Optical detection of Aharonov-Bohm oscillations of a single electron on a quantum ring.

M.Korkusinski, P. Hawrylak
Institute for Microstructural Science, National Research Council of Canada
Ottawa, Ontario, Canada K1A OR6

M. Bayer[1,2], T.Gutbrod[2], M.Michel[2] , A. Forchel [2]
[1] *Experimentelle Physik //,Universitat Dortmund, D44221-Dortmund, Germany*
[2] *Technische Physik, Universitat Wurzburg, D-97074, Wurzburg,Germany*

We demonstrate that emission from a negatively charged exciton on a nano-scale quantum ring allows for optical detection of Aharonov-Bohm oscillations of a single electron. This claim is based on results of theoretical and experimental study of an exciton (X) and charged exciton (X-) localized on a quantum ring in an external magnetic field. In the case of a single electron or a single hole the magnetic field couples to the phase of the single-particle wave function via charge resulting in the Aharonov-Bohm (AB) oscillations. If both carriers are present, they form a charge neutral exciton complex and AB oscillations are suppressed. By adding a second electron, the negatively charged complex, X-, is formed. In the case of an X- the weak AB oscillations are present for all ring radii due to the charged character of the complex. In the recombination process from the X- the outgoing photon energy is dominated by the AB oscillations of the final state electron. This conclusions are drawn on the basis of extensive calculations of a model system consisting of two electrons and one valence hole confined to a one dimensional ring. The electrons and a hole interact via repulsive and/or attractive interactions. The Hamiltonian is transformed into a coordinate system relative to the hole. The resulting system of Center of Mass particle and two relative interacting quasi-particles is solved by expanding the wavefunction in several hundred of configurations and diagonalizing the Hamiltonian in the space of these configurations. The transformation allows us to understand the effect of the mass of the valence hole and charge of the complex on AB oscillations.

We compare our theoretical results to interband magneto-photoluminescence measurements on InGaAs/GaAs rings manufactured by etching and lithography[1].

[1] M.Bayer,M.Korkusinski,P.Hawrylak,T.Gunbrodt,M.Michel and A. Forchel, Phys.Rev.Lett.90, 186801 (2003)