Optical orientation of carriers through Mn-ions photoneutralization in GaAs-based structures

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The charge and spin properties of quantum states localized in the nano-sized solid volumes could be significantly enriched by means of doping. Manganese is one of the most attractive dopants for GaAs due to its intrinsic magnetic properties. Exchange interaction between d-electrons and hole localized on the impurity brings neutral manganese acceptor (Mn^0) to the ground state with full angular momentum F=1 [1] while an ionized, negatively charged manganese acceptor (Mn^-) has full angular momentum J=5/2. It makes possible to use spin-charge interplay in an effort to develop novel quantum and spintronic devices. It was shown that it is possible to control spin of manganese acceptors in GaAs based quantum sized systems by means of optical pumping using the exchange interaction with optically oriented charge carriers [2–4].

We suggest another promising way of spin addressing. In this work we demonstrate optical orientation that is due to the so-called photoneutralization process, i.e. when the optical pumping occurs from the ionized impurity state. This leads to a formation of the neutral impurity and a free charge carrier in the band. Recently we have reported [5] optical orientation of free and localized charge carriers in GaAs/AlGaAs quantum wells (QWs) via the Mn-acceptor photoneutralization. To the best of our knowledge, such a scheme of optical orientation has never been used before, although the photoneutalization by itself is a well-known process [6].

Here we present a theoretical description of the processes mentioned above. Our predictions show that the orientation degree both of electrons [7] and Mn^0 localized holes can be significant. The electron polarization strongly depends on QW width and can reach the value about 80% at excitation, whereas Mn^0 holes acquire polarization in the range of 0.5-0.6. Moreover, the ionized Mn^- centers are oriented with high efficiency through excitation-recombination processes.

The photoluminescence (PL), which usually used for monitoring the carrier spin polarization, is shown to have a high degree of circular polarization. It is due to high spin orientation of photo-excited carriers, and especially due to slow spin relaxation of localized holes in contrast with the case of free holes [8]. The PL polarization as a function of excitation intensity is studied and is shown to have non-monotonic character.

The results can be easily generalized to the case of transitions from nonmagnetic acceptor states.

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