and integrating matter wave optics on a chip. In our vision the Atom Chip [1] as a monolithic integrated matter wave device combining the best of two worlds: The extensive techniques of coherent quantum manipulation established in quantum optics and atomic physics with the capabilities of micro-fabrication, micro-electroncs and micro-optics to implement these processes in a very robust way. A successful implementation will allow us to establish a new experimental toolbox to study fundamental questions in mesoscopic quantum physics and may lead to wide spread applications from highly sensitive inertial sensors to quantum information technology.

Cold neutral atoms can be stored, guided and manipulated in miniaturized magnetic traps above a substrate using either microscopic patterns of permanent magnetization or micro fabricated wire structures carrying current or charge. Bose-Einstein condensates (BEC) can be loaded into such atom chip microtraps, which then serves as a coherent source of atoms. The next step is be to individually select, address, manipulate and detect single atoms and small mesoscopoic ensembles on the chip. To achieve this we work towards the integration with other quantum optics, micro optics and photonics techniques like micro lenses, waveguides, micro cavities, photonic bandgap materials.

As an example we will discuss a scheme to detect single atoms using moderate Q cavity micro cavities. Such cavity could be created for example by two wave guides on a chip or using a DBR fiber cavity with a small gap for the cold atoms. Having atoms localized to better then 100 nm ($\ll$ wavelength of light) in steep traps should allow a small gap a small waist and precise positioning of the atom for maximum coupling. Recently we could show that signal to noise ration of $> 5\sigma$ can be obtained for detection of a single atom in 10 μs using existing technology [2]. I will discuss the progress towards an experimental realization of such a detector.

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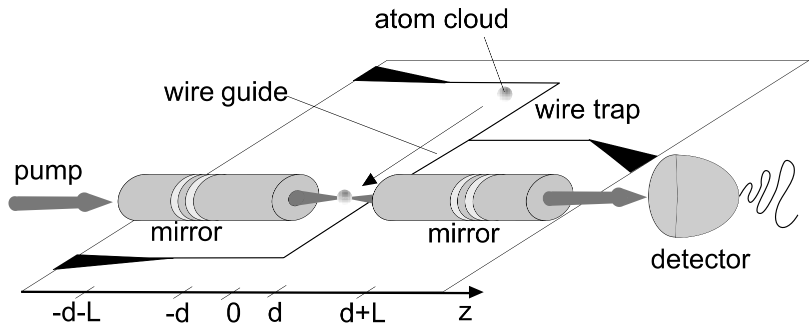

Fig. 1. Schematic presentation of the fiber cavity for atom detection on an atom chip. The atoms will be guided from the reservoir (wire trap) towards the detector along the wire guide.

[1] For a comprehensive review see: R. Folman, P. Krueger, J. Schmiedmayer, J. Denschlag, and C. Henkel, Adv. At. Mol. Opt. Phys. **48**,263 (2002).

[2] P. Horak, et. al, quant-ph/0210090, Phys. Rev. A accepted (2003).