Initialization of a hole spin bound to an isoelectronic center in ZnSe

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In the present work, we demonstrate the ability to initialize, in a well-defined quantum state, a hole spin qubit bound to an isoelectronic center (IC). Charges bound to ICs, which are atomic-size defects form by a small number of isovalent impurities inside a semiconductor host, are promising candidates for solid-state qubits, because, unlike other optically controlled qubits, they combine a very low inhomogeneous broadening and a strong electric dipole moment.

This work focuses on spin qubits bound to Te dyads in ZnSe, for which long relaxation and coherence times are expected. Indeed, most isotopes of Zn, Se, and Te have vanishing nuclear spins, leading to weak hyperfine interactions between bound charges and surounding nuclei, and Te dyads can bound holes, which exhibit a lower hyperfine interaction than electrons.

Using time-resolved photoluminescence (PL) of a positive trion (2 holes and 1 electron) bound to a Te dyad, we demonstrated that, under resonant excitation of the heavy-hole (HH) valence band of the ZnSe host, the degree of polarization of the emission reaches almost 90% (Fig. 1(a)), indicating that, most of the time, the residual hole has been initialized in a well-defined quantum state. Under non-resonant excitation (Fig. 1(b)), the degree of polarization decreases to 30% .

Interestingly, when the excitation is resonant with the emission associated to donors and acceptors present in the host ZnSe, the degree of polarization of the emission become almost unitary (Fig. 1 (c)), indicating a very efficient initialization of hole spins. This latter mechanism of initialization, associated to the tunnelling of charges from donors and acceptors impurities to Te dyads, is very promising because charge tunnelling is known to preserve the coherence of quantum states.

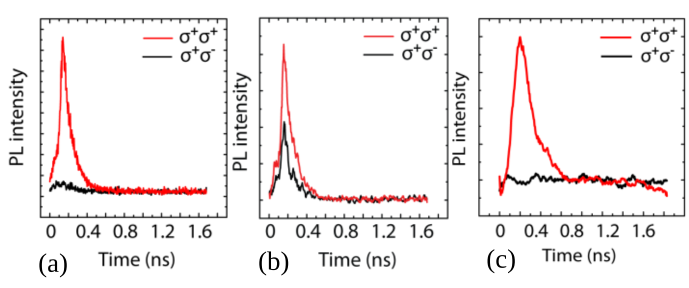

Figure 1- Time-resolved PL of a positive trion under (a) resonant excitation of the HH valence band of the ZnSe host, (b) non-resonant excitation, and (c) resonant excitation of donors and acceptors states. Red (black) curves show the emission co- (cross-) polarized with the excitation