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Interaction and manipulation of nanofiber-trapped atoms with spin–orbit coupled light

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ABSTRACT:

Light is often described as an electro-magnetic wave that is transversely polarized with respect to its propagation direction. This description however breaks down when the light field is strongly transversely confined. Such a light field exhibits a longitudinal component of its electro-magnetic field. In this situation the spin and the orbital angular momentum of light are coupled and thus not independent quantities anymore, e.g., the local spin depends on the propagation direction of the light field. In this thesis the interaction between nanofiber-trapped atoms and spin—orbit coupled light fields is studied in the dispersive and the resonant regime. In our system the nanofiber provides an evanescent field interface between the strongly guided optical mode and neutral cesium atoms. The atoms are confined in two diametric arrays in the vicinity of the nanofiber surface using a nanofiber-based two-color optical dipole trap. It is demonstrated that by using the peculiar polarization pattern of the guided light fields, the two atomic ensembles can be simultaneously optically pumped to opposite Zeeman states. Furthermore, it is shown that the state-dependent light shifts induced by a fictitious magnetic field can be locally distinct. This enables the independent coherent manipulation of the two ensembles via microwave radiation. Moreover, due to the spin—orbit interaction of light the system exhibits asymmetric scattering of photons by the atoms into counter-propagating nanofiber-guided modes. An asymmetry of the scattering rates into the two propagation directions higher than 10:1 is demonstrated. It is presented that this asymmetry can be tailored by the internal state of the atom and the polarization of the excitation light field. Additionally it is shown that the spin—orbit interaction in our system can lead to non-reciprocal transmission of a nanofiber-guided light field. Building on this property a nanoscale optical diode is demonstrated that can be operated down to the single-photon regime.