Towards nonlinear optics with cold atoms in a hollow fiber

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Photons are essentially noninteracting particles which makes them an excellent choice for transmitting information. However, for the same reason, processing of information stored in photons is challenging. Tailoring photon-photon interactions has therefore been a long standing goal in nonlinear optics. One approach is to use a polarizable medium, e.g. an atomic gas, as a mediator for photon-photon interactions to perform all-optical switching or cross-phase modulation [1]. A crucial factor for successful implementation is a large interaction probability between photons and atoms. This can be achieved by placing an atom into a light mode with an area close to the scattering cross section. Our approach presented in this contribution is to load cold Rubidium atoms into the hollow core (diameter 8 µm) of a photonic crystal fiber (PCF). In such a system, tight confinement of the light mode as well as near perfect overlap with the atoms is naturally achieved. The experimental concept is depicted in fig. 1: A far red detuned dipole trap beam is coupled into the fiber and drives a cloud of cold atoms towards the fiber tip. Once inside the fiber, the trap tightly confines the atoms at the center of the core thus preventing atom-wall collisions. To demonstrate the feasibility of our setup, we have guided cold atoms through an 88 mm piece of fiber with a bandgap centered around 1060 nm [2]. Fibers at this wavelength exhibit clean Gaussian light modes and we benefit from very low scattering rates while sustaining a deep optical potential using a high power fiber laser. We present a detailed analysis of the dynamics of the atoms guided through the fiber. In order to directly interrogate the atomic ensemble in the hollow core with resonant light we have extended our experimental setup to a hollow fiber which guides light at the Rubidium D1 line. We present a thorough description of the revised experimental setup including a detailed characterization of the hollow fiber and the laser systems for trapping and probing atoms inside the fiber. We furthermore present preliminary results including the loading dynamics of the dipole trap and electromagnetically induced transparency with cold atoms.

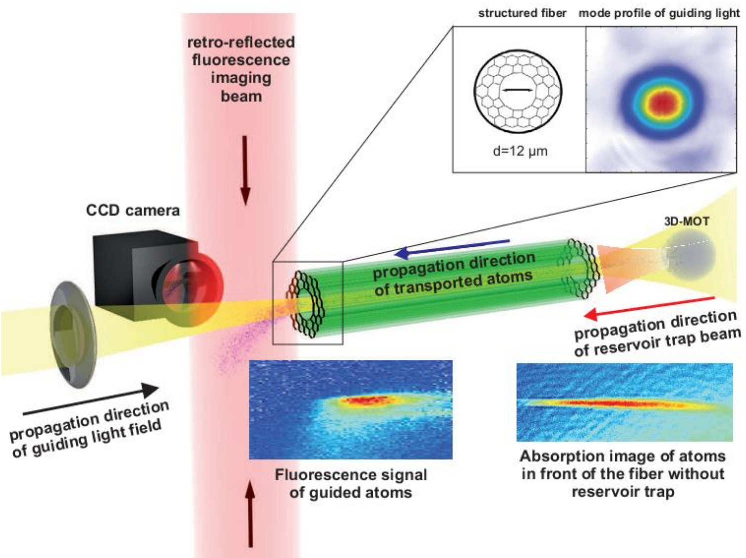

Figure 1: Illustration of the experimental concept. A cold atomic cloud is attracted towards the fiber tip and guided through the fiber by a far red detuned guiding light field and detected at the other end of the fiber using fluorescence imaging.

References:
[1] Vivek Venkataraman, Kasturi Saha and Alexander L. Gaeta, Nat. Photon. **7**, 138 (2012).
[2] Stefan Vorrath, Sönke Möller, Patrick Windpassinger, Kai Bongs and Klaus Sengstock, New J. Phys. **12**, 123015 (2010).