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Simulating gravity-assisted loading and motion of laser-cooled atoms in hollow-core optical fibres

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Hollow-core optical fibres provide μm-scale confinement of photons and atoms and reduce the power requirements for optical nonlinearities. This platform has opened tantalizing possibilities to study and engineer light-matter interactions in atomic ensembles. However, the purity, efficiency and nature of these interactions are contingent on the number, geometry and movement of atoms within the fiber. It is thus of interest to have a handle on loading atoms into and their motion inside the fiber.

Starting from ˜ μK MOT (Magneto-Optical Trap) clouds positioned a few mm above the fiber, optical dipole potentials have been used to guide matter into the hollow fibers. To study the effect of different experimental conditions on the loading process, we use parallel programs to re-create the trajectories of atoms into vertically oriented hollow fibres with core diameters: 7 μm and 30 μm. We make predictions about the effects of the initial MOT temperature and position, of different guiding optical potentials on the loading efficiency, as well as of higher-order waveguide modes excited in the fiber. We compare the results of these simulations with reported experiments. Additionally, atomic motion inside the hollow fiber is visualized in order to predict ensemble features such as atom-cloud length, atom-atom distances and position-velocity distributions. These play a role in determining how transversely-confined light couples with the ensemble. Lastly, as the attempted schemes of gravity-assisted loading from a vertically positioned MOT appear to grant efficiencies in the limited range of 0.01 to 1%, potential alternatives are explored in order to realize a more direct interfacing of atoms into the fiber.

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